OFFSHORE STANDARD
DNV-OS-C201

STRUCTURAL DESIGN OF OFFSHORE UNITS (WSD METHOD)

OCTOBER 2008

DET NORSKE VERITAS

FOREWORD

DET NORSKE VERITAS (DNV) is an autonomous and independent foundation with the objectives of safeguarding life, property and the environment, at sea and onshore. DNV undertakes classification, certification, and other verification and consultancy services relating to quality of ships, offshore units and installations, and onshore industries worldwide, and carries out research in relation to these functions.

DNV Offshore Codes consist of a three level hierarchy of documents:

— *Offshore Service Specifications.* Provide principles and procedures of DNV classification, certification, verification and consultancy services.
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— *Recommended Practices.* Provide proven technology and sound engineering practice as well as guidance for the higher level Offshore Service Specifications and Offshore Standards.

DNV Offshore Codes are offered within the following areas:

A) Qualification, Quality and Safety Methodology

B) Materials Technology

C) Structures

D) Systems

E) Special Facilities

F) Pipelines and Risers

G) Asset Operation

H) Marine Operations

J) Wind Turbines

O) Subsea Systems

Amendments and Corrections

Whenever amendments and corrections to the document are necessary, the electronic file will be updated and a new Adobe PDF file will be generated and made available from the Webshop (http://webshop.dnv.com/global/).

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CHANGES

- **General**

Being class related, this document is published electronically only (as of October 2008) and a printed version is no longer available. The update scheme for this category of documents is different compared to the one relevant for other offshore documents (for which printed versions are available).

For an overview of all types of DNV offshore documents and their update status, see the "Amendments and Corrections" document located at: http://webshop.dnv.com/global/, under category "Offshore Codes".

- **Main changes**

Since the previous edition (April 2005), this document has been amended, latest in April 2008. All changes have been incorporated.

CONTENTS

SECTION 1
INTRODUCTION

A. General

A 100 Introduction

101 This offshore standard provides principles, technical requirements and guidance for the structural design of offshore structures, based on the Working Stress Design (WSD) method.

102 This standard has been written for general world-wide application. Statutory regulations may include requirements in excess of the provisions by this standard depending on size, type, location and intended service of the offshore unit or installation.

103 The standard is organised with general sections containing common requirements and sections containing specific requirement for different type of offshore units. In case of deviating requirements between general sections and the object specific sections, requirements of the object specific sections shall apply.

A 200 Objectives

201 The objectives of this standard are to:

— provide an internationally acceptable level of safety by defining minimum requirements for structures and structural components (in combination with referred standards, recommended practices, guidelines, etc.)
— serve as a contractual reference document between suppliers and purchasers
— serve as a guideline for designers, suppliers, purchasers and regulators
— specify procedures and requirements for offshore structures subject to DNV certification and classification.

A 300 Scope and application

301 This standard is applicable to the following types of offshore structures:

— column-stabilised units
— self-elevating units
— tension leg platforms
— deep draught floaters.

302 For utilisation of other materials, the general design principles given in this standard may be used together with relevant standards, codes or specifications covering the requirements to materials design and fabrication.

303 The standard is applicable to structural design of complete units including substructures, topside structures and vessel hulls.

304 This standard gives requirements for the following:

— design principles
— structural categorisation
— material selection and inspection principles
— loads and load effect analyses
— design of steel structures and connections
— special considerations for different types of units.

Requirements for foundation design are given in DNV-OS-C101.

A 400 Other than DNV codes

401 Other recognised codes or standards may be applied provided it is shown that the codes and standards, and their application, meet or exceed the level of safety of the actual DNV standard.

402 In case of conflict between requirements of this standard and a reference document other than DNV documents, the requirements of this standard shall prevail.

403 Where reference is made to codes other than DNV documents, the latest revision of the documents shall be applied, unless otherwise specified.

404 When code checks are performed according to other than DNV codes, the usage factors as given in the respective code shall be used.

A 500 Classification

501 Classification principles, procedures and applicable class notations related to classification services of offshore units are specified in the DNV Offshore Service Specifications given in Table A1.

Table A1 DNV Offshore Service Specifications

Reference	*Title*
DNV-OSS-101	Rules for Classification of Offshore Drilling and Support Units
DNV-OSS-102	Rules for Classification of Floating Production and Storage Units
DNV-OSS-103	Rules for Classification of LNG/LPG Floating Production and Storage Units or Installations
DNV-OSS-121	Classification Based on Performance Criteria Determined by Risk Assessment Methodology
	Rules for Planning and Execution of Marine Operations

502 Documentation for classification shall be in accordance with the NPS DocReq (DNV Nauticus Production System for documentation requirements) and Guideline No.17.

B. References

B 100 General

101 The DNV documents in Table B1 are referred to in the present standards and contain acceptable methods for fulfilling the requirements in this standard.

102 The latest valid revision of the DNV reference documents in Table B2 applies. See also current DNV List of Publications.

103 The documents listed in Table B2 are referred in the present standard. The documents include acceptable methods for fulfilling the requirements in the present standard and may be used as a source of supplementary information. Only the referenced parts of the documents apply for fulfilment of the present standard.

Table B1 DNV Reference Documents

Reference	Title
DNV-OS-A101	Safety Principles and Arrangement
DNV-OS-B101	Metallic Materials
DNV-OS-C101	Design of Offshore Steel Structures, General (LRFD method)
DNV-OS-C301	Stability and Watertight Integrity

DNV-OS-C401	Fabrication and Testing of Offshore Structures
DNV-OS-D101	Marine Machinery Systems and Equipment
DNV-OS-E301	Position Mooring
DNV-OS-F201	Dynamic Risers
DNV-RP-C103	Column Stabilised Units
DNV-RP-C201	Buckling Strength of Plated Structures
DNV-RP-C202	Buckling Strength of Shells
DNV-RP-C203	Fatigue Strength Analysis of Offshore Steel Structures
Classification Note 30.1	Buckling Strength Analysis of Bars and Frames, and Spherical Shells
Classification Note 30.4	Foundations
Classification Note 30.5	Environmental Conditions and Environmental Loads
Classification Note 31.5	Strength Analysis of Main Structures of Self-elevating Units

Table B2 Other references

Reference	Title
AISC-ASD	Manual of Steel Construction ASD
API RP 2A – WSD with supplement 1	Planning, Designing and Constructing Fixed Offshore Platforms – Working Stress Design
API RP 2T	Planning, Designing and Constructing Tension Leg Platforms
BS 7910	Guide on methods for assessing the acceptability of flaws in fusion welded structures
NACE TPC	Publication No. 3. The role of bacteria in corrosion of oil field equipment
SNAME 5-5A	Site Specific Assessment of Mobile Jack-Up Units

C. Definitions

C 100 Verbal forms

101 *Shall:* Indicates a mandatory requirement to be followed for fulfilment or compliance with the present standard. Deviations are not permitted unless formally and rigorously justified, and accepted by all relevant contracting parties.

102 *Should:* Indicates a recommendation that a certain course of action is preferred or particularly suitable. Alternative courses of action are allowable under the standard where agreed between contracting parties but shall be justified and documented.

103 *May:* Indicates a permission, or an option, which is permitted as part of conformance with the standard.

C 200 Terms

201 *Accidental condition:* When the unit is subjected to accidental loads such as collision, dropped objects, fire explosion, etc.

202 *Accidental loads:* Loads which may occur as a result of accident or exceptional events, e.g. collisions, explosions, dropped objects.

203 *Atmospheric zone:* The external surfaces of the unit above the splash zone.

204 *Cathodic protection:* A technique to prevent corrosion of a steel surface by making the surface to be the cathode of an electrochemical cell.

205 *Characteristic load:* The reference value of a load to be used in the determination of load effects. The characteristic load is normally based upon a defined fractile in the upper end of the distribution function for load.

206 *Characteristic strength:* The reference value of structural strength to be used in the determination of the design strength. The characteristic strength is normally based upon a 5% fractile in the lower end of the distribution function for resistance.

207 *Characteristic value:* The representative value associated with a prescribed probability of not being unfavourably exceeded during the applicable reference period.

208 *Classic spar:* Shell type hull structure.

209 *Classification Note:* The Classification Notes cover proven technology and solutions which is found to represent good practice by DNV, and which represent one alternative for satisfying the requirements given in the DNV Rules or other codes and standards cited by DNV. The Classification Notes will in the same manner be applicable for fulfilling the requirements in the DNV Offshore Standards.

210 *Coating:* Metallic, inorganic or organic material applied to steel surfaces for prevention of corrosion.

211 *Column-stabilised unit:* A floating unit that can be relocated. A column-stabilised unit normally consists of a deck structure with a number of widely spaced, large diameter, supporting columns that are attached to submerged pontoons.

212 *Corrosion allowance:* Extra wall thickness added during design to compensate for any anticipated reduction in thickness during the operation.

213 *Damaged condition:* The unit condition after accidental damage.

214 *Deep draught floater (DDF):* A floating unit categorised with a relative large draught. The large draught is mainly introduced to obtain reduced wave excitation in heave and sufficiently high eigenperiod in heave such that resonant responses in heave can be omitted or minimised.

215 *Design brief:* An agreed document presenting owner's technical basis, requirements and references for the unit design and fabrication.

216 *Design temperature:* The design temperature for a unit is the reference temperature for assessing areas where the unit can be transported, installed and operated. The design temperature shall be lower or equal to the *lowest mean daily temperature* in air for the relevant areas. For seasonal restricted operations the *lowest mean daily temperature* in air for the season may be applied.

217 *Driving voltage:* The difference between closed circuit anode potential and the protection potential.

218 *Dry transit:* A transit where the unit is transported on a heavy lift unit from one geographical location to another.

219 *Dynamic upending:* A process where seawater is filled or flooded into the bottom section of a horizontally floating DDF hull and creating a trim condition and subsequent water filling of hull or moonpool and dynamic upending to bring the hull in vertical position.

220 *Environmental loads:* Loads directly and indirectly due to environmental phenomena. Environmental loads are not a necessary consequence of the structures existence, use and treatments. All external loads which are responses to environmental phenomena shall be regarded as environmental loads, e.g. support reactions, mooring forces, and inertia forces.

221 *Expected loads and response history:* Expected load and response history for a specified time period, taking into account the number of load cycles and the resulting load levels and response for each cycle.

222 *Expected value:* The most probable value of a load during a specified time period.

223 *Fail to safe:* A failure shall not lead to new failure, which may lead to total loss of the structure.

224 *Fatigue:* Degradation of the material caused by cyclic loading.

225 *Fatigue critical:* Structure with calculated fatigue life less than three times the design fatigue life.

226 *Functional loads:* Loads which are a necessary consequence of the structure's existence, use and treatment under ideal circumstances, i.e. no environmental loads, for each design condition. All external loads which are responses to functional loads shall be regarded as functional loads, e.g. support reactions and still water buoyancy forces.

227 *Gross scantlings:* Scantlings, including thickness as shown on structural drawings, i.e. the actual (full) thickness provided at the newbuilding stage applies.

228 *Guidance note:* Information in the standard added in order to increase the understanding of the requirements.

229 *Gust wind velocity:* The average wind velocity during a time interval of 3 s. The "N years gust wind velocity" is the most probable highest gust velocity in a period of N years.

230 *Hard tank area:* Usually upper part of the hull providing sufficient buoyancy for a DDF unit.

231 *High frequency (HF) responses:* Defined as rigid body motions at, or near heave, roll and pitch eigenperiods due to non-linear wave effects.

232 *Hindcasting:* A method using registered meteorological data to reproduce environmental parameters. Mostly used for reproducing wave parameters.

233 *Inspection:* Activities such as measuring, examination, testing, gauging one or more characteristics of an object or service and comparing the results with specified requirements to determine conformity.

234 *Installation condition:* A temporary condition where the unit is under construction such as mating or in preparation for operational phase such as upending of DDFs, lowering the legs and elevating the self-elevating units or tether pretension for TLPs.

235 *Load effect:* Effect of a single design load or combination of loads on the equipment or system, such as stress, strain, deformation, displacement, motion, etc.

236 *Lowest mean daily temperature:* The lowest value on the annual mean daily average temperature curve for the area in question. For temporary phases or restricted operations, the lowest mean daily temperature may be defined for specific seasons. In the above definition:
Mean daily average temperature: The statistical mean average temperature for a specific calendar day.
Mean: Statistical mean based on number of years of observations.
Average: Average during one day and night.

237 *Low frequency (LF) responses:* Defined as TLP rigid body non-linear motions at, or near surge, sway and yaw eigenperiods.

238 *Lowest waterline:* Typical light ballast waterline for ships, wet transit waterline or inspection waterline for other types of units.

239 *Material strength:* The nominal value of material strength to be used in the determination of the design resistance. The material strength is normally based upon a 5% fractile in the lower end of the distribution function for material strength.

240 *Mean:* Statistical mean over observation period.

241 *Moulded baseline:* A horizontal line extending through the upper surface of hull bottom shell.

242 *Non-destructive testing (NDT):* Structural tests and inspection of welds with radiography, ultrasonic or magnetic powder methods.

243 *Offshore Standard:* The DNV Offshore Standards are documents which presents the principles and technical requirements for design of offshore structures. The standards are offered as DNV's interpretation of engineering practice for general use by the offshore industry for achieving safe structures.

244 *One hour wind velocity:* The average wind velocity during a time interval of one hour.

245 *Operating condition:* A conditions wherein a unit is on location for purposes of production, drilling or other similar operations, and combined environmental and operational loadings are within the appropriate design limits established for such operations (including normal operations, survival, accidental).

246 *P-delta effect:* Second order effect due to vertical forces in combination with second order displacements. For self-elevating units the P-delta effect describes non-linear amplification due to second order bending of the legs for the unit in the hull elevated mode. For DDF units the P-delta effect describes global bending or shear effects due to relatively high roll or pitch angles in harsh environment.

247 *Potential:* The voltage between a submerged metal surface and a reference electrode.

248 *Recommended Practice (RP):* The Recommended Practice publications cover proven technology and solutions which have been found by DNV to represent good practice, and which represent one alternative for satisfying the requirements given in the DNV Offshore Standards or other codes and standards cited by DNV.

249 *Redundancy:* The ability of a component or system to maintain or restore its function when a failure of a member or connection has occurred. Redundancy can be achieved for instance by strengthening or introducing alternative load paths.

250 *Reference electrode:* Electrode with stable open-circuit potential used as reference for potential measurements.

251 *Reliability:* The ability of a component or a system to perform its required function without failure during a specified time interval.

252 *Representative value:* The value assigned to each load for a design situation.

253 *Resistance:* The reference value of structural strength to be used in the determination of the design strength. The resistance is normally based upon a 5% fractile in the lower end of the distribution function for resistance.

254 *Retrieval condition:* A condition, normally applicable for self-elevating units only, and for which the unit is lowering the hull and elevating the legs.

255 *Ringing:* The non-linear high frequency resonant response induced by transient loads from high, steep waves.

256 *Riser frame:* Framed steel structures installed at different vertical elevations along the hull or moonpool in order to separate the different risers.

257 *Risk:* The qualitative or quantitative likelihood of an accidental or unplanned event occurring considered in conjunction with the potential consequences of such a failure. In quantitative terms, risk is the quantified probability of a defined failure mode times its quantified consequence.

258 *Self-elevating unit or jack-up:* A mobile unit having hull with sufficient buoyancy to transport the unit to the desired location, and that is bottom founded in its operating mode. The unit reaches its operating mode by lowering the legs to the seabed and then jacking the hull to the required elevation.

259 *Service temperature:* The service temperature is a reference temperature on various structural parts of the unit used as a criterion for the selection of steel grades.

260 *Shakedown:* A linear elastic structural behaviour is established after yielding of the material has occurred.

261 *Slamming:* Impact load on an approximately horizontal member from a rising water surface as a wave passes. The direction of the impact load is mainly vertical.

262 *Specified minimum yield strength (SMYS):* The minimum yield strength prescribed by the specification or standard under which the material is purchased.

263 *Specified value:* Minimum or maximum value during the period considered. This value may take into account operational requirements, limitations and measures taken such that the required safety level is obtained.

264 *Splash zone:* The external surfaces of the unit that are periodically in and out of the water. The determination of the splash zone includes evaluation of all relevant effects including influence of waves, tidal variations, settlements, subsidence and vertical motions.

265 *Springing:* The high frequency non-linear resonant response induced by cyclic (steady state) loads in low to moderate sea states.

266 *Strake:* Usually helical devices (strake) welded to outer hull with the purpose of reducing the vortex induced crossflow motion of DDF hull due to current (mainly). Also the term suppression device may be used to describe the strake.

267 *Submerged zone:* The part of the installation, which is below the splash zone, including buried parts.

268 *Survival condition:* A condition during which a unit may be subjected to the most severe environmental loadings for which the unit is designed. Drilling or similar operations may have been discontinued due to the severity of the environmental loadings. The unit may be either afloat or supported on the seabed, as applicable.

269 *Sustained wind velocity:* The average wind velocity during a time interval (sampling time) of 1 minute. The most probable highest sustained wind velocity in a period of N years will be referred to as the "N years sustained wind". This is equivalent to a wind velocity with a recurrence period of N years.

270 *Target safety level:* A nominal acceptable probability of structural failure.

271 *Temporary conditions:* Design conditions not covered by operating conditions, e.g. conditions during fabrication, mating and installation phases, transit phases, accidental.

272 *Tensile strength:* Minimum stress level where strain hardening is at maximum or at rupture.

273 *Tension leg platform (TLP):* A buoyant unit connected to a fixed foundation by pre-tensioned tendons. The tendons are normally parallel, near vertical elements, acting in tension, which usually restrain the motions of the TLP in heave, roll and pitch. The platform is usually compliant in surge, sway and yaw.

274 *Transit conditions:* The unit conditions in wet transit from one geographical location to another.

275 *Truss spar:* A spar buoy with truss structure for the hull part below hard tank area.

276 *Unit:* A general term for an offshore installation such as ship shaped, column stabilised, self-elevating, tension leg or deep draught floater.

277 *Usage factor:* The ratio between permissible stress and the characteristic strength of the structural member.

278 *Verification:* Examination to confirm that an activity, a product or a service is in accordance with specified requirements.

279 *Wave frequency (WF) responses:* Linear rigid body motions at the dominating wave periods.

280 *Wet transit:* A transit where the unit is floating during the move from one geographical location to another.

281 *Ultimate strength:* Corresponding to the maximum load carrying resistance.

D. Abbreviations and Symbols

D 100 Abbreviations

101 The abbreviations given in Table D1 are used in this standard.

Table D1 Abbreviations	
Abbreviation	*In full*
AISC	American Institute of Steel Construction
API	American Petroleum Institute
ASD	allowable stress design
BS	British Standard (issued by British Standard Institution)
CTOD	crack tip opening displacement
DDF	deep draught floaters
DFF	design fatigue factor
DNV	Det Norske Veritas
DP	dynamic positioning
EHS	extra high strength
FE	finite elements
HAT	highest astronomical tide
HF	high frequency
HISC	hydrogen induced stress cracking
HRTLP	heave resisted TLP
HS	high strength
IC	inspection category
IIP	in service inspection program
ISO	International Organisation for Standardisation
LAT	lowest astronomic tide
LF	low frequency
LRFD	load and resistance factor design
MPI	magnetic particle inspection
MSL	mean sea level
NACE	National Association of Corrosion Engineers
NDT	non destructive testing
NS	normal strength
QTF	quadratic transfer function
RAO	response amplitude operator
RP	recommended practice
SCF	stress concentration factor
SMYS	specified minimum yield stress
SNAME	Society of Naval Architects and Marine Engineers
TLP	tension leg platform
TLWP	tension leg wellhead platform
VIV	vortex induced vibrations
WF	wave frequency
WSD	working stress design

D 200 Symbols

201 The following units are used in this standard:

g	gram
k	kilo
m	meter
cm	centimetre
mm	millimetre

t	tonne
N	Newton
s	second.

202 The following Latin characters are used in this standard:

a	sectional area of weld
$\bar{a}$	the intercept of the design S-N curve with the log N axis
a_0	total connection area at supports of stiffeners
a_h	horizontal acceleration
a_v	vertical acceleration
b	breadth of plate flange
b_e	effective flange width
c	flange breadth
d	web height
d_p	diameter of pipe
f	distributed load factor for primary design
f_r	strength ratio
f_u	lowest ultimate tensile strength
f_w	strength ratio
f_y	yield stress
g_0	acceleration due to gravity
h	the shape parameter of the Weibull stress range distribution
h_{op}	vertical distance from the load point to the position of maximum filling height
k	roughness height
k_a	factor for aspect ratio of plate field
k_m	bending moment factor
k_{pp}	factor dependent on support condition for plate
k_{ps}	factor dependent on support condition for stiffener
k_τ	shear force factor
l	stiffener span
l_0	distance between points of zero bending moments
m	the inverse slope of the S-N curve
n_i	the number of stress variations in i years
n_0	total number of stress variations during the lifetime of the structure
p	lateral tank or sea pressure
p_d	lateral pressure
P_{dyn}	pressure due to flow through pipes
p_s	permanent sea pressure
p_e	environmental sea pressure
q	distributed load
q_c	contact pressure
r	root face
s	stiffener spacing
t	thickness
t_0	net thickness abutting plate
t_f	thickness of flange
t_k	corrosion addition
t_m	factor used in formulas for minimum plate thickness
t_p	thickness of pipe
t_w	web thickness
t_W	throat thickness of weld
x_D	load effect with a return period of D-year
z_b	vertical distance from moulded base line to load point
A	area
A_W	web area
C	buckling coefficient
C_e	effective plate flange factor
C_D	hydrodynamic coefficient, drag
C_M	hydrodynamic coefficient, added mass
C_S	shape coefficient for wind force
C_W	reduction factor due to wave particle motion
D	number of years
D_D	vertical distance from moulded base line to underside of deck structure
D_m	diameter of member
D_B	depth of barge
E	modulus of elasticity, 2.1 10^5 N/mm^2
F_V	maximum axial force
F_{VP}	maximum required preload
$F_x(x)$	long-term peak distribution
H_s	significant wave height
K_C	Keulegan-Carpenter number
L	length
L_i	variables used in determining splash zone
M	bending moment
M_c	mass of component
M_e	eccentricity moment
M_O	overturning moment
M_p	plastic moment resistance
M_S	stabilising moment
M_U	maximum moment restraint
My	elastic moment resistance
N	number of stress cycles to failure
N_D	total number of load effect maxima during D years
N_p	number of supported stiffeners on the girder span
N_s	number of stiffeners between considered section and nearest support
P	load
P_E	Euler buckling load
P_H	horizontal force
P_p	average point load
P_V	vertical force
R	radius of curvature, or equivalent radius of spudcan contact area
S	stress range
S_g	girder span
SZ_L	lower limit of the splash zone
SZ_U	upper limit of the splash zone
T	wave period
T_E	extreme operational draught
T_{TH}	heavy transit draught
T_Z	average zero-upcrossing period
U_i	variables used in determining splash zone
U_m	maximum orbital particle velocity
Z	steel grade with proved through thickness properties
Z_s	section modulus for stiffener section
Z_g	section modulus for simple girder section.

203 The following Greek characters are used in this standard:

α	length ratio
β	coefficient depending on type of structure, failure mode and reduced slenderness
β_w	correlation factor
ε	relative strain
$\Gamma( )$	the complete gamma function
γ_s	safety coefficient
η_0	basic usage factor
η_p	maximum permissible usage factor
φ	angle between the stiffener web plane and the plane perpendicular to the plating
λ	reduced slenderness parameter
θ	rotation
ρ	density
σ	stress
σ_e	elastic buckling stress
σ_{fw}	yield stress of weld deposits
σ_j	equivalent stress for global in-plane membrane stress
$\Delta\sigma_{ampl\_n0}$	extreme stress amplitude
$\Delta\sigma_{ni}$	extreme stress range
$\Delta\sigma_{n0}$	extreme stress range
σ_p	permissible stress
σ_{p1}	permissible bending stress
σ_{p2}	permissible bending stress
$\sigma_\perp$	normal stress perpendicular to an axis
σ_x	membrane stress in x- direction
σ_y	membrane stress in y- direction
τ	shear stress
τ_p	permissible shear stress
$\tau_\perp$	shear stress perpendicular to an axis
$\tau_{\|\|}$	shear stress parallel to an axis
ψ	stress ratio.

SECTION 2
DESIGN PRINCIPLES

A. Introduction

A 100 General

101 This section describes design principles and design methods including:

— working stress design method
— design assisted by testing
— probability based design.

102 General design considerations regardless of design method are also given in B.

103 This standard is based on the working stress design (WSD) method also known as the allowable stress method.

104 Direct reliability analysis methods are mainly considered as applicable to special case design problems, to calibrate the usage factors to be used in the WSD method and for conditions where limited experience exists.

105 As an alternative or as a supplement to analytical methods, determination of load effects or resistance may in some cases be based either on testing or on observation of structural performance of models or full-scale structures.

A 200 Aim of the design

201 Structures and structural elements shall be designed to:

— sustain loads liable to occur during all temporary, operating and damaged conditions if required
— maintain acceptable safety for personnel and environment
— have adequate durability against deterioration during the design life of the structure.

B. General Design Considerations

B 100 General

101 The design of a structural system, its components and details should, as far as possible, account for the following principles:

— resistance against relevant mechanical, physical and chemical deterioration is achieved
— fabrication and construction comply with relevant, recognised techniques and practice
— inspection, maintenance and repair are possible.

102 Structures and elements thereof, shall possess ductile resistance unless the specified purpose requires otherwise.

103 Fatigue life improvements with methods such as grinding or hammer peening of welds should not provide a measurable increase in the fatigue life at the design stage. The fatigue life should instead be extended by means of modification of structural details. Fatigue life improvements due to compression stress level should not be considered for welded structure, ref. DNV-RP-C203.

104 Structural elements may be fabricated according to the requirements given in DNV-OS-C401.

B 200 Overall design

201 The overall structural safety shall be evaluated on the basis of preventive measures against structural failure put into design, fabrication and in-service inspection as well as the unit's residual strength against total collapse in the case of structural failure of vital elements.

For vital elements, which are designed according to criteria given for intact structure, the likelihood and consequence of failure should be considered as part of the redundancy evaluations. The consequence of credible accidental events shall be documented according to Sec.8.

202 When determining the overall structural design, particular care shall be taken such that the solution does not lead to unnecessarily complicated connections.

B 300 Details design

301 In the design phase particular attention should be given to structural detailing, and requirements for reinforcement in areas that may be subjected to high local stresses, for example:

— critical connections
— locations that may be subjected to wave impact
— locations that may be subjected to accidental or operational damage
— locations where cutouts are made or discontinuities are present.

302 Structural connections should, in general, be designed with the aim to minimise stress concentrations and reduce complex stress flow patterns. Connections should be designed with smooth transitions and proper alignment of elements. Large cut-outs should be kept away from flanges and webs of primary girders in regions with high stresses.

303 Transmission of high tensile stresses through the thickness of plates during welding, block assembly and operation shall be avoided as far as possible. In cases where transmission of high tensile stresses through thickness occur, structural material with proven through thickness properties shall be used. The below sections for different types of units may give examples where to use plates with proven through thickness properties.

304 Units intended for operations in cold areas shall be so arranged that water cannot be trapped in local structures or machinery exposed to the ambient temperature.

C. Design Conditions

C 100 Basic conditions

101 Different modes of operation or phases during the life of structure may be governing for the design. The following design conditions, as defined in Sec.1 C, should normally be considered:

— installation condition
— operating conditions(s)
— retrieval condition
— survival condition
— transit condition.

Guidance note:
For many units the operating condition will be the same as the survival condition. The retrieval condition is normally applicable for self-elevating units only.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

102 Relevant load cases shall be established for the various design conditions based on the most unfavourable combinations of functional loads, environmental loads and/or accidental loads, see Sec.3.

103 Limiting environmental and operational conditions (design data) for the different design conditions shall be specified. The limiting conditions shall be stated in the operation manual.

D. Loading Conditions

D 100 General

101 Each structural member shall be designed for the most unfavourable of the loading conditions given in Table D1.
For definitions and description about the different types of loads see Sec.1 and Sec.3, respectively.

Table D1 Loading conditions	
Case	*Description*
a)	functional loads
b)	maximum combination of environmental loads and associated functional loads
c)	accidental loads and associated functional loads
d)	annual most probable value of environmental loads and associated functional loads after credible failures, or after accidental events
e)	annual most probable value of environmental loads and associated functional loads in a heeled condition corresponding to accidental flooding

102 For each of the loading conditions in Table D1 and for each structural element, the combinations of loads, position, and direction giving the most unfavourable load effect shall be used in the analysis.

103 All directions of wind, waves and current relative to the unit are normally to be assumed equally probable.

104 If, however, statistics show clearly that wind, waves and current of the prescribed probability are different for different directions, this may be taken into account in the analysis. It is assumed that orientation of the unit will be under complete control of the operator.

D 200 Load

201 The representative values for load components in the different design conditions shall be based on Sec.3.

202 For installation, transit and retrieval the loads may be based on specified values, which shall be selected dependent on the measurers taken to achieve the required safety level. The value may be specified with due attention to the actual location, season of the year, operation schedule and weather forecast, and consequences of failure.

E. Design by the WSD Method

E 100 Permissible stress and usage factors

101 In WSD the target component safety level is achieved by comparing the calculated stress for different loading conditions with maximum permissible stress defined by multiplication of the characteristic strength or capacity of the structural member with permissible usage factors.

102 The permissible usage factors are a function of loading condition, failure mode and importance of strength member.

103 The maximum permissible usage factor, η_p, is calculated by:

$$\eta_p = \beta \eta_0$$

η_0 = basic usage factor as given in 200
β = coefficient depending on type of structure, failure mode and reduced slenderness, see Sec.5.

104 Stresses shall be calculated using net scantlings, i.e. with any corrosion addition deducted.

E 200 Basic usage factors

201 The basic usage factor for different loading conditions, η_0, is given in Table E1.

Table E1 Basic usage factors η_0					
	Loading conditions				
	a)	*b)*	*c)*	*d)*	*e)*
η_0	0.60 [1)]	0.80 [1)]	1.00	1.00	1.00
1) For units unmanned during extreme environmental conditions, the usage factor η_0 may be taken as 0.84 for loading condition b).					

202 The basic usage factors account for:

- possible unfavourable deviations of the loads
- the reduced probability that various loads acting together will act simultaneously
- uncertainties in the model and analysis used for determination of load effects
- possible unfavourable deviations in the resistance of materials
- possible reduced resistance of the materials in the structure, as a whole, as compared with the values deduced from test specimens.

203 If the residual strength of the unit after collapse of a vital structural member does not satisfy the accidental damage criteria, the usage factors in Table E1 for the pertinent vital structural members shall be multiplied by a factor 0.9.

F. Design Assisted by Testing

F 100 General

101 Design by testing or observation of performance is in general to be supported by analytical design methods.

102 Load effects, structural resistance and resistance against material degradation may be established by means of testing or observation of the actual performance of full-scale structures.

F 200 Full-scale testing and observation of performance of existing structures

201 Full-scale tests or monitoring on existing structures may be used to give information on response and load effects to be utilised in calibration and updating of the safety level of the structure.

SECTION 3
LOADS AND LOAD EFFECTS

A. Introduction

A 100 General

101 This section defines and specifies load components and load combinations to be considered in the overall strength analysis as well as design pressures applicable in formulae for local design.

102 Further details regarding load design values may be found in the sections containing special considerations for the different types of units, e.g. specification of impact pressure caused by the sea (e.g. slamming or bow impact) or by liquid cargoes in partly filled tanks (sloshing).

103 For loads from mooring system, see DNV-OS-E301.

B. Basis for Selection of Loads

B 100 General

101 Unless specific exceptions apply, as documented within this standard, the loads documented in Table B1 and Table B2 shall apply in the temporary and operational design conditions, respectively.

102 Where environmental and accidental loads may act simultaneously, the representative values may be determined based on their joint probability distribution.

103 The load point for which the design pressure shall be calculated is defined for various strength members as follows:

a) For plates: midpoint of a horizontally stiffened plate field. Half of the stiffener spacing above the lower support of vertically stiffened plate field, or at lower edge of plate when the thickness is changed within the plate field.

b) For stiffeners: midpoint of the span.

   When the pressure is not varied linearly over the span, the pressure shall be taken as the greater of the pressure at the midpoint, and the average of the pressures calculated at each end of the stiffener.

c) For girders: midpoint of the load area.

Table B1 Basis for selection of representative loads for temporary design conditions, e.g. installation, retrieval and transit

Load category	*Loading conditions, see Sec.2 Table E1*				*Fatigue*
	a)	*b)*	*c)*	*d) and e)*	
Permanent functional	Expected value				
Variable functional	Specified value				
Environmental		Specified value	Specified value	Specified value	Expected load history
Accidental			Specified value		
Deformation	Expected extreme value				

For definitions, see Sec.1.
Ref. also DNV Rules for Planning and Execution of Marine Operations.

Table B2 Basis for selection of representative loads for in-place design conditions, e.g. operating and survival

Load category	*Loading conditions, see Sec.2 Table E1*				*Fatigue*
	a)	*b)*	*c)*	*d) and e)*	
Permanent functional	Expected value				
Variable functional	Specified value				
Environmental		The annual probability 1) of being exceeded = 10^{-2} for the load effect (100 year return period) 2)		Load with return period not less than one year.	Expected load history
Accidental			Specified value, see also DNV-OS-A101		
Deformation	Expected extreme value				

For definitions, see Sec.1.

1) The joint probability of exceedance may be considered, see F.

2) The annual probability of 10^{-2} for environmental loads applies for the survival condition. For the operation condition the maximum environmental loads for which operations can be performed applies.

C. Permanent Functional Loads

C 100 General

101 Permanent functional loads are loads that will not vary in magnitude, position or direction during the period considered.

Examples are:

— mass of structure
— mass of permanent ballast and equipment
— external and internal hydrostatic pressure of a permanent nature
— reaction to the above e.g. articulated tower base reload.

102 The representative value of a permanent load is defined as the expected value based on accurate data of the unit, mass of the material and the volume in question.

D. Variable Functional Loads

D 100 General

101 Variable functional loads are loads which may vary in magnitude, position and direction during the period under consideration, and which are related to operations and normal use of the installation.

102 Examples of variable functional loads are:

— personnel
— stored materials, equipment, gas, fluids and fluid pressure
— crane operational loads
— loads from fendering
— loads associated with installation operations
— loads associated with drilling operations
— loads from variable ballast and equipment
— variable cargo inventory for storage vessels
— helicopters
— lifeboats.

103 The variable functional load is the maximum (or minimum) specified value, which produces the most unfavourable load effects in the structure and design condition under consideration.

104 The specified value shall be determined on the basis of relevant specifications. An expected load history shall be used in fatigue design.

D 200 Variable functional loads on deck areas

201 Variable functional loads on deck areas of the topside structure, e.g. hull and superstructures, shall be based on Table D1 unless specified otherwise in the design basis or design brief. The intensity of the distributed loads depends on local and global aspects as shown in Table D1.

The following notations are used:

Local design: e.g. design of plates, stiffeners, beams and brackets
Primary design: e.g. design of girders and columns
Global design: e.g. design of deck main structure and substructure

Table D1 Variable functional loads on deck areas

Area	*Local design*		*Primary design*	*Global design*
	Distributed load, q (kN/m^2)	*Point load, P (kN)*	*Apply factor to distributed load*	*Apply factor to primary design load*
Storage areas	q	1.5 q	1.0	1.0
Lay down areas	q	1.5 q	f	f
Lifeboat platforms	9.0	9.0	1.0	may be ignored
Area between equipment	5.0	5.0	f	may be ignored
Walkways, staircases and platforms, crew spaces	4.0	4.0	f	may be ignored
Walkways and staircases for inspection only	3.0	3.0	f	may be ignored
Areas not exposed to other functional loads	2.5	2.5	1.0	-

Notes:

- Wheel loads to be added to distributed loads where relevant. (Wheel loads can normally be considered acting on an area of 300 x 300 mm.)
- Point loads, P, may be applied on an area 100 x 100 mm, and at the most severe position, but not added to wheel loads or distributed loads.
- The distributed loads, q, to be evaluated for each case. Lay down areas should not be designed for less than 15 kN/m^2.
- The factor f may be taken as: $f = \min\{1.0; (0.5 + 3/\sqrt{A})\}$, where A is the loaded area in m^2.
- Global load cases should be established based upon "worst case", characteristic load combinations, complying with the limiting global criteria to the structure. For buoyant structures these criteria are established by requirements for the floating position in still water, and intact and damage stability requirements, as documented in the operational manual, considering variable load on the decks and in tanks.
- The right column of the table, i.e. "Global design", presents variable functional loads to be included in load model for the global analysis. In the capacity checks, stresses from the global analysis shall be combined with the effect of local loads, i.e. tank pressures, weight of equipment, etc.

D 300 Tank pressures

301 The structure shall be designed to resist the maximum hydrostatic pressure of the heaviest filling in tanks that may occur during fabrication, installation and operation.

302 Hydrostatic pressures in tanks should normally be based on a minimum density equal to that of seawater, $\rho = 1.025\ t/m^3$. Tanks for higher density fluids (e.g. mud) shall be designed on basis of special consideration. The density, upon which the scantlings of individual tanks are based, shall be given in the operating manual.

303 Pressure loads that may occur during emptying of water or oil filled structural parts for condition monitoring; maintenance or repair shall be evaluated.

304 Hydrostatic pressure heads shall be based on tank filling arrangement by for example pumping, gravitational effect, accelerations as well as venting arrangements.

305 Pumping pressures may be limited by installing appropriate alarms and auto-pump cut-off system, i.e. high level and high-high level with automatic stop of the pumps. In such a situation the pressure head may be taken to be the cut-off pressure head. Descriptions and requirements related to different tank arrangements are given in DNV-OS-D101 Ch.2 Sec.3 C300.

306 Dynamic pressure heads due to flow through pipes shall be considered, see 308.

307 The internal pressure in full tanks should be defined by the formula:

$$p_d = \rho\ g_0\ h_{op}\left(1 + \frac{a_v}{g_0}\right) \quad (kN/m^2)$$

h_{op} = vertical distance (m) from the load point to the position of maximum filling height. For tanks adjacent to the sea that are situated below the extreme operational or transit draught, the maximum filling height should not be taken lower than the extreme operational draught
a_v = maximum vertical acceleration, (m/s^2), being the coupled motion response applicable to the tank in question.
ρ = density of liquid (t/m^3)
g_0 = 9.81 m/s^2

308 For tanks where the air-pipe may be filled during filling operations, a special tank filling design condition shall be checked according to loading condition a). The following additional internal design pressure conditions shall be used:

$$p_d = \rho\, g_0\, h_{op} + p_{dyn} \quad (\mathrm{kN/m^2})$$

p_{dyn} = pressure (kN/m^2) due to flow through pipes, minimum 25 kN/m^2

309 In cases where the maximum filling height is less than the height to the top of the air pipe, it shall be ensured that the tank will not be over-pressured during operation and tank testing conditions.

310 In a situation where design pressure head might be exceeded, should be considered as an accidental condition.

311 Requirements for testing of tank tightness and structural strength are given in DNV-OS-C401 Ch.2 Sec.4.

D 400 Lifeboat platforms

401 Lifeboat platforms shall be checked for the strength and accidental design conditions if relevant. A dynamic factor of 0.2 g_0 due to retardation of the lifeboats when lowered shall be included in both strength and accidental design conditions.

E. Environmental Loads

E 100 General

101 All environmental phenomena which may contribute to structural damages shall be considered. Examples are:

— hydrodynamic loads induced by waves and current
— inertia forces
— wind
— tidal effects
— marine growth
— snow and ice
— earthquake.

102 The probability of occurrence of the different types of environmental loads and their variation in magnitude, position and direction during the period under consideration, and related to operations and normal use of the unit, shall accounted for.

103 Practical information regarding environmental loads and conditions are given in Classification Note 30.5.

E 200 Environmental conditions for mobile units

201 The design of mobile offshore units shall be based on the most severe environmental loads that the structure may experience during its design life. The applied environmental conditions shall be defined in the design basis or design brief, and stated in the unit's Operation Manual.

202 The North Atlantic scatter diagram should be used for strength and fatigue for unrestricted world wide operation.

E 300 Environmental conditionss for site specific units

301 The parameters describing the environmental conditions shall be based on observations from or in the vicinity of the relevant location and on general knowledge about the environmental conditions in the area. Data for the joint occurrence of for example wave, wind and current conditions should be applied.

302 According to this standard, the environmental loads shall be determined with stipulated probabilities of exceedance. The statistical analysis of measured data or simulated data should make use of different statistical methods to evaluate the sensitivity of the result. The validation of distributions with respect to data should be tested by means of recognised methods.

303 The analysis of the data shall be based on the longest possible time period for the relevant area. In the case of short time series the statistical uncertainty shall be accounted for when determining design values. Hindcasting may be used to extend measured time series, or to interpolate to places where measured data have not been collected. If hindcasting is used, the model shall be calibrated against measured data, to ensure that the hindcast results comply with available measured data.

E 400 Determination of hydrodynamic loads

401 Hydrodynamic loads shall be determined by analysis. When theoretical predictions are subjected to significant uncertainties, theoretical calculations shall be supported by model tests or full scale measurements of existing structures or by a combination of such tests and full scale measurements.

402 Hydrodynamic model tests should be carried out to:

— confirm that no important hydrodynamic feature has been overlooked by varying the wave parameters (for new types of installations, environmental conditions, adjacent structure, etc.)
— support theoretical calculations when available analytical methods are susceptible to large uncertainties
— verify theoretical methods on a general basis.

403 Models shall be sufficient to represent the actual installation. The test set-up and registration system shall provide a basis for reliable, repeatable interpretation.

404 Full-scale measurements may be used to update the response prediction of the relevant structure and to validate the response analysis for future analysis. Such tests may especially be applied to reduce uncertainties associated with loads and load effects, which are difficult to simulate in model scale.

405 In full-scale measurements it is important to ensure sufficient instrumentation and logging of environmental conditions and responses to ensure reliable interpretation.

406 Wind tunnel tests should be carried out when:

— wind loads are significant for overall stability, offset, motions or structural response
— there is a danger of dynamic instability.

407 Wind tunnel test may support or replace theoretical calculations when available theoretical methods are susceptible to large uncertainties (e.g. due to new type of installations or adjacent installation influence the relevant installation).

408 Theoretical models for calculation of loads from icebergs or drift ice should be checked against model tests or full-scale measurements.

409 Proof tests of the structure may be necessary to confirm assumptions made in the design.

410 Hydrodynamic loads on appurtenances (anodes, fenders, strakes etc,) shall be taken into account, when relevant.

E 500 Wave loads

501 Wave theory or kinematics shall be selected according to recognised methods with due consideration of actual water depth and description of wave kinematics at the surface and the water column below.

502 Linearised wave theories (e.g. Airy) may be used when appropriate. In such circumstances the influence of finite amplitude waves shall be taken into consideration.

503 Wave loads can be determined according to Classification Note 30.5.

504 For large volume structures where the wave kinematics is disturbed by the presence of the structure, typical radiation and diffraction analyses shall be performed to determine the wave loads e.g. excitation forces or pressures.

505 For slender structures (typically chords and bracings, tendons, risers) where the Morison equation is applicable, the wave loads should be estimated by selection of drag and inertia coefficients as specified in Classification Note 30.5.

506 In the case of adjacent large volume structures disturbing the free field wave kinematics, the presence of the adjacent structures may be considered by radiation and diffraction analyses for calculation of the wave kinematics.

E 600 Wave induced inertia forces

601 The load effect from inertia forces shall be taken into account in the design. Examples where inertia forces can be of significance is:

— heavy objects
— tank pressures
— flare towers
— drilling towers
— crane pedestals.

E 700 Current

701 Current design velocities shall be based upon appropriate consideration of velocity and height profiles and directionality.

Guidance note:
Further details regarding current loads are given in Classification Note 30.5.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

E 800 Wind loads

801 The wind velocity at the location of the installation shall be established on the basis of previous measurements at the actual and adjacent locations, hindcast predictions as well as theoretical models and other meteorological information. If the wind velocity is of significant importance to the design and existing wind data are scarce and uncertain, wind velocity measurements should be carried out at the location in question.

802 Characteristic wind design velocities shall be based upon appropriate considerations of velocity and height profiles for the relevant averaging time.

Guidance note:
Practical information in respect to wind conditions, including velocity and height profiles, is documented in Classification Note 30.5.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

803 Formulas for calculation of wind loads may be taken from Classification Note 30.5 Sec.5. Applicable shape coefficient for different structures may also be found in the below sections for different types of units.

804 The pressure acting on vertical external bulkheads exposed to wind shall not be taken less than 2.5 kN/m^2 unless otherwise documented.

E 900 Vortex induced oscillations

901 Consideration of loads from vortex shedding on individual elements due to wind, current and waves may be based on Classification Note 30.5. Vortex induced vibrations of frames shall also be considered. The material and structural damping of individual elements in welded steel structures shall not be set higher than 0.15% of critical damping.

E 1000 Water level and tidal effects

1001 When determining water level in the calculation of loads, the tidal waters and storm surge shall be taken into account, see Classification Note 30.5.

1002 For floating structures constrained by tendon mooring systems, tidal effects can significantly influence the structure's buoyancy and the mean loads in the mooring components. Therefore the choice of tide conditions for static equilibrium analysis is important. Tidal effects should be considered in evaluating the various responses of interest. Higher mean water levels tend to increase maximum mooring tensions, hydrostatic loads, and current loads on the hull, while tending to decrease under deck wave clearances.

1003 These effects of tide may be taken into account by performing a static balance at the various appropriate tide levels to provide a starting point for further analysis, or by making allowances for the appropriate tide level in calculating extreme responses.

Guidance note:
For example, the effects of the highest tide level consistent with the probability of simultaneous occurrence of other extreme environmental conditions should be taken into account in estimating maximum tendon tensions for a TLP.

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E 1100 Marine growth

1101 Marine growth is a common designation for a surface coating on marine structures, caused by plants, animals and bacteria. In addition to the direct increase in structure weight, marine growth may cause an increase in hydrodynamic drag and added mass due to the effective increase in member dimensions, and may alter the roughness characteristics of the surface.

E 1200 Snow and ice accumulation

1201 Ice accretion from sea spray, snow, rain and air humidity shall be considered, where relevant.

1202 Snow and ice loads may be reduced or neglected if snow and ice removal procedures are established.

1203 When determining wind and hydrodynamic load, possible increases of cross-sectional area and changes in surface roughness caused by icing shall be considered, where relevant.

1204 For buoyant structures the possibility of uneven distribution of snow and ice accretion shall be considered.

E 1300 Direct ice load

1301 Where impact with sea ice or icebergs may occur, the contact loads shall be determined according to relevant, recognised theoretical models, model tests or full-scale measurements.

1302 When determining the magnitude and direction of the loads, the following factors shall be considered:

— geometry and nature of the ice
— mechanical properties of the ice
— velocity and direction of the ice
— geometry and size of the ice and structure contact area
— ice failure mode as a function of the structure geometry
— environmental forces available to drive the ice
— inertia effects for both ice and structure.

E 1400 Earthquake

1401 Earthquake effects shall be considered for bottom fixed structures where relevant.

1402 Earthquake excitation design loads and load histories may be described either in terms of response spectra or in terms of time histories. For the response spectrum method all modes of vibration which contribute significantly to the response shall be included. Correlation effects shall be accounted for when combining the modal response maximum.

1403 When performing time-history earthquake analysis, the response of the structure/foundation system shall be analysed for a representative set of time histories. Such time histories shall be selected and scaled to provide a best fit of the earthquake motion in the frequency range where the main dynamic response is expected.

1404 The dynamic characteristics of the structure and its foundation should be determined using a three-dimensional analytical model. A two-dimensional or asymmetric model may be used for the soil and structure interaction analysis provided compatibility with the three-dimensional structural model is ensured.

1405 Where characteristic ground motions, soil characteristics, damping and other modelling parameters are subject to great uncertainties, a parameter sensitivity study should be carried out.

1406 Consideration shall be given to the possibility that earthquakes in the local region may cause other effects such as subsea earth slides, critical pore pressure built-up in the soil or major soil deformations affecting foundation slabs, piles or skirts.

F. Combination of Environmental Loads

F 100 General

101 Where applicable data are available joint probability of environmental load components, at the specified probability level, may be considered. Alternatively, joint probability of environmental loads may be approximated by combination of characteristic values for different load types as shown in Table F1.

102 Generally, the long-term variability of multiple loads may be described by a scatter diagram or joint density function including information about direction. Contour curves may then be derived which give combination of environmental parameters, which approximately describe the various loads corresponding to the given probability of exceedance.

103 Alternatively, the probability of exceedance may be referred to the load effects. This is particularly relevant when direction of the load is an important parameter.

104 The load intensities for various types of loads may be combined according to the probabilities of exceedance as given in Table F1.

105 In a short-term period with a combination of waves and fluctuating wind, the individual variations of the two load processes may be assumed uncorrelated.

Table F1 Possible combinations of environmental loads to represent combinations with 10^{-2} annual probability of exceedance for loading condition b and loads with return period not less than one year for loading condition d and e

Condition	*Wind*	*Waves*	*Current*	*Ice*	*Sea level*
Strength (loading condition b)	10^{-2}	10^{-2}	10^{-1}		10^{-2}
	10^{-1}	10^{-1}	10^{-2}		10^{-2}
	10^{-1}	10^{-1}	10^{-1}	10^{-2}	mean water level
Accidental (loading condition d and e)	return period not less than one year	return period not less than one year	return period not less than one year		return period not less than one year

G. Accidental Loads

G 100 General

101 Accidental loads are loads related to abnormal operations or technical failure. Examples of accidental loads are loads caused by:

- dropped objects
- collision impact
- explosions
- fire
- change of intended pressure difference
- accidental impact from vessel, helicopter or other objects
- unintended change in ballast distribution
- failure of a ballast pipe or unintended flooding of a hull compartment
- failure of mooring lines
- loss of dynamic positioning (DP) system causing loss of heading.

102 Relevant accidental loads should be determined on the basis of an assessment and relevant experiences. With respect to planning, implementation, use and updating of such assessment and generic accidental loads, see DNV-OS-A101.

103 For temporary design conditions, the representative value may be a specified value dependent on practical requirements. The level of safety related to the temporary design conditions shall not be inferior to the safety level required for the operating design conditions.

H. Deformation Loads

H 100 General

101 Deformation loads are loads caused by inflicted deformations such as:

- temperature loads
- built-in deformations
- settlement of foundations
- tether pre-tension on a tension leg platform (TLP).

H 200 Temperature loads

201 Structures shall be designed for the most extreme temperature differences they may be exposed to. This applies, but not limited, to:

- storage tanks
- structural parts that are exposed to radiation from the top of a flare boom. For flare born radiation a one hour mean wind with a return period of one year may be used to calculate the spatial flame extent and the air cooling in the assessment of heat radiation from the flare boom
- structural parts that are in contact with pipelines, risers or process equipment.

202 The ambient sea or air temperature is calculated as an extreme value with an annual probability of exceedance equal to 10^{-2} (100 years).

H 300 Settlements and subsidence of sea bed

301 Settlement of the foundations into the sea bed shall be considered for permanently located bottom founded units.

302 The possibility of, and the consequences of, subsidence of the seabed as a result of changes in the subsoil and in the production reservoir during the service life of the installation, shall be considered.

303 Reservoir settlements and subsequent subsidence of the seabed should be calculated as a conservatively estimated mean value.

I. Fatigue loads

I 100 General

101 Repetitive loads, which may lead to significant fatigue damage, shall be evaluated. The following listed sources of fatigue loads shall, where relevant, be considered:

— waves (including those loads caused by slamming and variable (dynamic) pressures)
— wind (especially when vortex induced vibrations may occur)
— currents (especially when vortex induced vibrations may occur)
— mechanical loading and unloading (e.g. crane loads).

The effects of both local and global dynamic response shall be properly accounted for when determining response distributions related to fatigue loads.

102 Further considerations in respect to fatigue loads are given in DNV-RP-C203 and Classification Note 30.5.

J. Load Effect Analysis

J 100 General

101 Load effects, in terms of motions, displacements, or internal forces and stresses of the structure, shall be determined considering:

— the spatial and temporal nature of the loads, including possible non-linearities of the load as well as non-linear and dynamic character of the response
— the relevant conditions for design check
— the desired accuracy for the relevant design phase.

102 Permanent, functional, deformation, and fire loads may generally be treated by static methods of analysis. Environmental (wave and earthquake) loads and certain accidental loads (impacts, explosions) may require dynamic analysis. Inertia and damping forces are important when the periods of steady-state loads are close to natural periods or when transient loads occur.

103 In general, three frequency bands need to be considered for offshore structures:

High frequency (HF)	Rigid body natural periods below dominating wave periods (typically ringing and springing responses in TLP's).
Wave frequency (WF)	Area with wave periods in the range 4 to 25 s typically. Applicable to all offshore structures located in the wave active zone.
Low frequency (LF)	Frequency band relating to slowly varying responses with natural periods above dominating wave energy (typically slowly varying surge and sway motions for column-stabilised units as well as slowly varying roll and pitch motions for deep draught floaters).

104 A global wave motion analysis is required for structures with at least one free mode. For fully restrained structures a static or dynamic wave-structure-foundation analysis is required.

105 Uncertainties in the analysis model are expected to be taken care of by the basic usage factors. If uncertainties are particularly high, conservative assumptions shall be made.

106 If analytical models are particularly uncertain, the sensitivity of the models and the parameters utilised in the models shall be examined. If geometric deviations or imperfections have a significant effect on load effects, conservative geometric parameters shall be used in the calculation.

107 In the final design stage theoretical methods for prediction of important responses of any novel system should normally be verified by appropriate model tests. (See Sec.2 F).

108 Earthquake loads need only be considered for restrained modes of behaviour. See sections with special considerations for each type of unit for requirements related to the different objects.

J 200 Global motion analysis

201 The purpose of a motion analysis is to determine displacements, accelerations, velocities and hydrodynamic pressures relevant for the loading on the hull and superstructure, as well as relative motions (in free modes) needed to assess air gap and green water requirements. Excitation by waves, current and wind should be considered.

J 300 Load effects in structures and soil or foundation

301 Displacements, forces or stresses in the structure and foundation, shall be determined for relevant combinations of loads by means of recognised methods, which take adequate account of the variation of loads in time and space, the motions of the structure and the design condition which shall be verified. Characteristic values of the load effects shall be determined.

302 Non-linear and dynamic effects associated with loads and structural response, shall be accounted for when relevant.

303 The stochastic nature of environmental loads should be adequately accounted for.

304 Description of the different types of analyses are covered in the sections for special considerations for each type of unit and recommended practices.

SECTION 4 STRUCTURAL CATEGORISATION, MATERIAL SELECTION AND INSPECTION PRINCIPLES

A. General

A 100

101 This section describes the structural categorisation, selection of steel materials and inspection principles to be applied in design and construction of offshore steel structures.

B. Temperatures for Selection of Material

B 100 General

101 The design temperature for a unit is the reference temperature for assessing areas where the unit can be transported, installed and operated.

The design temperature shall be lower or equal to the *lowest mean daily temperature* in air for the relevant areas. For seasonal restricted operations the *lowest mean daily temperature* in air for the season may be applied.

102 The service temperatures for different parts of a unit apply for selection of structural steel.

103 The service temperature for various structural parts is given in B200 and B300. In case different service temperatures are defined in B200 and B300 for a structural part the lower specified value shall be applied. Further details regarding service temperature for different structural elements are given in the sections for different types of units.

104 In all cases where the temperature is reduced by localised cryogenic storage or other cooling conditions, such factors shall be taken into account in establishing the service temperatures for considered structural parts.

B 200 Floating units

201 External structures above the lowest waterline shall be designed with service temperature not higher than the *design temperature* for the area(s) where the unit is to operate.

202 External structures below the lowest waterline need not be designed for service temperatures lower than 0°C. A higher service temperature may be accepted if adequate supporting data can be presented relative to the lowest mean daily temperature applicable to the relevant actual water depths.

203 Internal structures in way of permanently heated rooms need not be designed for service temperatures lower than 0°C.

B 300 Bottom fixed units

301 External structures above the lowest astronomical tide (LAT) shall be designed with service temperature not higher than the *design temperature*.

302 Materials in structures below the lowest astronomical tide (LAT) need not be designed for service temperatures lower than of 0°C. A higher service temperature may be accepted if adequate supporting data can be presented relative to the *lowest mean daily* temperature applicable for the relevant water depths.

C. Structural Category

C 100 General

101 The purpose of the structural categorisation is to assure adequate material and suitable inspection to avoid brittle fracture. The purpose of inspection is also to remove defects that may grow into fatigue cracks during service life.

Guidance note:

Conditions that may result in brittle fracture are sought avoided. Brittle fracture may occur under a combination of:

- presence of sharp defects such as cracks
- high tensile stress in direction normal to planar defect(s)
- material with low fracture toughness.

Sharp cracks resulting from fabrication may be found by inspection and repaired. Fatigue cracks may also be discovered during service life by inspection.

High stresses in a component may occur due to welding. A complex connection is likely to provide more restraint and larger residual stress than a simple one. This residual stress may be partly removed by post weld heat treatment if necessary. Also a complex connection shows a more three-dimensional stress state due to external loading than simple connections. This stress state may provide basis for a cleavage fracture.

The fracture toughness is dependent on temperature and material thickness. These parameters are accounted for separately in selection of material. The resulting fracture toughness in the weld and the heat affected zone is also dependent on the fabrication method.

Thus, to avoid brittle fracture, first a material with a suitable fracture toughness for the actual service temperature and thickness is selected. Then a proper fabrication method is used. In special cases post weld heat treatment may be performed to reduce crack driving stresses, see D501 and DNV-OS-C401. A suitable amount of inspection is carried out to remove planar defects larger than acceptable. In this standard selection of material with appropriate fracture toughness and avoidance of unacceptable defects are achieved by linking different types of connections to different structural categories and inspection categories.

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C 200 Selection of structural category

201 Components are classified into structural categories according to the following criteria:

— significance of component in terms of consequence of failure
— stress condition at the considered detail that together with possible weld defects or fatigue cracks may provoke brittle fracture.

Guidance note:

The consequence of failure may be quantified in terms of residual strength of the structure when considering failure of the actual component.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

202 Structural category for selection of materials shall be determined according to principles given in Table C1. Further details regarding selection of structural categories for different types of units are given in Sec.11 to 14.

Table C1 Structural categories for selection of materials	
Structural category	*Principles for determination of structural category*
Special	Structural parts where failure will have substantial consequences and are subject to a stress condition that may increase the probability of a brittle fracture.1)
Primary	Structural parts where failure will have substantial consequences.
Secondary	Structural parts where failure will be without significant consequence.
1) In complex joints a tri-axial or bi-axial stress pattern will be present. This may give conditions for brittle fracture where tensile stresses are present in addition to presence of defects and material with low fracture toughness.	

C 300 Inspection of welds

301 Requirements for type and extent of inspection are given in DNV-OS-C401 dependent on assigned inspection category for the welds. The requirements are based on the consideration of fatigue damage and assessment of general fabrication quality.

302 The inspection category is by default related to the structural category according to Table C2.

Table C2 Inspection categories	
Inspection category	*Structural category*
I	Special
II	Primary
III	Secondary

303 The weld connection between two components shall be assigned an inspection category according to the highest of the joined components. For stiffened plates, the weld connection between stiffener and stringer and girder web to the plate may be inspected according to inspection category III.

304 If the fabrication quality is assessed by testing, or well known quality from previous experience, the extent of inspection required for elements within structural category *primary* may be reduced, but not less than for inspection category III.

305 Fatigue critical details within structural category *primary* and *secondary* shall be inspected according to requirements in category I.

306 Welds in fatigue critical areas not accessible for inspection and repair during operation shall be inspected according to requirements in category I during construction.

307 Inspection categories determined in accordance with the above provide requirements for the minimum extent of required inspection. When considering the economic consequence that repair may entail, for example, in way of complex connections with limited or difficult access, it may be considered prudent engineering practice to require more demanding requirements for inspection than the required minimum.

308 When determining the extent of inspection, and the locations of required NDT, in addition to evaluating design parameters (for example fatigue utilisation) consideration should be given to relevant fabrication parameters including;

— location of block (section) joints
— manual versus automatic welding
— start and stop of weld etc.

309 The extent of NDT for welds in block joints and erection joints transverse to main stress direction shall not be less than for IC II.

D. Structural Steel

D 100 General

101 Where the subsequent requirements for steel grades are dependent on plate thickness, these are based on the nominal thickness as built.

102 The requirements in this subsection deal with the selection of various structural steel grades in compliance with the requirements given in DNV-OS-B101. Where other, agreed codes or standards have been utilised in the specification of steels, the application of such steel grades within the structure shall be specially considered.

103 When considering criteria appropriate to material grade selection, adequate consideration shall be given to all relevant phases in the life cycle of the unit. There may be conditions and criteria, other than those from the in-service, operational phase, that provide the design requirements in respect to the selection of material, e.g. design temperature and/or stress levels during the construction phase or marine operations.

104 The steel grades selected for structural components shall be related to calculated stresses and requirements to toughness properties. Requirements for toughness properties are in general based on the Charpy V-notch test and are dependent on service temperature, structural category and thickness of the component in question.

105 The material toughness may also be evaluated by fracture mechanics testing in special cases, see D401 and DNV-OS-C401.

106 In structural cross-joints where high tensile stresses are acting perpendicular to the plane of the plate, the plate material shall be tested to prove the ability to resist lamellar tearing, e.g. by Z-quality, see 203.

107 Requirements for forging and castings are given in DNV-OS-B101.

D 200 Material designations

201 Structural steel of various strength groups will be referred to as given in Table D1.

202 Each strength group consists of two parallel series of steel grades:

— steels of normal weldability
— steels of improved weldability.

The two series are intended for the same applications. However, the improved weldability grades have in addition to leaner chemistry and better weldability, extra margins to account for reduced toughness after welding. These grades are also limited to a specified minimum yield stress of 500 N/mm^2.

Table D1 Material designations		
Designation	*Strength group*	*Specified minimum yield stress f_y (N/mm^2)1)*
NV	Normal strength steel (NS)	235
NV-27	High strength steel (HS)	265
NV-32		315
NV-36		355
NV-40		390

NV-420	Extra high strength steel (EHS)	420
NV-460		460
NV-500		500
NV-550		550
NV-620		620
NV-690		690
1) For steels of improved weldability the required specified minimum yield stress is reduced for increasing material thickness, see DNV-OS-B101.		

203 Different steel grades are defined within each strength group, depending upon the required impact toughness properties. The grades are referred to as A, B, D, E, F or AW, BW, DW, EW for improved weldability grades as shown in Table D2.

Additional symbol:

Z = steel grade of proven through-thickness properties. This symbol is omitted for steels of improved weldability although improved through-thickness properties are required.

Table D2 Applicable steel grades

Strength group	*Grade*		*Test temperature 2) (°C)*
	Normal weldability	*Improved weldability 1)*	
NS	A	-	Not tested
	B 3)	BW	0
	D	DW	-20
	E	EW	-40
HS	A	AW	0
	D	DW	-20
	E	EW	-40
	F	-	-60
EHS	A	-	0
	D	DW	-20
	E	EW	-40
	F	-	-60

1) For steels with improved weldability, through-thickness properties are specified, see DNV-OS-B101.
2) Charpy V-notch impact tests, see DNV-OS-B101.
3) Charpy V-notch tests are required for thickness above 25 mm but are subject to agreement between the contracting parties for thickness of 25 mm or less.

D 300 Selection of structural steel

301 The grade of steel to be used shall in general be related to the service temperature and thickness for the applicable structural category as shown in Table D3.

302 Selection of a better steel grade than minimum required in design shall not lead to more stringent requirements in fabrication.

303 Grade of steel to be used for thickness less than 10 mm and/or service temperature above 10°C may be specially considered.

304 Welded steel plates and sections of thickness exceeding the upper limits for the actual steel grade as given in Table D3 shall be evaluated in each individual case with respect to the fitness for purpose of the weldments. The evaluation should be based on fracture mechanics testing and analysis, e.g. in accordance with BS 7910.

305 For structural parts subjected to compressive and/or low tensile stresses, consideration may be given to the use of lower steel grades than stated in Table D3.

306 The use of steels with specified minimum yield stress greater than 550 N/mm^2 (NV550) shall be subject to special consideration for applications where anaerobic environmental conditions such as stagnant water, organically active mud (bacteria) and hydrogen sulphide may predominate.

307 Predominantly anaerobic conditions can for this purpose be characterised by a concentration of sulphate reducing bacteria, SRB, in the order of magnitude >10^3 SRB/ml (method according to NACE TPC Publication No.3).

308 The steels' susceptibility to hydrogen induced stress cracking (HISC) shall be specially considered when used for critical applications (such as jack-up legs and spud cans). See also Sec.10.

Table D3 Thickness limitations(mm) of structural steels for different structural categories and service temperatures (°C)

Structural Category	*Grade*	*≥ 10*	*0*	*-10*	*-20*	*-25*	*-30*
Secondary	A	35	30	25	20	15	10
	B/BW	70	60	50	40	30	20
	D/DW	150	150	100	80	70	60
	E/EW	150	150	150	150	120	100
	AH/AHW	60	50	40	30	20	15
	DH/DHW	120	100	80	60	50	40
	EH/EHW	150	150	150	150	120	100
	FH	150	150	150	150	*)	*)
	AEH	70	60	50	40	30	20
	DEH/DEHW	150	150	100	80	70	60
	EEH/EEHW	150	150	150	150	120	100
	FEH	150	150	150	150	*)	*)
Primary	A	30	20	10	N.A.	N.A.	N.A.
	B/BW	40	30	25	20	15	10
	D/DW	70	60	50	40	35	30
	E/EW	150	150	100	80	70	60
	AH/AHW	30	25	20	15	12.5	10
	DH/DHW	60	50	40	30	25	20
	EH/EHW	120	100	80	60	50	40
	FH	150	150	150	150	*)	*)
	AEH	35	30	25	20	17.5	15
	DEH/DEHW	70	60	50	40	35	30
	EEH/EEHW	150	150	100	80	70	60
	FEH	150	150	150	150	*)	*)
Special	D/DW	35	30	25	20	17.5	15
	E/EW	70	60	50	40	35	30
	AH/AHW	15	10	N.A.	N.A.	N.A.	N.A.
	DH/DHW	30	25	20	15	12.5	10
	EH/EHW	60	50	40	30	25	20
	FH	120	100	80	60	50	40
	AEH	20	15	10	N.A.	N.A	N.A.
	DEH/DEHW	35	30	25	20	17.5	15
	EEH/EEHW	70	60	50	40	35	30
	FEH	150	150	100	80	70	60

*) For service temperature below -20°C the upper limit for use of this grade must be specially considered.

N.A. = no application

D 400 Fracture mechanics (FM) testing

401 For units which are intended to operate continuously at the same location for more than 5 years, FM testing shall be included in the qualification of welding procedures for joints which all of the following apply:

— the design temperature is lower than +10°C
— the joint is in special area
— at least one of the adjoining members is fabricated from steel with a SMYS larger than or equal to 420 MPa.

For details on FM testing methods, see DNV-OS-C401 Ch.2 Sec.1 C800.

D 500 Post weld heat treatment (PWHT)

501 For units which are intended to operate continuously at the same location for more than 5 years, PWHT shall be applied for joints in C-Mn steels in special areas when the material thickness at the welds exceeds 50mm. For details, see DNV-OS-C401 Ch.2 Sec.1 F200.

SECTION 5 STRUCTURAL STRENGTH

A. General

A 100 General

101 This section gives provisions for checking of ultimate strength for typical structural elements used in offshore steel structures.

102 The ultimate strength capacity (yield and buckling) of structural elements shall be assessed using a rational, justifiable, engineering approach.

103 Structural capacity checks of all structural components shall be performed. The capacity checks shall consider both excessive yielding and buckling.

104 Simplified assumptions regarding stress distributions may be used provided the assumptions are made in accordance with generally accepted practice, or in accordance with sufficiently comprehensive experience or tests.

105 Gross scantlings may be utilised in the calculation of hull structural strength, provided a corrosion protection system in accordance with Sec.10 is installed and maintained.

106 In case corrosion protection in accordance with Sec.10 is not installed (and maintained) corrosion additions as given in Sec.10 B407 shall be used. The corrosion addition shall not be accounted for in the determination of stresses and resistance for local capacity checks.

A 200 Structural analysis

201 The structural analysis may be carried out as linear elastic, simplified rigid-plastic, or elastic-plastic analyses. Both first order or second order analyses may be applied. In all cases, the structural detailing with respect to strength and ductility requirement shall conform to the assumption made for the analysis.

202 When plastic or elastic-plastic analyses are used for structures exposed to cyclic loading e.g. wave loads, checks shall be carried out to verify that the structure will shake down without excessive plastic deformations or fracture due to repeated yielding. A characteristic or design cyclic load history needs to be defined in such a way that the structural reliability in case of cyclic loading e.g. storm loading, is not less than the structural reliability for ultimate strength for non-cyclic loads.

203 In case of linear analysis combined with the resistance formulations set down in this standard, shakedown can be assumed without further checks.

204 If plastic or elastic-plastic structural analyses are used for determining the sectional stress resultants, limitations to the width to thickness ratios apply. Relevant width to thickness ratios are found in the relevant codes used for capacity checks.

205 When plastic analysis and/or plastic capacity checks are used e.g. cross section Type I and II, according to Appendix A, the members shall be capable of forming plastic hinges with sufficient rotation capacity to enable the required redistribution of bending moments to develop. It shall also be checked that the load pattern will not be changed due to the deformations.

206 Cross sections of beams are divided into different types dependent of their ability to develop plastic hinges. A method for determination of cross sectional types is found in Appendix A.

A 300 Ductility

301 It is a fundamental requirement that all failure modes are sufficiently ductile such that the structural behaviour will be in accordance with the anticipated model used for determination of the responses. In general all design procedures, regardless of analysis method, will not capture the true structural behaviour. Ductile failure modes will allow the structure to redistribute forces in accordance with the presupposed static model. Brittle failure modes shall therefore be avoided or shall be verified to have excess resistance compared to ductile modes, and in this way protect the structure from brittle failure.

302 The following sources for brittle structural behaviour may need to be considered for a steel structure:

— unstable fracture caused by a combination of the following factors: brittle material, low temperature in the steel, a design resulting in high local stresses and the possibilities for weld defects
— structural details where ultimate resistance is reached with plastic deformations only in limited areas, making the global behaviour brittle
— shell buckling
— buckling where interaction between local and global buckling modes occurs.

A 400 Yield check

401 Structural members for which excessive yielding are possible modes of failure shall be investigated for yielding.

Individual stress components and the von Mises equivalent stress for plated structures shall not exceed the permissible stress, see Sec.2 E.

Guidance note:

a) For plated structures the von Mises equivalent stress is defined as follows:

$$\sigma_j = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x\sigma_y + 3\tau^2}$$

where σ_x and σ_y are membrane stresses in x- and y-direction respectively, τ is shear stress in the x-y plane, i.e. local bending stresses in plate thickness not included.

b) In case local plate bending stresses are of importance for yield check, e.g. for lateral loaded plates, yield check may be performed according to DNV-RP-C201 Sec. 5.

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402 The coefficient β, defined in Sec.2 E as the ratio between the permissible and basic usage factors, shall be equal to 1.0 for the yield checks.

403 Local peak stresses from linear elastic analysis in areas with pronounced geometrical changes, may exceed the yield stress provided the adjacent structural parts has capacity for the redistributed stresses.

Guidance note:

a) Areas above yield determined by a linear finite element method analysis may give an indication of the actual area of plastification. Otherwise, a non-linear finite element method analysis may need to be carried out in order to trace the full extent of the plastic zone.

b) The yield checks do not refer to local stress concentrations in the structure or to local modelling deficiencies in the finite element model.

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404 For large volume hull structures gross scantlings may be applied for calculation of stresses in connection with the yield checks.

405 For yield check of welded connections, see Sec.9.

A 500 Buckling check

501 Elements of cross sections not fulfilling requirements to cross section type III shall be checked for local buckling.

Cross sectional types are defined in Appendix A.

502 Buckling analysis shall be based on the characteristic buckling resistance for the most unfavourable buckling mode.

503 The characteristic buckling strength shall be based on the 5th percentile of test results.

504 The coefficient β, defined in Sec.2 E as the ratio between the permissible and basic usage factors, shall be equal to 1.0 for buckling check of flat plated structures and stiffened panels, beams, columns and frames. The coefficient β to be applied for buckling of shell structures are presented in C103.

505 Initial imperfections and residual stresses in structural members shall be accounted for.

506 It shall be ensured that there is conformity between the initial imperfections in the buckling resistance formulas and the tolerances in the applied fabrication standard.

Guidance note:

If buckling resistance is calculated in accordance with DNV-RP-C201 for plated structures, DNV-RP-C202 for shells, or Classification Note 30.1 for bars and frames, the tolerance requirements given in DNV-OS-C401 should not be exceeded, unless specifically documented.

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B. Flat Plated Structures and Stiffened Panels

B 100 Yield check

101 Yield check of plating and stiffeners may be performed as given in Sec.6.

102 Yield check of girders may be performed as given in Sec.6.

B 200 Buckling check

201 The buckling stability of plated structures may be checked according to DNV-RP-C201.

B 300 Capacity checks according to other codes

301 Stiffeners and girders may be designed according to provisions for beams in recognised standards such as AISC-ASD.

Guidance note:

The principles and effects of cross section types are included in the AISC-ASD.

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C. Shell Structures

C 100 General

101 The buckling stability of cylindrical and un-stiffened conical shell structures may be checked according to DNV-RP-C202.

102 For interaction between shell buckling and column buckling, DNV-RP-C202 may be used.

103 For shell bucking the coefficient β, defined in Sec.2 E as the ratio between the permissible and basic usage factors, shall be taken as shown in Table C1.

Table C1 The coefficient β for shell buckling

Type of structure	$\lambda \le 0.5$	$0.5 < \lambda < 1.0$	$\lambda \ge 1.0$
Girder, beams stiffeners on shells	1.0	1.0	1.0
Shells of single curvature (cylindrical shells, conical shells)	1.0	1.2 - 0.4 λ	0.8
Spherical shells	0.8	0.96 - 0.32 λ	0.64
Note that the slenderness is based on the buckling mode under consideration			

λ = reduced slenderness parameter

$$\sqrt{\frac{f_y}{\sigma_e}}$$

f_y = specified minimum yield stress

σ_e elastic buckling stress for the buckling mode under consideration.

D. Tubular Members, Tubular Joints and Conical Transitions

D 100 General

101 Tubular members may be checked according to Classification Note 30.1 or API RP 2A - WSD.

For interaction between local shell buckling and column buckling, and effect of external pressure, DNV-RP-C202 may be considered.

102 Cross sections of tubular member are divided into different types dependent of their ability to develop plastic hinges and resist local buckling. Effect of local buckling of slender cross sections shall be considered.

Guidance note:

a) Effect of local buckling of tubular members without external pressure, i.e. subject to axial force and/or bending moment) are given in Appendix A, cross section type IV.

Section 3.8 of DNV-RP-C202 may be used, see C100.

b) Effect of local buckling of tubular members with external pressure need not be considered for the following diameter (D_m) to thickness (t) ratio:

$$\frac{D_m}{t} \le 0.5\sqrt{\frac{E}{f_y}}$$

where

E = modulus of elasticity and

f_y = minimum yield stress.

In case of local shell buckling, see C100, section 3.8 of DNV-RP-C202, or API RP 2A-WSD may be used.

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103 Tubular members with external pressure, tubular joints and conical transitions may be checked according to API RP 2A-WSD.

E. Non-Tubular Beams, Columns and Frames

E 100 General

101 The design of members shall take into account the possible limits on the resistance of the cross section due to local buckling.

Guidance note:

Cross sections of member are divided into different types dependent of their ability to develop plastic hinges and resist local buckling, see Appendix A. In case of local buckling, i.e. for cross sectional type IV, DNV-RP-C201 may be used.

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102 Buckling checks may be performed according to Classification Note 30.1, or other recognised standards such as AISC-ASD.

SECTION 6
SECTION SCANTLINGS

A. General

A 100 Scope

101 The requirements in this section are applicable for:

— plate thicknesses and local strength of panels
— simple girders
— calculations of complex girder systems.

B. Strength of Plating and Stiffeners

B 100 Scope

101 The requirements in this section will normally give minimum scantlings for plate and stiffened panels with respect to yield. Dimensions and further references with respect to buckling capacity are given in Sec.5.

B 200 Minimum thickness

201 The thickness t of structures should not to be less than:

$$t = 15.3 \frac{t_m}{\sqrt{f_y}} \quad \text{(mm)}$$

t_m = 7 mm for primary structural elements
= 5 mm for secondary structural elements
f_y = minimum yield stress in N/mm^2, defined in Sec.4 Table D1.

B 300 Bending of plating

301 The thickness t of plating subjected to lateral pressure shall not be less than:

$$t = 15.8 \frac{k_a s \sqrt{p}}{\sqrt{\sigma_{p1} k_{pp}}} \quad \text{(mm)}$$

k_a = correction factor for aspect ratio of plate field
= $(1.1 - 0.25\ s/l)^2$
maximum 1.0 for $s/l = 0.4$
minimum 0.72 for $s/l = 1.0$
s = stiffener spacing in m, measured along the plating
p = lateral pressure in kN/m^2 as given in Sec.3 D
σ_{p1} = permissible bending stress (N/mm^2), taken as the smaller of:
$1.3\ (\sigma_p - \sigma_j)$ and

$\sigma_p = \eta_0\ f_y$

σ_j = equivalent stress for global in-plane membrane stress

$$\sigma_j = \sqrt{\sigma_x^{\ 2} + \sigma_y^{\ 2} - \sigma_x \sigma_y + 3\tau^2}$$

η_0 = basic usage factor, see Sec.2 Table E1
f_y = minimum yield strength, see Sec.4 Table D1
k_{pp} = fixation parameter for plate
= 1.0 for clamped edges
= 0.5 for simply supported edges.

Guidance note:

The design bending stress σ_{p1} is given as a bi-linear capacity curve for the plate representing the remaining capacity of plate when reduced for global in-plane membrane stress

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B 400 Stiffeners

401 The section modulus Z_s for longitudinals, beams, frames and other stiffeners subjected to lateral pressure shall not be less than:

$$Z_s = \frac{l^2 s\ p}{k_m \sigma_{p2} k_{ps}} 10^6 \quad (\text{mm}^3), \text{ minimum } 15\ 000 \text{ mm}^3$$

l = stiffener span in m
k_m = bending moment factor, see Table C1
σ_{p2} = permissible bending stress dependent on the type of loading condition, see Sec.2 D100
= $0.6\ f_y - \sigma_j$ (N/mm^2) for loading condition a)
= $0.8\ f_y - \sigma_j$ (N/mm^2) for loading condition b)
k_{ps} = fixation parameter for stiffeners
= 1.0 if at least one end is clamped
= 0.9 if both ends are simply supported.

Guidance note:

The design bending stress σ_{p2} is given as a linear capacity curve for the plate representing the remaining capacity of plate when reduced for global in-plane membrane stress

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402 For watertight bulkhead and deck or flat structures exposed to sea pressure (compartment flooded), see Sec.2 D100 loading condition e), 401 applies, taking:

$$\sigma_{p2} = f_y - \sigma_j \quad (\text{N/mm}^2)$$

403 The requirement in 401 applies to an axis parallel to the plating. For stiffeners at an oblique angle with the plating an approximate requirement to standard section modulus may be obtained by multiplying the section modulus from 401 with the factor:

$$\frac{1}{\cos\varphi}$$

φ = angle between the stiffener web plane and the plane perpendicular to the plating.

404 Stiffeners with sniped ends may be accepted where dynamic stresses are small and vibrations are considered to be of small importance, provided that the plate thickness t supported by the stiffener is not less than:

$$t = 19 \sqrt{\frac{(l - 0.5\ s)\ s\ p}{f_y}} \quad \text{(mm)}$$

In such cases the section modulus of the stiffener calculated as indicated in 401 is normally to be based on the following parameter values:

k_m = 8
k_{ps} = 0.9

The stiffeners should normally be snipped to an angle of maximum 30°.

Guidance note:

For typical sniped end details as described above, a stress range lower than 30 MPa can be considered as small dynamic stress.

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C. Bending and Shear in Girders

C 100 General

101 The requirements in this section give minimum scantlings to simple girders with respect to yield. Furthermore, procedures for the calculations of complex girder systems are indicated.

102 Dimensions and further references with respect to buckling capacity are given in Sec.5.

C 200 Minimum thickness

201 The thickness of web and flange plating shall not be less than given B201.

C 300 Bending and shear

301 The requirements for section modulus and web area given in 602 and 603 apply to simple girders supporting stiffeners or other girders exposed to linearly distributed lateral pressure. It is assumed that the girder satisfies the basic assumptions of simple beam theory, and that the supported members are approximately evenly spaced and similarly supported at both ends. Other loads should be specially considered based on the same beam-theory.

302 When boundary conditions for individual girders are not predictable due to dependence of adjacent structures, direct calculations according to the procedures given in 700 shall be carried out.

303 The section modulus and web area of the girder shall be taken in accordance with particulars as given in 400 and 500. Structural modelling in connection with direct stress analysis shall be based on the same particulars when applicable.

C 400 Effective flange

401 The effective plate flange area is defined as the cross-sectional area of plating within the effective flange width. The cross section area of continuous stiffeners within the effective flange may be included. The effective flange width b_e is determined by:

$$b_e = C_e b \quad (m)$$

C_e	=	parameter given in Fig.1 for various numbers of evenly spaced point loads (N_p) on the girder span
b	=	full breadth of plate flange in m, e.g. span of the supported stiffeners, or distance between girders, see also 602.
l_0	=	distance between points of zero bending moments in m
	=	S_g for simply supported girders
	=	0.6 S_g for girders fixed at both ends
S_g	=	girder span as if simply supported, see 602.

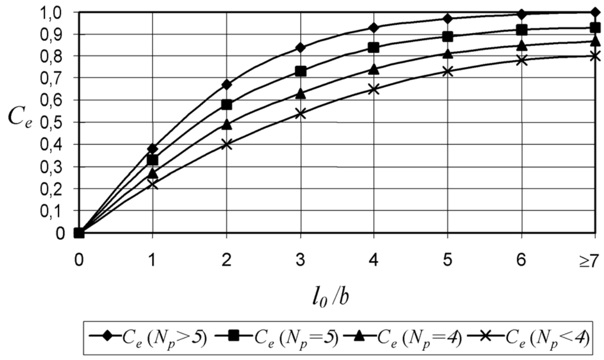


Figure 1
Graphs for the effective flange parameter C

C 500 Effective web

501 Holes in girders will generally be accepted provided the shear stress level is acceptable and the buckling capacity and fatigue life is documented to be sufficient.

C 600 Strength requirements for simple girders

601 Simple girders subjected to lateral pressure and which are not taking part in the overall strength of the unit, are to comply with the following:

— section modulus according to 602
— web area according to 603.

602 Section modulus Z_g:

$$Z_g = \frac{S_g^{\ 2}\, b\, p}{k_m \sigma_{p2}} 10^6 \quad (mm^3)$$

S_g	=	girder span in m. The web height of in-plane girders may be deducted. When bracket(s) are fitted at the end(s), the girder span S_g may be reduced by two thirds of the bracket arm length(s), provided the girder end(s) may be assumed clamped and provided the section modulus at the bracketed end(s) is satisfactory.
b	=	breadth of load area in m (plate flange), b may be determined as:
	=	0.5 ($l_1 + l_2$) where l_1 and l_2 are the spans of the supported stiffeners on both sides of the girder, respectively, or distance between girders
k_m	=	bending moment factor k_m-values in accordance with 605
σ_{p2}	=	bending stress, see B401.

603 Web area A_W:

$$A_W = \frac{k_\tau S_g b p - N_s P_p}{\tau_p} 10^3 \quad (mm^2)$$

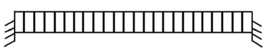
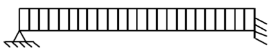
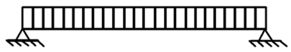
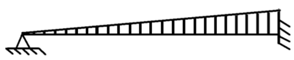
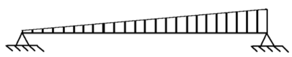
k_τ	=	shear force factor, see 605
N_s	=	number of stiffeners between considered section and nearest support. The N_s-value shall in no case be taken greater than (N_p + 1)/4
N_p	=	number of supported stiffeners on the girder span
P_p	=	average “point load” (kN) from stiffeners between considered section and nearest support
τ_p	=	0.39 f_y (N/mm^2) for loading condition a)
	=	0.46 f_y (N/mm^2) for loading condition b).

604 For watertight bulkhead and deck or flat structures exposed to sea pressure, i.e. compartment flooded in loading condition e), 602 and 603 apply, taking:

σ_{p2} = 0.91 f_y (N/mm^2) in 602
τ_p = 0.5 f_y (N/mm^2) in 603.

605 The k_m- and k_τ-values in 602 and 603 may be calculated according to general beam theory. In Table C1, k_m- and k_τ-values are given for some defined load and boundary conditions. Note that the smallest k_m-value shall be applied to simple girders. For girders where brackets are fitted or the flange area has been partly increased due to large bending moment, a larger k_m-value may be used outside the strengthened region.

Table C1 Values of k_m and k_τ

Load and boundary conditions	*Bending moment and shear force factors*		
Positions: *1 Support*, *2 Field*, *3 Support*	*1* k_{m1} $k_{\tau 1}$	*2* k_{m2} -	*3* k_{m3} $k_{\tau 3}$
	12 0.5	24	12 0.5
	- 0.38	14.2	8 0.63
	- 0.5	8	- 0.5
	15 0.3	23.3	10 0.7
	- 0.2	16.8	7.5 0.8
	- 0.33	7.8	- 0.67

C 700 Complex girder systems

701 For girders that are parts of a complex 2- or 3-dimensional structural system, a complete structural analysis shall be carried out to demonstrate that the stresses are acceptable.

702 Calculation methods or computer programs applied are to take into account the effects of bending, shear, axial and torsional deformations.

703 The calculations shall reflect the structural response of the 2- or 3-dimensional structure considered, with due attention to boundary conditions.

704 For systems consisting of slender girders, calculations based on beam theory, i.e. frame work analysis, may be applied, with due attention to:

— shear area variation , e.g. due to cut-outs
— moment of inertia variation
— effective flange
— lateral buckling of girder flanges.

705 The most unfavourable of the loading conditions given in Sec.2 D100 shall be applied.

706 For girders taking part in the overall strength of the unit, stresses due to the design pressures given in Sec.3 shall be combined with relevant overall stresses.

SECTION 7
FATIGUE

A. General

A 100 General

101 In this standard, requirements are given in relation to fatigue analyses based on fatigue tests and fracture mechanics. See DNV-RP-C203 for practical details with respect to fatigue design of offshore structures. See also Sec.2 B103.

102 The aim of fatigue design is to ensure that the structure has an adequate fatigue life. Calculated fatigue lives should also form the basis for efficient inspection programmes during fabrication and the operational life of the structure.

103 The resistance against fatigue is normally given as S-N curves, i.e. stress range (S) versus number of cycles to failure (N) based on fatigue tests. Fatigue failure is normally defined as when the crack has grown through the thickness.

104 The S-N curves shall in general be based on a 97.6% probability of survival, corresponding to the mean-minus-two-standard-deviation curves of relevant experimental data.

105 The design fatigue life for the structure components should be based on the structure service life specified. If a service life is not specified, 20 years should be used.

106 To ensure that the structure will fulfil the intended function, a fatigue assessment shall be carried out for each individual member, which is subjected to fatigue loading. Where appropriate, the fatigue assessment shall be supported by a detailed fatigue analysis. It shall be noted that any element or member of the structure, every welded joint and attachment or other form of stress concentration is potentially a source of fatigue cracking and should be individually considered.

107 The analyses shall be performed utilising relevant site specific environmental data for the area(s) in which the unit will be operated. The restrictions shall be described in the Operation Manual for the unit.

108 For world wide operation the analyses shall be performed utilising environmental data (e.g. scatter diagram, spectrum) given in Classification Note 30.5. The North Atlantic scatter diagram shall be utilised.

A 200 Design fatigue factors

201 *Design fatigue factors* (DFF) shall be applied to reduce the probability for avoiding fatigue failures.

202 The DFFs are dependent on the significance of the structural components with respect to structural integrity and availability for inspection and repair.

203 DFFs shall be applied to the design fatigue life. The calculated fatigue life shall be longer than the design fatigue life times the DFF.

204 The design requirement may alternatively be expressed as the cumulative damage ratio for the number of load cycles of the defined design fatigue life multiplied with the DFF shall be less or equal to 1.0.

205 The design fatigue factors in Table A1 are valid for units with low consequence of failure and where it can be demonstrated that the structure satisfies the requirement to damaged condition according to the accidental design condition with failure in the actual element as the defined damage.

Table A1 Design fatigue factors (DFF)

DFF	*Structural element*
1	Internal structure, accessible and not welded directly to the submerged part
1	External structure, accessible for regular inspection and repair in dry and clean conditions
2	Internal structure, accessible and welded directly to the submerged part
2	External structure not accessible for inspection and repair in dry and clean conditions
3	Non-accessible areas, areas not planned to be accessible for inspection and repair during operation

Guidance note:

Units intended to follow normal inspection schedule according to class requirements, i.e. the 5-yearly inspection interval in sheltered waters or drydock, may apply a Design Fatigue Factor (DFF) of 1

For units inspected during operation according to DNV requirements, the DFF for outer shell should be taken as 1. For units inspected afloat at a sheltered location, the DFF for areas above 1 m above lowest inspection waterline should be taken as 1, and below this line the DFF is 2 for the outer shell. Splash zone is defined as non-accessible area.

Where the likely crack propagation develops from a location which is accessible for inspection and repair to a structural element having no access, such location is itself to be deemed to have the same categorisation as the most demanding category when considering the most likely crack path. For example, a weld detail on the inside (dry space) of a submerged shell plate shall be allocated the same DFF as that relevant for a similar weld located externally on the plate.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

206 The design fatigue factors shall be based on special considerations where fatigue failure will entail substantial consequences such as:

- danger of loss of human life, i.e. not compliance with the accidental criteria
- significant pollution
- major economical consequences.

Guidance note:

Evaluation of likely crack propagation paths (including direction and growth rate related to the inspection interval), may indicate the use of a different DFF than that which would be selected when the detail is considered in isolation. For example where the likely crack propagation indicates that a fatigue failure starting in a non critical area grows such that there might be a substantial consequence of failure, such fatigue sensitive location should itself be deemed to have a substantial consequence of failure.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

207 Welds beneath positions 150 m below water level should be assumed inaccessible for in-service inspection.

208 Design fatigue factors to be applied for typical structural details may be found in Sec.11 to Sec.14.

A 300 Methods for fatigue analysis

301 The fatigue analysis should be based on S-N data, determined by fatigue testing of the considered welded detail, and the linear damage hypothesis. When appropriate, the fatigue analysis may alternatively be based on fracture mechanics.

302 In fatigue critical areas where the fatigue life estimate based on simplified methods is below the acceptable limit, a more accurate investigation or a fracture mechanics analysis shall be performed.

303 For calculations based on fracture mechanics, it should be documented that the in-service inspections accommodate a sufficient time interval between time of crack detection and the time of unstable fracture. See DNV-RP-C203 for more details.

304 All significant stress ranges, which contribute to fatigue damage in the structure, shall be considered. The long term distribution of stress ranges may be found by deterministic or spectral analysis. Dynamic effects shall be duly accounted for when establishing the stress history.

305 Local effects, for example due to:

- slamming
- sloshing
- vortex shedding
- dynamic pressures
- mooring and riser systems

shall be included in the fatigue damage assessment when relevant.

306 Principal stresses, see DNV-RP-C203, should be applied in the evaluation of fatigue responses.

A 400 Simplified fatigue analysis

401 Simplified fatigue analysis may be undertaken in order to establish the general acceptability of fatigue resistance, or as a screening process to identify the most critical details to be considered in a stochastic fatigue analysis, see 500.

402 Simplified fatigue analyses should be undertaken utilising appropriate conservative design parameters. A two-parameter, Weibull distribution, see DNV-RP-C203, may be utilised to describe the long-term stress range distribution:

$$\Delta\sigma_{n_0} = \frac{(\ln(n_0))^{\frac{1}{h}}}{(DFF)^{\frac{1}{m}}}\left[\frac{\bar{a}}{n_0\Gamma\left(1+\frac{m}{h}\right)}\right]^{\frac{1}{m}}$$

n_0	=	total number of stress cycles during the lifetime of the structure
$\Delta\sigma_{n_0}$	=	extreme stress range (MPa) that is exceeded once out of n_0 stress cycles. The extreme stress amplitude: $\Delta\sigma_{ampl\_n_0}$ is thus given by $\left(\Delta\sigma_{n_0}/2\right)$
h	=	shape parameter of the Weibull stress range distribution
$\bar{a}$	=	intercept of the design S-N curve with the log N axis
$\Gamma\left(1+\frac{m}{h}\right)$	=	complete gamma function
m	=	inverse slope of the S-N curve
DFF	=	Design Fatigue Factor.

403 The simplified fatigue evaluation should be based on dynamic stress from a global analysis, with the stresses scaled to the return period of the minimum fatigue life of the unit. In such cases, scaling may be undertaken utilising the appropriate factor found from the following:

$$\Delta\sigma_{n_0} = \Delta\sigma_{n_i}\left[\frac{\log n_0}{\log n_i}\right]^{\frac{1}{h}}$$

n_i	=	number of stress variations in i years appropriate to the global analysis
$\Delta\sigma_{n_i}$	=	extreme stress range that is exceeded once out of n_i stress variations.

A 500 Stochastic fatigue analysis

501 Stochastic fatigue analyses shall be based upon recognised procedures and principles utilising relevant site specific data or North Atlantic environmental data, see 107 and 108.

502 Simplified fatigue analyses may be used as a “screening” process to identify locations for which a detailed, stochastic fatigue analysis should be undertaken.

503 Fatigue analyses shall include consideration of the directional probability of the environmental data. Provided it can be satisfactorily verified, scatter diagram data may be considered as being directionally specific. Relevant wave spectra and energy spreading shall be utilised as relevant.

504 Structural response shall be determined based upon analyses of an adequate number of wave directions. Transfer functions shall be established based upon consideration of a sufficient number of periods, such that the number, and values of the periods analysed:

- adequately cover the distribution of wave energy over the frequency range
- satisfactorily describe transfer functions at, and around, the wave “cancellation” and “amplifying” periods
- satisfactorily describe transfer functions at, and around, the relevant natural periods of the unit.

It should be considered that "cancellation" and "amplifying" periods may be different for different elements within the structure.

505 Stochastic fatigue analyses utilising simplified structural model representations of the unit (e.g. a space frame model) may be used to form basis for identifying locations for which a stochastic fatigue analysis, utilising a detailed model of the structure, should be undertaken, e.g. at critical intersections.

SECTION 8
ACCIDENTAL CONDITIONS

A. General

A 100 General

101 Accidental conditions shall in principle be assessed for all units. Safety assessment is carried out according to the principles given in DNV-OS-A101.

102 The overall objective for design with respect to accidental conditions is that unit's main safety functions shall not be impaired by accidental events. Satisfactory protection against accidental damage may be achieved by two barriers:

— reduction of damage probability
— reduction of damage consequences.

103 The design against accidental loads may be done by direct calculation of the effects imposed by the loads on the structure, or indirectly, by design of the structure as tolerable to accidents. Examples of the latter are compartmentation of floating units which provides sufficient integrity to survive certain collision scenarios without further calculations.

B. Design Criteria

B 100 General

101 Structures shall be checked for accidental loads in two steps, according to the loading conditions presented in Sec.2 Table D1:

— resistance of the structure against design accidental loads, i.e. loading condition c).
— post accident resistance of the structure against environmental loads after accidental damage, i.e. loading conditions d) and e).

The unit shall be designed for environmental condition corresponding to 1 year return period after accidental damage.

102 Typical accidental loads of relevance for mobile offshore units are:

— impact from ship collisions
— impact from dropped objects
— fires
— explosions
— abnormal environmental conditions
— accidental flooding.

Generic values of accidental loads are given in DNV-OS-A101.

103 The different types of accidental loads require different methods and analyses to assess the structural resistance.

Local exceedance of the structural capacity is acceptable provided redistribution of forces due to yielding, buckling and fracture is accounted for.

104 The inherent uncertainty of the frequency and magnitude of the accidental loads, as well as the approximate nature of the methods for determination of accidental load effects, shall be recognised. It is therefore essential to apply sound engineering judgement and pragmatic evaluations in the design.

105 If non-linear, dynamic finite element analysis is applied for design, it shall be verified that all local failure modes (e.g. strain rate, local buckling, joint overloading, and joint fracture) are accounted for implicitly by the modelling adopted, or else subjected to explicit evaluation.

B 200 Collision

201 Ship collision, e.g. by supply vessels, shall be considered as relevant for the unit operation and transit regions.

B 300 Dropped objects

301 Critical areas for dropped objects shall be determined on the basis of the actual movement of potential dropped objects, e.g. crane or other lifting operation mass, relative to the structure of the unit itself. Where a dropped object is a relevant accidental event, the impact energy shall be established and the structural consequences of the impact assessed.

302 Critical areas for dropped objects should be determined assuming a minimum drop direction within an angle with the vertical direction:

— 5° in air, for bottom supported structures
— 10° in air, for floating units
— 15° in water.

Dropped objects should be considered for vital structural elements of the unit within the areas given above.

B 400 Fires

401 The structure that is subjected to a fire shall maintain sufficient structural before evacuation has occurred. The following fire scenarios shall be considered:

— jet fires
— fire inside or on the hull
— fire on the sea surface.

402 Assessment of fire may be omitted provided fire protection requirements made in DNV-OS-D301 are met.

B 500 Explosions

501 In respect to design, one or more of the following main design philosophies will be relevant:

— ensure that hazardous locations are located in unconfined (open) locations and that sufficient shielding mechanisms (e.g. blast walls) are installed
— locate hazardous areas in partially confined locations and design utilising the resulting, relatively small overpressures
— locate hazardous areas in enclosed locations and install pressure relief mechanisms (e.g. blast panels) and design for the resulting overpressure.

502 As far as practicable, structural design accounting for large plate field rupture resulting from explosion actions should be avoided due to the uncertainties of the actions and the consequences of the rupture itself.

503 Structural support of blast walls and the transmission of the blast action into main structural members shall be evaluated when relevant. Effectiveness of connections and the possible outcome from blast, such as flying debris, shall be considered.

B 600 Unintended flooding

601 Heeling of the unit, during transit condition, after damage flooding as described in DNV-OS-C301 shall be accounted for in the structural strength. Maximum static allowable heel after accidental flooding are specified in Sec.11 to Sec.14 for the different types of units. Structures that are wet when the static equilibrium angle is achieved shall be checked for external water pressure.

602 Wave pressure, slamming forces and green sea shall be accounted for in all relevant areas. Local damage may be accepted provided progressive structural collapse and damage of vital equipment is avoided.

603 Position of air-intakes and openings to areas with vital equipment which need to be available during an emergency situation e.g. emergency generators, shall be considered taking into account the wave elevation in a 1 year storm.

SECTION 9
WELD CONNECTIONS

A. General

A 100 Scope

101 The requirements in this section are related to types and size of welds.

B. Types of Welded Steel Joints

B 100 Butt joints

101 All types of butt joints should be welded from both sides. Before welding is carried out from the second side, unsound weld metal shall be removed at the root by a suitable method.

B 200 Tee or cross joints

201 The connection of a plate abutting on another plate may be made as indicated in Fig.1.

202 The throat thickness of the weld is always to be measured as the normal to the weld surface, as indicated in Fig.1 d.

203 The type of connection should be adopted as follows:

a) *Full penetration weld*

Important cross connections in structures exposed to high stress, especially dynamic, e.g. for special areas and fatigue utilised primary structure. All external welds in way of opening to open sea, e.g. pipes, sea chests or tee-joints as applicable.

b) *Partly penetration weld*

Connections where the static stress level is high. Acceptable also for dynamically stressed connections, provided the equivalent stress is acceptable, see C300.

c) *Fillet weld*

Connections where:

— stresses in the weld are mainly shear
— direct stresses are moderate and mainly static
— dynamic stresses in the abutting plate are small.

204 Double continuous welds are required in the following connections, irrespective of the stress level:

— oiltight and watertight connections
— connections at supports and ends of girders, stiffeners and pillars
— connections in foundations and supporting structures for machinery
— connections in rudders, except where access difficulties necessitate slot welds.

205 Intermittent fillet welds may be used in the connection of girder and stiffener webs to plate and girder flange plate, respectively, where the connection is moderately stressed. With reference to Fig.2, the various types of intermittent welds are as follows:

— chain weld
— staggered weld
— scallop weld (closed).

206 Where intermittent welds are accepted, scallop welds shall be used in tanks for water ballast or fresh water. Chain and staggered welds may be used in dry spaces and tanks arranged for fuel oil only.

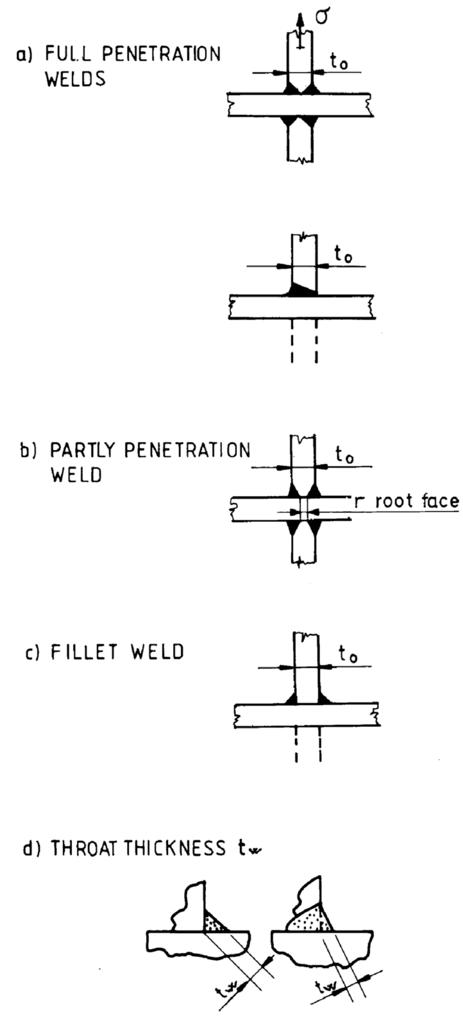


Figure 1
Tee or cross joints

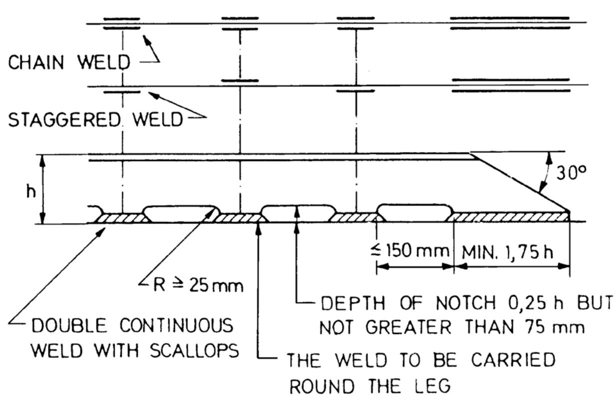


Figure 2
Intermittent welds

B 300 Slot welds

301 Slot weld, see Fig.3, may be used for connection of plating to internal webs, where access for welding is not practicable, e.g. rudders. The length of slots and distance between slots shall be considered in view of the required size of welding.

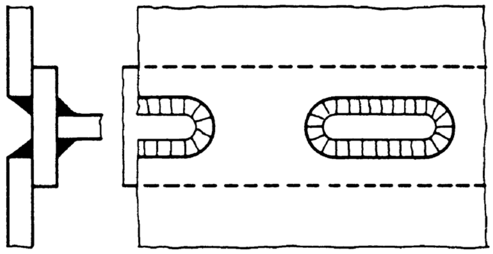


Figure 3
Slot welds

B 400 Lap joint

401 Lap joint as indicated in Fig.4 may be used in end connections of stiffeners. Lap joints should be avoided in connections with dynamic stresses.

Figure 4
Lap joint

C. Weld Size

C 100 General

101 The sizes of weld connections shall be as given in 200 to 500.

If the yield stress of the weld deposit is higher than that of the base metal, the size of ordinary fillet weld connections may be reduced as indicated in 103.

The yield stress of the weld deposit shall in no case be less than given in DNV-OS-C401.

102 Welding consumables used for welding of normal steel and some high strength steels are assumed to give weld deposits with yield stress σ_{fw} as indicated in Table C1. If welding consumables with deposits of lower yield stress than specified in Table C1 are used, the applied yield strength shall be clearly informed on drawings and in design reports.

103 The size of some weld connections may be reduced:

— Corresponding to the strength of the weld metal, f_w:

$$f_w = \left(\frac{\sigma_{fw}}{235}\right)^{0.75} \quad \text{or}$$

— Corresponding to the strength ratio value f_r, base metal to weld metal:

$$f_r = \left(\frac{f_y}{\sigma_{fw}}\right)^{0.75} \quad \text{minimum } 0.75$$

f_y = characteristic yield stress of base material, abutting plate (N/mm^2)
σ_{fw} = characteristic yield stress of weld deposit (N/mm^2)

Ordinary values for f_w and f_r for normal strength and high strength steels are given in Table C1.

104 When deep penetrating welding processes are applied, the required throat thicknesses may be reduced by 15% provided sufficient weld penetration is demonstrated.

Table C1 Strength ratios, f_w and f_r.

Base metal		*Weld deposit*	*Strength ratios*	
Strength group	Designation	Yield stress σ_{fw} (N/mm^2)	Weld metal $f_w = \left(\frac{\sigma_{fw}}{235}\right)^{0.75}$	Base metal/weld metal $f_r = \left(\frac{f_y}{\sigma_{fw}}\right)^{0.75}$
Normal strength steels	NV NS	355	1.36	0.75
High strength steels	NV 27	375	1.42	0.75
	NV 32	375	1.42	0.88
	NV 36	375	1.42	0.96
	NV 40	390	1.46	1.00

C 200 Fillet welds

201 Where the connection of girder and stiffener webs and plate panel or girder flange plate, respectively, are mainly shear stressed, fillet welds as specified in 202 to 204 should be adopted.

202 Unless otherwise calculated, the throat thickness of double continuous fillet welds t_W should not be less than:

$$t_w = 0.43\, f_r t_0 \quad \text{(mm), minimum 3 mm}$$

f_r = strength ratio as defined in 103
t_0 = net thickness (mm) of abutting plate. For stiffeners and girders within 60% of the middle of span, t_0 need normally not be taken greater than 11 mm, however, t_0 shall in no case be less than 0.5 times the net thickness of the web.

203 The throat thickness of intermittent welds may be as required in 202 for double continuous welds provided the welded length is not less than:

— 50% of total length for connections in tanks
— 35% of total length for connections elsewhere.

Double continuous welds shall be adopted at stiffener ends when necessary due to bracketed end connections.

204 For intermittent welds, the throat thickness t_W is not to exceed:

— chain welds and scallop welds

$$t_w = 0.6\, f_r t_0 \quad \text{(mm)}$$

— staggered welds

$$t_w = 0.75\ f_r t_0 \quad \text{(mm)}$$

If the calculated throat thickness exceeds that given above, the considered weld length shall be increased correspondingly.

C 300 Partly penetration welds and fillet welds in cross connections subject to high stresses

301 In structural parts where dynamic stresses or high static tensile stresses act through an intermediate plate, see Fig.1, penetration welds or increased fillet welds shall be used.

302 When the abutting plate carries dynamic stresses, the connection shall fulfil the requirements with respect to fatigue, see Sec.7.

303 When the abutting plate carries tensile stresses higher than 100 N/mm^2, the throat thickness t_W of a double continuous weld shall not be less than:

$$t_w = \frac{1.36}{f_w}\left[0.2 + \left(\frac{\sigma}{270} - 0.25\right)\frac{r}{t_0}\right]t_0 \quad \text{(mm)}$$

minimum 3 mm

f_w = strength ratio as defined in 103
σ = calculated maximum tensile stress in abutting plate (N/mm^2)
r = root face (mm), see Fig.1 b
t_0 = net thickness (mm) of abutting plate.

C 400 Connections of stiffeners to girders and bulkheads, etc.

401 Stiffeners may be connected to the web plate of girders in the following ways:

- welded directly to the web plate on one or both sides of the stiffener
- connected by single- or double-sided lugs
- with stiffener or bracket welded on top of frame
- a combination of the ways listed above.

In locations where large shear forces are transferred from the stiffener to the girder web plate, a double-sided connection or stiffening should be required. A double-sided connection may be taken into account when calculating the effective web area.

402 Various standard types of connections between girders and stiffeners are shown in Fig.5.

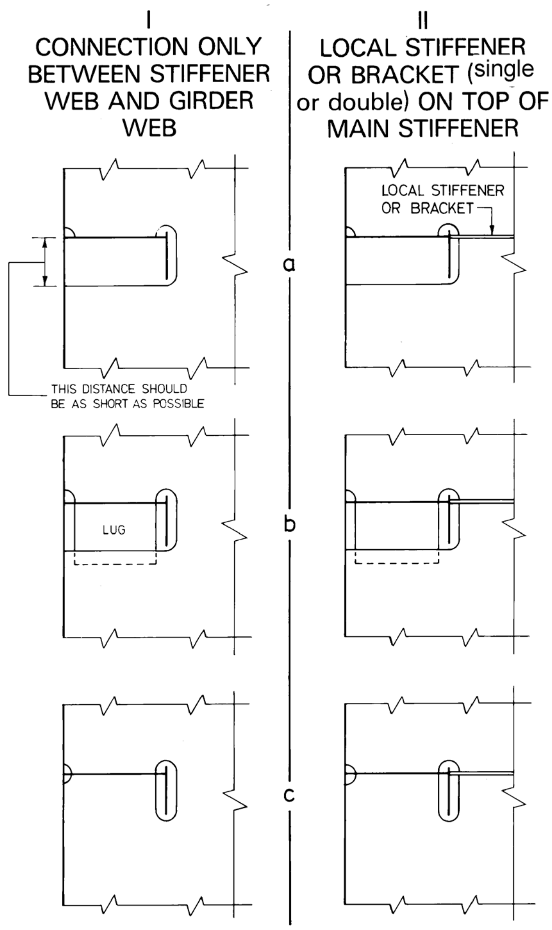


Figure 5
Connections of stiffeners

403 Connection lugs should normally have a thickness not less than 75% of the web plate thickness.

404 The total connection area a_0 (parent material) at supports of stiffeners should not be less than:

$$a_0 = \sqrt{3}\frac{c}{\sigma_p}10^3(l - 0.5s)\ s\ p \quad (\text{mm}^2)$$

c = detail shape factor as given in Table C2
σ_p = permissible stress (N/mm^2)
= $\eta_0\ f_y$
η_0 = allowable usage factor, see Sec.2
f_y = minimum yield strength, see Sec.4
l = span of stiffener (m)
s = spacing between stiffeners (m)
p = lateral pressure (kN/m^2).

Table C2 Detail shape factor c

Type of connection (see Fig.5)	*I Web to web connection only*	*II Stiffener or bracket on top of stiffener*	
		Single-sided	*Double-sided*
a	1.00	1.25	1.00
b	0.90	1.15	0.90
c	0.80	1.00	0.80

405 Weld area a shall not be less than:

$$a = f_r a_0 \quad (\text{mm}^2)$$

f_r = strength ratio as defied in 103
a_0 = connection area (mm^2) as given in 404.

The throat thickness is not to be exceed the maximum for scallop welds given in 204.

406 The weld connection between stiffener end and bracket is principally to be designed such that the shear stresses of the connection correspond to the permissible stress.

407 The weld area of brackets to stiffeners which are carrying longitudinal stresses or which are taking part in the strength of heavy girders etc., shall not be less than the sectional area of the longitudinal.

408 Brackets shall be connected to bulkhead by a double continuous weld, for heavily stressed connections by a partly or full penetration weld.

C 500 End connections of girders

501 The weld connection area of bracket to adjoining girders or other structural parts shall be based on the calculated normal and shear stresses. Double continuous welding shall be used. Where large tensile stresses are expected, design according to 300 shall be applied.

502 The end connections of simple girders shall satisfy the requirements for section modulus given for the girder in question.

Where the shear stresses in web plate exceed 75 N/mm^2, double continuous boundary fillet welds should have throat thickness not less than:

$$t_w = \frac{\tau}{174 f_w} f_r t_0 \quad (\text{mm})$$

τ = calculated shear stress (N/mm^2)
f_w = strength ratio as defined in 103
f_r = strength ratio as defied in 103
t_0 = net thickness (mm) of web plate

C 600 Direct calculation of weld connections

601 The distribution of forces in a welded connection may be calculated on the assumption of either elastic or plastic behaviour.

602 Residual stresses and stresses not participating in the transfer of load need not be included when checking the capacity of a weld. This applies specifically to the normal stress parallel to the axis of a weld.

603 Welded connections shall be designed to have adequate deformation capacity.

604 In joints where plastic hinges may form, the welds shall be designed to provide at least the same capacity as the weakest of the connected parts.

605 In other joints where deformation capacity for joint rotation is required due to the possibility of excessive straining, the welds require sufficient strength not to rupture before general yielding in the adjacent parent material.

Guidance note:
In general this will be satisfied if the capacity of the weld is not less than 80% of the capacity of the weakest of the connected parts..

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606 The capacity of fillet welds is adequate if, at every point in its length, the resultant of all the forces per unit length transmitted by the weld does not exceed its capacity.

607 The capacity of the fillet weld will be sufficient if both the following conditions are satisfied:

$$\sqrt{\sigma_\perp^2 + 3\left(\tau_{\parallel}^2 + \tau_\perp^2\right)} \le \frac{f_u}{\beta_w}\eta_0$$

and $$\sigma_\perp \le f_u \eta_0$$

$\sigma_\perp$ = normal stress perpendicular to the throat
$\tau_\perp$ = shear stress (in plane of the throat) perpendicular to the axis of the weld
$\tau_{\parallel}$ = shear stress (in plane of the throat) parallel to the axis of the weld, see Table C3
f_u = nominal lowest ultimate tensile strength of the weaker part joined
β_w = appropriate correlation factor, see Table C3
η_0 = basic usage factor, see Sec. 2 E

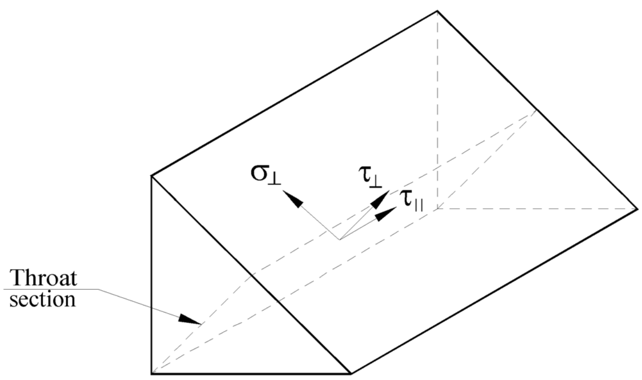

Figure 6
Stress components at a fillet weld

Table C3 The correlation factor β_w		
Steel grade	*Lowest ultimate tensile strength f_u*	*Correlation factor β_w*
NV NS	400	0.83
NV 27	400	0.83
NV 32	440	0.86
NV 36	490	0.89
NV 40	510	0.9
NV 420	530	1.0
NV 460	570	1.0

SECTION 10
CORROSION CONTROL

A. General

A 100 Scope

101 Corrosion control of structural steel for offshore structures comprises:

— coatings and/or cathodic protection
— use of a corrosion allowance
— inspection/monitoring of corrosion
— control of humidity for internal zones (compartments).

102 This section gives technical requirements and guidance for the design of corrosion control of structural steel associated with offshore steel structures. The manufacturing/installation of systems for corrosion control and inspection and monitoring of corrosion in operation are covered in DNV-OS-C401.

B. Techniques for Corrosion Control Related to Environmental Zones

B 100 Atmospheric zone

101 Steel surfaces in the atmospheric zone shall be protected by a coating system (see D100) proven for marine atmospheres by practical experience or relevant testing.

Guidance note:
The 'Atmospheric Zone" is defined as the areas of a structure above the Splash Zone (see B201) being exposed to sea spray, atmospheric precipitation and/or condensation.

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B 200 Splash zone

201 Steel surfaces in the splash zone shall be protected by a coating system (see D100) proven for splash zone applications by practical experience or relevant testing. A corrosion allowance should also be considered in combination with a coating system for especially critical structural items.

202 Steel surfaces in the splash zone, below the mean sea level (MSL) for bottom fixed structures or below the normal operating draught for floating units, shall be designed with cathodic protection in addition to coating.

203 The splash zone is that part of an installation, which is intermittently exposed to air and immersed in the sea. The zone has special requirements to fatigue for bottom fixed units and floating units that have constant draught.

Guidance note:
Constant draught means that the unit is not designed for changing the draught for inspection and repair for the splash zone and other submerged areas.

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204 For floating units with constant draught, the extent of the splash zone shall extend 5 m above and 4 m below this draught.

205 For bottom fixed structures, such as jackets and TLPs, the definitions of splash zone given in 205 to 207 apply.

The wave height to be used to determine the upper and lower limits of the splash zone shall be taken as 1/3 of the wave height that has an annual probability of being exceeded of 10^{-2}.

206 The upper limit of the splash zone (SZ_U) shall be calculated by:

$$SZ_U = U_1 + U_2 + U_3 + U_4 + U_5$$

where:

U_1	=	60 % of the wave height defined in 205
U_2	=	highest astronomical tide level (HAT)
U_3	=	foundation settlement, if applicable
U_4	=	range of operation draught, if applicable
U_5	=	motion of the structure, if applicable.

The variables (U_i) shall be applied, as relevant, to the structure in question, with a sign leading to the largest or larger value of SZ_U.

207 The lower limit of the splash zone (SZ_L) shall be calculated by:

$$SZ_L = L_1 + L_2 + L_3 + L_4$$

where:

L_1	=	40% of the wave height defined in 205
L_2	=	lowest astronomical tide level (LAT)
L_3	=	range of operating draught, if applicable
L_4	=	motions of the structure, if applicable.

The variables (L_i) shall be applied, as relevant, to the structure in question, with a sign leading to the smallest or smaller value of SZ_L.

B 300 Submerged zone

301 Steel surfaces in the submerged zone shall have a cathodic protection system. The cathodic protection design shall include current drain to any electrically connected items for which cathodic protection is not considered necessary (e.g. piles).

The cathodic protection shall also include the splash zone beneath MSL (for bottom fixed structures) and splash zone beneath normal operating draught (for floating units), see B202.

Guidance note:
The 'Submerged Zone' is defined as the zone below the splash zone.

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302 For certain applications, cathodic protection is only practical in combination with a coating system. Any coating system shall be proven for use in the submerged zone by practical experience or relevant testing demonstrating compatibility with cathodic protection.

Guidance note:
Cathodic protection may cause damage to coatings by blistering or general disbondment ("cathodic disbondment").

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B 400 Internal zone

401 Internal zones exposed to seawater for a main period of time (e.g. ballast tanks) shall be protected by a coating system (see D100) proven for such applications by practical experience or relevant testing. Cathodic protection should be considered for use in combination with coating (see also 402).

Guidance note:

Internal Zones' are defined as tanks, voids and other internal spaces containing a potentially corrosive environment, including seawater.

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402 Internal zones that are empty (including those occasionally exposed to seawater for a short duration of time) shall have a coating system and/or corrosion allowance. For internal zones with continuous control of humidity, no further corrosion control is required. Further, no coating is required for zones that do not contain water and that are permanently sealed.

403 Tanks for fresh water shall have a suitable coating system. Special requirements will apply for coating systems to be used for potable water tanks.

404 To facilitate inspection, light coloured and hard coatings shall be used for components of internal zones subject to major fatigue forces requiring visual inspection for cracks. Regarding restrictions for use of coatings with high content of aluminium, see D101.

405 Only anodes on aluminium or zinc basis shall be used. Due to the risk of hydrogen gas accumulation, anodes of magnesium or impressed current cathodic protection are prohibited for use in tanks.

406 For cathodic protection of ballast tanks that may become affected by hazardous gas from adjacent tanks for storage of oil or other liquids with flash point less than 60°C, anodes on zinc basis are preferred. Due to the risk of thermite ignition, any aluminium base anodes shall in no case be installed such that a detached anode could generate an energy of 275 J or higher (i.e. as calculated from anode weight and height above tank top). For the same reason, coatings containing more than 10% aluminium on dry weight basis shall not be used for such tanks.

407 A corrosion allowance shall be implemented for internal compartments without any corrosion protection (coating and/or cathodic protection) but subject to a potentially corrosive environment such as intermittent exposure to seawater, humid atmosphere or produced/cargo oil.

Any corrosion allowance for individual components (e.g. plates, stiffeners and girders) shall be defined taking into account:

— design life
— maintenance philosophy
— steel temperature
— single or double side exposure.

As a minimum, any corrosion allowance (t_k) to be applied as alternative to coating shall be as follows:

— one side unprotected: t_k = 1.0 mm
— two sides unprotected: t_k = 2.0 mm.

C. Cathodic Protection

C 100 General

101 Cathodic protection of offshore structures may be effected using galvanic anodes (also referred to as "sacrificial anodes") or impressed current from a rectifier. Impressed current is almost invariably used in combination with a coating system.

Guidance note:

The benefits of a coating system (e.g. by reducing weight or friction to seawater flow caused by excessive amounts of anodes) should also be considered for systems based on galvanic anodes.

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102 Cathodic protection systems in marine environments are typically designed to sustain a protection potential in the range - 0.80 V to - 1.10 V relative to the Ag/AgCl/seawater reference electrode. More negative potentials may apply in the vicinity of impressed current anodes.

Guidance note:

The use of galvanic anodes based on aluminium and zinc limits the most negative potential to - 1.10 V relative to Ag/AgCl/seawater.

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103 Design of cathodic protection systems for offshore structures shall be carried out according to a recognised standard.

104 Cathodic protection may cause hydrogen induced stress cracking (HISC) of components in high strength steels that are exposed to severe straining in service

It is recommended that the welding of high strength structural steels is qualified to limit the hardness in the weld zone to max. 350 HV (Vicker hardness). The use of coatings reduces the risk of hydrogen embrittlement further and is recommended for all critical components in high strength structural steel.

Guidance note:

There is no evidence in the literature that structural steels with SMYS up to 550 N/mm^2 have suffered any cracking when exposed to cathodic protection in marine environments at the protection potential range given in 102.

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C 200 Galvanic anode systems

201 Unless replacement of anodes is allowed for in the design, galvanic anode cathodic protection systems shall have a design life at least equal to that of the offshore installation. For ballast tanks with access for replacement of anodes and any other such applications, the minimum design life should be 5 years.

202 Anode cores shall be designed to ensure attachment during all phases of installation and operation of the structure. Location of anodes in fatigue sensitive areas shall be avoided.

203 The documentation of cathodic protection design by galvanic anodes shall contain the following items as a minimum:

— reference to design code and design premises
— calculations of surface areas and cathodic current demand (mean and initial/final) for individual sections of the structure
— calculations of required net anode mass for the applicable sections based on the mean current demands
— calculations of required anode current output per anode and number of anodes for individual sections based on initial/final current demands
— drawings of individual anodes and their location.

204 Requirements to the manufacturing of anodes (see 205) shall be defined during design, e.g. by reference to a standard or in a project specification.

205 Galvanic anodes shall be manufactured according to a manufacturing procedure specification (to be prepared by manufacturer) defining requirements to the following items as a minimum:

— chemical compositional limits
— anode core material standard and preparation prior to cast-

ing
— weight and dimensional tolerances
— inspection and testing
— marking, traceability and documentation.

206 The needs for a commissioning procedure including measurements of protection potentials at pre-defined locations should be considered during design. As a minimum, recordings of the general protection level shall be performed by lowering a reference electrode from a location above the water level.

207 Manufacturing and installation of galvanic anodes are addressed in DNV-OS-C401 Sec.5.

C 300 Impressed current systems

301 Impressed current anodes and reference electrodes for control of current output shall be designed with a design life at least equal to that of the offshore installation unless replacement of anodes (and other critical components) during operation is presumed. It is recommended that the design in any case allows for replacement of any defective anodes and reference electrodes (see 304) during operation.

302 Impressed current anodes shall be mounted flush with the object to be protected and shall have a relatively thick non-conducting coating or sheet ("dielectric shield") to prevent any negative effects of excessively negative potentials such as disbondment of paint coatings or hydrogen induced damage of the steel. The sizing of the sheet shall be documented during design. Location of impressed current anodes in fatigue sensitive areas shall be avoided.

303 Impressed current cathodic protection systems shall be designed with a capacity of minimum 1.5 higher than the calculated final current demand of the structure.

Guidance note:
Impressed current cathodic protection provide a more non-uniform current distribution and are more vulnerable to mechanical damage which requires a more conservative design than for galvanic anode systems.

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304 A system for control of current output based on recordings from fixed reference electrodes located close to and remote from the anodes shall be included in the design. Alarm functions indicating excessive voltage/current loads on anodes, and too negative or too positive protection potential should be provided. A failure mode analysis should be carried out to ensure that any malfunction of the control system will not lead to excessive negative or positive potentials that may damage the structure or any adjacent structures.

305 Cables from rectifier to anodes and reference electrodes should have steel armour and shall be adequately protected by routing within a dedicated conduit (or internally within the structure, if applicable). Restriction for routing of anode cables in hazardous areas may apply.

306 The documentation of cathodic protection design by impressed current shall contain the following items as a minimum:

— reference to design code and design premises
— calculations of surface areas and cathodic current demand (mean and initial/final) for individual sections of the structure
— general arrangement drawings showing locations of anodes, anode shields, reference electrodes , cables and rectifiers
— detailed drawings of anodes, reference electrodes and other major components of the system
— documentation of anode and reference electrode performance to justify the specified design life
— documentation of rectifiers and current control system
— documentation of sizing of anode shields
— specification of anode shield materials and application
— commissioning procedure, incl. verification of proper protection range by independent potential measurements
— operational manual, including procedures for replacement of anodes and reference electrodes.

307 Manufacturing and installation of impressed current cathodic protection systems are addressed in DNV-OS-C401 Sec.5.

D. Coating Systems

D 100 Specification of coating

101 Requirements to coatings for corrosion control (including those for any impressed current anode shields) shall be defined during design (e.g. by reference to a standard or in a project specification), including as a minimum:

— coating materials (generic type)
— surface preparation (surface roughness and cleanliness)
— thickness of individual layers
— inspection and testing.

For use of aluminium containing coatings in tanks that may become subject to explosive gas, the aluminium content is limited to maximum 10% on dry film basis.

Guidance note:
It is recommended that supplier specific coating materials are qualified by relevant testing or documented *performance* in service.

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102 Coating materials and application of coatings are addressed in DNV-OS-C401 Sec.5.

SECTION 11
SPECIAL CONSIDERATIONS FOR COLUMN STABILISED UNITS

A. General

A 100 Assumptions and application

101 The requirements and guidance documented in this section are generally applicable to all configurations of column-stabilised units, including those with:

— ring (continuous) pontoons
— twin pontoons.

The requirements come in addition to those of Sections 1 through 10, see Sec.1 A103.

102 A column-stabilised unit is a floating unit that can be relocated. A column stabilised unit normally consists of a deck box structure with a number of widely spaced, large diameter, supporting columns that are attached to submerged pontoons.

103 Column-stabilised units may be kept on station by either a passive mooring system (e.g. anchor lines), or an active mooring system (e.g. thrusters), or a combination of these methods.

104 A column-stabilised unit may be designed to function in a number of modes, e.g. transit, operational and survival. Limiting design criteria for modes of operation shall be established and documented. Such limiting design criteria shall include relevant consideration of the following items:

— intact condition - structural strength
— damaged condition - structural strength
— air gap
— watertight integrity and hydrostatic stability.

105 For novel designs, or unproved applications of designs where limited or no direct experience exists, relevant analyses and model testing, shall be performed to clearly demonstrate that an acceptable level of safety is obtained

B. Structural Categorisation, Material Selection and Inspection Principles

B 100 General

101 The structural application categories are determined based on the structural significance, consequences of failure and the complexity of the joints and shall be selected according to the principles as given in Sec.4.

102 The steel grades selected for structural components shall be related to weldability and requirements for toughness properties and shall be in compliance with the requirements given in the DNV-OS-B101.

B 200 Structural categorisation

201 Application categories for structural components are defined in Sec.4. Structural members of column stabilised units are normally found in the following groups:

Special category

a) Portions of deck plating, heavy flanges, and bulkheads within the upper hull or platform which form "Box" or "I" type supporting structure which receive major concentrated loads.
b) External shell structure in way of high stressed intersections of vertical columns, decks and lower hulls.
c) Major intersections of bracing members.
d) "Through" material used at connections of vertical columns, upper platform decks and upper or lower hulls which are designed to provide proper alignment and adequate load transfer.
e) External brackets, portions of bulkheads, and frames which are designed to receive concentrated loads at intersections of major structural members.
f) Highly utilised areas supporting anchor line fairleads and winches, crane pedestals, flare etc.

Guidance note:
Highly stressed areas are normally considered to be areas utilised more than 85 % of the allowable yield capacity.

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Primary category

a) Deck plating, heavy flanges, and bulkheads within the upper hull or platform, which form "Box" or "I". type supporting structure which do not receive major concentrated loads.
b) External shell structure of vertical columns, lower and upper hulls, and diagonal and horizontal braces.
c) Bulkheads, decks, stiffeners and girders, which provide local reinforcement or continuity of structure in way of intersections, except areas where the structure is considered for special application.
d) Main support structure of heavy substructures and equipment, e.g. anchor line fairleads, cranes, drill floor substructure, life boat platform, thruster foundation and helicopter deck.

Secondary category

a) Upper platform decks, or decks of upper hulls except areas where the structure is considered primary or special application.
b) Bulkheads, stiffeners, flats or decks and girders in vertical columns, decks, lower hulls, diagonal and horizontal bracing, which are not considered as primary or special application.
c) Deckhouses.
d) Other structures not categorised as special or primary.

Fig.1 to Fig.4 show examples of structural application category.

B 300 Material selection

301 Material selection shall be performed in accordance with in Sec.4. The selection shall refer to structural categorisation and service temperatures as stated in Sec.4 and in the present section.

302 For column-stabilised units of conventional type, the pontoon deck need not be designed for service temperatures lower than 0ºC, even if the unit's service temperature for external structures above water, i.e. the design temperature, is lower.

303 External structures below the light transit waterline need not be designed for service temperatures lower than 0°C.

304 Internal structures of columns, pontoons and decks shall have the same service temperature as the adjacent external structure if not otherwise documented.

305 Internal structures in way of permanently heated rooms need not to be designed for service temperatures lower than 0ºC.

B 400 Inspection categories

401 Welding, and the extent of non-destructive examination during fabrication, shall be in accordance with the requirements stipulated for the appropriate inspection category as defined in Sec.4.

402 Minimum requirements for structural categorisation and inspection for typical column-stabilised unit configurations are illustrated in Fig.1 to Fig.4.

403 In way of the pontoon and column connection as indicated in Fig.1 and Fig.2, the pontoon deck plate should be the continuous material. These plate fields should be material with through-thickness properties (Z-quality material).

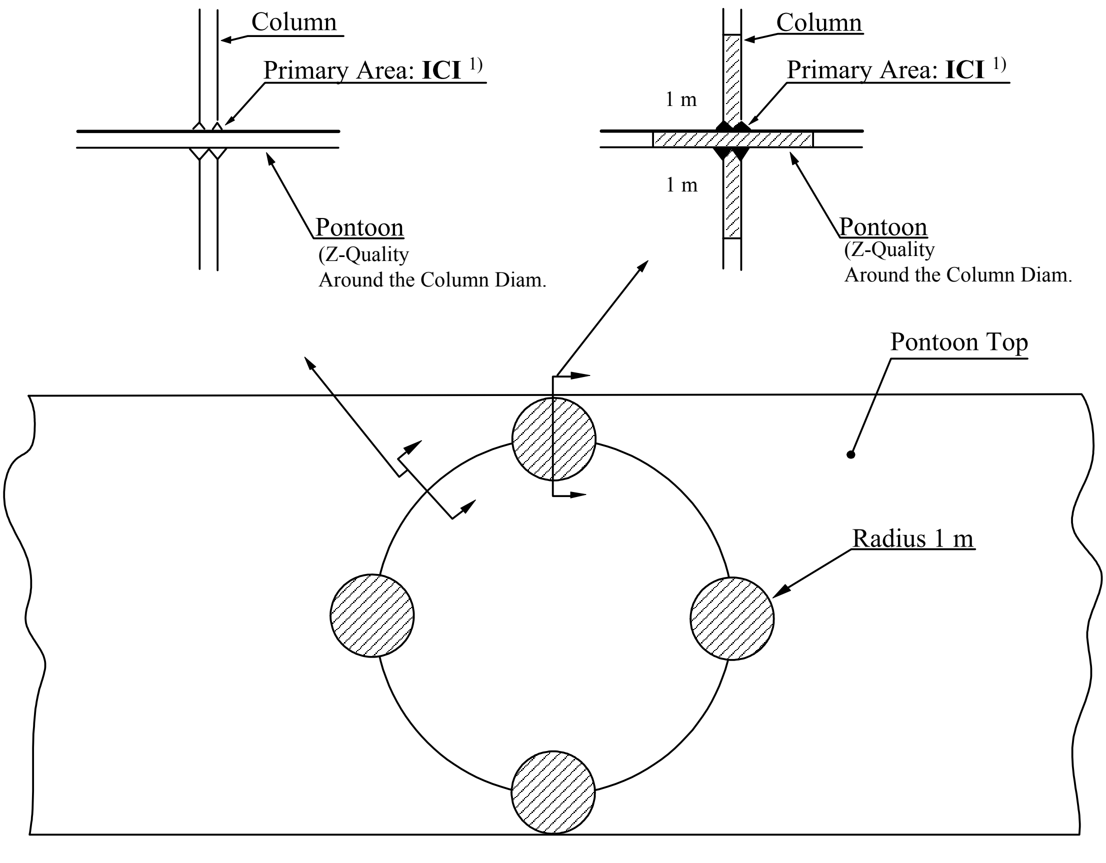
404 Shaded areas indicated in the figures are intended to be three-dimensional in extent. This implies that, in way of these locations, the shaded area logic is not only to apply to the outer surface of the connection but is also to extend into the structure. However, stiffeners and stiffener brackets within this area should be of primary category and the bracket toe locations on the stiffeners should be designated with mandatory magnetic particle inspection (MPI).

405 Stiffeners welded to a plate categorised as special area should be welded with full penetration welds and no notches should be used.

406 The inspection categories for general pontoon, plate butt welds and girder welds to the pontoon shell are determined based upon, amongst others: accessibility and fatigue utilisation.

407 Major bracket toes should be designated as locations with a mandatory requirement to MPI. In way of the brace connections as indicated in Fig.3 the brace and brace bracket plate fields should be the continuous material. These plate fields should be material with through-thickness properties (Z-quality material).

408 In way of the column and upper hull connection as indicated in Fig.4 the upper hull deck plate fields will normally be the continuous material. These plate fields should be material with through-thickness properties (Z-quality material).



1) This is normally fatigue critical, and hence the inspection category is increased from II to I, see Sec.4 C305.

Figure 1
Pontoon and column connection, twin pontoon design

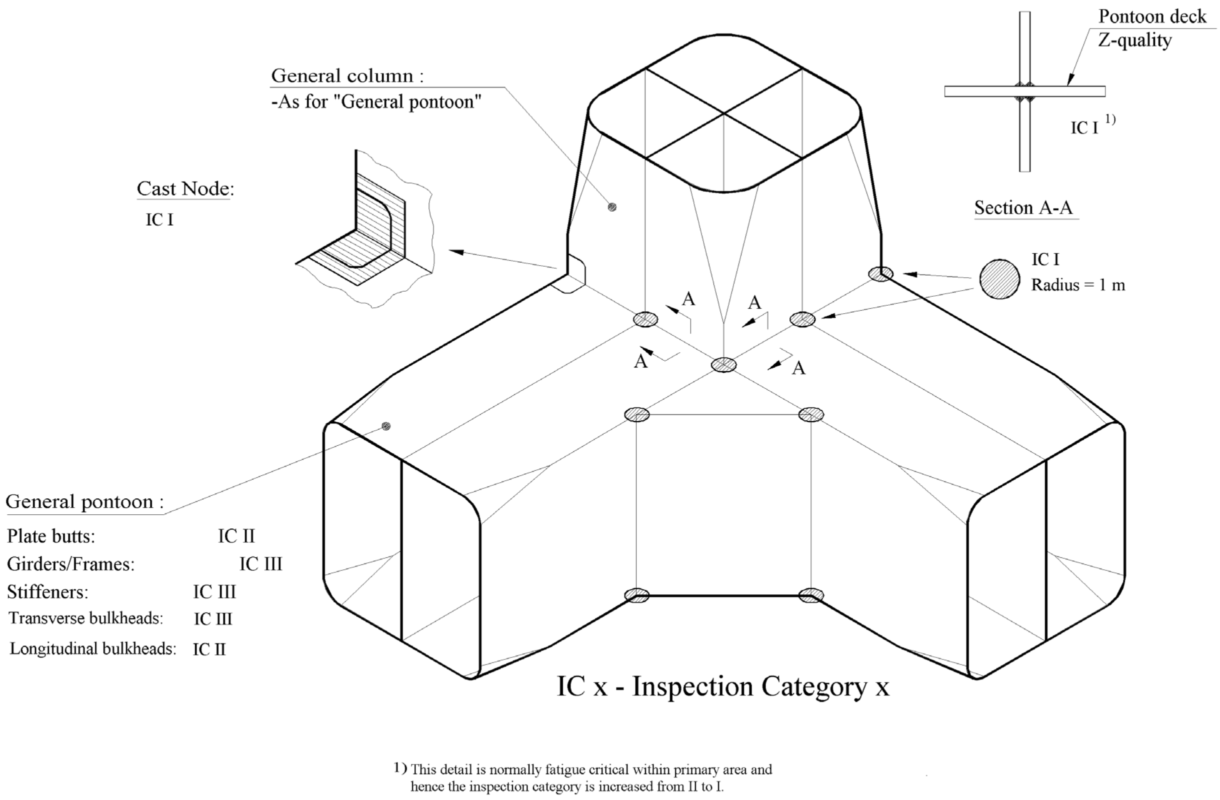


Figure 2
Column and ring pontoon connection, ring pontoon design

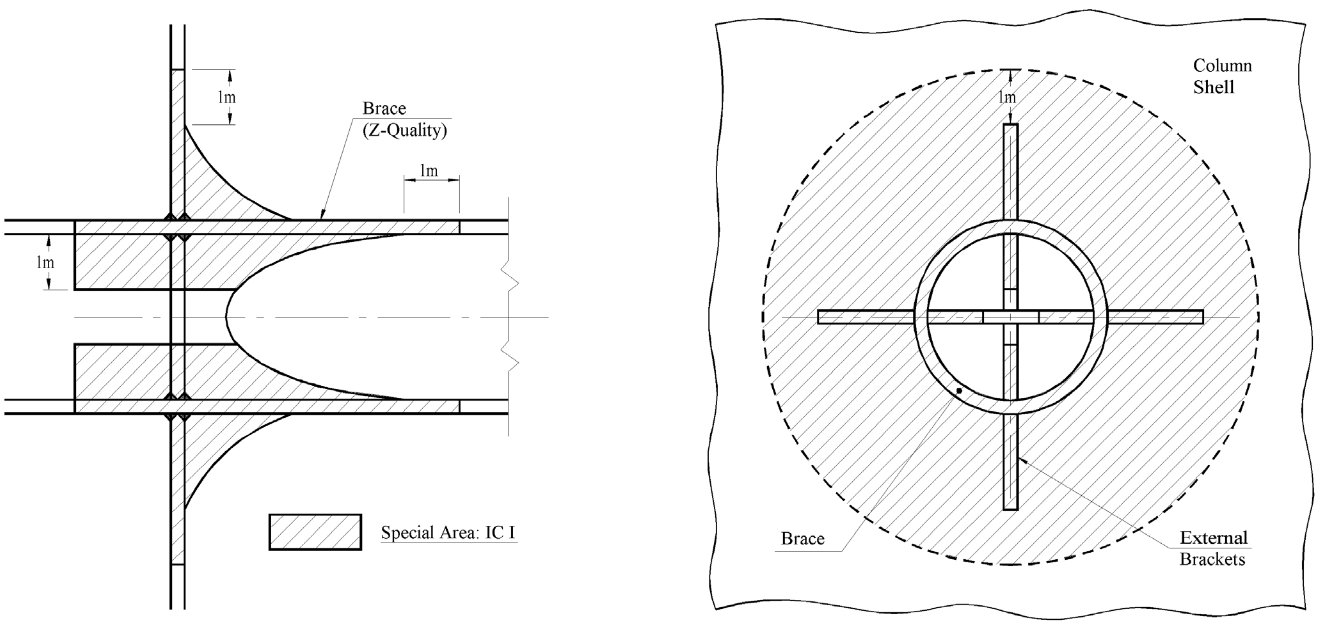


Figure 3
Brace connection

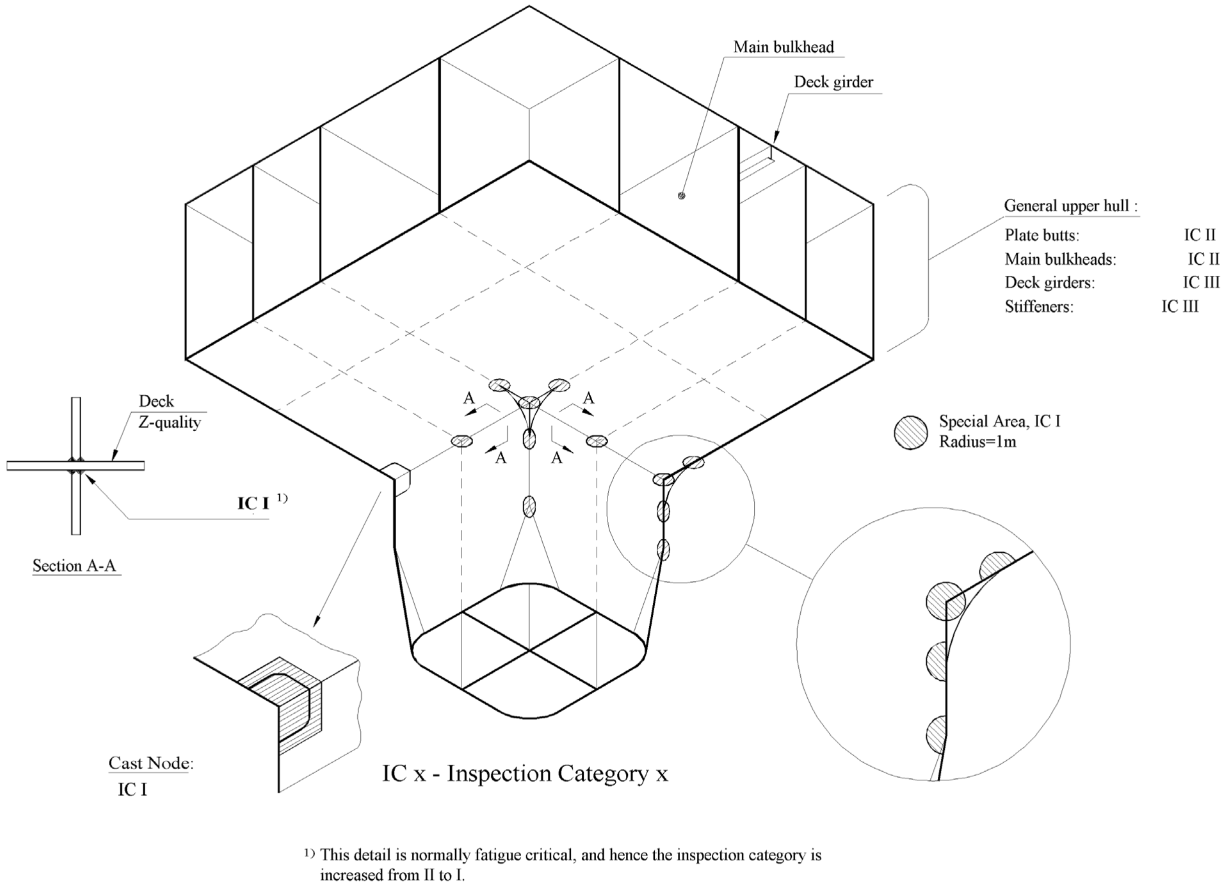


Figure 4
Connection column and upper hull

C. Design and Loading Conditions

C 100 General

101 The general definitions of design and loading conditions are given in Secs.2 and 3. Further details regarding loads on column-stabilised units are presented in DNV-RP-C103.

C 200 Permanent loads

201 Permanent loads will not vary in magnitude, position, or direction during the period considered, and include:

— lightweight of the unit, including mass of permanently installed modules and equipment, such as accommodation, helicopter deck, drilling and production equipment
— hydrostatic pressures resulting from buoyancy
— pre-tension in respect to mooring, drilling and production systems (e.g. mooring lines, risers etc.) see DNV-OS-E301.

C 300 Variable functional loads

301 Except where analytical procedures or design specifications otherwise require, the value of the variable loads utilised in structural design shall be taken as either the lower or upper value, whichever gives the more unfavourable effect. Variable loads on deck areas for local design and global strength analysis are given in Sec.3 D200.

302 Variations in operational mass distributions (including variations in tank load conditions in pontoons) shall be adequately accounted for in the structural design.

303 Design criteria resulting from operational requirements shall be fully considered. Examples of such operations may be:

— drilling, production, workover, and combinations thereof
— consumable re-supply procedures
— maintenance procedures
— possible mass re-distributions in extreme conditions.

C 400 Tank loads

401 Formulas for tank pressures are given in Sec.3 D300. Descriptions and requirements related to different tank arrangements are given in DNV-OS-D101 Ch.2 Sec.3 C300.

402 The extent to which it is possible to fill sounding, venting or loading pipe arrangements shall be fully accounted for in determination of the maximum pressure to which a tank may be subjected to.

403 For external plate field boundaries, it is allowed to consider the external pressure up to the lowest waterline occurring in the environmental extreme condition in compliance with relevant tank loads (including relative motion of the unit).

Guidance note:
For preliminary design calculations, a_v in Sec.3 D307 may be taken as 0.3 g_0 and external pressure for external plate field boundaries may be taken up to half the pontoon height.

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C 500 Environmental loads, general

501 General descriptions and formulas for environmental loads are given in Secs.3 E and F, with further considerations also given in Classification Note 30.5.

502 Typical environmental loads to be considered in the structural design of a column-stabilised unit are:

— wave loads (including variable pressure, inertia, wave

"run-up", and slamming loads)
— wind loads
— current loads
— snow and ice loads.

503 The following responses due to environmental loads shall be considered in the structural design of a column-stabilised unit:

— dynamic stresses for all design conditions
— rigid body motion (e.g. in respect to air gap and maximum angles of inclination)
— sloshing
— slamming induced vibrations
— vortex induced vibrations (e.g. resulting from wind loads on structural elements in a flare tower)
— environmental loads from mooring and riser system.

504 For column-stabilised units with traditional catenary mooring systems, earthquake loads may be ignored.

C 600 Sea pressures

601 For load conditions where environmental load effects shall be considered the pressures resulting from sea loading are to include consideration of the relative motion of the unit.

602 The sea pressure acting on pontoons and columns of column-stabilised platforms in operating conditions shall be taken as:

$$p_d = p_s + p_e$$

where

$$p_s = \rho\ g_0\ C_w(T_E - z_b) \quad (kN/m^2) \quad \geq 0$$

and

$$p_e = \rho\ g_0\ C_w(D_D - z_b) \quad (kN/m^2) \text{ for } z_b \geq T_E$$

$$p_e = \rho\ g_0\ C_w(D_D - T_E) \quad (kN/m^2) \text{ for } z_b < T_E$$

T_E = extreme operational draught (m) measured vertically from the moulded baseline to the assigned load waterline
C_w = reduction factor due to wave particle motion (Smith effect)
= 0.9 unless otherwise documented
D_D = vertical distance in m from the moulded baseline to the underside of the deck structure (the largest relative distance from moulded baseline to the wave crest may replace D_D if this is proved smaller)
z_b = vertical distance in m from the moulded baseline to the load point
p_s = permanent sea pressure
p_e = environmental sea pressure.

603 The Smith effect (C_w = 0.9) shall only be applied for loading conditions including extreme wave conditions.

C 700 Wind loads

701 Description for calculation of wind loads may be found in Sec.3 E800 and Classification Note 30.5.

C 800 Heavy components

801 The forces acting on supporting structures and lashing systems for rigid units of cargo, equipment or other structural components should be taken as:

$$P_V = (g_0 + a_v)M_c \quad (kN)$$
$$P_H = a_h M_c \quad (kN)$$

For components exposed to wind, a horizontal force due to the gust wind shall be added to P_H.

a_v = vertical acceleration (m/s^2)
a_h = horizontal acceleration (m/s^2)
M_c = mass of cargo, equipment or other components (t)
P_V = vertical force
P_H = horizontal force.

C 900 Combination of loads

901 Load combinations and acceptance criteria are in general given in Sec.2.

902 Structural strength shall be evaluated considering all relevant, realistic load conditions and combinations for column-stabilised units. For each individual structural element, scantlings shall be determined on the basis of criteria that combine, in a rational manner, the most critical combined effects of relevant global and local loads. Further guidance on relevant load combinations is given in DNV-RP-C103.

903 A sufficient number of load conditions shall be evaluated to ensure that the characteristic largest (or smallest) response, for the appropriate return period, has been established.

D. Structural Strength

D 100 General

101 Global and local structural capacity shall be checked according to Secs. 5 and 6.

102 Analytical models shall adequately describe the relevant properties of loads, stiffness, displacement, response, satisfactory account for the local system, effects of time dependency, damping, and inertia.

103 The usage factors η_0 are given in section 2, E201, Table E1.

104 The environmental loads may be disregarded in loading condition e), ref. section 2, E201, Table E1, if a basic usage factor of 0.75 is applied.

D 200 Global capacity

201 Strength capacity check shall be performed for all structural members contributing to the global and local strength of the column-stabilised unit. The structures to be checked includes, but are not limited to, the following:

— outer skin of pontoons
— longitudinal and transverse bulkheads, girders and decks in pontoons
— connections between pontoon, columns and bracings
— bracings
— outer skin of columns
— decks, stringers and bulkheads in columns
— main bearing bulkheads, frameworks and decks in the deck structure
— connection between bracings and the deck structure
— connection between columns and the deck structure
— girders in the deck structure.

D 300 Transit condition

301 The structure shall be analysed for zero forward speed. For units in transit with high speed, also maximum speed shall be considered in the load and strength calculations.

Guidance note:

Roll and pitch motion at resonance should be somewhat smaller than calculated by a linear wave theory due to flow of water on top of the pontoons. This effect may be accounted for provided rational analysis or tests prove its magnitude.

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302 Slamming on bracings shall be considered as a possible limiting criterion for operation in transit. The effect of forward speed shall be accounted for in the slamming calculations.

D 400 Method of analysis

401 The analysis shall be performed to evaluate the structural capacity due to global and local effects.

Consideration of relevant analysis methods and procedures are given in DNV-RP-C103 and Appendix B.

402 Model testing shall be performed when significant non-linear effects cannot be adequately determined by direct calculations. In such cases, time domain analysis may also be considered as being necessary. Model tests shall also be performed for new types of column-stabilised units.

403 Where non-linear effects may be considered insignificant, or where such loads may be satisfactorily accounted for in a linear analysis, a frequency domain analysis can be undertaken. Transfer functions for structural response shall be established by analysis of an adequate number of wave directions, with an appropriate radial spacing. A sufficient number of periods shall be analysed to:

— adequately cover the site specific wave conditions
— satisfactorily describe transfer functions at, and around, the wave “cancellation” and “amplifying” periods
— satisfactorily describe transfer functions at, and around, the heave resonance period of the unit.

404 Global, wave-frequency, structural responses shall be established by an appropriate methodology, for example:

— a regular wave analysis
— a “design wave” analysis
— a stochastic analysis.

405 Design waves established based on the "design wave" method, see DNV-RP-C103, shall be based on the 90% percentile value of the extreme response distribution (100 years return period) developed from contour lines and short term extreme conditions.

406 A global structural model shall represent the global stiffness and should be represented by a large volume, thin-walled three dimensional finite element model. A thin-walled model should be modelled with shell or membrane elements sometimes in combination with beam elements. The structural connections in the model shall be modelled with adequate stiffness in order to represent the actual stiffness in such a way that the resulting responses are appropriate to the model being analysed. The global model usually comprises:

— pontoon shell, longitudinal and transverse bulkheads
— column shell, decks, bulkheads and trunk walls
— main bulkheads, frameworks and decks for the deck structure (“secondary” decks which are not taking part in the global structural capacity should not be modelled)
— bracing and transverse beams.

407 The global analyses should include consideration of the following load effects as found relevant:

— built-in stresses due to fabrication or mating
— environmental loads
— different ballast conditions including operating and survival
— transit.

408 Wave loads should be analysed by use of sink source model in combination with a Morison model when relevant. For certain designs a Morison model may be relevant. Details related to normal practice for selection of models and methods are given in Appendix B.

D 500 Air gap

501 Positive air gap should in general be ensured for waves with a 10^{-2} annual probability of exceedance. However, local wave impact may be accepted if it is documented that such loads are adequately accounted for in the design and that safety to personnel is not significantly impaired.

502 Analysis undertaken to check air gap should be calibrated against relevant model test results when available. Such analysis should take into account:

— wave and structure interaction effects
— wave asymmetry effects
— global rigid body motions (including dynamic effects)
— effects of interacting systems (e.g. mooring and riser systems)
— maximum and minimum draughts.

503 Column “run-up” load effects shall be accounted for in the design of the structural arrangement in the way of the column and bottom plate of the deck connection. These “run-up” loads shall be treated as environmental load component, however, they should not be considered as occurring simultaneously with other environmental loads.

504 Evaluation of sufficient air gap shall include consideration of all affected structural items including lifeboat platforms, riser balconies, overhanging deck modules etc.

E. Fatigue

E 100 General

101 General methods and requirements for design against fatigue are presented in Sec. 7 and DNV-RP-C203.

102 Units intended to follow normal inspection requirements according to class requirements, i.e. inspection every five years in sheltered waters or dry dock, may apply a design fatigue factor (DFF) of 1.0.

103 Units intended to operate continuously at the same location for more than 5 years, i.e. without planned sheltered water inspection, shall comply with the requirements given in Appendix C.

104 In the assessment of fatigue resistance, relevant consideration shall be given to the effects of stress concentrations including those occurring as a result of:

— fabrication tolerances (including due regard to tolerances in way of connections involved in mating sequences or section joints)
— cut-outs
— details at connections of structural sections (e.g. cut-outs to facilitate construction welding)
— attachments.

105 Local detailed FE-analysis of critical connections (e.g. pontoon and pontoon, pontoon and column, column and deck and brace connections) should be undertaken in order to identify local stress distributions, appropriate SCFs, and/or extrapolated stresses to be utilised in the fatigue evaluation. Dynamic stress variations through the plate thickness shall be checked and considered in such evaluations, see DNV-RP-C203, for further details.

106 For well known details the local FE-analysis may be omitted, provided relevant information regarding SCF are available.

E 200 Fatigue analysis

201 The basis for determining the acceptability of fatigue resistance, with respect to wave loads, shall be in accordance with the requirements given in Appendix B. The required models and methods are dependent on type of operation, environment and design type of the unit.

202 In case a simplified fatigue analyses as presented in Sec.7 A400 is undertaken, appropriate conservative design parameters should be utilised. A two-parameter, Weibull distribution with the Weibull shape parameter 'h' equal to 1.1, see DNV-RP-C203, may be used for the long-term stress range distribution of a two-pontoon column-stabilised unit.

F. Accidental Conditions

F 100 General

101 A column-stabilised unit shall be checked for credible accidental events in accordance with principles and requirements given in Sec.8.

102 The structural arrangement of the upper hull shall be considered with regard to the structural integrity of the unit after the failure of relevant parts of any primary structural element essential for the overall integrity caused by fire or explosion. Where considered necessary, a structural analysis may be required with strength criteria as loading condition d).

F 200 Collision

201 A collision between a supply vessel and a column of column-stabilised units shall be considered for all elements of the unit that may be exposed to sideway, bow or stern collision. The vertical extent of the collision zone shall be based on the depth and draught of the supply vessel and the relative motion between the supply vessels and the unit.

202 A collision against a column will normally only cause local damage of the column, i.e. loading condition c) and d) need not be checked. However, for units with slender columns, the global strength of the unit at the moment of collision and the residual strength after collision shall be checked according to Sec.5.

203 A collision against a bracing will normally cause complete failure of the bracing and its connections (e.g. K-joints). These parts should be assumed non-effective for check of the residual strength of the unit after collision.

204 For especially strong bracings, a collision damage may be limited to local denting. The residual strength of the bracing may be included for check of the unit after the accident.

F 300 Dropped objects

301 A dropped object on a bracing will normally cause complete failure of the bracing or its connections (e.g. K-joints). These parts should be assumed to be non-effective for the check of the residual strength of the unit after dropped object impact.

302 For especially strong bracings, the damage caused by dropped objects may be limited to local denting. The residual strength of the bracing may be included for check of the unit after the accident.

F 400 Fire

401 The main load bearing structure that is subjected to a fire shall not lose the structural integrity. The following fire scenarios should be considered as appropriate:

— fire inside the unit
— fire on the sea surface.

F 500 Explosion

501 Principles and requirements with respect to design against explosion are presented in Sec.8.

F 600 Heeled condition

601 Heeling of the unit after damage flooding as described in DNV-OS-C301 shall be accounted for in the assessment of structural strength. Maximum static allowable heel after accidental flooding is 17° including wind. Structures that are wet when the static equilibrium angle is achieved, shall be checked for external water pressure.

Guidance note:

The heeled condition corresponding to accidental flooding in transit conditions will normally not be governing for the design.

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602 The unit shall be designed for environmental condition corresponding to one year return period after damage. See Sec.2 Table E1.

Guidance note:

The environmental loads may be disregarded in load condition e) provided a usage factor of 0.75 is applied.

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G. Redundancy

G 100 General

101 Structural robustness shall, when considered necessary, be demonstrated by appropriate analysis. Slender, main load bearing structural elements shall normally be demonstrated to be redundant in the accidental design condition.

G 200 Brace arrangements

201 For bracing systems the following considerations shall apply:

a) Brace structural arrangements shall be investigated for relevant combinations of global and local loads.

b) Structural redundancy of slender bracing systems (see G100) shall normally include brace node redundancy (i.e. all bracings entering the node), in addition to individual brace element redundancy.

c) Brace end connections (e.g. brace and column connections) shall normally be designed such that the brace element itself will fail before the end connection.

d) Underwater braces shall be watertight and have a leakage detection system.

e) The effect of slamming on braces shall be considered, e.g. in transit condition.

H. Structure in Way of a Fixed Mooring System

H 100 Structural strength

101 Structure supporting mooring equipment such as fairleads and winches, towing brackets etc. shall be designed for the loads and acceptance criteria specified in DNV-OS-E301 Ch.2 Sec.4. Details related to design of supporting structure for mooring equipment may be found in DNV-RP-C103.

I. Structural Details

I 100 General

101 In the design phase particular attention should be given to structural details, and requirements for reinforcement in areas that may be subjected to high local stresses, for example:

— critical connections
— locations that may be subjected to wave impact (including wave run-up effects along the columns)
— locations in way of mooring arrangements
— locations that may be subjected to damage.

102 In way of critical connections, structural continuity should be maintained through joints with the axial stiffening members and shear web plates being made continuous. Particular attention should be given to weld detailing and geometric form at the point of the intersections of the continuous plate fields with the intersecting structure.

SECTION 12
SPECIAL CONSIDERATIONS FOR SELF-ELEVATING UNITS

A. Introduction

A 100 Scope and application

101 This section contains specific requirements and guidance applicable for all types of self-elevating units. The requirements come in addition to those of Secs.1 - 10, see Sec.1 A103.

102 Requirements regarding certification of jacking gear machinery are given in DNV-OS-D101.

B. Structural Categorisation, Material Selection and Inspection Principles

B 100 General

101 The structural application categories are determined based on the structural significance, consequences of failure and the complexity of the joints and shall be selected according to the principles as given in Sec.4.

102 The steel grades selected for structural components shall be related to weldability and requirements for toughness properties and shall be in compliance with the requirements given in the DNV-OS-B101.

B 200 Structural categorisation

201 Application categories for structural components are defined in Sec.4. Structural members of self-elevating units are normally found in the following groups:

Special category

a) Vertical columns in way of intersection with the mat structure.

b) Highly stressed elements of bottom of leg, including leg connection to spudcan or mat.

c) Intersections of lattice type leg structure, which incorporates novel construction, including the use of steel castings.

d) Highly stressed elements of guide structures, jacking and locking system(s), jackhouse and support structure.

e) Highly stressed elements of crane pedestals, etc. and their supporting structure.

Guidance note:
Highly stressed areas are normally considered to be areas utilised more than 85% of the allowable yield capacity.

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Primary category

a) Combination of bulkhead, deck, side and bottom plating within the hull which form "Box" or "I" type main supporting structure.

b) All components of lattice type legs and external plating of cylindrical legs.

c) Jackhouse supporting structure and bottom footing structure, which receives initial transfer of load from legs.

d) Internal bulkheads, shell and deck of spudcan or bottom mat supporting structures which are designed to distribute major loads, either uniform or concentrated, into the mat structure.

e) Main support structure of heavy substructures and equipment, e.g. cranes, drill floor substructure, life boat platform and helicopter deck.

Secondary category

a) Deck, side and bottom plating of hull except areas where the structure is considered primary or special application.

b) Bulkheads, stiffeners, decks and girders in hull that are not considered as primary or special application.

c) Internal bulkheads and girders in cylindrical legs.

d) Internal bulkheads, stiffeners and girders of spudcan or bottom mat supporting structures except where the structures are considered primary or special application.

B 300 Material selection

301 Material selection shall be performed in accordance with the principles and requirements given in Sec.4. The selection shall refer to structural categorisation and service temperatures as stated in Sec.4 and in the present section.

302 For rack plates with yield strength equal to 690 N/mm^2 in rack and pinion jacking systems steel grade NV E690 or higher shall be applied.

303 For a self-elevating unit external structures above water during elevated operation shall be designed with a service temperature not higher than the design temperature, i.e. lowest mean daily temperature, for the area(s) the unit us to operate. At the same time the service temperature for design of structures above the transit waterline during transportation shall not be higher than the lowest mean daily temperature for the area(s) where the unit shall be transported.

304 Internal structures of maths, spud cans, legs and hull are assumed to have the same service temperature as the adjacent external structure if not otherwise documented, according to Sec.4.

B 400 Inspection categories

401 Welding, and the extent of non-destructive examination during fabrication, shall be in accordance with the requirements stipulated for the appropriate inspection category as defined in Sec.4.

C. Design and Loading Conditions

C 100 General

101 The general definitions of design and loading conditions are given in Secs.2 and 3. whilst the loading conditions within each design condition are defined in 102.

102 The structure shall be designed to resist relevant loads associated with conditions that may occur during all stages of the life-cycle of the unit. The conditions that should be considered are:

— transit condition(s)
— installation condition
— operating condition(s)
— survival condition
— retrieval condition.

103 Relevant loading conditions for the different design condition are shown in Table C1.

Table C1 Relevant design and loading conditions

Design conditions	*Loading conditions*				
	a)	b)	c)	d)	e)
Transit	X	X			X
Installation		X			
Operation	X	X	X	X	
Survival	X	X			
Retrieval		X			

104 Load cases shall be established for the various design conditions based on the most unfavourable combinations of functional loads, environmental loads and/or accidental loads. Analysis should include built in stresses due to assembly of the structure during fabrication.

105 Limiting environmental and operating conditions (design data) for the different design conditions shall be specified by the builder.

106 Limiting design criteria for going from one design condition to another shall be clearly established and documented.

107 If the unit is intended to be dry docked the footing structure (i.e. mat or spudcans) shall be suitably strengthened to withstand such loads.

C 200 Transit

201 The present standard considers requirements for wet transits. Requirements in case of dry transit on a heavy lift vessel are considered to be covered by the warranty authority for the operation.

202 Wet transits are characterised as either

- a *field move* requiring no more than a 12-hour voyage to a location where the unit could be elevated, or to a protected location
- an *ocean transit* requiring more than a 12-hour voyage to a location where the unit could be elevated, or to a protected location.

203 A detailed transportation assessment shall be undertaken for wet transits. The assessment should include determination of the limiting environmental criteria, evaluation of intact and damage stability characteristics, motion response of the global system and the resulting, induced loads. The occurrence of slamming loads on the structure and the effects of fatigue during transport phases shall be evaluated when relevant.

Guidance note:
For guidance on global analysis for the transit condition see Classification Note 31.5, 5.3 and for environmental loading see Classification Note 30.5.

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204 The structure shall be analysed for zero forward speed in analysis of wet transit.

205 The legs shall be designed for the static and inertia forces resulting from the motions in the most severe environmental transit conditions, combined with wind forces resulting from the maximum wind velocity.

206 The leg positions for both field moves and ocean moves shall be assessed when considering structural strength for transit condition.

207 In lieu of a more accurate analysis, for the ocean transit condition the legs shall be designed for the following forces considered to act simultaneously:

- 120% of the acceleration forces caused by the roll and pitch of the platform
- 120% of the static forces at the maximum amplitude of roll or pitch
- wind forces from a 45 m/s wind velocity.

Guidance note:
The effect of heave, surge and sway are implicitly accounted for by use of the 20% upscaling of the motions.

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208 For the field move position the legs may be designed for the acceleration forces caused by a 6° single amplitude roll or pitch at the natural period of the unit plus 120% of the static forces at a 6° inclination of the legs unless otherwise verified by model tests or calculations.

209 Dynamic amplification of the acceleration forces on the legs shall be accounted for if the natural periods of the legs are such that significant amplification may occur.

210 If considered relevant, the effect of vortex shedding induced vibrations of the legs due to wind shall be taken into account.

Guidance note:
For guidance relating to vortex induced oscillations see Classification Note 30.5.

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211 The hull shall be designed for global mass and sea pressure loads, local loads and leg loads during transit.

212 Satisfactory compartmentation and stability during all floating operations shall be ensured, see DNV-OS-C301.

213 Unless satisfactory documentation exists demonstrating that shimming is not necessary, relevant leg interfaces (e.g. leg and upper guide) shall be shimmed in the transit condition.

214 All aspects of transportation, including planning and procedures, preparations, seafastenings and marine operations should comply with the requirements of the warranty authority.

C 300 Installation and retrieval

301 Relevant static and dynamic loads during installation and retrieval shall be accounted for in the design, including consideration of the maximum environmental conditions expected for the operations and leg impact on the seabed.

Guidance note:
Guidance relating to simplified analytical methodology for bottom impact on the legs is given in Classification Note 31.5, 5.8.

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302 The capacity of the unit during pre-loading must be assessed. The purpose of pre-loading is to develop adequate foundation capacity to resist the extreme vertical and horizontal loadings. The unit should be capable of pre-loading to exceed the maximum vertical soil loadings associated with the worst storm loading.

Guidance note:
Guidance relating to pre-loading is given in Classification Note 30.4, 1 and 8.

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303 The hull structure shall be analysed to ensure it can withstand the maximum pre-loading condition.

304 The structural strength of the hull, legs and footings during installation and retrieval shall comply with the strength condition given in Sec.5.

C 400 Operation and survival

401 The operation and survival conditions cover the unit in the hull elevated mode.

402 A detailed assessment shall be undertaken which includes determination of the limiting soils, environmental and weight criteria and the resulting, induced loads.

403 Dynamic structural deflection and stresses due to wave loading shall be accounted for if the natural periods of the unit are such that significant dynamic amplification may occur.

404 Non-linear amplification (large displacement effects) of the overall deflections due to second order bending effects of the legs shall be accounted for whenever significant.

405 The effect of leg fabrication tolerances and guiding system clearances shall be accounted for.

406 The leg/soil interaction shall be varied as necessary within the design specifications to provide maximum stress in the legs, both at the bottom end and at the jackhouse level.

407 Critical aspects to be considered in the elevated condition are structural strength, overturning stability and air gap.

408 The structural strength of the hull, legs and footings during operation and survival shall comply with the requirements of this section and Sec.5. The strength assessment should be carried out for the most limiting conditions with the maximum storm condition and maximum operating condition examined as a minimum.

Guidance note:

The hull will typically comprise the following elements:

- decks
- side and bottom plating
- longitudinal bulkheads
- transverse frames
- longitudinal girders and stringers
- stringers and web frames on the transverse bulkheads
- jackhouses.

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409 The strength of the hull shall be assessed based on the characteristic load conditions that result in maximum longitudinal tension and compression stresses (for yield and buckling assessment) in deck and bottom plating.

410 The effect of large openings in the hull (e.g. drill slot) which affect the distribution of global stresses should be determined by a finite element model accounting for three-dimensional effects.

D. Environmental Conditions

D 100 General

101 Environmental conditions for design of self-elevating units should be specified in accordance with Sec.3.

102 Metocean data for the design may be given as maximum wave heights with corresponding wave periods and wind- and current velocities and design temperatures or as acceptable geographical areas for operation. In the latter case the builder is to specify the operational areas and submit documentation showing that the environmental data for these areas are within the environmental design data.

D 200 Wind

201 Wind velocity statistics shall be used as a basis for a description of wind conditions, if such data are available. Different averaging periods of wind velocities, see Sec.1 D, should be used depending on the actual wind force and effect considered.

202 Characteristic wind design velocities shall be based upon appropriate considerations of velocity and height profiles for the relevant averaging time.

Guidance note:

Practical information in respect to wind conditions, including velocity and height profiles, is documented in Classification Note 30.5.

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D 300 Waves

301 Wave conditions which shall be considered for design purposes, may be described either by deterministic (regular) design wave methods or by stochastic (irregular seastate) methods applying wave energy spectra.

302 Short term irregular seastates are described by means of wave energy spectra, which are characterised by significant wave height (H_S), and average zero-upcrossing period (T_Z).

Analytical spectrum expressions are to reflect the width and shape of typical spectra for the considered height.

The shortcrestedness of waves in a seaway, i.e. the directional dispersion of wave energy, may be taken into account. The principal direction of wave encounter is defined as the direction of maximum wave energy density.

Guidance note:

For open sea locations the Pierson-Moskowitz (P-M) type of spectrum may be applied. For shallow water, or locations with a narrow "fetch", a more narrow spectrum should be considered (e.g. Jonswap spectrum).

Practical information in respect to wave conditions is documented in Classification Note 30.5, 3 and Classification Note 31.5, 3.2.

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303 In deterministic design procedures, based on simple regular wave considerations, the wave shall be described by the following parameters:

— wave period
— wave height
— wave direction
— still water depth.

The choice of an appropriate design wave formulation has to be based on particular considerations for the problem in question. Shallow water effects shall be accounted for.

304 The wave height for the occurrence period, e.g. 100-years, should be the most probable largest individual wave height during the period.

305 The design waves shall be those, which produce the most unfavourable loads on the considered structure, taking into account the shape and size of structure, etc.

The wave period shall be specified in each case of application. It may be necessary to investigate a representative number of wave periods, in order to ensure a sufficiently accurate determination of the maximum loads.

D 400 Current

401 Adequate current velocity data shall be selected from the statistics available. Different components of current shall be considered, such as tidal current and wind generated current.

D 500 Snow and ice

501 Snow and ice shall be considered as necessary for the areas where the unit is to operate or be transported.

E. Method of Analysis

E 100 General

101 Structural analysis shall be performed to evaluate the structural strength due to global and local effects.

102 The following responses shall be considered in the structural design whenever significant:

- dynamic stresses for all design conditions
- non-linear wave loading effects, (e.g. effect of drag and finite wave elevation)
- non-linear amplification due to second order bending effects of the legs (P-delta effect)
- effects of leg fabrication tolerances and leg guiding system clearances
- slamming induced vibrations
- vortex induced vibrations (e.g. resulting from wind loads on structural elements in a flare tower or in lattice legs above jackhouses)
- wear resulting from environmental loads at riser system interfaces with hull structures.

103 Non-linear amplification of the overall deflections due to second order bending effects of the legs shall be accounted for whenever significant. The non-linear bending response may be calculated by multiplying the linear leg response by an amplification factor as follows:

$$\alpha = \frac{1}{1 - P/P_E}$$

P = axial load on one leg

P_E = Euler buckling load for one leg.

104 In the unit elevated mode the global structural behaviour may be calculated by deterministic quasi-static analysis, directly considering non-linear wave and leg bending effects. The effect of dynamics should be represented by an inertia force contribution at the level of the hull centre of gravity or by a dynamic amplification factor, as specified in Classification Note 31.5.

105 In case of significant uncertainties related to the non-linear, dynamic behaviour, stochastic time domain analysis may be performed. The selection of critical seastate for the analysis should be properly considered.

Guidance note:

For shallow waters the significant wave height should be corrected as shown in Classification Note 30.5, 3.2.11.

The irregular wave simulation may be performed as presented in Classification Note 30.5, 3.2.12.

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106 Where non-linear loads may be considered as being insignificant, or where such loads may be satisfactorily accounted for in a linearised analysis, a frequency domain analysis may be undertaken. Transfer functions for structural response shall be established by analysis of an adequate number of wave directions, with an appropriate radial spacing. A sufficient number of periods shall be analysed to:

- adequately cover the site specific wave conditions
- to satisfactorily describe transfer functions at, and around, the wave 'cancellation' and 'amplifying' periods
- to satisfactorily describe transfer functions at, and around, the resonance period of the unit.

107 As an alternative to time domain analysis model testing may be performed when non-linear effects cannot be adequately determined by direct calculations. Model tests should also be performed for new types of self-elevating units.

108 For independent leg units, the static inclination of the legs shall be accounted for. The inclination is defined as the static angle between the leg and a vertical line and may be due to fabrication tolerances, fixation system and hull inclination, as specified in Classification Note 31.5.

109 The seabed conditions, and therefore the leg and soil interaction, need to be considered as it effects the following

- leg bending moment distribution
- overall structure stiffness and therefore the natural period of the unit
- load distribution on the spudcans.

110 The leg and soil interaction should be varied as necessary between an upper and lower bound to provide conservative response limits at the bottom leg and footing area and at the jackhouse level.

Guidance note:

As the leg and soil interaction is difficult to predict, it is acceptable and conservative to assume pinned and fixed conditions as the upper and lower bounds.

For further guidance see Classification Note 30.4 Sec.8 and Classification Note 31.5, Sec.3.6 and Sec.5.5.

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111 The leg and hull connection may be designed by any of or combination of the following methods:

- a fixation system, i.e. rack chock
- a fixed jacking system, i.e. pinions rigidly mounted to the jackhouse
- a floating jacking system, i.e. pinions mounted to the jackhouse by means of flexible shock pads
- a guiding system by upper and lower guides.

The characteristics and behaviour of the actual leg and hull connection system need to be properly represented in the appropriate global and local analyses.

Guidance note:

Practical information in respect to modelling leg and hull interaction is documented in Classification Note 31.5 Sec.5.4 or SNAME 5-5A, Section 5.6.

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E 200 Global structural models

201 A global structural model shall represent the global stiffness and behaviour of the platform. The global model should usually represent the following:

- footing main plating and stiffeners
- leg truss or shell and stiffeners
- jackhouse and leg/hull interaction
- main bulkheads, frameworks and decks for the deck structure ("secondary" decks which are not taking part in the global structural capacity should not be modelled)
- mass model.

202 Depending on the purpose of the analysis and possible combination with further local analysis the different level of idealisation and detailing may be applied for a global structure. The hull may either be represented by a detailed plate and shell model or a model using grillage beams. The legs may be modelled by detailed structural models or equivalent beams, or a combination of such.

Guidance note:

For further guidance regarding modelling procedures see Classification Note 31.5 or SNAME 5-5A.

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E 300 Local structural models

301 An adequate number of local structural models should be created in order to evaluate response of the structure to variations in local loads. The model(s) should be sufficiently detailed such that resulting responses are obtained to the required degree of accuracy. A number of local models may be required in order to fully evaluate local response at all relevant sections. The following local models should be analysed in the evaluation of strength:

— footing, mat or spudcan
— stiffened plates subjected to tank pressures or deck area loads
— leg and hull connection system including jackhouse support structure
— support structure for heavy equipment such as drill floor and pipe racks
— riser hang off structure
— crane pedestal support structure
— helicopter deck support structure.

302 A detailed FE model should be applied to calculate the transfer of leg axial forces, bending moments and shears between the upper and lower guide structures and the jacking and/or fixation system. The systems and interactions should be properly modelled in terms of stiffness, orientation and clearances. The analysis model should also include a detailed model of the leg in the hull interface area, the guides, fixation and/or jacking system, together with the main jackhouse structure.

Guidance note:

The detailed leg model should normally extend 4 bays below and above the lower and upper guides, respectively.

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Guidance note:

For further guidance regarding modelling procedures see Classification Note 31.5 or SNAME 5-5A.

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E 400 Fatigue analysis

401 The fatigue life shall be calculated considering the combined effects of global and local structural response. The expected dynamic load history shall be specified in the design brief as basis for the calculations.

402 Stress concentration factors for fatigue sensitive structural details that cannot be obtained from standard tables, e.g. due to different structural arrangement or that dimensions are out of range of the formula, should be determined by a finite element analysis.

F. Design Loads

F 100 General

101 The requirements in this section define and specify load components and load combinations to be considered in the overall strength analysis as well as design pressures applicable in formulae for local scantlings.

102 Characteristic loads shall be used as reference loads. General description of load components and combinations are given in Sec.3. Details regarding environmental loads are described in Classification Note 30.5. Presentation of load categories relevant for self-elevating units are given in F200 to F1500.

F 200 Permanent loads

201 Permanent loads are loads that will not vary in magnitude, position, or direction during the period considered and include:

— 'lightweight' of the unit, including mass of permanently installed modules and equipment, such as accommodation, helicopter deck, drilling and production equipment
— permanent ballast
— hydrostatic pressures resulting from buoyancy
— pretension in respect to drilling and production systems (e.g. risers, etc.).

F 300 Variable functional loads

301 Variable functional loads are loads that may vary in magnitude, position and direction during the period under consideration.

302 Except where analytical procedures or design specifications otherwise require, the value of the variable loads utilised in structural design should be taken as either the lower or upper design value, whichever gives the more unfavourable effect. Variable loads on deck areas may be found in Sec.3. These should be applied unless specified otherwise in design basis or design brief.

303 Variations in operational mass distributions (including variations in tank load conditions) shall be adequately accounted for in the structural design.

304 Design criteria resulting from operational requirements should be fully considered. Examples of such operations may be:

— drilling, production, workover, and combinations thereof
— consumable re-supply procedures
— maintenance procedures
— possible mass re-distributions in extreme conditions.

F 400 Tank loads

401 Formulas for tank pressures are given in Sec.3 D300. Descriptions and requirements related to different tank arrangements are given in DNV-OS-D101 Ch.2 Sec.3 C300.

402 The extent to which it is possible to fill sounding, venting or loading pipe arrangements shall be fully accounted for in determination of the maximum design pressure which a tank may be subjected to.

403 The vertical acceleration, a_V, in the formula in Sec.3 D308 only applies to transit conditions. For the operation and survival conditions with the deck elevated av may be take equal to zero.

F 500 Environmental loads, general

501 General considerations for environmental loads are given in Sec.3 E, F, G, H and I , and in Classification Note 30.5.

502 Combinations of environmental loads are stated in Sec.3 F.

F 600 Wind loads

601 In conjunction with maximum wave forces the sustained wind velocity, i.e. the 1 minute average velocity, shall be used. If gust wind alone is more unfavourable than sustained wind in conjunction with wave forces, the gust wind velocity shall be used. For local load calculations gust wind velocity shall be used.

602 Formulas for calculation of wind loads may be taken from Classification Note 30.5 Sec.5.

603 Applicable shape coefficients for different structure parts are given in Table F1. For shapes or combination of shapes which do not readily fall into the categories in Table F1 the formulas in Classification Note 30.5 Sec.5 should be applied.

Table F1 Shape coefficient	
Type of structure or member	C_s
Hull, based on total projected area	1.0
Deckhouses, jack-frame structure, sub-structure, draw-works house, and other above deck blocks, based on total projected area of the structure.	1.1
Leg sections projecting above the jack-frame and below the hull	See Classification Note 30.5.
Isolated tubulars, (e.g. crane pedestals, etc.)	0.5
Isolated structural shapes, (e.g. angles, channels, boxes, I-sections), based on member projected area	1.5
Derricks, crane booms, flare towers (open lattice sections only, not boxed-in sections)	According to Classification Note 30.5 or by use of the appropriate shape coefficient for the members concerned applied to 50% of the total projected area.

604 For structures being sensitive to dynamic loads, for instance tall structures having long natural period of vibration, the stresses due to the gust wind pressure considered as static shall be multiplied by an appropriate dynamic amplification factor.

605 The possibility of vibrations due to instability in the flow pattern induced by the structure itself should also be considered.

F 700 Waves

701 The basic wave load parameters and response calculation methods in this standard shall be used in a wave load analysis where the most unfavourable combinations of height, period and direction of the waves are considered.

702 The liquid particle velocity and acceleration in regular waves shall be calculated according to recognised wave theories, taking into account the significance of shallow water and surface elevation.

Linearised wave theories may be used when appropriate. In such cases appropriate account shall be taken of the extrapolation of wave kinematics to the free surface.

703 The wave design data shall represent the maximum wave heights specified for the unit, as well as the maximum wave steepness according to the unit design basis.

The wave lengths shall be selected as the most critical ones for the response of the structure or structural part to be investigated.

Guidance note:

Practical information in respect to wave conditions, including wave steepness criteria and wave "stretching", is documented in Classification Note 30.5, Sec.3.

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704 For a deterministic wave analysis using an appropriate non-linear wave theory for the water depth, i.e. Stokes' 5th or Dean's Stream Function, the fluid velocity of the maximum long-crested 100 year wave may be multiplied with a kinematics reduction factor of 0.86. The scaling of the velocity shall be used only in connection with hydrodynamic coefficients defined according to 903, i.e. $C_D \geq 1.0$ for submerged tubular members of self-elevating units.

Guidance note:

The kinematics reduction factor is introduced to account for the conservatism of deterministic, regular wave kinematics traditionally accomplished by adjusting the hydrodynamic properties.

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F 800 Current

801 Characteristic current design velocities shall be based upon appropriate consideration of velocity and height profiles. The variation in current profile with variation in water depth, due to wave action shall be appropriately accounted for.

Guidance note:

Practical information in respect to current conditions, including current stretching in the passage of a wave, is documented in Classification Note 30.5 Sec.4.

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F 900 Wave and current

901 Wave and current loads should be calculated using Morison's equation.

Guidance note:

For information regarding use of Morison's equation see Classification Note 30.5, Sec.6.

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902 Vector addition of the wave and current induced particle velocities should normally be used for calculation of the combined wave and current drag force. If available, computations of the total particle velocities and acceleration based on more exact theories of wave and current interaction may be preferred.

903 Hydrodynamic coefficients for circular cylinder in oscillatory flow with in-service marine roughness, and for high values of the Keulegan-Carpenter number, i.e. $K_C > 37$, may be taken as given in Table F2.

Table F2 Hydrodynamic coefficients C		
Surface condition	*Drag coefficient* $C_D\ (k/D_m)$	*Inertia coefficient* $C_M\ (k/D_m)$
Multiyear roughness $k/D_m > 1/100$	1.05	1.8
Mobile unit (cleaned) $k/D_m < 1/100$	1.0	1.8
Smooth member $k/D_m < 1/10000$	0.65	2.0

The Keulegan-Carpenter number is defined by:

$$K_c = \frac{U_m T}{D_m}$$

k = the roughness height
D_m = the member diameter
U_m = the maximum orbital particle velocity
T = the wave period.

More detailed formulations for C_D of tubular members depending on surface condition and Keulegan-Carpenter number can be found in Classification Note 30.5 Sec.6.

904 The roughness for a "mobile unit cleaned" applies when marine growth roughness is removed between submersion of members.

905 The smooth values may be applied above MWL + 2 m and the rough values below MWL + 2 m, where MWL is the mean still water level, as defined in Classification Note 30.5, Figure 4.2.

906 The above hydrodynamic coefficients may be applied both for deterministic wave analyses when the guidance given in 704 is followed, and for stochastic wave analysis.

907 Assumptions regarding allowable marine growth shall be stated in the basis of design.

908 For non-tubular members the hydrodynamic coefficients should reflect the actual shape of the cross sections and member orientation relative to the wave direction.

Guidance note:

Hydrodynamic coefficients relevant to typical self-elevating unit chord designs are stated in Classification Note 30.5 Sec.5 and Classification Note 31.5 Sec.4.5. See also SNAME 5-5A.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

F 1000 Sea pressures during transit

1001 Unless otherwise documented the characteristic sea pressure acting on the bottom, side and weather deck of a self-elevating unit in transit condition should be taken as:

$$p_d = p_s + p_e$$

where the static pressure is:

$$p_s = \rho g_0 (T_{TH} - z_b) \quad (kN/m^2) \text{ for } z_b \le T_{TH}$$

$$p_s = 0 \quad (kN/m^2) \text{ for } z_b > T_{TH}$$

The dynamic pressure for sides and bottom is:

$$p_e = 0.07 \rho g_0 L \quad (kN/m^2) \text{ for } z_b \le T_{TH}$$

$$p_e = \rho g_0 (T_{TH} + 0.07 L - z_b) \quad (kN/m^2) \text{ for } z_b > T_{TH}$$

and for weather decks:

$$p_e = \rho g_0 (0.75\, D_B + 0.07\, L - z_b) \quad (kN/m^2)$$

$$p_e \ge 6.0\ (kN/m^2)$$

T_{TH}	=	heavy transit draught (m) measured vertically from the moulded baseline to the uppermost transit waterline
z_b	=	vertical distance in m from the moulded baseline to the load point
D_B	=	depth of barge (m)
L	=	greater of length or breadth (m)

1002 In cases where pressure difference on bulkhead sides is investigated, i.e. transit condition, the pressures shall be combined in such a way that the largest pressure difference is used for design.

F 1100 Heavy components during transit

1101 The forces acting on supporting structures and lashing systems for rigid units of cargo, equipment or other structural components should be taken as:

$$P_V = (g_0 + a_v) M_c \quad (kN)$$

$$P_H = a_h M_c \quad (kN)$$

For units exposed to wind, a horizontal force due to the design gust wind shall be added to P_H.

a_v	=	vertical acceleration (m/s^2)
a_h	=	horizontal acceleration (m/s^2)
M_c	=	mass of component (t)
P_V	=	vertical force
P_H	=	horizontal force.

Guidance note:

For self-elevating units in transit condition, a_h and a_v need not be taken larger than 0.5 g_0 (m/s^2).

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F 1200 Combination of loads

1201 Load combinations for the design conditions are in general given in Sec.2.

1202 Structural strength shall be evaluated considering all relevant, realistic load conditions and combinations for self-elevating units. For each individual structural element, scantlings shall be determined on the basis of criteria that combine, in a rational manner, the most critical combined effects of relevant global and local loads.

1203 A sufficient number of load conditions shall be evaluated to ensure that the characteristic largest (or smallest) response, for the appropriate return period, has been established.

Guidance note:

For example, maximum global, characteristic responses for a self-elevating unit may occur in environmental conditions that are not associated with the characteristic, largest, wave height. In such cases, wave period and associated wave steepness parameters are more likely to be governing factors in the determination of maximum and minimum responses.

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G. Structural Strength

G 100 General

101 Both global and local capacity shall be checked with respect to strength according to Secs.5 and 6. The global and local stresses shall be combined in an appropriate manner.

102 Analytical models shall adequately describe the relevant properties of loads, stiffness, displacement, satisfactory account for the local system, effects of time dependency, damping, and inertia.

G 200 Global capacity

201 The strength capacity shall be checked for all structural members contributing to the global and local strength of the self-elevating unit. The structure to be checked includes, but is not limited to, all plates and continuous stiffeners in the following structures:

- main load bearing plating in mat and spudcan type footings
- all leg members in truss type legs
- outer plating in column type legs
- jackhouse and supporting structure
- main bearing bulkheads, frameworks and decks in the hull structure
- girders in the hull structure.

202 Initial imperfections in structural members shall be accounted for. For lattice leg structure this will include imperfections for single beam elements as well as for complete leg assembly.

G 300 Footing strength

301 In the operating condition account shall be taken of the forces transferred from the legs and the seabed reactions. The internal structure shall be designed to facilitate proper diffusion of these forces.

302 High stress concentrations at the connection between leg and mat/spudcan shall be avoided as far as possible.

303 The effect of an uneven distribution of critical contact stresses over the foundation area shall be examined taking into account a maximum eccentricity moment from the soil resulted from 304, uneven seabed conditions and scouring.

304 For separate type spudcans the maximum eccentricity moment M_e should normally not be taken less than:

$$M_e = 0.5\, F_V R$$

The corresponding critical contact pressure q_c should normally not be taken less than:

$$q_c = \frac{F_V}{R^2}$$

F_V	=	maximum axial force in the leg accounting for functional loads and environmental overturning loads
R	=	equivalent radius of spudcan contact area.

For other types of bottom support, e.g. mats special considerations should be made.

G 400 Leg strength

401 The boundary conditions for the legs at the seabed shall be varied within realistic upper and lower limits when the scantlings of the legs are determined. The variation in boundary conditions is to take into account uncertainties in the estimation of soil properties, non-linear soil-structure interaction, effects due to repeated loadings, possible scouring, etc.

402 When determining the forces and moments in the legs, different positions of the hull supports along the legs shall be considered.

403 Due attention shall be paid to the shear force in the leg between supporting points in the hull structure, and the position and duration of load transfer between the leg and hull.

404 Lattice-type legs shall be checked against overall buckling, buckling of single elements and punching strength of the nodes, see Sec.5.

405 Bottom impact forces occurring during installation and retrieval conditions shall to be satisfactorily accounted in the design.

Guidance note:
A simplified analytical methodology relevant to installation and retrieval condition is described in Classification Note 31.5.

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G 500 Jackhouse support strength

501 Special attention shall be paid to the means for the leg support, the jackhouses, the support of the jackhouse to the main hull, and the main load transfer girders between the jackhouses.

G 600 Hull strength

601 Scantlings of the hull shall be checked for the transit conditions with external hydrostatic pressure and inertia forces on the legs as well as for the pre-loading and elevated conditions, see Sec.5.

H. Fatigue Strength

H 100 General

101 General methods and requirements for design against fatigue are presented in Sec.7 and DNV-RP-C203.

102 For units intended to follow normal inspection requirements according to class requirements, i.e. 5 yearly inspections in dry dock or sheltered waters, a Design Fatigue Factor (DFF) of 1.0 may be applied for accessible members. For not accessible members DFF shall be applied to structural elements according to the principles in Sec.7 A200.

103 Units intended to operate continuously at the same location for more than 5 years, i.e. without planned dry dock or sheltered water inspection, shall comply with the requirements given in Appendix C.

H 200 Fatigue analysis

201 The required models and methods for fatigue analysis for self-elevating units are dependent on type of operation, environment and design type of the unit. For units operating at deeper waters where the first natural periods are in a range with significant wave energy, e.g. for natural periods higher than 3 s, the dynamic structural response need to be considered in the fatigue analysis.

I. Accidental Conditions

I 100 General

101 A self-elevating unit shall be checked for credible accidental events in accordance with principles and requirements given in Sec.8.

I 200 Collisions

201 Collision by a supply vessel against a leg of a self-elevating unit shall be considered for all elements that may be hit either by sideways, bow or stern collision. The vertical extent of the collision zone shall be based on the depth and draught of visiting supply vessels.

Guidance note:
Simplified procedures for calculation of vessel impact on self-elevating unit legs may be found in Classification Note 31.5.

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202 A collision will normally only cause local damage of the leg. However, the global strength and overturning stability of the unit shall also be checked. With lattice type legs the damaged chord or bracing and connections may be assumed to be non-effective for check of residual strength of the unit after collision.

203 Assessment of dynamic effects and non-linear structural response (geometrical and material) should be performed as part of the impact evaluation.

I 300 Dropped objects

301 Principles and requirements with respect to design for dropped objects are presented in Sec.8.

I 400 Fires

401 The main load bearing structure subjected to a fire shall maintain it's structural integrity until evacuation has been performed, see Sec.8. The following fire scenarios should be considered as appropriate:

— fire inside the unit
— fire on the sea surface.

I 500 Explosions

501 Principles and requirements with respect to design against explosion are presented in Sec.8.

I 600 Unintended flooding

601 For the transit condition, structural effects as a results of heeling of the unit after damage flooding as described in DNV-OS-C301 shall be accounted for in the structural strength assessment. Boundaries which shall remain watertight after unintended flooding, shall be checked for external water pressure.

602 The unit shall be designed for environmental condition corresponding to 1 year return period after damage flooding.

J. Miscellaneous requirements

J 100 General

101 Some special items to be considered in relation to robust design and safe operation of self-elevating units are described in this section.

J 200 Pre-load capasity

201 Units with separate footings which are designed for a pinned leg-bottom connection are to have a capability to preload the legs up to at least 100% of the maximum design axial loads in the legs accounting for functional loads and environmental overturning loads.

For units that shall operate in soil conditions where exceedance of the soil capacity will result in large penetrations, a pre-load higher than the maximum survival axial load will be required. Examples of such soils are generally soft clays, or conditions where hard soils are underlain by softer soils and there is a risk of a punch-through failure.

A recommended approach for determination of required preload is given in Classification Note 30.4.

202 Units with separate footings where the design is based on a specified moment restraint of the legs at the seabed are to have a capability to pre-load the legs up to a level which shall account for the maximum design axial loads in the legs due to functional loads and environmental overturning loads plus the specified moment restraint at the bottom.

In lieu of a detailed soil/structure interaction analysis the required pre-load may in this case be determined by the following factor:

For cohesive soils, e.g. clay:

$$\frac{F_{VP}}{F_V} = \frac{1}{1 - \frac{2\sqrt{A}}{\pi R^2}\frac{M_U}{F_V}}$$

For cohesionless soils, e.g. sand:

$$\frac{F_{VP}}{F_V} = \left(\frac{1}{1 - \frac{2\sqrt{A}}{\pi R^2}\frac{M_U}{F_V}}\right)^2$$

F_{VP} = minimum required pre-load on one leg
F_V = maximum axial force in the leg accounting for functional loads and environmental overturning loads
M_U = minimum moment restraint of the leg at the seabed
A = area of spudcan in contact with soil
R = equivalent radius of spudcan contact area.

203 For cohesionless soils, the above requirement to preload capacity may be departed from in case where a jetting system is installed which will provide penetration to full soil contact of the total spudcan area.

204 The potential of scour at each location should be evaluated. If scour takes place, the beneficial effect of pre-loading related to moment restraint capacity may be destroyed. At locations with scour potential, scour protection should normally be provided in order to rely on a permanent moment restraint.

J 300 Overturning stability

301 The safety against overturning is determined by the equation:

$$\gamma_s \le \frac{M_s}{M_O}$$

M_O = overturning moment, i.e. caused by environmental loads
M_S = stabilising moment, i.e. caused by functional loads
γ_s = safety coefficient against overturning
= 1.1.

302 The stabilising moment due to functional loads shall be calculated with respect to the assumed axis of rotation, and with the unit's lateral deflection taken into consideration.

For self-elevating units with separate footings the axis of rotation may, in lieu of a detailed soil-structure interacting analysis, be assumed to be a horizontal axis intersecting the axis of two of the legs. It may further be assumed that the vertical position of the axis of rotation is located at a distance above the spudcan tip equivalent to the lesser of:

— half the maximum predicted penetration or
— half the height of the spudcan.

For self-elevating units with mat support, the location of the axis of rotation may have to be specially considered.

303 The overturning moment due to wind, waves and current shall be calculated with respect to the axis of rotation defined in 302.

The overturning stability shall be calculated for the most unfavourable direction and combination of environmental and functional loads according to the load plan for the unit. The dynamic amplification of the combined wave and current load effect shall be taken into account.

304 The lower ends of separate legs shall be prevented from sideway slipping by ensuring sufficient horizontal leg and soil support.

J 400 Air gap

401 Clearance between the hull structure and the wave crest is normally to be ensured for the operating position.

402 The requirement to the length of the leg is that the distance between the lower part of the deck structure in the operating position and the crest of the maximum design wave, including astronomical and storm tides, is not to be less than 10% of the combined storm tide, astronomical tide and height of the design wave above the mean low water level, or 1.2 m, whichever is smaller. Expected subsidence of the structure shall be taken into account.

403 Crest elevation above still water level is given in Fig.1.

404 A smaller distance may be accepted if wave impact forces on the deck structure are taken into account in the strength and overturning analysis.

405 Clearance between the structure and wave shall be ensured in floating condition for appurtenances appendices such as helicopter deck, etc.

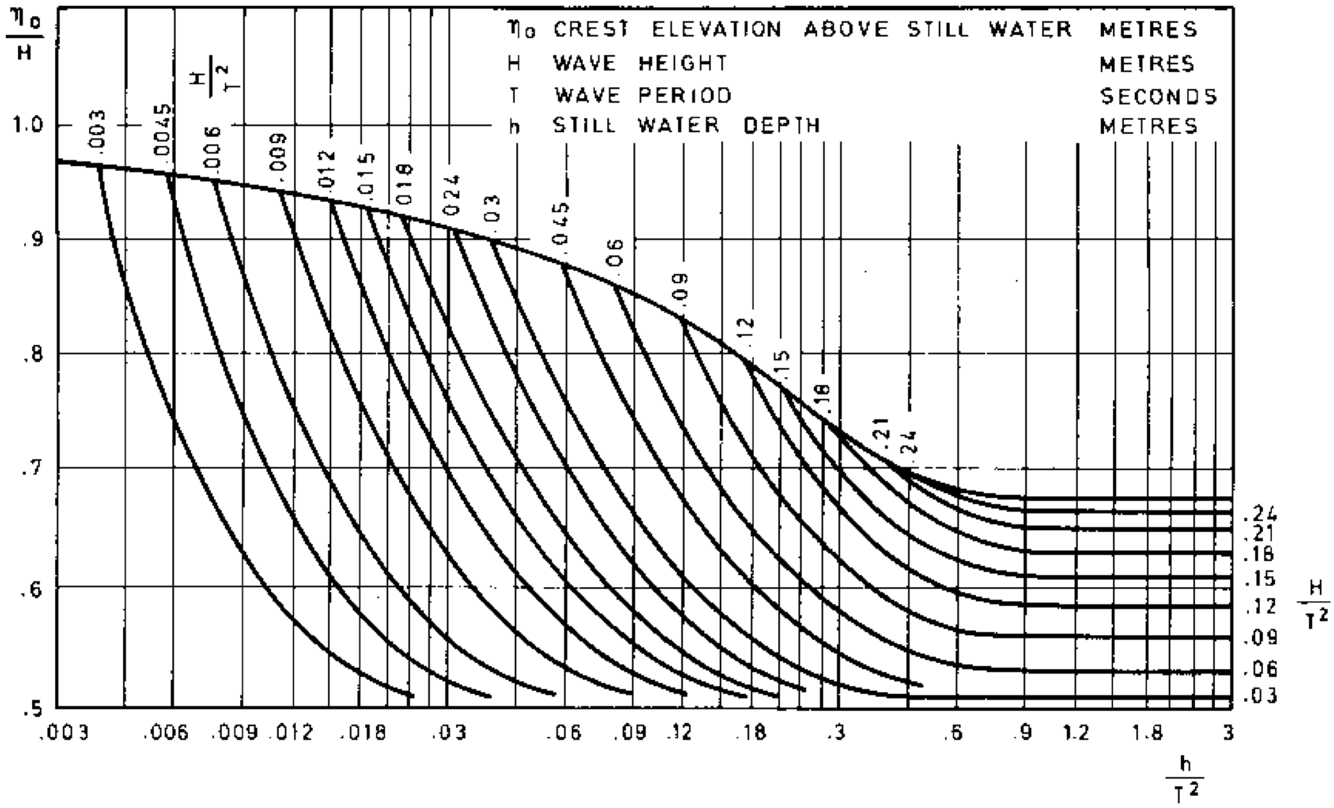


Figure 1
Crest elevation

SECTION 13 SPECIAL CONSIDERATIONS FOR TENSION LEG PLATFORMS (TLP)

A. General

A 100 Scope and application

101 This section provides requirements and guidance to the structural design of TLPs, fabricated in steel. The requirements and guidance documented in this standard are generally applicable to all configurations of tension leg platforms.

The requirements come in addition to those of Sections 1 through 10, see Sec.1 A103.

102 A tension leg platform (TLP) is defined as a buoyant unit connected to a fixed foundation by pre-tensioned tendons. The tendons are normally parallel, near vertical elements, acting in tension, which usually restrain the motions of the TLP in heave, roll and pitch. The platform is usually compliant in surge, sway and yaw. Fig.1 shows an example of a TLP configuration.

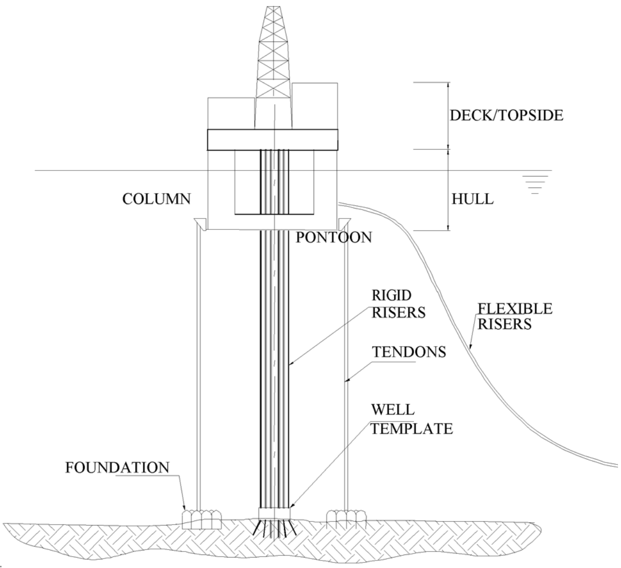


Figure 1
Example of TLP configuration

103 A TLP is usually applied for drilling, production and export of hydrocarbons. Storage may also be a TLP function.

104 A TLP may be designed to function in different modes, typically operation and survival. Also horizontal movement (e.g. by use of catenary or taut mooring) of TLP above wells may be relevant. Limiting design criteria when going from one mode of operation to another shall be established.

105 The TLP unit should also be designed for transit relocation, if relevant.

106 For novel designs, or unproved applications of designs where limited, or no direct experience exists, relevant analyses and model testing shall be performed which clearly demonstrate that an acceptable level of safety can be obtained, i.e. safety level is not inferior to that obtained when applying this standard to traditional designs.

107 Requirements concerning riser systems are given in DNV-OS-F201.

108 In case of application of a catenary or taut mooring system in combination with tendons, see DNV-OS-E301.

109 Requirements related to stability (intact and damaged) are given in Sec.13 F for normal operating condition and Sec.13 H for accidental condition.

A 200 Description of tendon system

201 Individual tendons are considered within this standard as being composed of three major parts:

- interface at the platform
- interface at the foundation (seafloor)
- link between platform and foundation.

In most cases, tendons will also have intermediate connections or couplings along their length, see Fig.2.

202 Tendon components at the platform interface shall adequately perform the following main functions:

- apply, monitor and adjust a prescribed level of tension to the tendon
- connect the tensioned tendon to the platform
- transfer side loads and absorb bending moments or rotations of the tendon.

203 Tendon components providing the link between the platform and the foundation consist of tendon elements (tubulars, solid rods etc.), termination at the platform interface and at the foundation interface, and intermediate connections of couplings along the length as required. The intermediate connections may take the form of mechanical couplings (threads, clamps, bolted flanges etc.), welded joints or other types of connections. Fig.2 shows an example of a TLP tendon system.

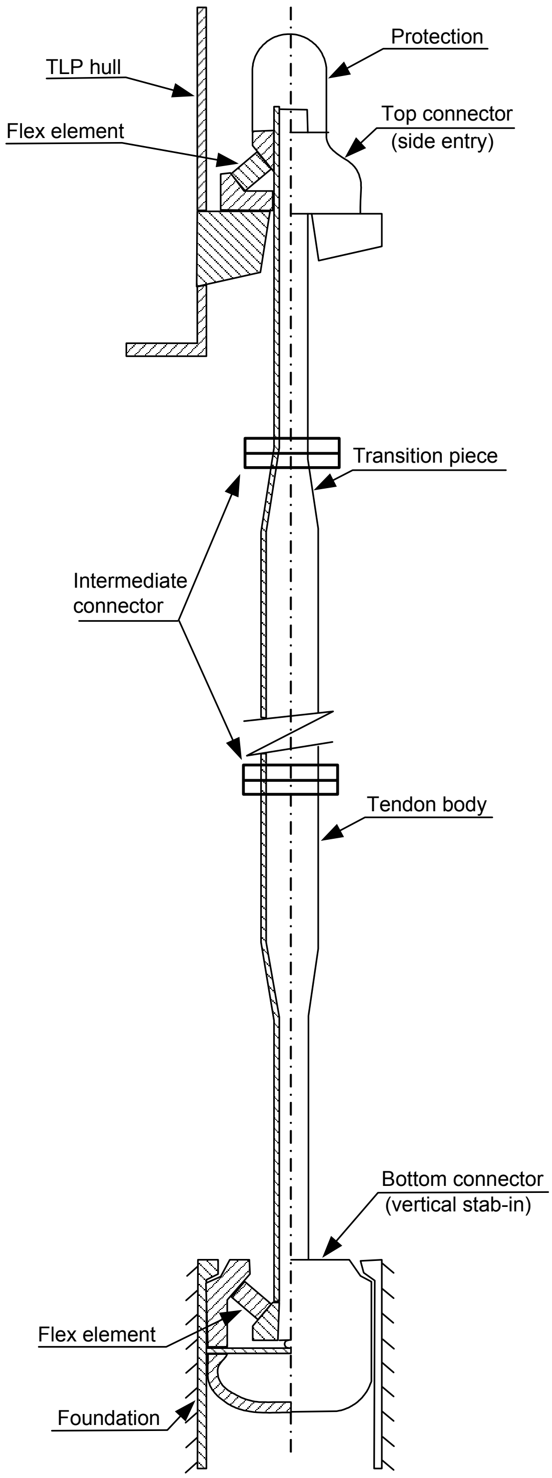


Figure 2
Example of TLP tendon system

204 Tendon components at the foundation interface shall adequately perform the following main functions:

a) Provide the structural connection between the tendon and the foundation.

b) Transfer side loads and absorb bending moments, or rotations of the tendon.

205 The tendon design may incorporate specialised components, such as:

— corrosion-protection system components
— buoyancy devices
— sensors and other types of instrumentation for monitoring the performance and condition of the tendons
— auxiliary lines, umbilicals etc. for tendon service requirements and/or for functions not related to the tendons
— provisions for tendons to be used as guidance structure for running other tendons or various types of equipment
— elastomeric elements.

206 Certification requirements for tendon system are specified in Appendix D.

B. Structural Categorisation, Material Selection and Inspection Principles

B 100 General

101 Selection of materials and inspection principles shall be based on a systematic categorisation of the structure according to the structural significance and the complexity of the joints and connections as given in Sec.4.

102 In addition to in-service operational phases, consideration shall be given to structural members and details utilised for temporary conditions, e.g. fabrication, lifting arrangements, towing and installation arrangements, etc.

103 For TLP structures, which are similar to column stabilised units, the structural categorisation and extent of inspection for the structural components should follow the requirements as given in Sec.11. For TLPs, which are similar to deep draught floaters, the structural categorisation and extent of inspection for the structural components should follow the requirements as given in Sec.14.

B 200 Structural categorisation

201 Application categories for structural components are defined in Sec.4. Structural members of TLPs are grouped as follows, see Fig.1 and Fig.2.

Special category

a) Portions of deck plating, heavy flanges, and bulkheads within the upper hull which form "box" or "I" type supporting structure which receive major concentrated loads.

b) External shell structure in way of intersections of columns, topside deck, lower hull and tendon porch etc.

c) "Through" material used at connections of columns, topside decks and lower hull which are designed to provide proper alignment and adequate load transfer.

d) External brackets, portions of bulkheads, and frames which are designed to receive concentrated loads at intersections of major structural members.

e) Tendon interfaces with the foundation and the TLP hull.

f) Tendon and tendon connectors.

Primary category

a) Deck plating, heavy flanges, and bulkheads within the upper hull which form "box" or "I" type supporting structure which do not receive major concentrated loads.

b) External shell structure of columns, lower and upper hulls.

c) Bulkheads, decks, stiffeners and girders which provide local reinforcement or continuity of structure in way of intersections, except areas where the structure is considered for special application.

d) Main support structure of heavy substructures and equipment, e.g. cranes, drillfloor substructure, life boat platform, thruster foundation and helicopter deck.

Secondary category

a) Decks of upper hulls except areas where the structure is considered primary or special application.

b) Bulkheads, stiffeners, flats or decks and girders in columns, decks and lower hulls, which are not considered as primary or special application.

c) Other structures not categorised as special or primary.

202 When using composite materials the structural categories (special, primary and secondary) as defined in B101 are equivalent to safety class high, normal and low in DNV-OS-C501, Sec.2.

B 300 Material selection

301 Material specifications shall be established for all structural materials. Such materials shall be suitable for their intended purpose and have adequate properties in all relevant design conditions. Material selection shall be undertaken in accordance with the principles given in Sec.4.

302 Examples of considerations with respect to structural categorisation of tendons and tendon interfaces are given in the Fig.3 and Fig.4. These examples provide minimum requirements.

303 Material selection is defined in Sec.4. Further detailed information about material designation is defined in DNV-OS-B101.

304 Composite materials shall be designed in accordance with DNV-OS-C501.

B 400 Design temperatures

401 For TLPs, materials in structures above the lowest astronomical tide (LAT) shall be designed for service temperatures lower or equal to the lowest of mean daily temperature in air for the area(s) where the unit is to operate.

402 Materials in structures below the LAT should be designed for service temperatures of 0°C. A higher service temperature may be used if adequate supporting data shows relative to the lowest mean daily temperature applicable to the relevant actual water depths.

B 500 Inspection categories

501 Welding and the extent of non-destructive examination during fabrication, shall in general be in accordance with the requirements given for the appropriate inspection category as defined in Sec.4.

502 Inspection categories provide requirements for the minimum extent of required inspection. When considering consequences during in-service operation, it may be necessary to specify more demanding inspection requirements than the required minimum. Examples are in way of complex connections with limited or difficult access, or special material/process without proven characteristics.

503 When determining the extent of inspection and the locations of required NDT, in addition to evaluating design parameters (for example fatigue utilisation), consideration should be given to relevant fabrication parameters including:

— location of block (section) joints
— manual versus automatic welding
— start and stop of weld, etc.

The Fig.3 and Fig.4 show examples of structural categorisation and inspection category.

504 Inspection of composite components is described in DNV-OS-C501 Sec.12 B. Quality aspects regarding fabrication are described in DNV-OS-C501 Sec.11.

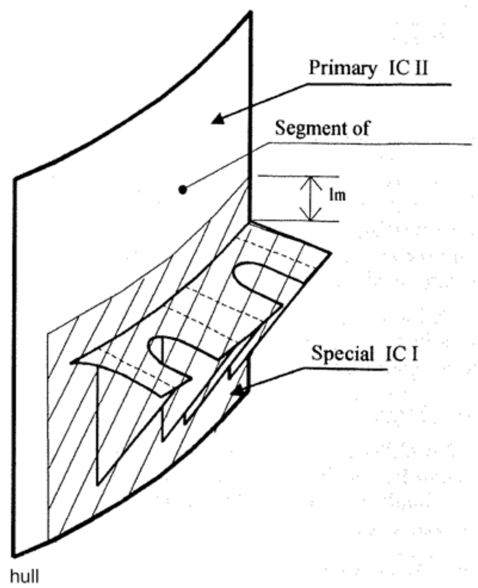
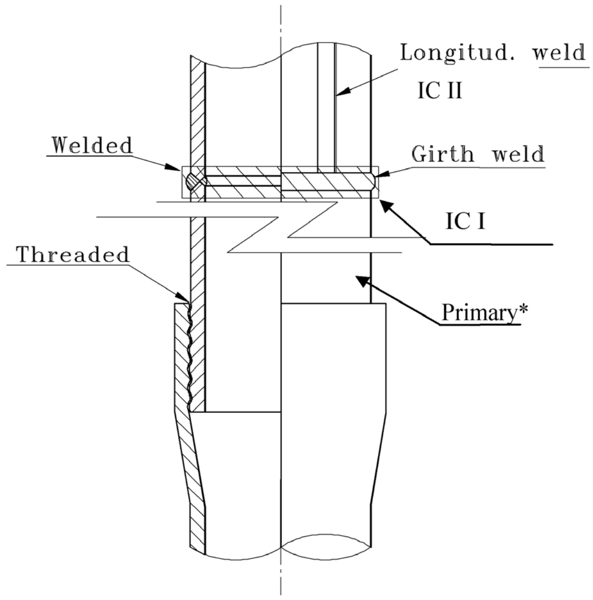


Figure 3
Principles of the extent of special structure at tendon foundation



* Special if damaged condition is not fulfilled, see 303.

Figure 4
Example of tendon connection

C. Design Principles

C 100 General

101 The following basic design criteria shall be complied with for the TLP design:

a) The TLP shall be able to sustain all loads liable to occur during all relevant temporary and operating design conditions for all applicable design conditions.

b) Wave loading on the deck structure should not occur in the extreme environmental load condition, i.e. loading condition b) in Sec.2 Table D1. Wave loading on the deck structure may be accepted in the accidental condition provided that such loads are adequately included in the design.

c) Momentary (part of a high frequency cycle) loss of tendon tension may be accepted provided it can be documented that there will be no detrimental effects on tendon system and supporting (foundation and hull) structures.

102 Operating tolerances shall be specified and shall be achievable in practice. The most unfavourable operating tolerances should be included in the design. Active operation shall not be dependent on high reliability of operating personnel in an emergency situation.

Guidance note:

Active operation of the following may be considered in an emergency situation, as applicable:

- ballast distribution
- weight distribution
- tendon tension
- riser tension.

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A clearly defined and well calibrated Load Management Program or equivalent shall be available onboard to facilitate safe management of these parameters in normal operation and emergency situation. Details of Load Management Program is given in Appendix D, E1100.

C 200 Design conditions

201 The structure shall be designed to resist relevant loads associated with conditions that may occur during all stages of the lifecycle of the unit. Such stages may include:

— fabrication
— site moves
— mating
— sea transportation
— installation
— operation
— decommissioning.

202 Structural design covering marine operation and fabrication sequences shall be undertaken in accordance with this standard.

203 Marine operations may be undertaken in accordance with the requirements stated in the DNV Rules for Planning and Execution of Marine Operations. All marine operations shall, as far as practicable, be based upon well proven principles, techniques, systems and equipment and shall be undertaken by qualified, competent personnel possessing relevant experience.

204 Structural responses resulting from one temporary phase condition (e.g. a fabrication or transportation operation) that may effect design criteria in another phase shall be clearly documented and considered in all relevant design workings.

C 300 Fabrication

301 The planning of fabrication sequences and the methods of fabrication shall be performed. Loads occurring in fabrication phases shall be assessed and, when necessary, the structure and the structural support arrangement shall be evaluated for structural adequacy.

302 Major lifting operations shall be evaluated to ensure that deformations are within acceptable levels, and that relevant strength criteria are satisfied.

C 400 Hull and Deck Mating

401 All relevant load effects incurred during mating operations shall be considered in the design process e.g. hydrostatic load, lock-in stresses, tolerances, deflections etc.

C 500 Sea transportation

501 A detailed transportation assessment shall be undertaken which includes determination of the limiting environmental criteria, evaluation of intact and damage stability characteristics, motion response of the global system and the resulting, induced load effects. The occurrence of slamming loads on the structure and the effects of fatigue during transport phases shall be evaluated when relevant.

The accumulated fatigue damage during transportation phases shall be included in the fatigue assessment of in-place condition.

502 In case of transportation (surface and subsurface) of tendons; this operation shall be carefully planned and analysed. Special attention shall be given to attachment or securing of buoyancy modules. Model testing shall be considered.

503 Satisfactory compartmentation and stability during all floating operations shall be ensured.

See details in Sec.13 F for normal operating condition and Sec.13 H for accidental condition.

504 All aspects of the transportation, including planning and procedures, preparations, seafastenings and marine operations should comply with the requirements of the warranty authority.

C 600 Installation

601 Installation procedures of foundations (e.g. piles, suction anchor or gravity based structures) shall consider relevant static and dynamic loads, including consideration of the maximum environmental conditions expected for the operations.

602 For novel installation activities (foundations and tendons), relevant model testing should be considered.

603 Free standing tendon (pending TLP installation) phases shall be considered with respect to loads and responses.

604 The loads induced by the marine spread mooring involved in the operations, and the forces exerted on the structures utilised in positioning the unit, such as fairleads and pad eyes, shall be considered for local strength checks.

C 700 Decommissioning

701 Abandonment of the unit shall be planned for in the design stage.

C 800 Design principles, tendons

801 Essential components of the tendon system shall be designed on the principle that, as far as practicable, they shall be capable of being inspected, maintained, repaired and/or replaced.

802 Tendon mechanical components shall, as far as practicable, be designed “fail to safe”. Consideration shall be given in the design to possible early detection of failure for essential components, which cannot be designed according to this principle.

803 Certain vital tendon components may, due to their specialised and unproven function, require extensive engineering and prototype testing to determine:

— confirmation of anticipated design performance
— fatigue characteristics
— fracture characteristics
— corrosion characteristics
— mechanical characteristics.

804 A TLP shall be designed with sufficient safety margin to prevent the potential of tendon rupture. The tendon system and the securing or supporting arrangements shall be designed in such a manner that a possible failure or removal of one tendon is not to cause progressive tendon failure or excessive damage to the securing or supporting arrangement at the platform or at the foundation.

805 A fracture control strategy should be adopted to ensure consistency of design, fabrication and in service monitoring assumptions. The objective of such a strategy is to ensure that the largest undetected flaw from fabrication of the tendons will not grow to a size that could induce failure within the design life of the tendon, or within the planned in-service inspection interval, within a reasonable level of reliability. Elements of this strategy include:

— design fatigue life
— fracture toughness
— reliability of inspection during fabrication
— in-service inspection intervals and methods.

See Sec.13 H for guidance on fracture control and required fatigue life for tendons.

806 Inspection to detect damage due to accidental loads or overloads may be replaced by monitoring the loads and comparing them to the design loads, provided that the events can be measured by the monitoring system. If this method is used the component must be replaced after any overload occurrence or other events exceeding the design scenario.

807 All materials liable to corrode shall be protected against corrosion. Special attention should be given to:

— local complex geometries
— areas that are difficult to inspect and/or repair
— consequences of corrosion damage
— possibilities for electrolytic corrosion.

808 All sliding surfaces shall be designed with sufficient additional thickness against wear. Special attention should be given to the following:

— cross-load bearings
— seals
— ball joints.

809 Satisfactory considerations shall be given to settlement or subsidence, which may be a significant factor in determining tendon-tension adjustment requirements.

D. Design Loads

D 100 General

101 Design loads are, in general, defined in Sec.3. Guidance concerning load categories relevant for TLP designs are given in 200.

D 200 Load categories

201 All relevant loads that may influence the safety of the structure or its parts from commencement of fabrication to permanent decommissioning should be considered in design. The different loads are defined in Sec.3.

202 For the deck and hull of the TLP, the loads are similar to those described in Sec.11 for TLPs similar to column stabilised units. TLPs similar to deep draught floaters shall be designed with loads as given in Sec.14. Loads are described in 101 and 201 with the exception of the tendon loads (inclusive potential ringing and springing effects).

203 In relation to determination of environmental conditions and loads, see Classification Note 30.5 and DNV-OS-C501 for composites.

204 The wave loads on the tendons can be described as recommended in Sec.3 (and Classification Note 30.5) for slender structures with significant motions.

205 The disturbance of wave kinematics from hull (columns and pontoons) in relation to the riser system and tendons shall be accounted for if it is of importance.

206 The earthquake loads at the foundation of the tendons are described in Sec.3 and DNV-OS-C101 Sec.11.

207 The following loads should be considered:

— permanent loads
— variable functional loads
— environmental loads
— deformation loads
— accidental loads.

208 For preliminary design stages it is recommended that "contingency factors" are applied in relation to permanent loads to reflect uncertainties in load estimates and centres of gravity.

209 "Contingency factors" should also be considered for early design stages in relation to variable functional loads, especially for minimum facilities TLPs (e.g. TLWP and Mini TLP).

210 The environmental loads are summarised as:

— wind loads
— mean (sustained) wind
— dynamic (gust) wind.
— wave and current loads
— loads on slender members
— loads induced by TLP motions
— slamming and shock pressure
— wave diffraction and radiation
— mean drift forces
— higher order non-linear wave loads (slowly varying, ringing and springing)
— wave enhancement
— vortex shedding effects.
— marine growth
— snow and ice accumulation
— direct ice loads (icebergs and ice flows)
— earthquake
— tidal and storm surge effects.
— effects from sand/marine growth getting into the connectors or the tendon body
— resistance to sunlight during transport, storage and operation if above the water.

211 Resistance of the tendon to fire on or near the platform shall be evaluated.

E. Global Performance

E 100 General

101 The selected methods of response analysis are dependent on the design conditions, dynamic characteristics, non-linearities in loads and response and the required accuracy in the actual design phase.

Guidance note:
For a detailed discussion of the different applicable methods for global analysis of tension leg platforms, see API RP 2T.

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102 The selected methods of analysis and models employed in the analysis shall include relevant non-linearities and motion-coupling effects. The approximations, simplifications and/or assumptions made in the analysis shall be justified, and their possible effects shall be quantified for example by means of simplified parametric studies.

103 During the design process, the methods for analytical or numerical prediction of important system responses shall be verified (calibrated) by appropriate model tests.

104 Model tests may also be used to determine specific responses for which numerical or analytical procedures are not yet developed and recognised.

105 Motion components shall be determined, by relevant analysis techniques, for those applicable design conditions specified in Sec.2. The basic assumptions and limitations associated with the different methods of analysis of global performance shall be duly considered prior to the selection of the methods.

106 The TLP should be analysed by methods as applicable to column stabilised units or deep draught floaters when the unit is free floating, respectively. See Sec.11 or Sec.14.

107 The method of platform motion analysis as outlined in this standard is one approximate method, which may be applied. The designer is encouraged also to consider and apply other methods in order to discover the effects of possible inaccuracies etc. in the different methods.

E 200 Frequency domain analysis

201 Frequency domain HF, WF and LF analyses techniques may be applied for a TLP. Regarding load effects due to mean wind, current and mean wave drift, see Sec.3.

202 For typical TLP geometries and tendon arrangements, the analysis of the total dynamic load effects may be carried out as:

— a high frequency (HF) analysis of springing
— a wave frequency (WF) analysis in all six degrees of freedom
— a low frequency (LF) analysis in surge, sway and yaw.

203 The following assumptions are inherent in adopting such an independent analysis approach:

— the natural frequencies in heave, roll and pitch are included in the wave frequency analysis
— the natural frequencies in surge, sway and yaw are included in the low frequency analysis
— the high and low natural frequencies are sufficient separate to allow independent dynamic analysis to be carried out
— the low frequency excitation forces have negligible effect on the wave frequency motions
— the low frequency excitation forces have a negligible dynamic effect in heave, roll and pitch
— tendon lateral dynamics are unimportant for platform surge and sway motions.

204 Typical parameters to be considered for global performance analyses are different TLP draughts, wave conditions and headings, tidal effects, storm surges, set down, foundation settlement (s), subsidence, mis-positioning, tolerances, tendon flooding, tendon removal and hull compartment(s) flooding. Possible variations in vertical centre of gravity shall also be analysed (especially if ringing responses are important). This may be relevant in case of:

— changes in topside weights (e.g. future modules)
— tendon system changes (altered utilisation)
— changes in ballast weights and distributions
— deviations from weight estimate.

E 300 High frequency analyses

301 Frequency domain springing analyses shall be performed to evaluate tendon and TLP susceptibility to springing responses.

302 Recognised analytical methods exist for determination of springing responses in tendons. These methods include calculation of quadratic transfer functions (QTFs) for axial tendon (due to sum frequency loads on the hull) stresses which is the basis for determination of tendon fatigue due to springing.

303 Damping level applied in the springing response analyses shall be duly considered and documented.

E 400 Wave frequency analyses

401 A wave frequency dynamic analysis may be carried out by using linear wave theory in order to determine first-order platform motions and tendon response.

402 First order wave load analyses shall also serve as basis for structural response analyses. Finite wave load effects shall be evaluated and taken into account. This may for example, be performed by use of beam models and application of Morison load formulation and finite amplitude waves.

403 In linear theory, the response in regular waves (transfer functions) is combined with a wave spectrum to predict the response in irregular seas.

404 The effect of low-frequency set-down variations on the WF analysis shall be investigated by analysing at least two representative mean offset positions determined from the low frequency analysis.

405 Set-down or offset induced heave motion may be included in the wave frequency RAOs.

406 A sufficient number of wave approach headings shall be selected for analyses (e.g. with basis in global configuration, number of columns, riser configuration etc.).

407 In determination of yaw induced fatigue responses (e.g. tendon and flex element design) due account must be given to wave spreading when calculating the long term responses.

E 500 Low frequency analyses

501 A low frequency dynamic analysis could be performed to determine the slow drift effects at early design stages due to fluctuating wind and second order wave loads.

502 Appropriate methods of analysis shall be used with selection of realistic damping levels. Damping coefficients for low frequency motion analyses are important as the low frequency motion may be dominated by resonant responses.

E 600 Time domain analyses

601 For global motion response analyses, a time domain approach will be beneficial. In this type of analyses it is possible to include all environmental load effects and typical nonlinear effects such as:

— hull drag forces (including relative velocities)
— finite wave amplitude effects
— non-linear restoring (tendons, risers).

602 Highly non-linear effects such as ringing may also require a time domain analysis approach. Analytical methods exist for estimation of ringing responses. These methods can be used for the early design stage, but shall be correlated against model tests for the final design. Ringing and springing responses of hull and deck may however be analysed within the frequency domain with basis in model test results, or equivalent analytical results.

603 For deep waters, a fully coupled time domain analysis of tendons, risers and platform may be required. This may for example, be relevant if:

— model basin scale will not be suitable to produce reliable design results or information
— consistent global damping levels (e.g. in surge, sway and yaw) due to the presence of slender structures (risers, tendons) are needed
— it is desirable to perform the slender structure response analyses with basis in coupled motion analyses.

604 A relevant wave spectrum shall be used to generate random time series when simulating irregular wave elevations and kinematics.

605 The simulation length shall be long enough to obtain sufficient number of LF maxima (surge, sway, and yaw).

606 Statistical convergence shall be checked by performing sensitivity analyses where parameters as input seed, simulation length, time step, solution technique etc. are varied.

607 Determination of extreme responses from time domain analyses shall be performed according to recognised principles.

608 Depending on selected TLP installation method, time domain analyses will probably be required to simulate the situation when the TLP is transferred from a free floating mode to the vertical restrained mode. Model testing shall also be considered in this context.

Guidance note:

Combined loading

Common practice to determine extreme responses has been to expose the dynamic system to multiple stationary design environmental conditions. Each design condition is then described in terms of a limited number of environmental parameters (e.g. H_s, T_p) and a given seastate duration (3 to 6 hours). Different combinations of wind, wave and current with nearly the same return period for the combined environmental condition are typically applied.

The main problem related to design criteria based on environmental statistics is that the return period for the characteristic load effect is unknown for non-linear dynamic systems. This will in general lead to an inconsistent safety level for different design concepts and failure modes.

A more consistent approach is to apply design based on response statistics. Consistent assessment of the D-year load effect will require a probabilistic response description due to the long-term environmental loads on the system. The load effect with a return period of D-year, denoted x_D, can formally be found from the long-term load effect distribution as:

$$F_x(x_D) = 1 - \frac{1}{N_D}$$

N_D = total number of load effect maxima during D years

$F_x(x)$ = long-term peak distribution of the (generalised) load effect

The main challenge related to this approach is to establish the long-term load effect distribution due to the non-linear behaviour. Design based on response statistics is in general the recommended procedure and should be considered whenever practicable for consistent assessment of characteristic load effects.

Further details may be found in Appendices to DNV-OS-F201.

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For guidance on coupled analysis, see DNV-RP-C205.

E 700 Model testing

701 Model testing will usually be required for final check of TLP designs. The main reason for model testing is to check that analytical results correlate with model tests.

702 The most important parameters to evaluate are:

- air gap
- first order motions
- total offset
- set-down
- WF motions versus LF motions
- tendon responses (maximum, minimum)
- accelerations
- ringing
- springing
- susceptibility to hull VIM.

703 The model scale applied in testing shall be appropriate such that reliable results can be expected. A sufficient number of seastates needs to be calibrated covering the relevant design conditions.

704 Wave headings and other variable parameters (water levels, vertical centre of gravity, etc.) need to be varied and tested as required.

705 If HF responses (ringing and springing) shows to be governing for tendon extreme and fatigue design respectively, the amount of testing may have to be increased to obtain confidence in results.

E 800 Load effects in the tendons

801 Load effects in the tendons comprise mean and dynamic components.

802 The steady-state loads may be determined from the equilibrium condition of the platform, tendon and risers.

803 Tendon load effects arise from platform motions, any ground motions and direct hydrodynamic loads on the tendon.

804 Dynamic analysis of tendon responses shall take into account the possibility of platform heave, roll and pitch excitation (springing and ringing effects).

805 Linearised dynamic analysis does not include some of the secondary wave effects, and may not model accurately extreme wave responses. A check of linear-analysis results using non-linear methods may be necessary. Model testing may also be used to confirm analytical results. Care shall be exercised in interpreting model-test results for resonant responses, particularly for loads due to platform heave, roll and pitch, since damping may not be accurately modelled.

806 Lift and overturning moment generated on the TLP by wind loads shall be included in the tendon response calculations.

807 Susceptibility to vortex induced vibrations shall be evaluated in operational and non-operational phases.

808 Interference (tendon and riser, tendon and tendon, tendon and hull, tendon and foundation) shall be evaluated for non-operational as well as the operational phase.

F. Structural Strength

F 100 General

101 General considerations in respect to methods of analysis and capacity checks of structural elements are given in Sec.5.

102 The TLP hull shall be designed for the loading conditions that will produce the most severe load effects on the structure. A dynamic analysis shall be performed to derive characteristic largest stresses in the structure.

103 Analytical models shall adequately describe the relevant properties of loads, stiffness and displacement, and shall account for the local and system effects of, time dependency, damping and inertia.

104 Stability of a TLP in the in-place condition is typically provided by the pretension and stiffness of the tendon system, rather than by the waterplane area. The stability analysis is to demonstrate that the system is sufficiently constrained by the tendon system, and is safe from overturning in all environmental conditions. It is therefore important to monitor the weight change and COG (Centre of Gravity) shift in various operational modes and environmental conditions.

105 The allowable horizontal shift of the COG shall be calculated for at least the following three load conditions or operational modes:

— still water
— operating environment
— survival environment.

106 The allowable weight and horizontal COG shift shall be calculated based on maximum and minimum allowable tendon tension derived in global performance analysis as defined in Sec.13 E. Variation of the vertical COG, which results in changes in motion response and dynamic loads, shall be taken into account in the calculation. The derivation of maximum and minimum tendon tension shall cover all failure modes defined in this Section with appropriate usage factor as given in Sec.2. Design loads shall be calculated for the environment at the intended operation site.

107 An inclining test or equivalent procedure shall be conducted to accurately determine the weight and COG of the TLP. Proper load management tools shall be installed onboard and appropriate procedures shall be defined in the operations manual to control weight, COG and tendon tensions during service.

F 200 Hull

201 The following analysis procedure to obtain characteristic platform-hull response shall be applied:

1) *Analysis of the initial mean position in still water condition*

   In this analysis, all vertical loads are applied (masses, live loads, buoyancy etc.) and equilibrium is achieved taking into account pretension in tendons and risers.

2) *Mean response analysis*

   In this analysis the lateral mean wind, mean wave-drift and current loads are applied to the TLP resulting in a static offset position with a given set-down.

3) *Wave response analysis*

   Design wave approach

   To satisfy the need for simultaneity of the responses, a design wave approach may be used for maximum stress analysis.

   The merits of the stochastic approach are retained by using the extreme stochastic values of some characteristic parameters in the selection of the design wave. Effects due to offset as described in 2) shall be taken into account in the analysis.

   or

   Spectral approach

   An analysis is carried out using 'n' wave frequencies from 'm' directions. Effects due to offset as described in 2) shall be taken into account in the analysis. Traditional spectral analysis methods should be used to compute the relevant response spectra and their statistics.

202 For a TLP hull, the following characteristic global sectional loads due to wave forces shall be considered as a minimum, see also Sec.11:

— split forces (transverse, longitudinal or oblique sea for odd columned TLPs)
— torsional moment about a transverse and longitudinal, horizontal axis (in diagonal or near-diagonal)
— longitudinal opposed forces between parallel pontoons (in diagonal or near-diagonal seas)
— longitudinal, transverse and vertical accelerations of deck masses.

203 It is recommended that a full stochastic wave load analysis is used as basis for the final design.

204 Local load effects (e.g. maximum direct environmental load on an individual member, wave slamming loads, external hydrostatic pressure, ballast distribution, internal tank pressures etc.) shall be considered. Additional loads from for example, high-frequency ringing accelerations shall be taken into account.

205 Hull vibration due to current induced vibration of tendons or risers shall be evaluated.

F 300 Structural analysis

301 For global structural analysis, a complete three-dimensional structural model of the TLP is required. See Sec.5 and Appendix B.

302 Additional detailed finite-element analyses may be required for complex joints and other complicated structural parts to determine the local stress distribution more accurately and/or to verify the results of a space-frame analysis, see also Sec.11.

303 Local environmental load effects, such as wave slamming and possible wave- or wind-induced vortex shedding, shall be considered as appropriate.

F 400 Structural design

401 Special attention shall be given to the structural design of the tendon supporting structures to ensure a smooth transfer and redistribution of the tendon concentrated loads through the hull structure without causing undue stress concentrations.

402 The internal structure in columns in way of bracings should be designed stronger than the axial strength of the bracing itself.

403 Special consideration shall be given to the pontoon strength in way of intersections with columns, accounting for possible reduction in strength due to cut-outs and stress concentrations.

404 Special attention shall be given to the structural design of the columns in way of intersection with deck structure to ensure smooth load transfer.

F 500 Deck

501 Structural analysis and design of deck structure shall follow the principles as outlined in Sec.11, additional load effects (e.g. global accelerations) from high-frequency ringing and springing shall be taken into account when relevant.

502 In the operating condition, positive air gap should be ensured. However, wave impact may be permitted to occur on any part of the structure provided that it can be demonstrated that such loads are adequately accounted for in the design and that safety to personnel is not significantly impaired.

503 Analysis undertaken to document air gap should be calibrated against relevant model test results. Such analysis shall include relevant account of:

— wave and structure interaction effects
— wave asymmetry effects
— global rigid body motions (including dynamic effects)
— effects of interacting systems (e.g. riser systems)
— maximum and minimum draughts (set-down, tidal surge, subsidence, settlement effects).

504 Column ‘run-up’ load effects shall be accounted for in the design of the structural arrangement in way of the column and deck box connection. These 'run-up' loads should be treated as an environmental load component, however, they need not be considered as occurring simultaneously with other environmental responses.

505 Evaluation of air gap adequacy shall include consideration of all influenced structural items including lifeboat platforms, riser balconies, overhanging deck modules, module support beams etc.

F 600 Extreme tendon tensions

601 As a minimum the following tension components shall be taken into account:

- pretension (static tension at MSL)
- tide (tidal effects)
- storm surge (positive and negative values)
- tendon weight (submerged weight)
- overturning (due to current, mean wind or drift load)
- set-down (due to current, mean wind or drift load)
- WF tension (wave frequency component)
- LF tension (wind gust and slowly varying drift)
- ringing (HF response)
- hull VIM influence on tendon responses.

602 Additional components to be considered are:

- margins for fabrication, installation and tension reading tolerances
- operational requirements (e.g. operational flexibility of ballasting operations)
- allowance for foundation mis-positioning
- field subsidence
- foundation settlement and uplift
- loads due to spooling during transportation and storage of flexible tendons.

603 Bending stresses along the tendon shall be analysed and taken into account in the design. For the constraint mode the bending stresses in the tendon will usually be low. In case of surface, or subsurface, tow (non-operational phase) the bending stresses shall be carefully analysed and taken into account in the design.

604 For nearly buoyant tendons the combination of environmental loads (axial and bending) and high hydrostatic water pressure may be a governing combination (buckling).

605 Limiting combinations (envelopes) of tendon tension and rotations (flex elements) need to be established.

606 For specific tendon components such as couplings, flex elements, top and bottom connections etc. the stress distribution shall be determined by appropriate finite-element analysis.

607 If temporary (part of a high frequency cycle) tendon tension loss is permitted, tendon dynamic analyses shall be conducted to evaluate its effect on the complete tendon system and supporting structures. Alternatively, model tests may be performed. The reasoning behind this is that loss of tension could result in detrimental effects from tendon buckling and/or damage to flex elements.

F 700 Structural design of tendons

701 The structural design of tendons shall be carried out according to this standard with the additional considerations given in this subsection.

702 Buckling checks of tendon body may be performed according to API RP 2T.

703 When deriving maximum stresses in the tendons relevant stress components shall be superimposed on the stresses due to maximum tendon tension, minimum tendon tension or maximum tendon angle, as relevant.

704 Such additional stress components may be:

- tendon-bending stresses due to lateral loads and motions of the tendon
- tendon-bending stresses due to flex-element rotational stiffness
- thermal stresses in the tendon due to temperature differences over the cross sections
- hoop stresses due to hydrostatic pressure.

705 Composite tendons shall be designed in accordance with DNV-OS-C501 with additional considerations given in this section.

F 800 Foundations

801 Foundation design may be carried out according to DNV-OS-C101 Sec.11.

802 Relevant combinations of tendon tensions and angles of load components shall be analysed for the foundation design.

803 For gravity foundations the pretension shall be compensated by submerged weight of the foundation, whereas the varying loads may be resisted by for example suction and friction.

G. Fatigue

G 100 General

101 Structural parts where fatigue may be a critical mode of failure shall be investigated with respect to fatigue. All significant loads contributing to fatigue damage (non-operational and operational) shall be taken into account. For a TLP, the effects of springing and ringing resonant responses shall be considered for fatigue.

102 Fatigue design may be carried out by methods based on fatigue tests and cumulative damage analysis, methods based on fracture mechanics, or a combination of these.

103 General requirements and guidance to fatigue design are given in Sec.7 and DNV-RP-C203.

Fatigue design for composite tendon is given in DNV-OS-C501. Improved fatigue performance (comparing to what is defined in DNV-RP-C203) of base material may be accounted for in the design provided that the fatigue performance and fracture mechanic properties of the same are documented through testing.

104 Careful design of details as well as stringent quality requirements for fabrication is essential in achieving acceptable fatigue strength. It shall be ensured that the design assumptions made concerning these parameters are achievable in practice.

105 The results of fatigue analyses shall be fully considered when the in-service inspection plans are developed for the platform.

G 200 Hull and deck

201 Fatigue design of hull or deck structure shall be performed in accordance with principles given in Sec.11 or Sec.14, as appropriate.

G 300 Tendons

301 All parts of the tendon system shall be evaluated for fatigue.

302 First order wave loads (direct or indirect) will usually be governing, however also fatigue due to springing shall be carefully considered and taken into account.

Combined load effect due to wave frequency, high frequency and low frequency loads shall be considered in fatigue analysis.

303 In case of wet transportation (surface or subsurface) to field, these fatigue contributions shall be accounted for in design.

304 Vortex induced vibrations shall be considered and taken into account. This applies to operation and non-operational (e.g. free standing) phases.

305 Size effects (e.g. length of weld, number of connections) of welds and couplings etc. shall be evaluated. For guidance see Section 2.3 and Commentary 2,3 in DNV-RP-C203.

306 Tendon and tendon components shall have a minimum fatigue life of 10 times the tendon design life.

307 Material toughness of tendon components and welds shall be sufficient to meet design fatigue life and fracture criteria.

Guidance note:

Fracture toughness testing is performed to establish material properties that in turn can be used to calculate critical flaw sizes. The most common testing is CTOD (Crack Tip Opening Displacement) testing which in most cases are done using 3-point bend specimens. Testing should be performed for both weld metal and base material in heat affected zone locations. For welded pipes, CTOD testing performed in bending may give very conservative results. One way to reduce conservatism is to perform the testing in tension. Tests performed like this will give a testing condition (constraint) close to that associated with a defect in a girth welded pipe. As a minimum 3 tests should be performed per location and the lowest values of the 3 test results should be used in fracture mechanics assessment.

In case of materials with good toughness properties (typically CTOD values above 0.25 mm), CTOD - Resistance or J - Resistance testing can be performed to establish the tearing resistance of the material.

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308 Fracture mechanics assessment shall be performed in accordance with BS7910 or equivalent standard to estimate crack growth rates, define maximum allowable flaw sizes and thus help define inspection intervals and monitoring strategies.

309 The maximum allowable flaws under extreme design loads shall not grow to a critical size causing unstable crack growth in 5 times the tendon design life or tendon inspection period, whichever is less. The preferred critical flaw is a through-thickness fatigue crack. All possible initial flaws including surface flaws, embedded flaws and through thickness flaws shall be considered. Various aspect ratio and initial location shall be evaluated. Stress concentration factors (SCFs) shall be included when assessing the maximum allowable flaw size.

310 The maximum allowable flaw size shall be reliably detectable by the NDT inspection system employed in fabrication of the tendons. Otherwise, either the NDT system or the design of the tendon system must be changed.

Guidance note:

Unless the system can be qualified with the criteria as follows, an initial flaw size of 3 x 25 mm (height x length) should be assumed for Automatic Ultrasonic Testing (AUT) or 9 x 50 mm (height x length) should be assumed for Manual Ultrasonic Testing.

The NDT inspection system employed in fabrication of the tendons should be capable of reliably detecting the maximum allowable initial defect size with a probability of at least 90% at a confidence level of 95%. The probability of under-sizing the defect by the NDT inspection system should be no more than 5%.

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311 When tendons are fixed to the seabed using piles, it is also important to perform a fatigue and fracture evaluation of the welded joints in the piles. The welds next to the tendon connection point will be the most critical as these will be exposed to the same loads as the tendons. The load due to pile driving shall be included in addition.

312 For tendon receptacles and other components connected to the pile while it is driving, fatigue damage due to pile driving shall also be taken into account.

313 Composite materials and their interfaces may also be treated with a fracture mechanics approach if a defect size can be defined and the propagation can be described. Otherwise fatigue analysis of composite materials should be described by SN curves and Miner sum calculations as given in DNV-OS-C501, Sec.6 K.

G 400 Foundation

401 Tendon responses (tension and angle) will be the main contributors to fatigue design of foundations. Local stresses shall be determined by use of finite element analyses.

H. Accidental Condition

H 100 Hull

101 Requirements concerning accidental events are given in Sec.7 and Sec.11.

102 Units shall be designed to be damage tolerant, i.e. credible accidental damage, or events, should not cause loss of global structural integrity. The capability of the structure to redistribute loads should be considered when designing the structure.

103 In the design phase, attention shall be given to layout and arrangements of facilities and equipment in order to minimise the adverse effects of accidental events.

104 Satisfactory protection against accidental damage may be obtained by a combination of the following principles:

— reduction of the probability of damage to an acceptable level
— reduction of the consequences of damage to an acceptable level.

105 Structural design with respect to the accidental condition shall involve a two-stage procedure considering:

— resistance of the structure to a relevant accidental event
— capacity of the structure after an accidental event.

106 Global structural integrity shall be maintained both during and after an accidental event. Loads occurring at the time of a design accidental event and thereafter shall not cause complete structural collapse.

The TLP structure shall be designed to sustain one hull compartment flooding, one tendon flooding or removal of one tendon.

107 In-place stability of a TLP under accidental event shall be measured by minimum and maximum tension criteria using same principle as defined in Sec.13 F100. Allowable weight and COG shift envelope shall be established for the damaged condition using same procedure as defined in Sec.13 F100.

The usage factors are defined in Sec.2. Time lapse between the occurrence of the damage and the restoring of stability should be considered in the design to assure the safety of the TLP unit during this period. In assessing the adequacy of the tendon tension the following flooding scenario shall be assumed:

1) Any one tendon compartment
2) All compartments that could be flooded as a result of damages that are 1.5 m deep and 3.0 m high occurring at any level between 5.0 m above and 3.0 m below the still waterline.
3) No vertical bulkhead shall be assumed damaged, except where bulkheads are spaced closer than a distance of one eighth of the column perimeter at the still waterline, measured at the periphery, in which case one or more of the bulkheads shall be disregarded.

All piping, ventilation systems, trunks, etc., within the extent of damage shall be assumed damaged. Positive means of closure shall be provided at watertight boundaries to preclude the progressive flooding of other spaces that are intended to be intact.

H 200 Hull and deck

201 The most relevant accidental events for hull and deck designs are:

- dropped objects
- fire
- explosion
- collision
- unintended flooding
- abnormal wave events.

H 300 Tendons

301 The most relevant accidental events for the tendons are:

- missing tendon
- tendon flooding
- dropped objects
- flooding of hull compartment(s).

302 Tendon removal condition (e.g. for maintenance and/or inspection) requires analysis of the TLP structure with environmental loads with 10^{-2} annual probability of exceedance to satisfy the ALS. The same applies to tendon flooding, if relevant. Consideration should be given to the expected frequency of tendon removal and the length of period for which one tendon is likely to be out of service.

303 Tendon failure will have substantial consequences and therefore the tendons shall be designed with sufficient safety margin. The effect on the surrounding structure due to possible accidental failure events and the consequential release of elastic energy stored in the tendon shall be considered.

Guidance note:

Damage to the TLP from tendon failure does not need to be considered provided the annual probability of tendon failure is less than 10^{-5} due to each accidental event.

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304 Dropped objects may cause damage to the tendons and in particular the top and bottom connectors may be exposed. Shielding may be required installed.

305 Flooding of hull compartments and the effects on design shall be analysed thoroughly.

H 400 Foundations

401 Accidental events to be considered for the foundations shall as a minimum be those listed for tendons.

SECTION 14
SPECIAL CONSIDERATIONS FOR DEEP DRAUGHT FLOATERS (DDF)

A. General

A 100 Introduction

101 This section provides requirements and guidance to the structural design of deep draught floaters (DDF), fabricated in steel. The requirements and guidance documented in this standard are generally applicable to all configurations of deep draught floaters.

The requirements come in addition to those of Sec.1-10, see Sec.1 A103.

102 A deep draught floater (DDF) is categorised with a relative large draught. This large draught is mainly introduced to obtain sufficiently high eigenperiod in heave and reduced wave excitation in heave such that resonant responses in heave can be omitted or minimised.

103 A DDF can have multiple vertical, or near vertical columns, single column without, or with (e.g. classic and truss spar) moonpool.

104 The unit is usually kept in position by a passive mooring system. The mooring system may also be activated in case of horizontal movements above wells (drilling riser placed vertically above well), or other needed operational adjustments like increase in pretension in order to reduce VIM.

105 The deck or topside solution may be modular, or integrated type.

A 200 Scope and application

201 The DDF unit may be applied for drilling, production, export and storage.

202 A DDF unit may be designed to function in different modes, typically operational (inclusive horizontal movement above wells) and survival. Limiting design criteria when going from one mode of operation to another shall be established.

203 The DDF unit should also be designed for transit relocation, if relevant.

204 For novel designs, or unproved applications of designs where limited, or no direct experience exists, relevant analyses and model testing shall be performed which clearly demonstrate that an acceptable level of safety can be obtained, i.e. safety level is not inferior to that obtained when applying this standard to traditional designs.

205 Requirements concerning mooring and riser systems are not considered in this standard. See DNV-OS-E301 and DNV-OS-F201.

206 Requirements related to floating stability is given in DNV-OS-C301.

B. Non-Operational Phases

B 100 General

101 In general the unit shall be designed to resist relevant loads associated with conditions that may occur during all phases of the life cycle of the unit. Such phases may include:

— fabrication
— load-out, load-on
— sea transportation (wet or dry)
— assembly of hull main sections
— installation (dynamic, or quasi-static upending, launching, deck mating, jacking, riser hook-up)
— relocation (drilling mode, new site)
— decommissioning.

102 Structural design covering marine operations and construction sequences shall be undertaken in accordance with this standard.

103 Marine operations may be undertaken in accordance with the requirements stated in Rules for Planning and Execution of Marine Operations.

104 All marine operations shall, as far as practicable, be based upon well proven principles, techniques, systems and equipment and shall be undertaken by qualified, competent personnel possessing relevant experience.

105 Structural responses resulting from one temporary phase condition (e.g. construction or assembly, or transportation) that may effect design criteria in another phase shall be clearly documented and considered in all relevant design workings.

B 200 Fabrication

201 The planning of fabrication sequences and the methods of fabrication shall be performed. Loads occurring in fabrication phases shall be assessed and, when necessary, the structure and the structural support arrangement shall be evaluated for structural adequacy.

202 Major lifting operations shall be evaluated to ensure that deformations are within acceptable levels, and that relevant strength criteria are satisfied.

B 300 Mating

301 All relevant load effects incurred during mating operations shall be considered in the design process. Particular attention should be given to hydrostatic loads imposed during mating sequences.

B 400 Sea transportation

401 A detailed transportation assessment shall be undertaken which includes determination of the limiting environmental criteria, evaluation of intact and damage stability characteristics, motion response of the global system and the resulting, induced load effects. The occurrence of slamming loads on the structure and the effects of fatigue during transport phases shall be evaluated when relevant.

402 Satisfactory compartmentation and stability during all floating operations shall be ensured.

403 All aspects of the transportation, including planning and procedures, preparations, seafastenings and marine operations should comply with the requirements of the warranty authority.

B 500 Installation

501 Installation procedures of foundations (e.g. piles, suction anchor or gravity based structures) shall consider relevant static and dynamic loads, including consideration of the maximum environmental conditions expected for the operations.

502 For novel installation activities, relevant model testing should be considered.

503 The loads induced by the marine spread mooring involved in the operations, and the forces exerted on the structures utilised in positioning the unit, such as fairleads and pad eyes, shall be considered for local strength checks.

504 In cases where the riser/tensioner system will influence the global motion of the floater, special attention should be given to the coupling effects between the floater, risers and moorings.

B 600 Decommissioning

601 Abandonment of the unit shall be planned for in the design stage.

C. Structural Categorisation, Selection of Material and Extent of Inspection

C 100 General

101 Application categories for structural components are defined in Sec.4. For novel designs of DDF, the structural categorisation shall be based on the definition in Sec.4.

102 Structural members of a DDF of caisson type are normally found in the following group:

Special category

a) Portions of deck plating, heavy flanges, and bulkheads within the structure, which receive major concentrated loads.
b) External shell structure in way of highly stressed connections to the deck structure.
c) Major intersections of bracing members.
d) External brackets, portions of bulkheads, and frames which are designed to receive concentrated loads at intersections of major structural members.
e) Highly stressed elements of anchor line fairleads, crane pedestals, flare boom etc. and their supporting structure.

Primary category

a) Deck plating, heavy flanges, transverse frames, stringers, and bulkhead structure, which do not receive major concentrated loads.
b) Moonpool shell.
c) External shell and diagonal and horizontal braces.
d) Bulkheads, decks, stiffeners and girders which provide local reinforcement or continuity of structure in way of intersections, except areas where the structure is considered special application.
e) Main support structure of heavy substructures and equipment, e.g. anchor line fairleads, cranes, drill floor substructure, lifeboat platform, thruster well and helicopter deck.
f) Interstitials (connecting plates between cells for a cell spar).
g) Strakes.

Secondary category

a) Upper platform decks, or decks of upper hulls except areas where the structure is considered primary or special application.
b) Bulkheads, stiffeners, flats or decks and girders, diagonal and horizontal beam columns, which are not considered as primary or special application.
c) Non-watertight bulkheads internal outfitting structure in general, and other non-load bearing components.

C 200 Material selection

201 Material specifications shall be established for all structural materials utilised in a DDF unit. Such materials shall be suitable for their intended purpose and have adequate properties in all relevant design conditions. Material selection shall be undertaken in accordance with the principles given in Sec.4.

202 When considering criteria appropriate to material grade selection, adequate consideration shall be given to all relevant phases in the life cycle of the unit. In this connection there may be conditions and criteria, other than those from the in-service, operational phase, that provide the design requirements in respect to the selection of material. (Such criteria may, for example, be design temperature and/or stress levels during marine operations.)

203 In structural cross-joints essential for the overall structural integrity where high tensile stresses are acting normal to the plane of the plate, the plate material shall be tested to prove the ability to resist lamellar tearing (Z-quality).

204 Material designations are defined in Sec.4.

C 300 Design temperatures

301 External structures above the inspection waterline shall be designed for service temperatures lower or equal to the lowest mean daily temperature for the area(s) where the unit is to operate.

302 External structures below the inspection waterline need normally not be designed for service temperatures lower than 0°C.

303 Internal structures are assumed to have the same service temperature as the adjacent external structure if not otherwise documented.

304 Internal structures in way of permanently heated rooms need normally not be designed for service temperatures lower than 0°C.

C 400 Inspection categories

401 Welding, and the extent of non-destructive examination during fabrication, shall be in accordance with the requirements stipulated for the structural categorisation as defined in Sec.4.

402 Inspection categories determined in accordance with Sec.4 provide requirements for the minimum extent of required inspection. When considering the economic consequence that repair during in-service operation may entail, for example, through complex connections with limited or difficult access, it may be considered prudent engineering practice to require more demanding requirements for inspection than the required minimum.

403 When determining the extent of inspection and the locations of required NDT, in addition to evaluating design parameters (for example fatigue utilisation), consideration should be given to relevant fabrication parameters including:

— location of block (section) joints
— manual versus automatic welding
— start and stop of weld etc.

C 500 Guidance to minimum requirements

501 The Fig.1 illustrates minimum requirements for selection of the structural category for one example of structural configurations of a DDF unit. The indicated structural categorisation should be regarded as guidance of how to apply the recommendations in Sec.4.

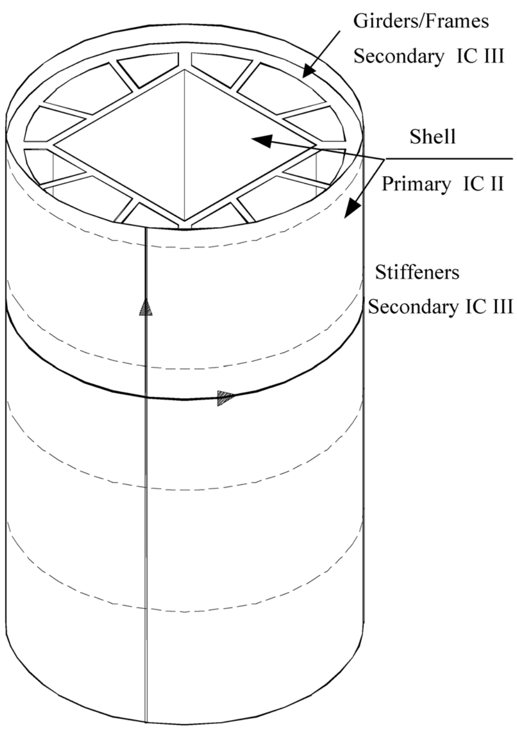

Figure 1
Example of typical structural categorisation in the hard tank area

D. Design Loads

D 100 Permanent loads

101 The type and use of permanent ballast (e.g. within soft tank of DDF units) for stability reasons must be carefully evaluated with respect to long term effects related to corrosion, wash out etc.

D 200 Variable functional loads

201 All relevant combinations of filling of hard tanks for the operation phase shall be taken into account in design.

202 Hydrostatic or hydrodynamic differential pressures acting on the hull or buoyancy tanks during launch and upending sequences shall be analysed or determined and taken into account in design of the hull.

203 All relevant combinations of differential pressures due to filling of ballast tanks, produced fluids, compressed air etc. shall be taken into account in design.

D 300 Environmental loads

301 If sufficient environmental data is available, environmental joint probability models may be developed and applied in the design of DDF units. This is especially important in areas with for example high loop current and frequently occurring hurricanes.

302 Due to the geometry (deep draught and large volume) of DDF units, the current loading may be of high importance for design of mooring and riser systems. If VIM is present, the influence from current will be intensified through increased floater offset and VIM trajectories. Consequently, attention must be given to the description of magnitude and direction of current along the depth.

D 400 Determination of loads

401 Calculation of hydrodynamic loads may be carried out according to Classification Note 30.5.

402 Hydrodynamic model tests should be carried out to:

— confirm that no important hydrodynamic feature has been overlooked (for new type of units, environmental conditions, adjacent structures, Mathieu instability etc.)
— support theoretical calculations when available analytical methods are susceptible to large uncertainties (e.g. in evaluating the need of VIM suppression devices (typically strakes on DDF hull))
— verify theoretical methods and models on a general basis.

403 Wind tunnel tests should be performed when:

— wind loads are significant for overall stability, motions or structural response
— there is a danger of dynamic instability.

404 Models applied in model tests shall be sufficient (reasonable scale and controllable scaling effects) to represent the actual unit. The test set-up and registration system shall provide a sound basis for reliable, repeatable interpretations.

405 A correlation report (tests and calculations) shall be prepared for validation purposes (design documentation).

D 500 Hydrodynamic loads

501 Resonant excitation (e.g. internal moonpool resonance, sloshing and roll and pitch resonance) shall be carefully evaluated. Wave on deck via moonpool has to be considered for DDF concepts with relatively short distances between moonpool and the outer wave active zone.

502 If hydrodynamic analyses of a DDF are performed with the moonpool 'sealed' at the keel level it must be validated that the results are equivalent to 'open' DDF hydrodynamic analyses. Special focus should be placed on the heave motion prediction (important for riser system) by using consistent added mass, total damping and excitation forces such that the eigenperiod and response in heave can be determined correctly.

503 In case of a DDF with damping and added mass plates and where it is possible that resonant, or near resonant heave motion may occur, the theoretical predictions should be validated against model test results.

504 If VIM suppression devices (e.g. spiral strakes) are attached to the hull, the increased loads (drag, inertia) must be taken into account. This applies to the operational as well as non-operational phases.

Guidance note:
DNV-OS-E301 provides more guidance on how to cater for VIM in mooring design.

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505 Simulation of loads and responses on riser system in the moonpool area shall be carried out according to a recognised code.

Guidance note:
DNV-OS-F201 may be applied for this purpose.

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506 In case of using air cans for tensioning the risers, gaps between the air cans and the riser frame within the moonpool, should be avoided.

E. Deformation Loads

E 100 General

101 Deformation loads are loads caused by inflicted deformations, such as:

— temperature loads
— built-in deformations

Further details and description of deformation loads are given in Sec.3 H.

F. Accidental Loads

F 100 General

101 The following ALS events shall be considered with respect to the structural design of a DDF unit:

— collision
— dropped objects
— fire
— explosion
— unintended flooding

102 Requirements and guidance on accidental loads are given in Sec.3 G and generic loads are given in DNV-OS-A101.

G. Fatigue Loads

G 100 General

101 Repetitive loads, which may lead to significant fatigue damage, shall be evaluated. The following listed sources of fatigue loads shall, where relevant, be considered:

— waves (including those loads caused by slamming and variable (dynamic) pressures)
— wind (especially when vortex induced vibrations may occur)
— currents (especially when vortex induced vibrations may occur)
— mechanical loading and unloading, e.g. crane loads.

The effects of both local and global dynamic response shall be properly accounted for when determining response distributions related to fatigue loads.

102 Further considerations with respect to fatigue loads are given in DNV-RP-C203 and Classification Note 30.5.

H. Combination of Loads

H 100 General

101 Load combinations for the different design conditions are in general, given in Sec.3.

102 A sufficient number of load conditions shall be evaluated to ensure that the characteristic largest (or smallest) response, for the appropriate return period, has been established. Due attention should be given to the global bending and shear forces along the length of the structure, including the P-delta effects due to heel or trim of the unit.

I. Load Effect Analysis in Operational Phase

I 100 General

101 Global, dynamic motion response analysis taking into account loads from wind (static and gust), waves (wave frequency and low frequency) and current shall be performed. Time domain analysis is the preferred option.

102 Coupled, time domain analyses may be performed for DDF units in order to determine the coupling effects due to the presence of mooring and risers. Actual riser installation program should be taken into account. Guidance and recommendations on coupled analyses are given in DNV-RP-F205.

103 Depending on actual water depth, dimensions and geometry and mooring system, DDF units will typically experience the following eigenmodes or eigenperiods:

— surge or sway; 100 to 400 s
— heave; 20 to 35 s
— roll or pitch; 40 to 90 s

The simulation length for determination of the different load effects must be sufficient such that reliable extreme response statistics can be obtained.

Guidance note:

Combined loading

Common practice to determine extreme responses has been to expose the dynamic system to multiple stationary design environmental conditions. Each design condition is then described in terms of a limited number of environmental parameters (e.g. H_s, T_p) and a given seastate duration (3 to 12 hours). Different combinations of wind, wave and current with nearly the same return period for the combined environmental condition are typically applied.

The main problem related to design criteria based on environmental statistics is that the return period for the characteristic load effect is unknown for non-linear dynamic systems. This will in general lead to an inconsistent safety level for different design concepts and failure modes.

A more consistent approach is to apply design based on response statistics. Consistent assessment of the D-year load effect will require a probabilistic response description due to the long-term environmental loads on the system. The load effect with a return period of D-year, denoted x_D, can formally be found from the long-term load effect distribution as:

$$F_x(x_D) = 1 - \frac{1}{N_D}$$

$F_x(x)$ = long-term peak distribution of the (generalised) load effect

N_D = total number of load effect maxima during D years

The main challenge related to this approach is to establish the long-term load effect distribution due to the non-linear behaviour. Design based on response statistics is in general the recommended procedure and should be considered whenever practicable for consistent assessment of characteristic load effects.

Further details may be found in Appendices to DNV-OS-F201, or DNV-RP-F205.

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I 200 Global bending effects

201 Global bending and shear forces along the length of the structure due to environmental load effects shall be determined. This applies to first order wave effects, as well as P-delta effects due to platform heel or trim.

202 Global bending and shear forces in the hull will be influenced by the non-linear restoring effect from the mooring system. This additional load effect shall be analysed and taken into account in design of the hull structure.

J. Load Effect Analysis in Non-Operational Phases

J 100 General

101 All temporary phases shall be carefully evaluated and sufficient level and amount of analyses shall be performed according to this standard. Further details regarding non-operational conditions may be found in Rules for Planning and Execution of Marine Operations.

J 200 Transportation

201 In case of wet tow in harsh environment (e.g. overseas), model tests shall be performed as a supplement to motion response analyses. Non-linear effects (e.g. slamming, global bending or shear, green seas) shall be taken into account.

202 Motion response analyses shall be performed for dry transports on for example heavy lift vessel, or barge. Special attention to:

— roll motions (roll angles, accelerations, viscous roll damping)
— slamming pressures and structural responses
— global strength (vessel, DDF unit)
— strength of sea-fastening
— stability, overhang
— model tests and time domain analyses may be required to determine relevant responses for new concepts of dry tow a large size platform.

J 300 Launching

301 Launching may be an alternative way of installation or upending a DDF (e.g. truss spar). Model testing of the launch process may be required if there is limited or no experience with such operations for similar concepts.

J 400 Upending

401 Pre-upending phases shall be analysed with respect to global bending moments and shear forces in the hull. In case of wave load effects in this pre-upending phase may be relevant, this shall be analysed and taken into account.

402 In case of dynamic upending, analyses shall be performed in order to determine global and local load effects in the DDF unit with its appurtenances.

403 Hydrostatic or hydrodynamic differential (outside and inside) pressures during dynamic upending shall be determined and further used in design of the hull structure.

404 Model testing of the dynamic upending may be avoided if the applied simulation software has been validated against similar or relevant operations and showing good correlation.

405 In case of lift assisted upending offshore, the limiting environmental criteria must be carefully selected. Dynamic analyses of the system (lift vessel, lifting gear, DDF unit) will be required in order to determine responses in lifting gear and DDF unit.

J 500 Deck mating

501 Offshore installation of deck structure and modules will require refined analyses in order to determine the governing responses. This applies to lifting operations as well as float-over operations with barge. Important factors are limiting environmental criteria, impact responses and floating stability requirements.

502 Floating concepts utilising jacking of legs to desired draft and subsequent deballasting to obtain sufficient air-gap, shall be carefully evaluated or analysed with respect to limiting environmental criteria.

J 600 Riser installations

601 For concepts where the global system stiffness (mainly heave & roll/pitch) is depending on number of risers installed, coupled time domain analyses and/or model testing shall be performed.

602 Special attention should be given to simulation of friction (stick/slip) effects related to riser/keel, riser/damping plates as well as tensioning system.

K. Structural Strength

K 100 Operation phase for hull

101 For global structural analysis, a complete three-dimensional structural model of the unit is required. This may be a complete shell type model, or a combined shell and space-frame model.

102 Additional detailed finite-element analyses may be required for complex joints and other complicated structural parts (e.g. fairlead area, hard tank area, column and brace connections, strake terminations and interactions, deck and hull connections, riser frame and hull connections, curved flanges) to determine the local stress distribution more accurately.

Guidance note:

In order to be able to assess the effect of all possible tank filling configurations, a local FEM-model covering the hard tank area may be utilised. Only those tanks used in the normal operation of the platform shall as a minimum be modelled. The stresses from a local FEM-model should be superimposed to global stresses.

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103 The additional global bending and shear due to P-delta and mooring restoring effects shall be combined with first order wave effects in a consistent way.

104 The following riser/hull interface loads shall typically be evaluated/analysed:

— riser (air can, or stem)/riser frame loads (horizontal & vertical)
— keel joint/soft tank interaction
— intermediate interactions between riser and damping plates
— hang off loads from export risers, or other fluid transfer lines from nearby floaters
— riser loads via riser tensioners and frame support structure interface with hull structure

105 If VIM suppression devices (e.g. strakes) are installed on the hull, both local (direct wave and current loads) and global bending effects should be considered in design of the suppression devices. Local effects on the hull induced by loads (wave/current) on the VIV suppression devices should be considered.

K 200 Non-operational phases for hull

201 Finite element analyses will be required performed for overseas wet tow and dry tow in harsh environment.

202 For dry tow this implies that the complete structural system (hull sections, sea-fastening, transport vessel) shall be modelled such that reliable stress-distributions can be obtained.

203 For wet tow in harsh environment special emphasis must be put on the simulation or modelling of the hydrodynamic wave pressures or accelerations acting on the wet hull structure. Further the non-linear hogging and sagging bending and shear effects due to the shape of the hull should be properly simulated or accounted for in the design.

204 The level or amount of finite element analyses for the upending process needs to be evaluated. As a minimum, the following considerations shall be made:

a) Global bending moments and shear forces to be compared (location and level) for the operational phase and pre-upending or dynamic upending.
b) Possibilities for local and global buckling (e.g. skirt area for a classic spar) due to global load effects and lateral differential pressures needs to be assessed or analysed.

K 300 Operation phase for deck or topside

301 Structural analysis of deck structure shall, in general, follow the same principles as outlined for the hull.

302 Horizontal accelerations at deck level due to wave loading will be high for some DDF units in harsh environment. Detailed FEM analyses of the deck and hull connections shall be performed in such instances.

303 In the extreme environmental load condition, i.e. loading condition b) in Sec.3 Table D1, positive air gap should be ensured, see Sec.11 D500. However, wave impact may be permitted to occur on any part of the structure provided that it can be demonstrated that such loads are adequately accounted for in the design and that safety to personnel is not significantly impaired

304 DDF deck is, in many designs, subject to wave 'run-up'. This may create water flowing over the deck with high velocities up to a certain height. The description of the flow should be based on model testing and analysis. In such cases, these load effects shall be accounted for in the structural design of the deck. The equipment on the deck critical for operation of the platform and the deck support shall be designed to withstand the loads from water flowing over the deck.

K 400 Non-operational phases for deck or topside

401 Typical non-operational phases as fabrication, transportation and installation of deck and topside modules shall be assessed and analysed to a sufficient level such that the actual stress level can be determined and further used in the design checks.

L. Fatigue

L 100 General

101 Criteria related to DFFs are given in Sec.6.

102 DNV-RP-C203 presents recommendations in relation to fatigue analyses based on fatigue tests and fracture mechanics.

L 200 Operation phase for hull

201 First order wave actions will usually be the dominating fatigue component for the hull in harsh environment. The long term distribution of wave induced stress fluctuations need to be determined with basis in the same type of load effect and finite element analyses as for strength analysis.

Guidance note:

Early phase evaluation or analysis of fatigue may incorporate modelling the hull as a beam with associated mass distribution and simulation of wave actions according to Morison formulation, or preferably, performing a radiation or diffraction analysis.

Final documentation related to first order wave induced fatigue damage should incorporate a stochastic approach. This implies establishing stress transfer functions, which are combined with relevant wave spectra (scatter diagram) in order to obtain long-term distribution of stresses. The stress transfer functions should be obtained from FEM analyses with appropriate simulation of wave loads (radiation/diffraction analysis). The P-delta effect due to platform roll and pitch must be taken into account.

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202 As for strength assessments, the P-delta effect due to platform roll or pitch shall be taken into account. This implies that both first order and second order, slowly varying roll or pitch motions need to be considered and taken into account if contributing to fatigue damage in the hull.

203 For special fatigue sensitive areas, local stress concentrations shall be determined by detailed finite element analyses.

204 Typical fatigue sensitive areas for DDF units will be:

- hull and deck connections
- collision ring area
- hull and deck and stiffener connections at location of peak wave induced global bending moments
- fairlead area
- hard tank area
- column and brace connections
- strake and hull connections and strake terminations
- riser frame and hull connections
- hard tank and truss spar connections
- tubular joints
- riser porches/hang-off
- tensioner support module/hull
- highly stressed manway areas opened up for construction and closed by welded caps.

205 Fatigue analyses shall be performed to check that the hull strakes have sufficient fatigue lives. Relative motions between the hull and disturbed wave kinematics around strakes must be properly taken into account. Hydrodynamic pressures from a radiation and diffraction analysis in combination with a Morison formulation (inertia and drag) will be sufficient to describe the environmental loads on the strakes.

Both global bending effects and local wave induced loads shall be taken into account in fatigue design of strakes. Local effect on the hull due to strake induced fatigue loads should be considered in hull fatigue design.

206 VIM load effects from mooring system (global hull in-line and cross-flow motions) into the fairlead/hull areas shall be outlined and taken into account. The same applies to VIV load effects from riser systems into the riser frame and hull areas.

207 Allowance for wear and tear shall be taken into account in areas exposed to e.g. friction and abrasion. For a DDF unit this will typically be interfaces between hull and risers (keel level, intermediate riser-frames, deck level). These relative motions are caused by movements of the unit and risers and subsequent pull-out and push-up of the risers in the moonpool.

L 300 Non-operational phases for hull

301 Wet, overseas transports in harsh environment will require quite detailed analyses to determine the fatigue damage during this temporary phase. Both global and local wave load effects shall be taken into account. Some level of monitoring of weather and load effects during towage will be required such that it is possible to recalculate the actual fatigue contribution during wet tow.

302 Dry, overseas transports will usually be less exposed to fatigue damage. It is however, required almost the same level of FE analyses as for wet tow in order to determine the stress fluctuations in hull, sea-fastenings and transport.

L 400 Splash zone

401 The definition of ‘splash zone’ as given Sec.10 B200, relates to a highest and lowest tidal reference. For DDF units, for the evaluation of fatigue, reference to the tidal datum should be substituted by reference to the draught that is intended to be utilised when condition monitoring shall be undertaken. The requirement that the extent of the splash zone is to extend 5 m above and 4 m below this draught may then be applied.

If a DDF may have a draught variation, this should be taken into account in evaluating the splash zone.

Guidance note:

If significant adjustment in draught is possible in order to provide for satisfactory accessibility in respect to inspection, maintenance and repair, a sufficient margin in respect to the minimum inspection draught should be considered when deciding upon the appropriate design fatigue factors. As a minimum this margin shall be at least 1 m, however it is recommended that a larger value is considered especially in the early design stages where sufficient reserve should be allowed for to account for design changes (mass and centre of mass of the unit). Consideration should further be given to operational requirements that may limit the possibility for ballasting and deballasting operations.

When considering utilisation of remotely operated vehicle (ROV) inspection, consideration should be given to the limitations imposed on such inspection by the action of water particle motion (e.g. waves). The practicality of such a consideration may be that effective underwater inspection by ROV, in normal sea conditions, may not be achievable unless the inspection depth is at least 10 m below the sea surface.

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L 500 Operation phase for deck or topside

501 Wave induced horizontal accelerations and P-delta effects will usually be governing for fatigue design of deck structure and topside modules and shall be duly taken into account.

502 A stochastic approach is the preferred option for determination of final fatigue damage for the deck or topside. See Guidance Note to L201 for the hull.

503 Deck and hull connections, joints in deck structure, module supports etc. will typically be fatigue sensitive areas. The amount or level of detailed FE analyses for these joints need to be considered. For the deck and hull connection some level or amount of detailed FE analyses shall be performed, at least for units located in harsh environment.

L 600 Non-operational phases for deck or topside

601 Fatigue damage of deck structure and topside modules shall be documented if the stress fluctuations in the different phases are significant.

M. Accidental Condition

M 100 General

101 The objective of this subsection is to provide supplemental guidance related to design for accidental condition as outlined in Sec.7.

102 Units shall be designed to be damage tolerant, i.e. credible accidental damage, or events, should not cause loss of global structural integrity. The capability of the structure to redistribute loads should be considered when designing the structure.

M 200 Fire

201 Deck area will be limited for some DDF concepts. Potential fire scenarios shall therefore be carefully considered and taken into account in design and layout planning.

M 300 Explosion

301 As for fire, the limiting deck space and protected moonpool area (potential gas or oil leakage) for some DDF units require that explosions are carefully considered in the design process.

302 In respect to design considering loads resulting from explosions one, or a combination of the following main design philosophies are relevant:

a) Ensure that the probability of explosion is reduced to a level where it is not required to be considered as a relevant design loadcase.
b) Ensure that hazardous areas are located in unconfined (open) locations and that sufficient shielding mechanisms (e.g. blast walls) are installed.
c) Locate hazardous areas in partially confined locations and design utilising the resulting, relatively small overpressures.
d) Locate hazardous areas in enclosed locations and install pressure relief mechanisms (e.g. blast panels) and design for the resulting overpressure.

303 As far as practicable, structural design accounting for large plate field rupture resulting from explosion loads should normally be avoided due to the uncertainties of the loads and the consequence of the rupture itself.

Structural support of blast walls, and the transmission of the blast load into main structural members shall be evaluated when relevant. Effectiveness of connections and the possible outcome from blast, such as flying debris, shall be considered.

M 400 Collision

401 Safety assessments shall be the basis for determination of type and size of colliding vessel and impact speed.

402 Collision impact shall be considered for all elements of the unit, which may be impacted by sideways, bow or stern collision. The vertical extent of the collision zone shall be based on the depth and draught of attending vessels and the relative motion between the attending vessels and the unit.

403 Resistance to unit collisions may be accounted for by indirect means, such as, using redundant framing configurations, collision ring in splash zone and materials with sufficient toughness in affected areas.

M 500 Dropped objects

501 Critical areas for dropped objects shall be determined on the basis of the actual movement of potential dropped objects (e.g. crane actions) relative to the structure of the unit itself. Where a dropped object is a relevant accidental event, the impact energy shall be established and the structural consequences of the impact assessed.

502 Generally, dropped object assessment will involve the following considerations:

a) Assessment of the risk and consequences of dropped objects impacting topside, wellhead, and riser system in moonpool and safety systems and equipment. The assessment shall identify the necessity of any local structural reinforcement or protections to such arrangements.
b) Assessments of the risk and consequences of dropped objects impacting externally on the hull structure (shell, or bracings) and hull attachments such as strakes, fairleads and pipes. The structural consequences are normally fully accounted for by the requirements for watertight compartmentation and damage stability and the requirement for structural redundancy of slender structural members.

M 600 Unintended flooding

601 A procedure describing actions to be taken after relevant unintended flooding shall be prepared. Unintended filling of hard tanks, collision ring and bracings for a DDF will be the most relevant scenarios for the operation phase.

602 It must be ensured that counter-filling of tanks and unit uprighting can be performed safely and without delays.

603 Structural aspects related to the tilted condition and counter-flooding (if relevant) shall be investigated. This applies to the complete unit including risers and mooring system.

604 If the unit can not be brought back to the design draught and verticality by counter-ballasting and redistribution of ballast water, this must be taken into account in design of the unit.

M 700 Abnormal wave events

701 Abnormal wave effects are partly related to air-gap and wave exposure to deck or topside structures. Consequences from such wave impacts shall be evaluated and taken into account in design of the relevant structural parts.

702 In areas with hurricanes, special considerations have to be made with respect to selection of relevant sea states to be applied in design of the unit.

APPENDIX A
CROSS SECTIONAL TYPES

A. Cross Sectional Types

A 100 General

101 Cross sections of beams are divided into different types dependent of their ability to develop plastic hinges as given in Table A1.

Table A1 Cross sectional types	
I	Cross sections that can form a plastic hinge with the rotation capacity required for plastic analysis
II	Cross sections that can develop their plastic moment resistance, but have limited rotation capacity
III	Cross sections where the calculated stress in the extreme compression fibre of the steel member can reach its yield strength, but local buckling is liable to prevent development of the plastic moment resistance
IV	Cross sections where it is necessary to make explicit allowances for the effects of local buckling when determining their moment resistance or compression resistance

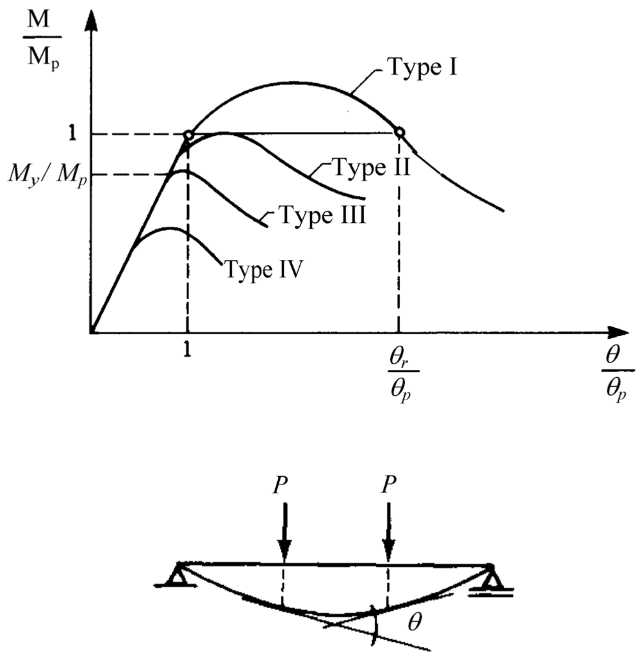


Figure 1
Relation between moment M and plastic moment resistance M_p, and rotation θ for cross sectional types. M_y is elastic moment resistance

102 The categorisation of cross sections depends on the proportions of each of its compression elements, see Table A3.

103 Compression elements include every element of a cross section which is either totally or partially in compression, due to axial force or bending moment, under the load combination considered.

104 The various compression elements in a cross section such as web or flange, can be in different classes.

105 The selection of cross sectional type is normally quoted by the highest or less favourable type of its compression elements.

A 200 Cross section requirements for plastic analysis

201 At plastic hinge locations, the cross section of the member which contains the plastic hinge shall have an axis of symmetry in the plane of loading.

202 At plastic hinge locations, the cross section of the member which contains the plastic hinge shall have a rotation capacity not less than the required rotation at that plastic hinge location.

A 300 Cross section requirements when elastic global analysis is used

301 When elastic global analysis is used, the role of cross section classification is to identify the extent to which the resistance of a cross section is limited by its local buckling resistance.

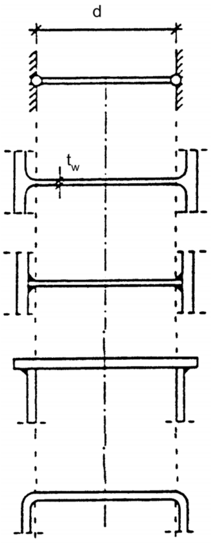
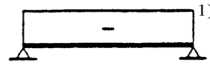
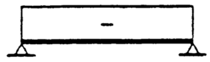
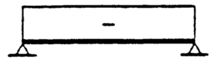
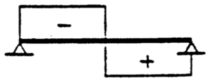
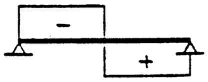
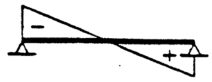
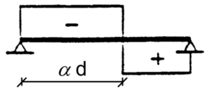
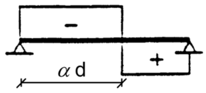
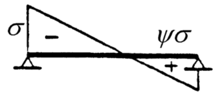
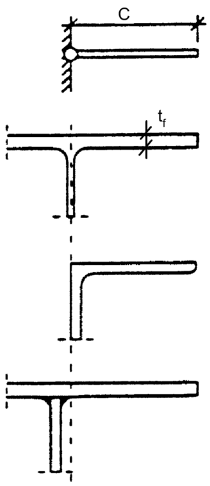
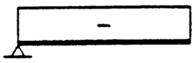
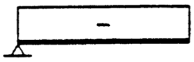
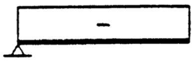
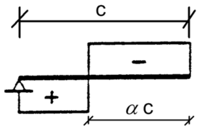
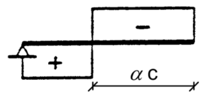
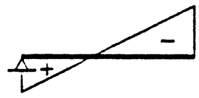
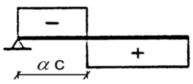
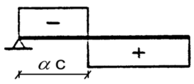
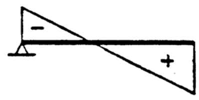
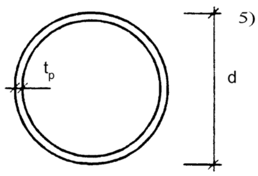
302 When all the compression elements of a cross section are type III, its resistance may be based on an elastic distribution of stresses across the cross section, limited to the yield strength at the extreme fibres.

Table A2 Coefficient related to relative strain	
NV Steel grade 1)	ε 2)
NV-NS	1
NV-27	0.94
NV-32	0.86
NV-36	0.81
NV-40	0.78
NV-420	0.75
NV-460	0.72
NV-500	0.69
NV-550	0.65
NV-620	0.62
NV-690	0.58

1) The table is not valid for steel with improved weldability. See Sec.4, Table D1, footnote 1).

2)

$$\varepsilon = \sqrt{\frac{235}{f_y}} \quad \text{where } f_y \text{ is yield strength}$$

Table A3 Maximum width to thickness ratios for compression elements			
Cross section part	*Type I*	*Type II*	*Type III*
 $d = h - 3\,t_w$ 3)	 1) $d / t_w \le 33\,\varepsilon$ 2)	 $d / t_w \le 38\,\varepsilon$	 $d / t_w \le 42\,\varepsilon$
	 $d / t_w \le 72\,\varepsilon$	 $d / t_w \le 83\,\varepsilon$	 $d / t_w \le 124\,\varepsilon$
	 when $\alpha > 0.5$: $d/t_w \le \frac{396\varepsilon}{13\alpha - 1}$ when $\alpha \le 0.5$: $d/t_w \le \frac{36\varepsilon}{\alpha}$	 when $\alpha > 0.5$: $d/t_w \le \frac{456\varepsilon}{13\alpha - 1}$ when $\alpha \le 0.5$: $d/t_w \le \frac{41.5\varepsilon}{\alpha}$	 when $\psi > -1$: $d/t_w \le \frac{126\varepsilon}{2 + \psi}$ when $\psi \le -1$: $d/t_w \le 62\varepsilon(1 - \psi)\sqrt{\lvert\psi\rvert}$
	 Rolled: $c/t_f \le 10\varepsilon$ Welded: $c/t_f \le 9\varepsilon$	 Rolled: $c/t_f \le 11\varepsilon$ Welded: $c/t_f \le 10\varepsilon$	 Rolled: $c/t_f \le 15\varepsilon$ Welded: $c/t_f \le 14\varepsilon$
	Tip in compression  Rolled: $c/t_f \le 10\varepsilon/\alpha$ Welded: $c/t_f \le 9\varepsilon/\alpha$	Tip in compression  Rolled: $c/t_f \le 11\varepsilon/\alpha$ Welded: $c/t_f \le 10\varepsilon/\alpha$	Tip in compression  4) Rolled: $c/t_f \le 23\varepsilon\sqrt{C}$ Welded: $c/t_f \le 21\varepsilon\sqrt{C}$
	Tip in tension  Rolled: $c/t_f \le \frac{10\varepsilon}{\alpha\sqrt{\alpha}}$ Welded: $c/t_f \le \frac{9\varepsilon}{\alpha\sqrt{\alpha}}$	Tip in tension  Rolled: $c/t_f \le \frac{11\varepsilon}{\alpha\sqrt{\alpha}}$ Welded: $c/t_f \le \frac{10\varepsilon}{\alpha\sqrt{\alpha}}$	Tip in tension  Rolled: $c/t_f \le 23\varepsilon\sqrt{C}$ Welded: $c/t_f \le 21\varepsilon\sqrt{C}$
 5)	$d / t_p \le 50\,\varepsilon^2$	$d / t_p \le 70\,\varepsilon^2$	$d / t_p \le 90\,\varepsilon^2$

1) Compression negative
2) ε is defined in Table A2
3) Valid for rectangular hollow sections (RHS) where h is the height of the profile
4) C is the buckling coefficient. See Eurocode 3 Table 5.3.3 (denoted k_σ)
5) Valid for axial and bending, not external pressure.

APPENDIX B
METHODS AND MODELS FOR DESIGN OF COLUMN-STABILISED UNITS

A. Methods and Models

A 100 General

101 The guidance given in this appendix is normal practice for methods and models utilised in design of typical column-stabilised units i.e. ring-pontoon design and two-pontoon design. For further details reference is made to DNV-RP-C103.

102 Table A1 gives guidance on methods and models normally applied in the design of typical column-stabilised units. For new designs deviating from well-known designs, e.g. by the slenderness of the structure and the arrangement of the load bearing elements, etc., the relevance of the methods and models should be considered.

A 200 World wide operation

201 Design for world wide operation shall be based on the environmental criteria given by the North Atlantic scatter diagram, see Classification Note 30.5.

202 The simplified fatigue method described in Sec.5 may be utilised with a Weibull parameter of 1.1. For units intended to operate for a longer period, see definition "Y" below, the simplified fatigue method should be verified by a stochastic fatigue analysis of the most critical details.

A 300 Benign waters or restricted areas

301 Design for restricted areas or benign waters shall be based on site specific environmental data for the area(s) the unit shall operate.

302 The simplified fatigue method described in Sec.7 shall be utilised with a Weibull parameter calculated based on site specific criteria.

Table B1 Methods and models which should be used for design of typical column-stabilised units

		Two-pontoon semisubmersible			*Ring-pontoon semisubmersible*		
		Hydrodynamic model, Morison	*Global structural strength model*	*Fatigue method*	*Hydrodynamic model, Morison*	*Global structural strength model*	*Fatigue method*
Harsh environment, restricted areas or world wide	X	1	4	6	1	5	7
	Y	1	4	7	1	5	7
Benign areas	X	2	3	6	1	5	7
	Y	1	4	6	1	5	7

Definitions

X-unit following normal class survey intervals (survey in sheltered waters or drydock every 4 to 5 years).
Y-unit located for a longer period on location – surveys carried out in-water at location.

Hydrodynamic models

1) Hybrid model - Sink-source and/or Morison (when relevant, for calculation of drag forces).

2) Morison model with contingency factor 1.3 for strength and 1.1 for fatigue.

Global structural models

3) Beam model.

4) Combined beam and shell model. The extent of the beam and shell models may vary depending on the design. For typical beam structures a beam model alone may be acceptable.

5) Complete shell model.

Fatigue method

6) Simplified fatigue analysis.

7) Stochastic fatigue analysis, based on a screening process with simplified approach to identify critical details.

Harsh environment, restricted areas or world wide

— Units (X) designed for operation based on world wide requirements given in Classification Note 30.5.

— Units (Y) designed for operation based on site specific requirements.

Benign waters

— Units (X) designed for operation based on site specific criteria for benign waters.

— Units (Y) designed for operation based on site specific criteria for benign waters.

Guidance note:

Benign area:

Simplifications with respect to modelling procedures required for design documentation may be accepted for units intended for operations in benign areas, where the environmental design conditions dominate for the design of the unit, are less strict than for world-wide operation.

Units operating in benign areas are less dominated by environmental loads. Therefore the load condition b) and the fatigue capacity for standard performed detail are of minor importance for the design, and simplifications as described in the table above may be accepted.

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APPENDIX C
PERMANENTLY INSTALLED UNITS

A. Introduction

A 100 Application

101 The requirements and guidance given in this Appendix are supplementary requirements for units that are intended to stay on location for prolonged periods, normally more than 5 years, see also DNV-OSS-101 and DNV-OSS-102 for requirements related to in-service inspections.

102 Permanently located units shall be designed for site specific environmental criteria for the area(s) the unit will be located.

B. Inspection and Maintenance

B 100 Facilities for inspection on location

101 Inspections may be carried out on location based on approved procedures outlined in a maintenance system and inspection arrangement, without interrupting the function of the unit. The following matters should be taken into consideration to be able to carry out condition monitoring on location:

— arrangement for underwater inspection of hull, propellers, thrusters and openings affecting the unit's seaworthiness
— means of blanking of all openings
— marking of the underwater hull
— use of corrosion resistant materials for propeller
— accessibility of all tanks and spaces for inspection
— corrosion protection
— maintenance and inspection of thrusters
— ability to gas free and ventilate tanks
— provisions to ensure that all tank inlets are secured during inspection
— testing facilities of all important machinery.

C. Fatigue

C 100 Design fatigue factors

101 Design Fatigue Factors (DFF) are introduced as fatigue safety factors. DFF shall be applied to structural elements according to the principles in Sec.7. See also Fig.1.

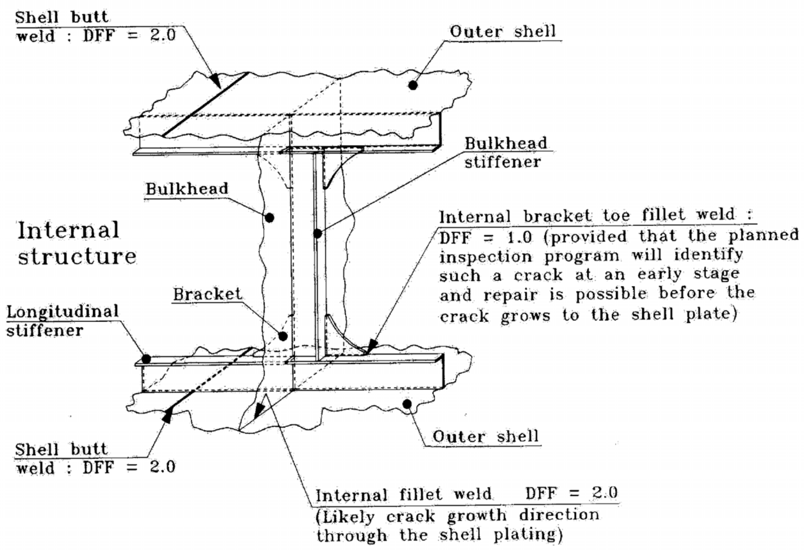

Figure 1
Example illustrating considerations relevant for selection of DFF in a typical section

102 Fatigue safety factors applied to the unit will be dependent on the accessibility for inspection and repair with special considerations in the splash zone, see 200.

103 When defining the appropriate DFF for a specific fatigue sensitive detail, consideration shall be given to the following as applicable:

— evaluation of likely crack propagation paths (including direction and growth rate related to the inspection interval), may indicate the use of a higher DFF, such that:
  — where the likely crack propagation indicates that a fatigue failure affect another detail with a higher design fatigue factor
  — where the likely crack propagation is from a location satisfying the requirement for a given 'Access for inspection and repair' category to a structural element having another access categorisation.

C 200 Splash zone for floating units

201 For fatigue evaluation of floating units, reference to the draught that is intended to be utilised during condition monitoring, shall be given as basis for the selection of DFF.

202 If significant adjustment in draught of the unit is possible to provide satisfactory access with respect to inspection, maintenance and repair, account may be taken of this possibility in the determination of the DFF. In such cases, a sufficient margin in respect to the minimum inspection draught should be considered when deciding upon the appropriate DFF in relation to the criteria for 'Below splash zone' as opposed to 'Above splash zone'. Where draught adjustment possibilities exist, a reduced extent of splash zone may be applicable.

203 Requirements related to vertical extent of splash zone are given in Sec.10 B200.

APPENDIX D
CERTIFICATION OF TENDON SYSTEM

A. General

A 100 Introduction

101 Certification of the tendon system is accomplished through the Certification of Material and Components (CMC) from various manufacturers. Since the Tendon system itself is an extension of the main load-bearing element of the TLP, it cannot be handled in a traditional CMC manner. Design approval of these various components need to be aligned with the global performance of the TLP and applicable load cases. Approval of all the components of the Tendon system and its interfaces shall be handled by the same DNV office whose is responsible for the approval of the TLP main structure. Survey can however be carried out by the local DNV stations in accordance with the requirements of this Appendix.

102 Tendon system generally consists of the following main elements:

- Tendon pipe
- Bottom Tendon Interface (BTI)
- Flex Bearings
- Foundation
- Top Tendon Interface (TTI)
- Tendon Intermediate Connectors
- Tendon Tension Monitoring System (TTMS)
- Tendon Porch
- Tendon Cathodic Protection System
- Load Management Program (LMP)

103 The following international standards and DNV standards are considered acceptable standards for design and fabrication of various components:

- API RP 2T
- API RP 2A
- API RP 2RD
- API RP 2R
- DNV-OS-C201
- DNV-OS-C401
- DNV-OS-B101
- DNV-RP-C201/202
- DNV CN 30.4
- DNV-RP-C203
- DNV-RP-B401
- BS 7910
- BS 7448

B. Equipment categorization

B 100 General

101 DNV uses categorization in order to clearly identify the certification and approval requirements for different equipment and components.

102 Categorization of equipment depends on importance for safety and takes operating and environmental conditions into account. Once assigned, the category of equipment refers to the scope of activities required for DNV certification and approval, as consistent with the importance of the equipment.

103 If there are any other equipment which is not defined in the following tables, categorisation of the same shall be decided on a case by case basis with prior discussion with DNV.

104 Equipment categorization for offshore installations or units is as follows:

I = Equipment/component important for safety & integrity of the TLP and for which a DNV certificate is required.
II = Equipment/component important for safety & integrity of the TLP and for which a works certificate prepared by the manufacturer is accepted.

Equipment category I

For equipment category 1, the following approval procedure shall be followed:

- design approval, documented by a design verification report (DVR) or type approval certificate.
- fabrication survey, documented by issue of a product certificate.

Specific requirements:

- pre-production meeting prior to the start of fabrication
- survey during fabrication, as applicable
- witness final functional, pressure and load tests, as applicable
- review of fabrication records.

These requirements are typical and the final extent of DNV survey required will be decided based on:

- complexity, size and previous experience of equipment type
- manufacturer's QA/QC system
- manufacturing survey arrangement (MSA) with DNV
- type of fabrication methods.

Equipment category II

Equipment of category II is normally acceptable on the basis of a works certificate prepared by the manufacturer. As a minimum, the certificate shall contain the following data:

- equipment specification or data sheet
- operating limitation(s) of the equipment
- statement from the manufacturer to confirm that the equipment has been constructed and manufactured according to recognised methods, codes, and standards
- test records as applicable.

Guidance note:
Independent test certificates or reports for the equipment, or approval certificate for manufacturing system, are also acceptable.

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C. Fabrication Record

C 100 General

101 Fabrication record shall be maintained by the manufacturer in a traceable manner, so that relevant information regarding design specifications, materials, fabrication processes, inspection, heat treatment, testing, etc. can be checked.

102 Fabrication record for category I equipment shall be available for review. The following particulars shall be included, as applicable:

- manufacturer's statement of compliance
- reference to design specifications and drawings

— location of materials and indication of respective material certificates
— welding procedure specifications and qualification test records
— location of welding indicating where the particular welding procedures have been used
— heat treatment records
— location of non-destructive testing (NDT) indicating where the particular NDT method has been used and its record
— load, pressure and functional test reports
— as-built part numbers and revisions.

D. Documentation Deliverables for Certification of Equipment

D 100 General

101 The following documentation will normally be issued by DNV for equipment and systems covered by certification activities (CMC):

a) *Design verification report, (DVR)*

— DVR will be issued by the design approval responsible for all equipment of category I, unless covered by a valid type approval certificate.
— In addition to each individual equipment, DVRs shall be issued for each system not covered by plan approval.

The DVR shall contain all information needed to be followed up by the surveyor attending fabrication survey and installation of the equipment, and as a minimum include:

— Design codes and standards used for design verification
— Design specification (e.g. temperature, pressure, SWL, etc.)
— Follow-up comments related to e.g. testing, fabrication and installation of the equipment or system.
An approval letter may be issued instead of a DVR, however such a letter shall as a minimum contain the same information as listed above.

b) *Inspection release note, (IRN)*

— An IRN shall only be issued if the component is delivered prior to issuance of final product certificate (PC). A final PC shall not be issued if there are non-conformances to the equipment or system. The IRN shall be used with detailed description of the non-conformances, and shall always be replaced by a certificate when all non-conformances are closed.

c) *Product certificate, (PC)*

— PC should be issued for all category I equipment or systems
— PC will be issued upon successful completion of design verification, fabrication survey and review of final documentation. As stated above, PC can not be issued if design verification or non-conformances are outstanding.

d) *Survey report*

— Survey report shall be issued for all category I equipment or systems upon satisfactory installation, survey and testing onboard. A survey report may cover several systems or equipment installed. The survey report shall contain clear references to all DVRs and PCs on which the survey report is based, and shall state testing and survey carried out.

E. Tendon Systems and Components

E 100 General

101 The loads for the tendon component analysis shall be obtained from the tendon global analysis. All relevant requirements as mentioned in Sec.1 to Sec.8 as applicable for the component shall be followed. The requirements specified below are some additional requirements that are specific to some of the components.

102 As most of these connectors are complex in design and fabrication, detailed linear elastic finite element analysis (FEA) shall be carried out using industry recognized FE programs. In general, a 3D finite element analysis using solid/brick elements will be required unless a 2D analysis can realistically represent and simulate the connectors, applicable loads and interfaces. Testing will be required where necessary to justify and document the FEA.

103 The design and construction shall cover all applicable load conditions transportation, lifting, installation and operation etc. The effects of fabrication tolerances, fit-up misalignment etc. shall be included. All connectors must be designed and fabricated with due consideration for installation and removal of damaged tendons.

104 If the transportation and installation phase of the tendons are not certified by DNV, information shall be submitted to DNV to document the fatigue damage, locked-in stresses etc. resulting from the lifting, transportation, free-standing tendon etc.

105 A higher safety margin shall be considered for the tendon components than for the tendon pipes due to the complexity of the components and uncertainties in the response calculation.

Guidance note:
In general a Design Fatigue Factor of minimum 10 shall be used for fatigue design of tendon and tendon components provided that the analyses are based on a reliable basis as described above. However, if the fatigue life assessment is associated with a larger uncertainty, a higher Design Fatigue Factor for complex tendon components may be recommended. In such cases, a higher Design Fatigue Factor should be determined based on an assessment of all uncertainties in the fatigue analysis with due consideration to the consequence of a fatigue failure. Before increasing the Design Fatigue Factor one should aim to reduce the uncertainties in the design basis as much as possible.

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E 200 Tendon pipe

201 Pipe manufacturer shall be an approved manufacturer or shall be certified by DNV. The pipes must be adequately specified for the service conditions. The following as a minimum shall be specified as applicable:

— the pipe shall be formed from Thermo-Mechanically Controlled Process (TMCP) plates
— Submerged Arc Welding (SAW) process shall be used for the manufacturing of the pipes
— the steel shall be fully killed and melted to fine grain practice.
— tensile and compression testing shall be performed also in the longitudinal direction.
— the variation in yield stress should be limited
— material fracture resistance properties shall be specified.
— the impact toughness of base material, weld and Heat-Affected Zone (HAZ) must be acceptable considering the service temperature.
— the hardness of welds must not exceed 330 Brinell's Hard-

ness Number (BHN) and tendons and weld areas must have a high grade coating to prevent hydrogen embrittlement (especially important for high tensile steels)
— NDT should be performed to ensure freedom of imperfections especially transverse to the direction of stress in the weld and
— base material as little variation as possible in wall thickness, diameter and out of roundness to reduce stress concentrations around welds.

The girth weld of the tendon pipes shall be qualified on the actual pipe material.

Guidance note:
API 5L pipes with additional service requirements shall be specified. Alternatively, Line pipes as mentioned in DNV OS-F101, Sec.6 with agreed applicable properties can be used.

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E 300 Bottom tendon interface (BTI)

301 The bottom tendon interface assembly must provide a secure connection throughout the design life of the TLP. The connector shall be designed adequately against yielding, fatigue and corrosion. BTI normally consist of the following main elements:

— a receptacle which will be welded to the pile
— a bottom tendon connector (BTC) which locks in to the receptacle
— a flex bearing element
— a tendon extension piece that is welded to the tendon pipe.

302 The maximum angular stiffness of the connection shall be specified consistent with the tendon design. There shall be no disengagement of the load bearing surfaces assuming a minimum tendon tension of “zero” at the bottom tendon interface.

303 The tendon receptacle and other interfaces attached to the pile shall be subjected to all applicable loads related to pile design and installation.

304 BTI and flex bearing design shall allow for rotation between the tendon and pile considering all applicable operation and installation conditions. Maximum installation angle shall be specified for the BTC to enter and lock in to the receptacle.

305 Pile installation loads and applicable impact loads for all components that are relevant during the installation and transportation phase shall be considered in the design

306 Guidance on fatigue methodology is defined in DNV RP-C203. If no documented S-N curve exists for the material selected, S-N curves shall be selected from DNV RP-C203.

307 Fracture mechanics tests shall be carried out in accordance with Sec.13 H.

E 400 Flex bearings

401 The selected material and manufacturer should have adequate prior experience with successful in-service history to demonstrate adequacy for its intended purpose. If a new material or manufacturer without sufficient prior experience for similar application is selected, the material and manufacturing process shall go through an adequate level of qualification.

Guidance note:
DNV-RP-A203 gives an outline for the qualification procedures.

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402 Manufacturer shall demonstrate by in-depth analysis and testing that the product meets the specified properties for the flex element including but not limited to:

— specified tendon loads
— maximum rotational stiffness
— minimum axial stiffness
— design life
— internal pressure (if applicable)
— other properties as specified.

403 Flex bearings shall be tested to adequately characterize rotational stiffness, axial capacity and angular capacity.

404 Acceptance criteria for the all elements of the finished product shall be clearly specified and agreed before fabrication.

E 500 Foundations

501 The loading for the foundation (pile or gravity based) design should be obtained from the tendon and geotechnical analysis. The loads resulting from all applicable load conditions including the damaged and removed tendon cases shall be considered.

502 Foundation design and fabrication shall be carried out in accordance with DNV CN 30.4 or other acceptable standards i.e. API RP 2A – WSD and API RP 2T. For gravity based concrete foundations, interface with tendon bottom connector and receptacle is given in DNV-OS-C502. Foundation system shall be designed for the same in-place conditions as the tendon system it supports, including tendon damage cases.

503 In particular, analysis shall reflect positioning tolerances for installation, installation loads like pile driving and installation and in-place damage. For gravity based structures, settlements (or uplift) needs to be taken into account.

504 Tendon foundation receptacle and pile above the mudline need to be protected from external corrosion by a combination of coatings and passive cathodic protection systems.

E 600 Top tendon interface (TTI)

601 The top tendon interface assembly must provide a secure connection throughout the life of the TLP. The connector shall be designed adequately against yielding, fatigue and corrosion. TTI normally consist of the following main elements:

— tendon porch that is attached to the HULL
— the length adjustment joint (LAJ) that will be welded to the top tendon piece
— tendon connector with the flex bearing
— TTMS interface

602 TTI and flex bearing design shall allow for rotation between the tendon and hull connection considering all applicable operation and installation conditions. Maximum installation angle shall be specified for the tendon to enter and lock in to the TTI.

603 Connector in way of the LAJ shall be checked for strength and fatigue with the reduced cross section.

604 Adequate protection mechanism shall be provided for the TTI including the “corrosion cap” on the top, protecting the LAJ.

E 700 Intermediate tendon connectors (ITC)

701 The intermediate tendon connectors (ITC) must provide a secure connection throughout the life of the TLP. The connector shall be designed adequately against yielding, fatigue and corrosion, racheting and fretting as applicable.

702 The connectors must be sealed and form a watertight connection. The design shall ensure that all potential damage during handling and installation for the sealing mechanism is identified and designed against.

E 800 Tendon tension monitoring system (TTMS)

801 Suitable and reliable tendon tension monitoring devices shall be installed to obtain the actual tension during operation.

802 This system generally consists of load cells, data acquisition system and alarm system. Load cells shall be calibrated to the required accuracy for the range of tension anticipated accounting for all possible system errors.

803 Alarm shall be pre-set for the values that exceed the design conditions so that adequate load balancing and operational measures can be taken to ensure that the tendon tension remains within the maximum allowable values. The alarms shall be audible and visually represented in the room where the LMP is monitored.

804 The load cells and all critical elements of the data acquisition system shall be redundant. There shall be more than one load cell per tendon. It shall monitor both tendon tension and bending moments (requires 3 load cells).

805 Marine quality cables shall be used and a watertight sealing shall be arranged for the top and bottom load ring interface.

E 900 Tendon porch

901 HULL interfaces with the tendons including the backup structure shall be designed for the breaking load of the tendons.

902 Cast steel shall be a weldable low carbon and fine grained steel. Test coupons representing the greatest end thickness of welding to the HULL shall be developed from each casting to facilitate actual production weld testing qualifications. NDT for the special areas (welding attachment to the HULL) or wherever the stress level exceeds 67% of yield shall be subjected to more rigorous NDT than other areas.

903 Acceptance criteria for weld repairs and acceptability shall be clearly defined in the specifications and agreed upon. Casting shall in general be in accordance with DNV offshore standard DNV-OS-B-101, Ch.2 Sec.4.

E 1000 Tendon corrosion protection system

1001 Tendon assembly shall be protected using a combination of coating systems, sacrificial-anodes, material selection, and corrosion allowance considered for the life time of the platform and the inspection philosophy during operation. Special areas like the TTI may need corrosion inhibitors, corrosion cap etc for protecting the moving parts. An affective corrosion protection system shall be in place from the time the structure is initially installed.

1002 Cathodic protection shall be carried out in accordance with DNV Recommended Practice DNV- RP-B401.

1003 Site specific data shall be used for the corrosion protection design. Special considerations shall be given for the higher ambient temperature effect for areas like West Africa.

1004 Anode and other attachment details and welding to the tendon system shall be specifically approved by DNV.

E 1100 Load management program (LMP)

1101 Load management program shall facilitate the safe operation of the TLP and the tendon systems under the defined load conditions by monitoring the weight changes and centre of gravity (CG) shifts compared with the pre-defined envelope. It shall be possible to automatically calculate weight redistribution of live loads and ballast water. Other relevant variable data such as draft, wave, wind etc. shall be used by the program as appropriate.

1102 The system shall operate from a UPS power supply and shall have a redundant fail safe system. Data shall be backed-up continuously and all important data saved on a regular basis.

F. Categorisation of Tendon Components

F 100 General

101 The load management system shall meet the continuous availability requirement as defined in DNV-OS-D202, Ch.2 Sec.1 B200.

Table XX Categories for tendon systems, equipment and components

Relevant text	*Material or equipment*	*DNV approval categories*	
		I	*II*
TENDON PIPE	*Pipe*	X	
		X	
TOP TENDON INTERFACE	*TTI Connector*	X	
	LAJ Assembly	X	
	Top Flex Bearing	X	
BOTTOM TENDON INTERFACE	*BTI Connector*	X	
	BTI Receptacle	X	
	BTI Flex Bearing	X	
INTERMEDIATE CONNECTORS	*Connectors*	X	
FOUNDATION (PILE)	*Pile*	X	
TENDON TENSION MONITORING SYSTEM	*Load Cell*	X	
	Hardware &Software		X
		X	
LOAD MANAGEMENT PROGRAM (LMP)	*Hardware & Software*	X	
TENDON CATHODIC PROTECTION SYSTEM	*Anodes*		X
	Attachments		X
FLEX BEARINGS	*Reinforcement*	X	
	Outer/Inner bulk metal	X	
	Elastomer	X	
TENDON PORCH	*Casting*	X	

G. Tendon Fabrication

G 100 General

101 Tendon systems are critical load carrying elements and are essential for the integrity of the TLP. Fabrication of the tendon system in general shall meet the requirements as applicable for “special areas”. NDT requirement on all welding shall, as a minimum, be in accordance with the butt weld requirement for inspection category 1 as defined in DNV Offshore standard DNV-OS-C401. In all cases, where the global design requires more stringent standards than what is outlined in the DNV standard, fabrication requirements shall be adjusted such that the tendon joints meet those higher requirements.

102 The extent and the methods of NDT chosen for the tendon fabrication shall meet the requirements of DNV-OS-C401, Ch.2 Sec.3 C105.

103 Casting, forging techniques used for the tendon fabrication shall, as a minimum, meet the good practices as outlined in DNV-OS-B101 Ch.2 Sec.4 and Ch.2 Sec.3.