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Submarine Systems Requirements Part 03

Submarine Stability

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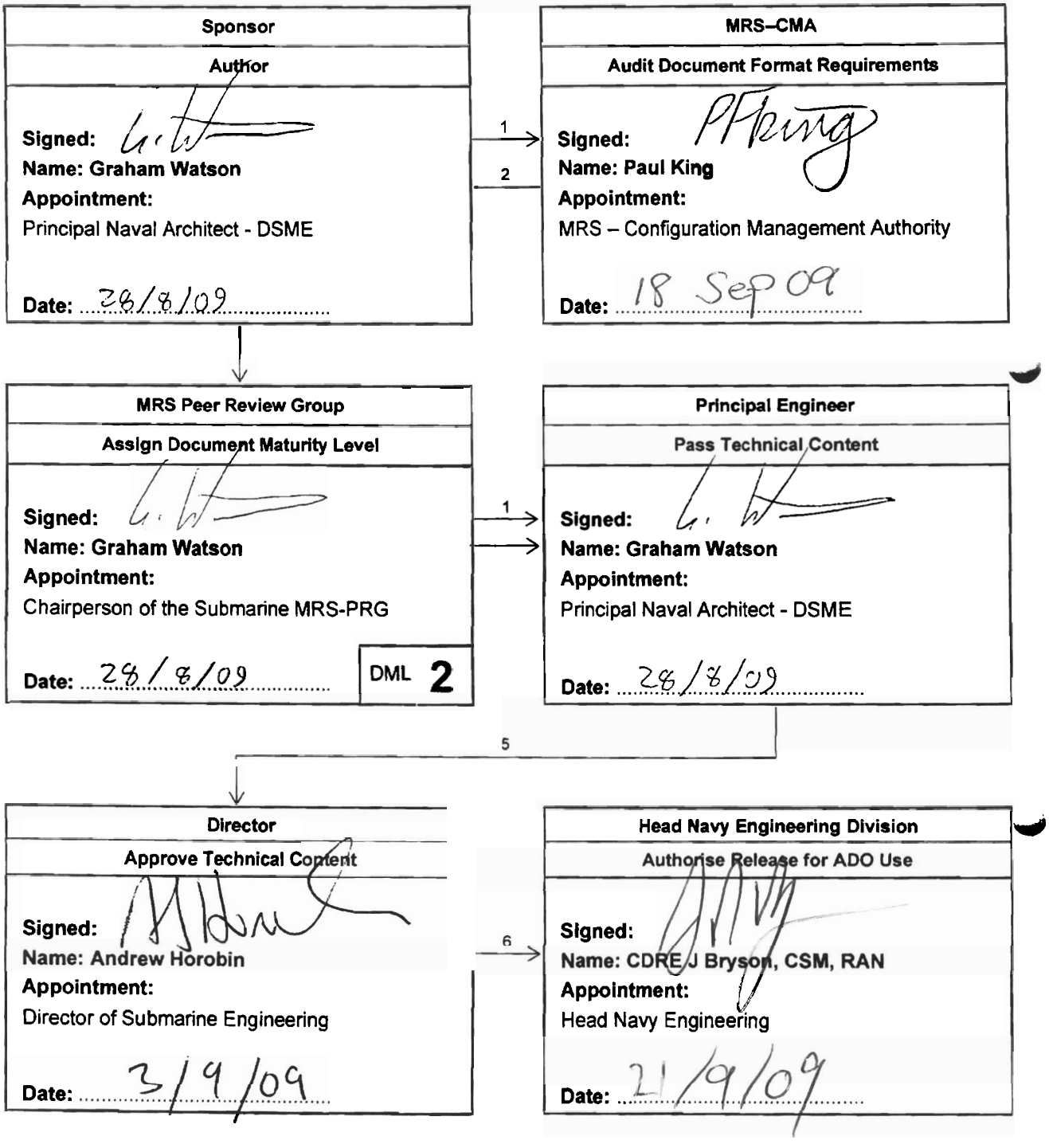
PROMULGATION



DEF(AUST)5000 CHANGE PROPOSAL

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PROPOSED CHANGE

Proposal:

The Above Discrepancy Materiel Safety ☐ Materiel Capability ☐ Other ☐

ORIGINATING SOURCE'S CONTACT DETAILS

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ISSUE HISTORY

Issue No.	Issue Date	Description of Changes	Affected Pages	Sponsor's Name
01	1	Original Issue	All	G.Watson
02				
03				
04				
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08				
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PREFACE

1. This document was prepared by Directorate of Submarine Engineering of the DMO and is an element of the DEF(AUST)5000—*ADF Maritime Materiel Requirements Set*.
2. The general requirements specified herein are to be used in the generation of capability-specific function and performance specifications associated with procurement, modification, maintenance, and repair of maritime materiel.
3. This document will be updated at regular intervals to reflect lessons learned and changes in National Standards, or to incorporate other nations' standards required for collaborative activities.
4. Queries and comments regarding the use and/or interpretation of this document are to be directed to the sponsor.

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1 SCOPE

1.1 Life Cycle

1.1.1 This document applies to the design construction and through life management of the stability and weight margins for RAN submarines. It does not apply retrospectively to submarines not designed in accordance with this MRS.

1.2 What is Covered

1.2.1 This standard covers the design requirements and margins to be met by the submarine in relation to weight, stability, freeboard, reserves of buoyancy and weight compensation systems.

1.2.2 This standard only applies to submarines with a submerged displacement of greater than 2000 tonnes.

1.3 What is Not Covered

1.3.1 This standard does not apply to unmanned submersibles, or rescue submersibles. Advice should be sought separately from DSME on the stability criteria to be adopted for submersibles/ROVs and submarines with a submerged displacement less than 2000 tonnes, or with unconventional hull geometries.

2 DOCUMENTS

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2.1 Applicable Documents

2.1.1 The following documents are called up in this document. When applying this DEF(AUST)5000 document, the user is required to use the dated version if specified, or otherwise negotiate with the sponsor a suitably dated version for each applicable document.

2.1.2 In accordance with DI(G) LOG 4–5–11 *Defence Policy on Materiel Standardisation* document selection shall be based on the following order of precedence. Noting that in situations where no other standard adequately addresses the ADO's requirements, Australian Defence Standards are to be used in preference to other standards. Government, operational and/or technical imperatives can override preference to other standards.

Documents Mandated by Federal and/or State Legislation

List of Applicable Documents	Applicability and Availability

Australian Defence Documents

List of Applicable Documents	Applicability and Availability
DEF(AUST)5000-Vol 09 Pt 11 Submarine Watertight Integrity.	This document sets the requirements for watertight integrity and recovery from flooding for RAN Submarines and is available on the defence restricted intranet at: http://defweb.cbr.defence.gov.au/navysyscom/mrs/Vol09_PDFs/Vol09_Pt11_Latestissue.pdf
DEF(AUST)5000-Vol 02 Pt 29 Margin Requirements	This document sets the requirements for management of Margins of RAN ships during design, construction and re-fit and is available on the defence restricted intranet at: http://defweb.cbr.defence.gov.au/navysyscom/mrs/Vol02_PDFs/Vol02_Pt29_Latestissue.pdf
DEF(AUST) 5000 Vol 3 Part 2 – Stability of Surface Ships and boats	Table 6-2 of Issue 2 of this document defines standard fluid densities for use in stability calculations and is available on the defence restricted intranet at: http://defweb.cbr.defence.gov.au/navysyscom/mrs/Vol03_PDFs/Vol03_Pt2_Latestissue.PDF
DEF(AUST) 5000 Vol 2 Part 18 – Technical Publication Requirements	This document sets the requirements for production of the Stability Book and is available on the defence restricted intranet at: http://defweb.cbr.defence.gov.au/navysyscom/mrs/Vol02_PDFs/Vol02_Pt18_Latestissue.pdf
DEF(AUST) 5000 Vol 2 Part 31 – Trim and Stability Handbooks	This document provides general guidance for production of the Stability Book and is available on the defence restricted intranet at: http://defweb.cbr.defence.gov.au/navysyscom/mrs/Vol02_PDFs/Vol02_Pt31_Latestissue.pdf

International Documents

List of Applicable Documents	Applicability and Availability

National Documents Implementing International Standards

List of Applicable Documents	Applicability and Availability

National Documents

List of Applicable Documents	Applicability and Availability

Commercial Documents

List of Applicable Documents	Applicability and Availability

International Military Agreements and Defence Documents Implementing International Military Agreements

List of Applicable Documents	Applicability and Availability

Other Nation's Military Documents

List of Applicable Documents	Applicability and Availability

2.2 Referenced Documents

2.2.1 The following document was used in the development of this MRS. General information and criteria from this document has been included and the authors are hereby acknowledged.

NES 189 Issue 1 Requirements and acceptance criteria for Submarine Hydromechanics, (UK Restricted)

3 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

3.1 Definitions

3.1.1 Requirement definitions used throughout DEF(AUST)5000 documents are contained in the DEF(AUST)5000–Vol 01 Pt 03—*MRS Definitions and Abbreviations.* Additional definitions not currently provided in the fore mentioned reference are listed as follows:

BG_V	Vertical separation of the centres of buoyancy and gravity of the submarine including corrections for the free surface effect of fluids
DDD	Deep Diving Depth. The maximum depth to which the submarine may intentionally be taken in peace time. Measured to the underside of keel.
FEG	Force Element Group. The group within the RAN responsible for operation of the vessel
GM_V	Transverse Metacentric Height including corrections for the free surface effect of fluids
GZ	Righting Lever
KG_v	Distance between keel and vertical centre of gravity of the submarine including corrections for the free surface effect of fluids
Mission Specific Equipment	Mission Specific Equipment is equipment or payload which may be routinely added or removed from a submarine to cater for specific missions or deployments.
OCD	Operational Concept Document. The document that details the operational requirements to be met by the submarine
SPO	Systems Program Office. The group within DMO responsible for management of the ongoing sustainment of a vessel
Standard Surfaced Condition	The standard condition is to be used for all stability assessments. The standard condition is the submarine fully equipped and stored for the start of a war patrol and trimmed to dive in standard density water (1.025 t/m^3) with all masts up and flooded if applicable. Main Ballast Tanks are to be assessed as containing any unpumpable or unblowable volumes of water. Where a submarine can deploy in alternative standard configurations (eg SSK role or SF role) the worst case shall be used for all analysis. Where compensating capacity or ready access ballast is available to allow for mission specific equipment the standard condition shall be based on the worst case combination of equipment, ballast and compensating water. Standard densities for tank contents are defined in DEF(AUST) 5000 Vol 3 Part 2 – Stability of Surface Ships and Boats (Table 6-2 of issue 2)
Standard Submerged Condition	The standard surfaced condition with all Main Ballast Tanks fully flooded.
Φ	Angle of Roll
∇_{subm}	The submerged volumetric displacement defined as the volume within the pressure hull envelope, external main ballast tanks and volume displaced by all structure, equipment and fittings external to the pressure hull and main ballast tanks (but not including free—flood spaces)
∇_{surf}	the surfaced volumetric displacement defined as the submerged displacement less the blowable/pumpable volume of main ballast tank water.

3.2 Acronyms

3.2.1 The majority of acronyms used in this document are contained in the ADFP 103—*Abbreviations and Military Symbols* or the *Macquarie Dictionary.* Additional acronyms not currently provided in the fore mentioned reference are provided as follows:

DSME	Directorate of Submarine Engineering.

3.3 Abbreviations

3.3.1 Requirement abbreviations used throughout DEF(AUST)5000 documents are contained in the DEF(AUST)5000–Vol 01 Pt 3—*MRS Definitions and Abbreviations*.

4 BACKGROUND

4.1 Significance to RAN

4.1.1 This MRS defines the minimum stability, reserves of buoyancy and freeboard required to maintain safety of the submarine and its crew**.**

4.1.2 Submarines will be subject to a number of hazards or operations with the potential for capsizing the submarine or causing excessive rolling motion. The stability criteria take into account the following:

4.1.2.1 The effects of wind and waves in beam seas, when surfaced.

4.1.2.2 Normal and emergency surfacing.

4.1.2.3 High speed manoeuvres when submerged.

4.1.2.4 Damage to main ballast tanks.

4.1.2.5 Compartment flooding

4.1.2.6 Docking.

4.1.2.7 Special Operations.

4.1.3 The stability criteria are based on examination of the values of BG_v, metacentric height, GM_v, and righting lever, GZ, achieved in submerged, surfaced and damaged conditions. The aims of the criteria are:
a. To provide sufficient stability to prevent capsize induced by environmental hazards which the submarine might encounter during its life.
b. To limit submarine motions to reasonable levels during normal operational evolutions.
c. To provide sufficient reserves of stability to enable the submarine to recover safely from flooding accidents and collision damage.

4.1.4 The MRS defines the weight margins to be provided in the initial design to provide for future upgrades and capability enhancements over the life of the submarine.

4.1.5 Alternative criteria may be proposed for use on any new vessel. Any such proposal shall be accompanied by a full risk assessment and a justification for the acceptability of the proposal. Acceptance of an alternative set of criteria shall be at the Commonwealth's discretion.

4.2 Consequences of Poor Performance or Hazard

4.2.1 Failure to achieve required stability levels represents a hazard to crews due to the impact of ship motions under a seaway while surfaced. Poor stability alongside can also lead to excessive heeling of the submarine during maintenance or related activities.

4.2.2 Failure to achieve required freeboards presents a flooding hazard when submarines are required to operate on the surface with a hatch open, or while moored alongside.

4.2.3 Failure to achieve the design weight margins for future growth will adversely impact on the ability to introduce new capabilities into the submarine through its life.

5 FUNCTIONAL AND PERFORMANCE REQUIREMENTS

5.1 Intact Surfaced Stability

5.1.1 Conditions to be assessed.

5.1.1.1 Surfaced stability is to be assessed for the submarine in the standard surfaced condition. The free surface of all partially filled tanks is to be included in calculations of BG_V and GM_V.

5.1.1.2 Where the submarine can operate in several alternative configurations the stability assessment is to be conducted against each of these conditions.

5.1.2 Requirements to be met.

5.1.2.1 The criteria for intact surfaced stability are based on consideration of the shape of the GZ curve, and on the ability of the submarine to withstand beam winds without adopting large angles of heel.

5.1.2.2 The shape of the GZ curve for a cylindrical submarine on the surface differs from those of most surface vessels in that GZ increases approximately in proportion to sin Φ. This results in a healthy reserve of stability at large heel angles and ensures that the GZ curve is not depressed at small angles. The criteria are as follows:

5.1.2.2.1 GMv is to be not less than 0.30 metres.

5.1.2.2.2 GZ at 30° heel is to be not less than 0.15 metres.

5.1.2.2.3 The area under the GZ curve up to 30° heel is to be not less than 2.4 metre degrees.

5.1.2.2.4 The area under the GZ curve up to 40° heel is to be not less than 4.0 metre degrees.

5.1.2.2.5 The angle of maximum GZ is to be not less than 50 degrees.

5.1.2.3 Very high values of GM_v may result in high roll accelerations when surfaced and this aspect is to be investigated further if GM_v is predicted to be in excess of 0.6 metres.

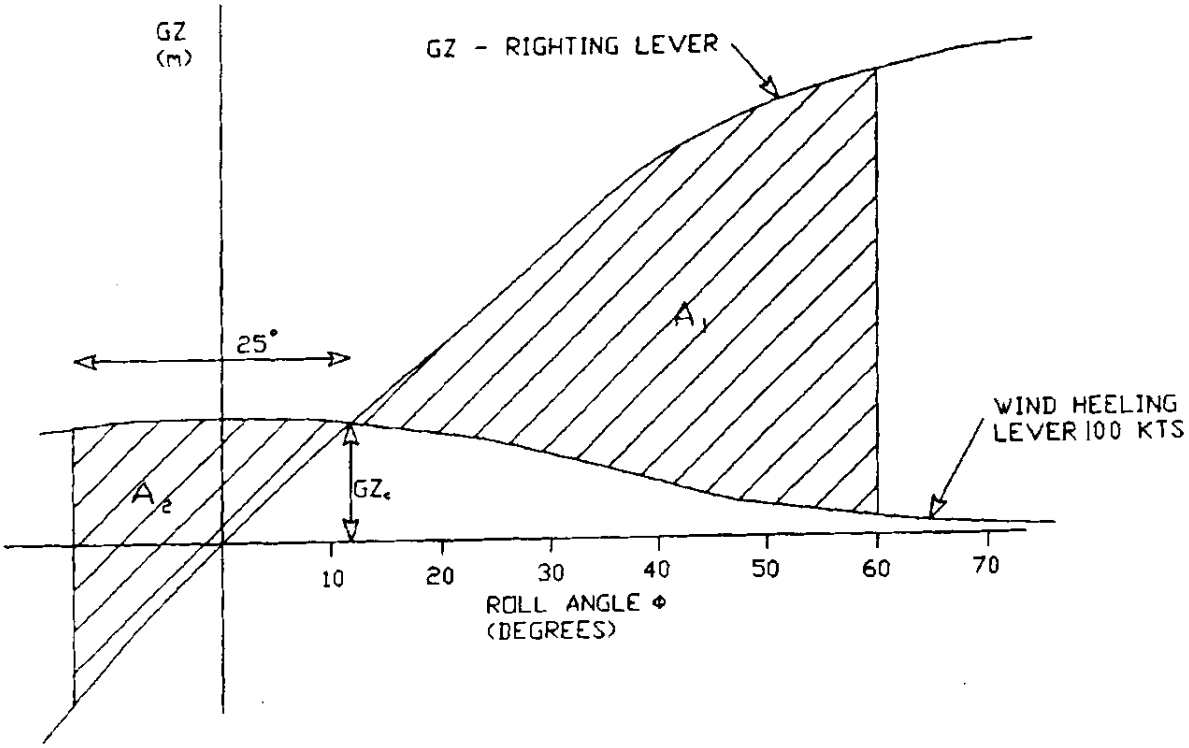

Figure 1 Wind Heeling Lever and GZ Curve Definitions

5.1.2.4 Low surfaced freeboard and lack of superstructure make submarines less susceptible to heeling due to beam winds than surface warships. Therefore for all seagoing surfaced conditions the submarine's stability is to be assessed against a 100 knot wind, the maximum expected to be encountered by ocean going vessels. The method of producing the curve of wind heeling lever is given in DEF(AUST) 5000 Vol 3 Part 2 – Stability of Surface Ships and boats. The wind heeling criteria are based on a comparison of the intact righting lever GZ and wind heeling lever as shown in Figure 1. The criteria are:

5.1.2.4.1 The angle of heel due to a 100 knot wind is not to exceed 15°.

5.1.2.4.2 The GZ at the steady heel angle (GZ_c) is not to exceed 60% of the GZ at 50°.

5.1.2.4.3 The area ratio A_1/A_2 is to be not less than 1.4. The limit of range is to be taken as 60°.

5.1.2.5 During the design the impact on surfaced stability of changes due to fuel or payload usage and subsequent changes to compensating water levels is to be considered. The following GM_v criterion is to be met:

5.1.2.5.1 GM_v is not to be less than 0.27 metres in the worst standard combination of fuel & payload usage and compensating water.

5.1.2.6 GM may be adversely impacted by unusual or non-standard loading states. To address this situation, an in-service Limiting GM_v of not less than 0.25 metres shall apply, regardless of loading or operating condition.

5.1.2.7 During maintenance periods alongside the impact of adding or removing equipment can have a major impact on the submarine's stability. It is necessary for the submarine to have sufficient stability alongside in harbour to avoid excessive heel due to wind or loading/unloading of fuel or stores. If necessary an ad-hoc inclining is to be undertaken to determine the submarine's GM. After taking into account any equipment added or removed from the submarine, the following criteria are to be met:

5.1.2.7.1 GMv is to be not less than 0.15 metres.

5.1.2.7.2 Heel under a 30 knot wind is not to exceed 7°.

5.1.2.8 All configuration changes to the submarine through its life are to be controlled to ensure that the stability is not compromised through the uncontrolled addition of equipment.

5.2 Intact Submerged Stability

5.2.1 Conditions to be assessed.

5.2.1.1 Submerged stability is to be assessed for the submarine in the standard submerged condition. The free surface of all partially filled tanks is to be included in calculations of BG_V and GM_V.

5.2.1.2 Where the submarine can operate in several alternative configurations the stability assessment is to be conducted against each of these conditions.

5.2.2 Requirements to be met.

5.2.2.1 The measure of intact submarine stability when submerged is BG_v. The tendency of the submarine to roll or heel due to underwater manoeuvres, operations under waves or transverse static imbalance will reduce with increased BG_v. The criterion to be met is:

5.2.2.1.1 BG_v is to be not less than 0.30 metres.

5.3 Stability during Normal Surfacing or Diving Evolutions

5.3.1 Conditions to be assessed.

5.3.1.1 During normal surfacing (non emergency) and diving the value of GM_v.is to be assessed using the following quasi-static assumptions:

5.3.1.1.1 Buoyancy equals weight at all times.

5.3.1.1.2 The submarine is at level trim.

5.3.1.1.3 The water in the casing and bridge fin has drained down to the surface waterline.

5.3.1.1.4 The main ballast tanks are emptied such that at any instant each contains the same percentage of its total capacity.

5.3.1.1.5 The free surface effect of main ballast tanks is taken into account.

5.3.1.2 Note: The above assumptions achieve equilibrium of static forces but not necessarily equilibrium of trimming moments.

5.3.2 Requirements to be met.

5.3.2.1 At any instant during transition GM_v is to be not less than 0.05 metres

5.4 Stability during Emergency Surfacing

5.4.1 Conditions to be assessed.

5.4.1.1 Emergency surfacing from deep having blown the main ballast tanks with HP air will produce a less stable condition than normal surfacing since free flood water in the bridge fin and casing will drain down slower than the rate of submarine emergence. Stability during emergency surfacing is an important consideration in sizing free flood space drainage holes. Calculation of surfacing stability is to be performed based on the following simplifying assumptions:

5.4.1.1.1 That the submarine surfaces at a level trim.

5.4.1.1.2 That all of the MBTs have been fully blown.

5.4.1.1.3 A rise rate of 4 metres/second, or when it is known, the maximum rise rate of the centre of gravity obtained from emergency recovery simulations.

5.4.1.1.4 The effects of water draining down from the bridge fin and casing are to be taken into account as follows:

5.4.1.1.4.1 Water above the surface waterline is to be treated as an added mass, allowing for permeability.

5.4.1.1.4.2 Free surface effects of water in the casing and bridge fin are to be included, allowing for the effect of longitudinal subdivision but ignoring the presence of internal equipment.

5.4.1.1.5 Free surface effects of the residue in the main ballast tanks are to be taken into account.

5.4.1.2 Ideally, the above assessment is to utilise a dynamic model of casing/bridge fin draining performance, should such a validated model be available. Alternatively, the stability of the submarine on the surface with the casing and bridge fin fully flooded can be calculated, together with a number of cases of partial drainage, eg bridge fin empty, casing full.

5.4.2 Requirements to be met.

5.4.2.1 Preferably the drainage arrangements are to be sized such that GM_v remains positive throughout emergency surfacing. However, other design requirements and constraints may prevent achievement of this criterion. In such cases GM_v is only to remain negative for a short period and it will be necessary to examine the dynamic rolling performance of the submarine under such conditions. Under these circumstances the submarine is not to roll to an angle greater than 20°.

5.5 Reserve of Buoyancy

5.5.1 Conditions to be assessed.

5.5.1.1 The reserve of buoyancy is to be calculated for the submarine in its standard surfaced condition.

5.5.1.2 Where the submarine can operate in several alternative standard configurations the reserve of buoyancy assessment is to be conducted against the least favourable of these conditions.

5.5.2 Requirements to be met.

5.5.2.1 The main factor affecting reserve of buoyancy is the capacity of the main ballast tanks, which is directly related to the reserve of buoyancy when operating on the surface as follows:

Reserve of buoyancy = $(\nabla_{subm} - \nabla_{surf})/\nabla_{surf}$

5.5.2.2 The reserve of buoyancy is based on the surface displacement related to the blowable (external) main ballast tank volume.

5.5.2.3 The reserve of buoyancy and its distribution affect many parameters in the surface condition, such as draught, freeboard, trim, propulsor/rudder immersion, vulnerability to damage and internal flooding, stability and seakeeping. However, these design parameters are not solely dependent on the reserve of buoyancy.

5.5.2.4 Also in the submerged condition the reserve of buoyancy influences the overall size and form of the submarine and hence its power/speed characteristics and detectabilty.

5.5.2.5 The required volumes of ballast tanks derived from the reserve of buoyancy are the net usable volume, ie the volume of water which can be expelled from the tanks. In order to determine the required gross capacity of the tanks (to the outside of plating it is necessary to make allowance for:

5.5.2.5.1 growth of equipment within the tank;

5.5.2.5.2 unblowable/pumpable residue;

5.5.2.5.3 tank structure;

5.5.2.5.4 stowed solid ballast;

5.5.2.5.5 air, bottles;

5.5.2.5.6 other equipment within the tanks.

5.5.2.6 Unless specified otherwise within the OCD, the reserve of buoyancy is to be not less than 10%

5.6 Freeboard

5.6.1 Conditions to be assessed.

5.6.1.1 The freeboard to the casing and each hatch is to be calculated for the submarine in its standard surfaced condition.

5.6.1.2 Where the submarine can operate in several alternative standard configurations the freeboard assessment is to be conducted against the least favourable of these conditions.

5.6.2 Requirements to be met.

5.6.2.1 The ability of the crew to operate on the casing depends on the freeboard, submarine length, hull lines, speed, heading and sea state. The freeboard requirements will be affected by the operational requirements for access to the casing. The design criteria is that the casing freeboard amidships is not to be less than 2.25 m.

5.6.2.2 A further requirement is that the freeboard to the upper hatch of the conning tower is not to be less than 4 metres.

5.6.2.3 For other hatches which may be opened at sea the freeboard is to be not less than 1 metre in any surface trim condition. Hatches with less freeboard are not to be opened at sea without a full operational risk assessment being conducted.

5.7 Weight & Compensation Margins

5.7.1 Conditions to be assessed.

5.7.1.1 The submarine is to be assessed to ensure it can maintain neutral buoyancy and level trim across the full range of operating conditions. This is to include:

5.7.1.1.1 Changes in seawater density as required by the OCD

5.7.1.1.2 Changes in displacement due to compression of the hull and anechoics etc over the full diving range to DDD

5.7.1.1.3 Consumption of consumables such as fuel, lube oil, stores, potable water, compressed air etc

5.7.1.1.4 Discharge of payload eg weapons, decoys, bathythermographs etc

5.7.1.1.5 Flooding or draining of diver lockouts, dry deck shelters etc

5.7.1.1.6 Flooding or draining of exhaust or induction masts

5.7.1.1.7 Accumulation or discharge of waste eg bilge water, sewage, slop drain tanks etc

5.7.1.1.8 Raising or lowering of masts and periscopes

5.7.1.1.9 Variations in diesel fuel oil density between 0.82 t/m^3 and 0.86 t/m^3.

5.7.1.1.10 Variations in crew numbers and movement of crew

5.7.1.1.11 Allowances as defined in the OCD for fitting/removal of mission specific equipment

5.7.1.1.12 Allowances for change in battery weight

5.7.1.2 The calculation of the weapon compensation, trim and compensation systems' ability to cater to changes in the submarines condition shall be based only on the useable volumes of the weapon compensation, trim and compensating tanks.

5.7.1.3 The submarine is to be designed with a margin on fixed ballast to allow for neutral buoyancy to be maintained through the life of the submarine. The initial design is also to include allowances for weight variances to occur during design and construction.

5.7.2 Requirements to be met.

5.7.2.1 The submarine shall be provided with sea water compensation to be able to achieve neutral buoyancy in a level trim across the full range of operating conditions defined for the submarine. In addition to the initial design compensation an allowance of 10% of the variable payload weight (including SF forces, UUVs, ROVs, decoys, weapons etc) shall be provided to cater for future upgrades of capability. A margin of 15 tonne meters and 1.5 tonnes shall be available between the compensation capacity required and that provide to allow for discrepancies in the allocation of fixed ballast in the submarine.

5.7.2.2 The addition or removal of mission specific equipment may be compensated for by either the provision of additional compensating water capacity and/or by the provision of readily accessible fixed ballast. Unless otherwise noted other compensation shall be by the provision of compensating water capacity.

5.7.2.3 The submarine shall be designed with a margin on fixed ballast to allow for the future addition of equipment to the submarine as well as the accumulation of weight due to paint build-up etc. A margin of 2.5% of submerged displacement is to be provided. This shall consist of 1% for future projects, and 1.5% for unattributable growth and minor modifications. The centre of gravity of the margin is to be located amidships on the vertical and transverse axis of the submarine. This margin is to be available in its entirety upon initial delivery of the submarine.

5.7.2.4 All configuration changes to the submarine through its life are to be controlled to ensure that the ability to maintain neutral buoyancy is not compromised through the uncontrolled conversion of

compensating tank capacity in lieu of ballast adjustments to cover the fitting of additional equipment through the life of the submarine.

5.7.2.5 The submarine is to be provided with an initial margin on fixed ballast of 1% of submerged displacement for the implementation of design changes during build. This margin is to cater for changes introduced by the Commonwealth during the design and build of the submarine, and shall only be utilised with the agreement of the Commonwealth. This margin is not intended to cover variances between design calculations and the as built state of the submarine. On delivery any unused margin shall become available for future growth.

5.7.2.6 The submarine shall be designed with a margin to allow for variances between initial design calculations and the as built state of the submarine. The magnitude of the allowance is to be determined by the designer/builder. On delivery any unused margin shall become available for future growth.

5.7.2.7 The submarine shall be designed with a fixed ballast margin of +/-1% of battery weight to cater for variations in dry weight between individual ship sets of battery cells. The centre of gravity of this margin shall be located as close to the centre of gravity of the battery as possible. This margin is to be retained through the life of the submarine. An allowance shall be made in the compensating water capacity to cater for changes in battery electrolyte level and density.

5.8 Damaged Conditions

5.8.1 Conditions to be assessed.

5.8.1.1 The surfaced damaged stability of the submarine and freeboard to each hatch is to be assessed by producing a GZ curve for the standard surfaced condition with each combination of two adjacent Main Ballast Tanks damaged. The damaged ballast tanks are to be assumed as free flooding for the damaged stability assessment. The curve is to be assessed together with a 60 knot beam wind.

5.8.1.2 The change in KG_v of the submarine is to be assessed for the standard surfaced condition plus water in bilges following the worst case flooding scenario defined in DEF(AUST)5000-Vol 09 Pt 11 Submarine Watertight Integrity with all main ballast tanks assumed to be half blown.

5.8.1.3 The surfaced damaged stability of the submarine is to be assessed by producing a GZ curve for the standard surfaced condition plus water in bilges following the worst case flooding scenario defined in DEF(AUST)5000-Vol 09 Pt 11 Submarine Watertight Integrity.. The curve is to be assessed together with a 60 knot beam wind.

5.8.1.4 Reserve of buoyancy is to be calculated for the submarine in the standard surfaced condition following the loss of the largest main ballast tank.

5.8.1.5 Reserve of buoyancy is to be calculated for the submarine in the standard submerged condition following the worst case flooding scenario defined in DEF(AUST)5000-Vol 09 Pt 11 Submarine Watertight Integrity. The reserve of buoyancy is to assume recovery to the surface has been conducted only by propulsion and blowing of main ballast tanks, ie full pumping of ballast tanks has not taken place.

5.8.2 Requirements to be met.

5.8.2.1 With any two adjacent ballast tanks damaged, the following criteria are to be met (see Figure 2):

5.8.2.1.1 The steady heel angle is to be less than 20°.

5.8.2.1.2 The ratio A_1/A_2 is to be greater than 1.4.

5.8.2.1.3 Freeboard to any hatch is to be not less than 0.25m

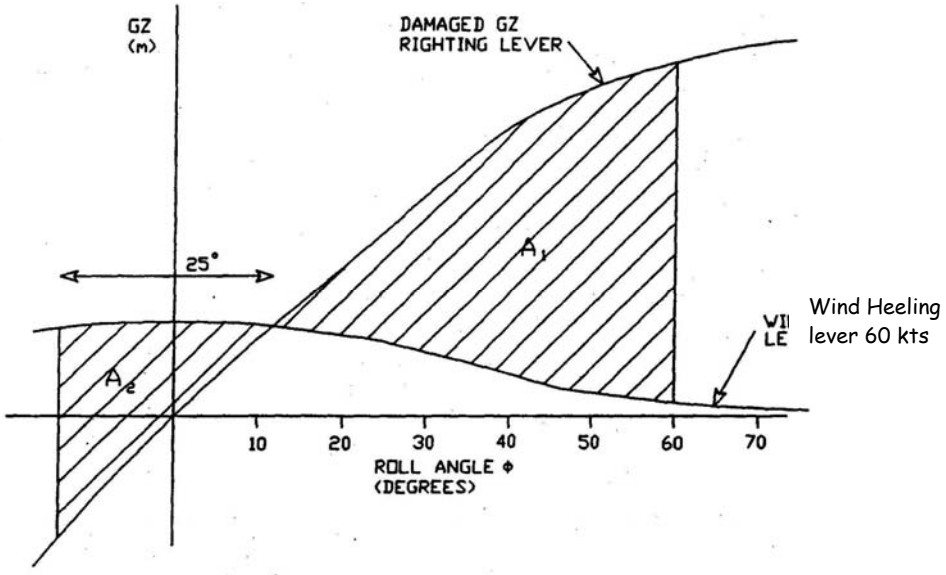

Figure 2 Damaged GZ Curve Definitions

5.8.2.2 The rise in KG_v following flooding of bilges and half blowing of all main ballast tanks should be no more than 0.05m

5.8.2.3 Following flooding of bilges the following criteria are to be met (see Figure 2):

5.8.2.3.1 The steady heel angle is to be less than 20°.

5.8.2.3.2 The ratio A_1/A_2 is to be greater than 1.4.

5.8.2.4 The minimum reserve of buoyancy following the loss of the largest individual main ballast tank is to be not less than 80% of the intact reserve of buoyancy.

5.8.2.5 The minimum reserve of buoyancy following flooding of bilges and surfacing shall be no less than 3%.

5.9 Stability While Docking

5.9.1 Conditions to be assessed.

5.9.1.1 The stability while docking is to be assessed. The standard surfaced condition less weapons is to be used as the initial basis for the calculations.

5.9.2 Requirements to be met.

5.9.2.1 GM_v must remain positive during docking until external support is provided. If it is necessary to impose any restrictions or variations to the submarine's condition for docking to achieve this criterion, these restrictions must be clearly identified.

6 DESIGN AND PRODUCT CONSTRAINTS

6.1 Specific Design/Engineering Constraints

6.1.1 There are no specific design/engineering constraints.

6.2 Navy Practice Constraints

6.2.1 There are no Navy Practice constraints.

6.3 Navy Personnel Constraints

6.3.1 There are no Navy Personnel constraints.

6.4 Navy Logistic Constraints

6.4.1 There are no Navy Logistic constraints.

6.5 Australian Industry Constraints

6.5.1 There are no Australian Industry constraints.

6.6 Legislative Constraints

6.6.1 There are no Legislative constraints.

6.7 Interoperability Constraints

6.7.1 There are no interoperability constraints.

6.8 Commonality Constraints

6.8.1 There are no commonality constraints.

6.9 Regulatory Constraints

6.9.1 There are no regulatory constraints.

7 DELIVERABLES (DIDs)

7.1 Design Documentation

7.1.1 **Hydrostatic Tables.** Hydrostatic tables for the submarine shall be provided during the design phase for the submarine. Hydrostatic tables are to be updated through the life of the submarine to reflect significant changes to the buoyancy of the submarine.

7.1.2 **Tank Capacity Tables.** Tank capacity tables are to be provided for all tanks on the submarine. Initially these shall be based on theoretical capacities, however the tables shall be updated to reflect measured data when this becomes available.

7.1.3 **Trim Polygon.** A trim polygon report for the submarine shall be developed during the design of the submarine. The trim polygon report shall identify all assumptions used in developing the trim polygon. The report shall contain a consumption pattern for the usage of consumables against each mission profile identified in the OCD. The trim polygon report shall be updated through the life of the submarine to reflect the actual condition of the submarine and any changing mission profiles. The trim polygon report shall also identify the impact of the use of consumables on the GM_V of the submarine.

7.1.4 **Stability Condition Assessments.** Where multiple standard configurations can apply to a submarine, a report shall be developed to demonstrate which the worst condition is.

7.2 Test Regime

7.2.1 **Submerged Inclining.** A procedure for the conduct and analysis of submerged inclinings shall be developed by the designer for approval by the DAR. A submerged inclining is to be undertaken as part of the licensing trials upon initial delivery of the submarine and following each full cycle docking, or any availability where major configuration changes have been implemented.

7.2.2 The responsibilities and timeframe for the submerged inclining are to be defined in the submarines licensing plan. The submerged inclining will require input from the builder, designer and ship's staff. Close co-operation will be required between these parties to enable timely completion and analysis of the trial.

7.2.3 A test report outlining the results of the inclining is to be forwarded to DSME upon completion of the trial. The trial will be used to validate the surfaced and submerged stability of the submarine and advise of any required ballast adjustments.

7.2.4 The results of the trial are to be used to update the stability handbook for that vessel.

7.2.5 **Surfaced Inclining.** A procedure for the conduct and analysis of surfaced inclinings shall be developed by the designer for approval by the DAR Where a submerged inclining cannot be conducted prior to the submarine proceeding to sea for the conduct of sea trials, a surfaced inclining is to be conducted.

7.2.6 The responsibilities and timeframe for the surfaced inclining are to be defined in the submarines licensing plan. The surfaced inclining will require input from the builder, designer and ship's staff. Close co-operation will be required between these parties to enable timely completion and analysis of the trial.

7.2.7 A test report outlining the results of the inclining is to be forwarded to DSME upon completion of the trial. The trial will be used to provide a preliminary validation of the surfaced and submerged stability of the submarine and advise of any required ballast adjustments.

7.2.8 The results of the trial are to be used to provide a preliminary update of the stability handbook for that vessel.

7.3 Stability Handbook

7.3.1 A stability handbook shall be produced for each submarine iaw DEF(AUST) 5000 Vol 2 Pt 18 Technical Publication Requirements. General guidance is provided by DEF(AUST) 5000 Vol 2 Pt 31 Trim and Stability Handbooks. The stability handbook shall as a minimum incorporate the following:

7.3.1.1 A stability statement identifying the surfaced and submerged GM and the load conditions for the submarine in its standard condition.

7.3.1.2 A statement identifying the draughts to be met in water of a density of 1.025 tonnes/m^3 in order to achieve neutral buoyancy when dived.

7.3.1.3 Safety recommendations for operating the submarine on the surface in rough weather.

7.3.1.4 GZ curves and guidance notes on the impact on draughts and stability of each of the damage conditions noted in section 5.8.

7.3.1.5 Guidance notes on the impact on stability of diving and surfacing as noted in section 5.3 & 5.4

7.3.1.6 Guidance notes on stability when docking or alongside.

7.3.1.7 Guidance notes on conducting an ad-hoc inclining using weapon racks or movement of compensating water from one side of the submarine to the other.

7.3.1.8 Draught Mark Drawings and guidance notes on interpolating draught mark readings to allow for trim and heel

7.3.1.9 Hydrostatic tables or charts and guidance notes on the use of those tables or charts

7.3.1.10 Tank capacity curves or tables and guidance notes on the use of those tables or curves

7.3.1.11 Docking plans and data

7.3.1.12 Trim polygon report

7.3.1.13 Trim crib to provide a ready reckoner to estimate requirements for compensation water movements to cater for changes in payload, fuel, or flooding of drydeck shelters or diver lockout compartments, raising or lowering of masts, or changes of seawater density.

7.3.1.14 Tonnage Certificates

7.4 Weight Management Plan - Build and Design

7.4.1 A weight management plan shall be developed to manage changes to weight estimates and measurements through the design and build of the submarine. This weight management plan is the responsibility of the designer/builder. The plan is to be developed in accordance with the requirements of DEF(AUST)5000-Vol 02 Pt 29 Margin Requirements

7.4.2 The management plan shall ensure that all weight variations that accumulate during the design and build of the submarine are reflected in the stability, ballasting and compensation calculations for the submarine.

7.4.3 No consumption of the weight margins for future growth or for Commonwealth introduced changes shall be made without the concurrence of the Commonwealth.

7.4.4 Reports shall be provided to the Commonwealth at a periodicity to be agreed.

7.5 Weight Management Plan - life

7.5.1 A weight management plan shall be developed to manage changes to weight through the life of the submarine. This management plan is the responsibility of the SPO. The plan is to be developed in accordance with the requirements of DEF(AUST)5000-Vol 02 Pt 29 Margin Requirements

7.5.2 This weight management plan shall capture all weight changes introduced through changes to configuration or stores. Close liaison will be required between the designer, SPO and FEG to ensure that all changes are captured and appropriately assessed.

7.5.3 The management plan shall provide for the assessment of proposed configuration changes to ensure that design proposals can be practically implemented. The assessment of the potential weight and stability impact of a proposed change is to be considered as part of the overall costing of any proposed change.