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# General

## Rules application

### 1.1 General

The Rules apply in general to ships of normal form, proportions and speed. Although the Rules are, in general, for steel ships of all welded construction, other materials for use in the construction will be considered.

### 1.2 Exceptions

Ships of unusual form, proportions or speed, or for special or restricted service, or purposes not covered specifically by the Rules, will receive individual consideration based on the general standards of the Rules.

### 1.3 Loading

The Rules are framed on the understanding that ships will be properly handled. The Committee may require additional strengthening to be fitted in any ship which, in their opinion, would otherwise be subjected to severe stresses due to particular features of the design, or where it is desired to make provision for exceptional load or ballast conditions.

### 1.4 Advisory services

The Rules do not cover certain technical characteristics, such as stability except as mentioned in Pt 1, Ch 2,1.1.8, trim, vibration (other than local panel) and docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

## Direct calculations

### 2.1 General

Direct calculations may be specifically required by the Rules or may be required for ships having novel design features, as defined in 1.2, or may be submitted in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of designers and make recommendations in regard to suitability of any required model tests.

### 2.1.2 Where model testing is undertaken to complement direct calculations the following details would normally be required to be submitted: schedule of tests, details of test equipment, input data, analysis and calibration procedure together with tabulated and plotted output.
2.2 Submission of direct calculations

2.2.1 In cases where direct calculations have been carried out, the following supporting information should be submitted as applicable:

(a) Reference to the direct calculation procedure and technical program used.
(b) A description of the structural modelling.
(c) A summary of analysis parameters including properties and boundary conditions.
(d) Details of the loading conditions and the means of applying loads.
(e) A comprehensive summary of calculation results. Sample calculations should be submitted where appropriate.

2.2.2 In general, submission of large volumes of input and output data associated with such programs as finite element analysis will not be necessary.

2.2.3 The responsibility for error free specification and input of program data and the subsequent correct transposition of output rests with the Designer.

3.1 Alternative arrangements and calculation methods

3.1.1 In addition to cases where direct calculations are specifically required by the Rules, LR will consider alternative scantlings which have been derived by direct calculations in lieu of specific Rule requirements. All direct calculations are to be submitted for examination.

3.1.2 Where calculation procedures are employed, supporting documentation is to be submitted for appraisal and this is to include details of the following:

- calculation methods;
- assumptions and references;
- loading;
- structural modelling;
- design criteria and their derivation, e.g. permissible stresses, factors of safety against plate panel instability, etc.

3.1.3 LR will be ready to consider the use of Builder’s programs for direct calculations in the following cases:

(a) Where it can be established that the program has previously been satisfactorily used to perform a direct calculation similar to that now submitted.
(b) Where sufficient information and evidence of satisfactory performance is submitted to substantiate the validity of the computation performed by the program.

3.1.4 Alternative arrangements or fittings which are considered to be equivalent to the Rule requirements will be accepted, in accordance with Pt 1, Ch 2.3.2.

3.1.5 Where no special reference is made in this Part to specific requirements, the construction is to be efficient for the intended purpose and to conform to good practice.

3.1.6 Where items are of a novel or unconventional design or manufacture, it is the responsibility of the designer to demonstrate their suitability and equivalence to the Rule requirements.

4.1 Submission of plans and data

4.1.1 Plans and data required to be submitted are indicated in Pt 6, Ch 1.2.2.

4.1.2 Plans are generally to be submitted in triplicate, but one copy only is necessary for supporting documents and calculations.

4.1.3 Plans are to contain all necessary information to fully define the structure, including construction details, equipment and systems as appropriate.

4.2 Standard designs

4.2.1 Where a ship is a standard design produced in several versions, the plans and data are to clearly define the differences between each version.

4.2.2 Where the ship is a Builder’s standard design to be built from previously approved plans and data, a schedule of applicable plans, etc., is to accompany the Request for Survey. Plans of any proposed modifications and changes to the previously approved plans are to be submitted for approval prior to the commencement of any work.

4.2.3 Plan approval of standard designs is only valid so long as no applicable Rule changes take place. When the Rules are amended, the plans for standard types are to be submitted for re-approval.

4.3 Plans and data to be supplied to the ship

4.3.1 A copy of the final Loading Manual or stability information book, (where applicable) when approved, and details of the loadings applicable to approved decks, are to be placed on board the ship.

4.3.2 Copies of all main scantling plans are to be readily available on board ship for the purposes of repairs, identifying materials and condition assessment.

4.3.3 Details of any corrosion control system fitted are to be placed on board the ship.
4.3.4 Where in-water surveys are required, approved plans and information covering the items detailed in Pt 6, Ch 1.2.2 are to be placed on board.

Section 5 Definitions

5.1 General

5.1.1 The following definitions apply except where they are inappropriate or where specifically defined otherwise.

5.2 Principal particulars

5.2.1 Length waterline, \( L_{WL} \), is the distance, in metres, measured on a waterline at the design draught from the fore side of the stem to the after side of the stern or transom as shown in Fig. 1.5.1.

5.2.2 Rule length, \( L_R \), is the distance, in metres, on a waterline at the design draught from the forward side of the stem to the after side of the rudder post or to the centre of the rudder stock if there is no rudder post. \( L_R \) is to be not less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on a waterline at the design draught. In vessels without rudders, the Rule length, \( L_R \), is to be taken as 97 per cent of the extreme length on a waterline at the design draught. In vessels with unusual stem or stern arrangements, the Rule length will be specially considered.

5.2.3 All references to longitudinal locations in the Rules are to be taken as forward of the aft end of \( L_R \) unless otherwise stated, e.g., 0.75\( L_R \) is 75 per cent of \( L_R \) forward of the aft end of \( L_R \).

5.2.4 Length between perpendiculars, \( L_{PP} \), is the distance, in metres, on the waterline at the design draught from the forward to the after perpendicular.

5.2.5 Forward perpendicular, F.P., is the perpendicular at the intersection of the waterline at the design draught with the fore side of the stem.

5.2.6 After perpendicular, A.P., is the perpendicular at the intersection of the waterline at the design draught with the after side of the rudder post or to the centre of the rudder stock for vessels without a rudder post or to the intersection with the transom profile on the centreline.

5.2.7 Length overall, \( L_{OA} \), is the distance, in metres, measured parallel to the deep load waterline from the fore side of the stem to the after side of the stern or transom, excluding rubbing strakes and other projections as shown in Fig. 1.5.1.

5.2.8 Waterline breadth, \( B_{WL} \), is generally the greatest moulded breadth, in metres, measured at the design draught, as shown in Fig. 1.5.2.

5.2.9 Breadth, \( B \), is generally the greatest moulded breadth, in metres, throughout the depth of the ship or as defined in appropriate Chapters. For vessels of unusual cross section the breadth will be specially considered.

5.2.10 Depth, \( D \), is measured, in metres, at amidships, from top of keel plate to the moulded deck line at side on the uppermost continuous deck, or as defined in appropriate Chapters or standards. When a rounded gunwale is arranged, the depth \( D \) is to be measured to the continuation of the moulded deck line at side.

5.2.11 Draught, \( T \), is the design draught, in metres, measured from moulded baseline.

5.2.12 Block coefficient, \( C_b \), is the block coefficient at draught \( T \) corresponding to a waterline at the design draught, based on Rule length \( L_R \) and breadth \( B_{WL} \), as follows:

\[
C_b = \frac{\text{moulded displacement \( m^3 \) at draught \( T \)}}{L_R \cdot B_{WL} \cdot T}
\]
5.2.13 Design draught may be determined from the waterline when the vessel is in a deep condition plus any specified margins. Where specified a higher waterline may be used.

5.2.14 Deep draught is measured at a displacement such that the ship is in all respects complete, and is fully loaded with full complement, stores, fuel, water and payload.

5.2.15 Payload is the equipment and stores that are carried by the vessel for the purposes of fulfilling its operational requirements.

5.3 Margins

5.3.1 Design margin is an allowance for uncertainties used in the estimation of weight for design purposes.

5.3.2 Build margin is an allowance for unforeseen changes that may need to be made by the builder of the vessel.

5.3.3 Admiralty board margin is an allowance to cater for modifications made by the Owner to the vessel or equipment during the design and build stages.

5.3.4 Growth margin is an allowance for future controlled and uncontrolled weight growth during the life of the ship.

5.3.5 In the absence of any specific requirements, the sum of the margins is to be taken as 15 per cent of the displacement at the deep draught.

5.4 Decks

5.4.1 Strength deck is normally the uppermost continuous deck. Other decks may be considered as the strength deck provided that such decks are structurally effective. Where the upper deck is stepped, as in the case of vessels with a quarter deck, the strength deck is stepped, see Pt 6, Ch 4.1.

5.4.2 The weather deck is generally the lowest continuous deck exposed to sea and weather loads. It is to be defined at the early stages of design in conjunction with LR and the Builder.

5.4.3 Other decks that are exposed to sea loads are to be assessed in accordance with the requirements for weather decks.

5.4.4 The damage control deck is the lowest deck on which continuous fore and aft access is provided to aid communications and recovery following damage. It is normally above the lowest vertical limit of watertight integrity the exact location being determined by the relevant sub-division and watertight integrity standard.

5.5 Co-ordinate system

5.5.1 Unless otherwise stated, the co-ordinate system is as shown in Fig. 1.5.3, that is, a right-hand co-ordinate system with the X axis positive forward, the Y axis positive to port and the Z axis positive upwards. Angular motions are considered positive in a clockwise direction about the X, Y or Z axes.

5.6 Superstructure

5.6.1 For the purposes of strength assessment a superstructure is defined as a decked structure on the strength deck, extending from side to side of the vessel, or with its side plating being less than four per cent of the breadth, B, inboard of the shell plating.

5.7 Deckhouse

5.7.1 A deckhouse is in general defined as a decked structure on or above the strength deck with its side plating being four per cent or more of the breadth, B, inboard of the shell plating.

5.8 Weathertight

5.8.1 A boundary or closing appliance is considered weathertight if it is capable of preventing the passage of water into the ship in any sea conditions.

5.9 Watertight

5.9.1 A boundary or closing appliance is considered watertight if it is capable of preventing the passage of water in either direction under a head of water for which the surrounding structure is designed.

5.10 Terminology

5.10.1 Fig. 1.5.4 shows the general terminology adopted for structural items for a transversely and longitudinally framed ship.
5.10.2 Fig. 1.5.5 shows the general configuration of Naval ships of the NS1 and NS2 types. Various features are pointed out and are dealt with by the relevant Section of the Rules.

5.11 Extent of watertight subdivision

5.11.1 The minimum extent of watertight subdivision (internal), and integrity (internal and external), is to be in accordance with the specified subdivision and stability standard(s).

5.11.2 The minimum extent of watertight subdivision may be defined by a combination of decks, side shell and bulkheads or by a single deck.

5.11.3 Watertight and watertight fittings and closing appliances are to be fitted in accordance with the requirements of the boundary on which they are placed.

5.11.4 For the calculation of watertight structural scantlings the pressure head is to be taken from the vertical limits of weathertightness determined by either intact or damage stability considerations in accordance with the specified subdivision and stability standard(s), see Ch 2,1.3 and Pt 5, Ch 3,5.5.

5.12 Critical compartments

5.12.1 A critical compartment is one which, at battle stations, contains equipment or personnel without whom functions critical to combat survivability would be lost. These functions include the ability to fight, manoeuvre or communicate.

5.12.2 Critical compartments are typically the chart room, operations room, conning position, ship’s control room and main communications office. Other compartments may be considered critical depending on ship’s layout and design. The need for protecting critical compartments can be reduced by avoiding single point failure nodes and by concentrating and protecting those which cannot be avoided. A vulnerability analysis can be used to identify vulnerable critical compartments and the essential pieces of equipment or systems that are required to be protected, see 2.2.

5.12.3 Critical pipe and cable runs are routes in which the connections for survivability critical components run. They can cover individual routes or concentrated areas. An example is a run containing wave guides and signal cables for all the above water sensors on the mast.

5.13 Units system

5.13.1 Unless otherwise stated, the variables used in the Rules are expressed in the following units.

5.13.2 General

<table>
<thead>
<tr>
<th>Unit</th>
<th>Symbol</th>
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</thead>
<tbody>
<tr>
<td>Distances</td>
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<tr>
<td>Primary spacings</td>
<td>m</td>
</tr>
<tr>
<td>Secondary spacings</td>
<td>mm</td>
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</tbody>
</table>

5.13.3 Hull girder properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions</td>
<td>m</td>
</tr>
<tr>
<td>Area</td>
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</tr>
<tr>
<td>Section modulus</td>
<td>m³</td>
</tr>
<tr>
<td>Inertia</td>
<td>m⁴</td>
</tr>
<tr>
<td>Area-moment</td>
<td>m³</td>
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</table>

5.13.4 Stiffeners

<table>
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<th>Property</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
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</tr>
<tr>
<td>Dimensions</td>
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</tr>
<tr>
<td>Inertia</td>
<td>cm⁴</td>
</tr>
<tr>
<td>Section modulus</td>
<td>cm³</td>
</tr>
<tr>
<td>Length/length effective</td>
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5.13.5 Plating

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</thead>
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<tr>
<td>Breadth</td>
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<tr>
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</tr>
<tr>
<td>Thickness</td>
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5.13.6 Loads

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<tbody>
<tr>
<td>Pressures</td>
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<tr>
<td>Loads</td>
<td>kN</td>
</tr>
<tr>
<td>Bending moment</td>
<td>kN-m</td>
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<tr>
<td>Shear force</td>
<td>kN</td>
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</tbody>
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5.13.7 Other items

<table>
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<th>Property</th>
<th>Unit</th>
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</thead>
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<tr>
<td>Yield strength</td>
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</tr>
<tr>
<td>Stress</td>
<td>N/mm²</td>
</tr>
<tr>
<td>Deflections</td>
<td>mm</td>
</tr>
<tr>
<td>Modulus of Elasticity</td>
<td>N/mm²</td>
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</table>
Fig. 1.5.4(a) Longitudinal framing system

Fig. 1.5.4(b) Transverse framing system
Fig. 1.5.5(a) NS1 Conventional aircraft carrier

Fig. 1.5.5(b) NS1 Short take off aircraft carrier

Fig. 1.5.5(c) NS2 Frigate/Destructor
Section 6
Building tolerances and associated repairs

6.1 Overview

6.1.1 The general tolerances for new building and subsequent repairs are to be in accordance with the requirements of the Naval Ship Survey Procedures Manual.

6.1.2 Tolerances to be used for constructional misalignment for all materials are to be discussed between Owners/Builders and the Surveyor and the Standards agreed subject to the requirements of 6.1.1. The permitted degree of inaccuracy/misalignment will vary according to whether the defect is:
(a) In primary structure.
(b) In secondary structure.
(c) Equipment supporting structure or underwater plate near acoustic equipment.
(d) Aesthetically pleasing.

6.1.3 The requirements of these Rules are primarily concerned with ensuring items (a) and (b). The equipment manufacturer will be able to give advice on the maximum noise or misalignment that can be tolerated from item (c). Aesthetics, item (d) are at the discretion of the Owner.

Section 7
Inspection and testing

7.1 Overview

7.1.1 The general requirements for testing and inspection of structural items are to be in accordance with the requirements of Pt 6, Ch 6,6 and LR’s Naval Survey Guidance for Steel Ships.

7.1.2 Adequate facilities are to be provided to enable the Surveyor to carry out a satisfactory inspection and testing of all components during each stage of prefabrication and construction.
1.3.2 Intact stability

1.3.2.1 Intact stability calculations to satisfy the applicable criteria may be based on the buoyancy of the main hull, together with any superstructures that have watertight and weathertight boundaries, see Fig. 2.1.1(a) and Fig. 2.1.2(a).

1.3.2.2 Doors, hatches, ventilators, windows, sidelights, etc., provided with closing appliances which can be secured weathertight, and small openings through which progressive flooding cannot take place are not considered as down flooding points.

1.3.2.3 If the angle of down flooding is less than $\theta_{df}$, see 1.2.2, with the ship at its design draught, it is necessary to establish whether there is sufficient area under the righting lever curve up to the angle of down flooding. If there is insufficient area, then the opening which is causing down flooding to occur is to be provided with a weathertight closing appliance, or be repositioned.
1.3.3 Damage stability

1.3.3.1 Typically there are two approaches to defining the limits of watertight and weathertight integrity:

(a) One where the watertight integrity is defined by the bulkhead or freeboard deck, in accordance with normal SOLAS requirements.

(b) The other is based on watertight integrity up to a damaged stability draft and heel envelope, the latter is commonly used by Navies. These two approaches are illustrated in Figs. 2.1.1(b) and 2.1.2(b) respectively.

1.3.3.2 Fig. 2.1.1(b) represents the SOLAS style requirements.

- Below the limit of watertight integrity the boundary structure is to be watertight.
- Below the limit of weathertight integrity defined by the transient roll angle the boundary structure is to be weathertight, in order to prevent ingress of water into the enclosed volume considered buoyant in the stability calculations and prevent downflooding.
- Above the limit of weathertight integrity the boundary structure, or some other internal boundary, may need to be gas-tight for CBRN protection.
- Below the limit of watertight integrity defined by the top of the watertight bulkhead, the bulkhead is to be designed as watertight.

1.3.3.3 Fig. 2.1.2 represents a standard based on damaged stability draft and heel envelope approach commonly used by Navies:

- Below the limit of watertight integrity the boundary structure is to be watertight.
- Below the limit of weathertight integrity defined by the transient roll angle the boundary structure is to be weathertight.
- Above the limit of weathertight integrity the boundary structure, or some other internal boundary, may need to be gas-tight for CBRN protection.
- Below the limit of watertight integrity defined by the loci of static damage waterlines the watertight bulkheads are to be designed as watertight.
- Below the limit of weathertight integrity defined by the transient roll angle and above the limit of watertight integrity the internal structure is to be weathertight in order to prevent progressive flooding of water into other compartments.

1.3.3.4 In the absence of specific information on the vertical limit of watertight integrity, the upper extent of the watertight boundary may be assumed with the apex of the triangle on the damage control deck at the location under consideration, see Fig. 2.1.2 and Pt 3,Ch 1,5.4.4.

1.4 Structural redundancy

1.4.1 The role and duty of a naval ship dictates that a certain degree of structural redundancy should be incorporated in the design. It is recommended that, as a minimum standard, a basic level of structural redundancy is included where practicable. This is normally achieved by considering likely damage scenarios, identifying the effects on structure, assessing the new loads and ensuring that the remaining structure will be satisfactory.

1.4.2 These Rules will not automatically ensure that a ship has structural redundancy. It is the responsibility of the designer to consider and design for the possible loads on a structure from damage scenarios. The RSA notation can be used to define residual strength requirements.

1.4.3 At a very basic level structural redundancy can be achieved by considering the removal of appropriate items of structure and re-evaluating the strength of remaining members using the loads presented in these Rules. Alternatively, the overall structural redundancy can be formally assessed and a notation assigned using the residual strength analysis detailed in 1.5.
1.5 Residual Strength Assessment, RSA

1.5.1 The design of a naval ship necessitates the reliable evaluation of its structural vulnerability to ensure the existence of adequate residual strength in the event of structural damage following a contact/collision incident or as a result of wartime activities. This strength assessment is additional to that required to cope with the design bending moments derived from environmental sea-state loading. The RSA notation within the Rules may be used to formally assess the overall structural redundancy.

1.5.2 The Owner may specify that a residual strength assessment is not required. In this case, the residual strength notation and all other notations which require the residual strength notation will not be assigned.

1.5.3 The capability to survive is to be judged on the residual structural strength after damage being able to meet specified global strength requirements and also local strength requirements in the event of damage leading to flooding, see Pt 6, Ch 4,4.

1.5.4 A residual strength assessment performed as defined in the Rules, assumes that a ship can remain operational for a limited period of time in reduced sea states, see Pt 6, Ch 4,1.2. Where a higher operational capability following damage is specified, special consideration will need to be given and revised criteria set.

1.5.5 The Owner may specify an alternative mission statement, in which case the requirements of the residual strength assessment procedure will be modified.

1.5.6 The residual strength assessment as defined in the Rules considers three main definitions of damage:
- Peacetime damage extents, see Pt 6, Ch 4,2.
- Military threats, see Pt 4, Ch 2,7.
- As defined by the Owner.

1.5.7 The environmental parameters for the residual strength assessment procedure are given in Pt 5, Ch 2. The local and global loads for use in the RSA assessment procedure are given in Pt 5, Ch 3,5 and Pt 5, Ch 4,5 respectively.

1.5.8 RSA notation assessment levels are given in Pt 4, Ch 2,7. The acceptance criteria and procedures to be adopted for the application of the residual strength notation are given in Pt 6, Ch 4,4. See also Pt 1, Ch 2,3,6,1.

1.5.9 Further guidance for undertaking residual strength analysis for the determination of a residual strength notation is given in LR's Naval Ship Guidance Notes.

2.2.5 Dynamic loadings are examined for both the local and global structures. These loadings are based upon the designer's stated operational and environmental conditions or the Rule minimum criteria, whichever is the greater.

2.2.6 Wave induced loads are considered both in the static condition, i.e., hydrostatic and pitching pressures, and in the dynamic mode, i.e., impact, slamming and hogging and sagging wave loading conditions.

2.2.7 Hull girder strength will in general require to be investigated dependent upon the length, configuration, proportions, proposed scenarios, etc., of the ship.

2.2.8 Structure in way of Replenishment at Sea, RAS, positions, cranes, heavy lift route points, weapon handling, etc., are to be designed in accordance with Pt 4, Ch 5. The equipment is to be designed in accordance with the specified standard(s), see Vol 1, Pt 1, Ch 2,1,1.
2.2.9 Scantling requirements in respect of miscellaneous items of structure such as local foundations, base plates, insert plates, bollards, etc., are not specifically indicated within these Rules. However the acceptance of such items will be specially considered on the basis of experience, good practice and direct calculation where appropriate.

2.3 Definitions and structural terms

2.3.1 For the purpose of clarifying the nomenclature of items of structure referred to throughout the Rules, the following definitions are given:

- Secondary members are stiffeners supporting shell, deck or bulkhead plating, e.g., side/bottom/deck longitudinals, frames and beams, and transverse/longitudinal bulkhead stiffeners.
- Primary members are those members supporting secondary members and will be the predominant members in grillage systems, e.g.:
  - Bottom structure – floors, bottom and inner bottom transverse and girders.
  - Deck structure – deck transverses and girders.
  - Side structure – side transverses and side stringers.
  - Bulkheads – vertical webs and bulkhead stiffeners.

Deep web frames are members supporting primary members between bulkheads or decks, where additional support is necessary.

2.3.2 The fore end region structure is considered to include all structure forward of 0,7L.

2.3.3 The aft end region structure is considered to include all structure aft of 0,3L.

### Section 3

#### Main hull structure

3.1 General

3.1.1 The Rules are formulated to provide for scantling derivation for designs comprising the following structural framing systems. Details of the requirements are given in Pt 6, Ch 2.

(a) Primary/secondary stiffener systems – where, due to the relative differences in stiffness of the members, the secondary members are considered to act independently of, and are supported by, the primary members.

(b) Grillage systems – where the relative stiffness of the orthogonal stiffening is similar and work together to support the applied loads. The grillage system is in turn supported by major structural members such as bulkheads or decks.

3.1.2 For practical reasons of fabrication and continuity of structure, orthogonal systems using members of the same depth should not be employed. A minimum web depth difference of 40 mm is generally to be used to allow for the passage through the web at the intersections.

3.1.3 It is recognised that there will be a reduction in transverse ‘racking’ strength in association with the grillage stiffening system where the predominantly stiffer transverse web of the primary/secondary system is missing. In large areas of grillage systems the ‘racking’ strength, therefore, will be specially considered.

3.1.4 For NS1 and NS2 ships, longitudinal framing, in general, is to be adopted in the bottom shell, decks and inner bottom, with transverse or longitudinal framing at the side shell and longitudinal bulkheads. In NS3 ships, transverse or longitudinal framing may be universally adopted.

3.1.5 The adopted framing system whether longitudinal or transverse is required to be continuous. Where it is impracticable to comply with these requirements or where it is proposed to terminate the framing structure in way of other primary members such as the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. Brackets are in general to have soft toes and to terminate on structure that is capable of supporting the transmitted bending moment and forces.

3.1.6 The arrangement of the connection between any stiffener and bracket is to be such that at no point in the connection are the section modulus and inertia reduced to less than that of the stiffener with associated plating.

3.1.7 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

3.1.8 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment and continuity of strength.

3.1.9 The fitting of pillar bulkheads is preferable to pillars. The fitting of pillars is to be avoided in hangar and vehicle decks and where connected to the inner bottom. Where enhanced shock and blast requirements are specified, only pillar bulkheads may be fitted. When fitted, pillars and pillar bulkheads are to be in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

3.1.10 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

3.1.11 The corners of large openings in the shell and decks from 0,25L to 0,75L are to be elliptical, parabolic or circular. Where predominantly unidirectional stress fields are anticipated, elliptical or parabolic corners are recommended. Where biaxial or torsional stress fields are expected, circular corners are recommended.
3.1.12 Where elliptical corners are arranged the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than 2 to 1 nor greater than 2.5 to 1, and the minimum half-length of the major axis is to be defined by $l_1$ in Fig. 2.3.1. Where parabolic corners are arranged, the dimensions are also to be as shown in Fig. 2.3.1. An increase in plate thickness will not generally be required.

![Fig. 2.3.1 Opening geometry](image)

3.1.13 Where circular corners are arranged, a radius not less than $1/20$ of the breadth of the opening is to be used with a minimum of 75 mm. For circular corners, inserts of the size and extent shown in Fig. 2.3.2 will, in general, be required. The thickness of insert plates is to be not less than 25 per cent greater than the adjacent plating with a minimum increase of 4 mm. The increase need not exceed 7 mm.

![Fig. 2.3.2 Inserts in way of openings](image)

3.1.14 For other shapes of corner, inserts of the size and extent shown in Fig. 2.3.2 will, in general, be required.

3.1.15 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or in floors and double bottom girders close to their span ends, or below the heels of pillars, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory. The size of openings are to be in accordance with 3.2.9.

3.1.16 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

3.1.17 Provision is made for the free passage of air and water taking into account the pumping rates required.

3.1.18 Particular care is to be given to the positioning of drain holes to reduce stress concentrations and ensure adequate drainage from all parts of the ship’s hull to the suctions. They are to be placed as close to the bottom as practicable.

3.1.19 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes. They are to be placed as close to the top of the tank as practicable. Air pipes of sufficient number and area are to be fitted to each tank in accordance with Pt 3, Ch 4,7.

3.1.20 Air and drain holes, notches and scallops are to be kept at least 200 mm clear of the toes of end brackets and other areas of high stress. Openings are to be well rounded with smooth edges. Closely spaced scallops are not permitted.

3.1.21 Widely spaced air or drain holes, cut entirely in the web adjacent to, but clear of the welded connection, may be accepted, provided that they are of elliptical shape, or equivalent, to minimise stress concentrations, see Fig. 2.3.3.

![Fig. 2.3.3 Air/drain hole geometry](image)

3.2 Primary members

3.2.1 The following guidelines for the design of primary members are to be adopted. Scantling requirements for primary members are given in Pt 6, Ch 3.
3.2.2 Primary members are to be so arranged as to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members are to form a continuous line of support and, wherever possible, a complete ring system.

3.2.3 Primary members are to have adequate lateral stability and web stiffening and the stiffening structure is to be arranged to minimise hard spots and other sources of stress concentration.

3.2.4 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member. Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

3.2.5 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended beyond the point of support and thereafter tapered and/or scarfed into the adjacent structure over a distance generally not less than two frame spaces.

3.2.6 Where primary members are subject to concentrated loads, particularly if these loads are out of line with the member web, additional strengthening may be required.

3.2.7 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support. Brackets are generally required but alternative arrangements will be considered.

3.2.8 The thickness of the brackets supporting primary members is to be not less than that of the primary member web. The free edge of the bracket is to be stiffened.

3.2.9 Where openings are cut in the web or primary members, the depth of opening is not to exceed 50 per cent of the web depth, and the opening is to be so located that the edges are not less than 25 per cent of the web depth from the face plate. The length of opening is not to exceed the web depth or 60 per cent of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be specially considered.

3.2.10 Openings are to have well rounded corners and smooth edges and are to be located having regard to the stress distribution and buckling strength of the panel in which they are situated.

3.2.11 Cut-outs for the passage of secondary members are to be designed to minimise the creation of stress concentrations. The breadth of cut-out is to be kept as small as practicable and the top edge is to be rounded, or the corner radii made as large as practicable. The extent of the direct connection to the web plating, or the scantlings of lugs or collars, is to be sufficient for the loads to be transmitted from the secondary member, see also Pt 6, Ch 6,5.5.

3.2.12 Stiffeners in areas likely to experience slamming, impact or dynamic loads are to be lugged or bracketed to the web of the primary member at their intersections, see also Pt 6, Ch 6,5.5.

3.3 Shell plating

3.3.1 Scantling requirements for shell plating are given in Pt 6, Ch 3,5.

3.3.2 The sheerstrake is generally to be taken as the side shell, locally reinforced in way of deck/hull connection. The amount of local reinforcement will be dependent upon the arrangement of structure and the proposed service.

3.3.3 In general, openings are not to be cut in the sheerstrake, however, if operational requirements dictate, openings that are less than 20 per cent of the depth of the sheerstrake may be accepted. Openings greater than 20 per cent of the depth of the sheerstrake will require special consideration.

3.3.4 Where large side shell openings, such as side aircraft lifts, are proposed, detailed calculations are to be submitted.

3.3.5 Where rounded gunwales are fitted, arrangements are to ensure a smooth transition from rounded gunwale to angled gunwale.

3.3.6 At the ends of superstructures where the side plating is extended and tapered to align with the bulwark plating, the transition plating is to be suitably stiffened and supported. Where freeing ports or other openings are essential in this plate, they are to be suitably framed and kept well clear of the free edge.

3.3.7 Sea-inlets, or other openings, are to have well rounded corners and, so far as is practicable, are to be kept clear of the bilge radius, chine or radiused sheerstrake. Arrangements are to be made to maintain the strength in way of the openings. Additional thickness is to be required in accordance with Pt 6, Ch 3,5.7. Adequate provision is to be taken to prevent local resonance problems. Additional guidance for the design of sea-inlets or other openings, is given in Pt 4, Ch 1,8.

3.3.8 Openings on or near the bilge radius may be accepted provided that they are of elliptical shape, or equivalent, to minimise stress concentrations and are, in general, to be kept clear of weld connections.
3.3.9 The scantlings of appendages (e.g., ‘A’ brackets) are covered in Chapter 3. However, in way of the hull penetrations, particular care will be required to be given to the strength and watertight integrity of the shell.

3.4 Shell framing

3.4.1 The scantlings of shell structure are to be determined in accordance with Pt 6, Ch 3.6.

3.4.2 Longitudinal framing is, in general, to be adopted in the bottom, but special consideration will be given to proposals for transverse framing in this region, see 3.1.4.

3.4.3 For NS1 and NS2 ships, the bottom and side longitudinals are to be continuous in way of both watertight and non-watertight floors, but equivalent arrangements will be specially considered.

3.4.4 Bottom and side longitudinals are to be supported by primary transverse structure such as bottom transverses, floors or bulkheads, generally spaced not more than 2.5 m apart in NS1 and NS2 ships, and 1.5 m in NS3 ships.

3.4.5 Bottom and side transverses, where fitted, are to be continuous and substantially bracketed at their end connections to side and deck transverses and bottom floors.

3.4.6 Bottom and side frames are to be effectively continuous and bracketed at their end connections to side frames, deck beams and bottom floors as appropriate. Side frames are to be supported by decks or stringers spaced not more than three metres apart.

3.4.7 Bottom girders and side stringers supporting transverse frames, are to be continuous through transverse bulkheads and supporting structures. They are to be supported by deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than three metres apart.

3.4.8 For primary members the web stability, openings in the web and continuity and alignment are to be in accordance with 3.2.9.

3.4.9 For ships intended for beach landing operations, see Pt 4, Ch 2.8.

3.4.10 For berthing and docking requirements, see Pt 3, Ch 5.10.

3.4.11 Where the shell framing is of unusual design or proportions, the scantlings are to be determined by direct calculation.

3.5 Single bottom structure

3.5.1 Scantling requirements for single bottom structure are given in Pt 6, Ch 3.7.

3.5.2 The requirements of this Section provide for single bottom construction in association with transverse and longitudinal framing systems, see 3.1.4.

3.5.3 All girders are to extend as far forward and aft as necessary and care is to be taken to avoid any abrupt discontinuities. Where girders are cut at bulkheads, alignment and longitudinal strength are to be maintained.

3.5.4 Particular care is to be taken to ensure that the continuity of structural strength in way of the intersection of transverse floors and longitudinal girders is maintained. The face flats of such stiffening members are to be effectively connected.

3.5.5 The single bottom structure in way of the keel and girders is to be sufficient to withstand the forces imposed by dry-docking the ship, see Pt 4, Ch 2.8.

3.5.6 A continuous centreline girder is, in general, to be fitted in all ships throughout the length of the hull as far forward and aft as practicable.

3.5.7 Where the floor breadth at the upper edge exceeds 6,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. In general, side girders where fitted are to be continuous, extend as far forward and aft as practicable and to terminate in way of bulkheads, deep floors or other primary transverse structure. In addition, continuous intercostal longitudinal stiffeners are to be fitted where the panel size exceeds the ratio 4 to 1.

3.5.8 In ships with a transversely framed bottom construction, the bottom shell plating is, in general, to be reinforced with additional continuous, or intercostal, longitudinal stiffeners. Alternative arrangements to be considered.

3.5.9 For ships intended for beach landing operations, see Pt 4, Ch 2.8.

3.5.10 In longitudinally framed ships, plate floors are to be fitted as given in 3.4.4. The connections with side transverse web frames are to be as required by 3.4.6. Additional transverse floors or webs are in general to be fitted at the half spacing of primary transverse structure in way of engine seatings, thrust bearings, pillars, skegs, bilge keels and the bottom of the ship forward.

3.5.11 The tops of the floors may be level from side to side. However, in ships having considerable rise of floor the depth of floors may require to be increased to maintain the required section modulus.

3.5.12 In general, the floors in way of the stern tubes, shaft brackets, etc., are to provide effective support for these items.

3.6 Double bottom structure

3.6.1 Scantlings of double bottoms are to be in accordance with Pt 6, Ch 3.8.
3.6.2  Double bottoms are in general to be fitted in NS1 ships and are to extend from the collision bulkhead to the aft peak bulkhead, as far as this is practicable within the design and proper working of the ship. The specified subdivision and stability standard may contain additional requirements for the height and extent of the double bottom.

3.6.3  A double bottom is generally not required in way of watertight compartments used exclusively for the carriage of liquids, provided the safety of the ship in the event of bottom damage is not thereby impaired. Suitable scarfing arrangements are to be made to maintain continuity of the inner bottom.

3.6.4  The inner bottom is to be continued to the ship’s side as far as practicable, in such a manner as to protect the bottom to the turn of bilge or chine.

3.6.5  The centreline girder and side girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuities. Where girders are cut at bulkheads, their alignment and longitudinal strength is to be maintained.

3.6.6  Small wells constructed in the double bottom structure are not to extend in depth more than necessary. A well extending to the outer bottom may, however, be permitted at the after end of the shaft tunnel of the ship. Other well arrangements (e.g., for lubricating oil under main engines) may also be considered provided they give protection equivalent to that afforded by the double bottom.

3.6.7  Sufficient manholes are to be cut in the inner bottom, floors and side girders to provide adequate access to, and ventilation of, all parts of the double bottom. Openings are to be in accordance with 3.2.9.

3.6.8  The number and position of manholes are to be such that access under service conditions is neither difficult nor dangerous.

3.6.9  Manholes and their covers are to be of an approved design or in accordance with a recognised National or International Standard.

3.6.10  Provision is to be made for the free passage of air and water from all parts of the tanks to the air pipes and suction, account being taken of the pumping rates required.

3.6.11  Adequate access is also to be provided to all parts of the double bottom for future maintenance, surveys and repairs. The edges of all openings are to be smooth.

3.6.12  A plan showing the location of manholes and access openings within the double bottoms is to be submitted.

3.6.13  Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. Details are given in 3.1.15.

3.6.14  Air and drain holes, notches and scallops are to be in accordance with 3.1.7.

3.6.15  The Rules are formed on the basis that access to double bottoms will be by means of manholes with bolted covers. However, alternative arrangements will be specially considered.

3.6.16  In way of ends of floors and girders and transverse bulkheads, the number and size of holes are to be kept to a minimum, the openings are to be circular or elliptical and edge stiffening may be required.

3.6.17  Holes are not to be cut in the centre girder, except in tanks at the forward and after ends of the ship or where tank widths are reduced unless additional stiffening and/or compensation is fitted to maintain the structural integrity.

3.6.18  Centreline and side girders are to be continuous and sufficient to withstand the forces imposed by dry-docking the ship, see Part 4. Vertical stiffeners are to be fitted at every bracket floor.

3.6.19  Where the breadth of floor is greater than 6.0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 3.0 m (for transversely framed ships, 5.0 m for longitudinally framed ships).

3.6.20  Side girders where fitted are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

3.6.21  Plate floors are, in general, to be continuous between the centre girder and the margin plate. Vertical stiffeners are to be fitted to the floors, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

3.6.22  In longitudinally framed ships, plate floors or equivalent structure are, in general, to be fitted in accordance with 3.4.4 and additionally at the following positions:

   (a) At every half spacing of primary transverse structure as given in 3.4.4, in way of the bottom of the ship forward of 0.8L.

   (b) Underneath pillars and bulkheads.

3.6.23  In transversely framed NS3 ships, plate floors are to be fitted at every frame in the engine room, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 1.5 m.

3.6.24  Between plate floors, the shell and inner bottom are to be supported by bracket floors. The brackets are to have the same thickness as plate floors and are to be stiffened on the unsupported edge.

3.6.25  In longitudinally framed ships, the bracket floors are to extend from the centre girder and margin plate to the adjacent longitudinal, but in no case is the breadth of the bracket floor to be taken as less than 75 per cent of the depth of the centre girder. They are to be fitted at every frame at the margin plate, and those at the centre girder are to be spaced not more than 1.0 m apart.
3.6.26 In transversely framed ships, the breadth of the bracket floors, attaching the bottom and inner bottom frames to the centre girder and margin plate, is to be not less than 75 per cent of the depth of the centre girder, see Fig. 1.5.4(b) in Chapter 1.

3.6.27 Inner bottom longitudinals are to be supported by inner bottom transverses, floors, bulkheads or other primary structure, generally spaced not more than 2.5 m apart in NS1 and NS2 ships, and 1.5 m in NS3 ships.

3.6.28 The inner bottom longitudinals are to be continuous through the supporting structure.

3.6.29 Inner bottom transverses are to be continuous and to be substantially bracketed at their end connections to bottom transverses, bottom floors and tank side brackets.

3.6.30 In general, whilst the fitting of pillars connecting to the inner bottom is to be avoided, where they are fitted, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided. Where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

3.6.31 Double bottoms are to be tested in accordance with the requirements of Pt 6, Ch 6.6 of the Rules.

3.6.32 The Rules are formed on the basis that access to double bottoms will be by means of manholes with bolted covers. However, alternative arrangements will be specially considered.

3.7 Deck structure

3.7.1 Scantlings of decks are to be in accordance with the requirements of Pt 6, Ch 3.10.

3.7.2 Where an inner bottom is not fitted, consideration of the ship’s stability and strength following bottom damage is required. It may be appropriate to consider designing the lowest deck to be watertight. This is to be determined in conjunction with the damage stability analysis, assuming bottom damage.

3.7.3 The deck plating is to be supported by transverse beams with fore and aft girders; by longitudinals with deck transverses, or alternatively, by a grillage system of orthogonal and primary structure as provided for in 3.1.1. The transverse beams and deck transverses are to align with side main frames and side transverses respectively. For NS1 and NS2 ships, longitudinal framing is generally to be adopted, see 3.1.4.

3.7.4 Where transversely stiffened, beams are to be fitted at every frame and bracketed to the side frames. Deck transverses should also be fitted at the ends of large openings in the deck.

3.7.5 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

3.7.6 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

3.7.7 The ends of beams, longitudinals, girders and transverses are to be effectively built into the adjacent structure, or equivalent arrangements provided.

3.7.8 Arrangements to prevent tripping are to be fitted on deep webs.

3.7.9 The deck plating and supporting structure are to be suitably reinforced in way of cranes, masts, and deck equipment or machinery.

3.7.10 Deck structures subject to concentrated loads, are to be suitably reinforced. Where concentrations of loading on one side of a stiffening member may occur, such as out of line pillars, the member is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

3.7.11 The end connection of strength deck longitudinals to bulkheads are to provide adequate fixity and, so far as is practicable, direct continuity of longitudinal strength. For NS1 and NS2 ships, the strength deck longitudinals are to be continuous through transverse structure, including bulkheads, but alternative arrangements will be considered.

3.7.12 Transverses supporting deck longitudinals are, in general, to be spaced not more than 2.5 m apart in NS1 and NS2 ships, and 1.5 m in NS3 ships. They are to be aligned with primary side structure.

3.7.13 All openings are to be supported by an adequate framing system, pillar bulkheads or cantilevers. When cantilevers are used, the scantlings are to be determined by direct calculation.

3.7.14 Where stiffening members terminate in way of an opening they are to be attached to carlings, girders, transverses or coaming plates, in such a way as to minimise stress concentrations.

3.7.15 Other openings in the strength deck outside the line of major openings are to be kept to the minimum number consistent with operational requirements. Openings are to be arranged clear of other opening corners and, so far as possible, clear of one another. Where necessary, plate panels in which openings are cut are to be adequately stiffened against compression and shear buckling. The corners of all openings are to be well rounded and the edges smooth. Attention is to be paid to structural continuity and abrupt changes of shape, section or thickness are to be avoided.
3.7.16 Gutterway bars and spurn waters at the upper deck are to be so arranged that the effect of main hull stresses on them is minimised and that they do not cause stress concentrations in the deck or sheerstrake, see also Pt 6, Ch 3.3.6.

3.7.17 For flight decks, consideration should be given to the effect on fatigue life of welding attachments (e.g., cable trays and piping brackets) directly to the deck plating or stiffeners. It is recommended that attachments be made by other means or that the effect be accounted for in any fatigue analysis which may be undertaken.

3.7.18 It is recommended that the working areas of the weather deck have an anti-slip surface. Working areas of all decks where there is the possibility of leakage of fuel, hydraulic or other oils are to be provided with anti-slip deck coatings, or equivalent, and guard rails, as appropriate.

3.7.19 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, see also Part 6.

3.7.20 Where large or novel hatch openings are proposed, detailed calculations are to be submitted to demonstrate that the scantlings and arrangements in way of the openings are adequate to maintain continuity of structural strength.

3.7.21 Where large side shell openings, such as side aircraft lifts, are proposed, detailed calculations are to be submitted.

3.7.22 Pipe or cable runs through watertight decks are to be kept to a minimum and are to be fitted with suitable watertight glands of a type approved and pressure tested for the maximum head of water indicated by any required damage stability calculations.

3.7.23 The specified subdivision and stability standard(s) may require all deck penetrations to be of a nominated standard.

3.7.24 Heat-sensitive materials are not to be used in pipe or cable runs which penetrate watertight decks, where deterioration of such systems in the event of fire would impair the watertight integrity of the deck.

3.7.25 The number of openings in watertight decks is to be reduced to the minimum compatible with the design and proper working of the ship. Where openings are permitted in watertight decks, they are to be provided with suitable closing devices in accordance with Ch 4.4.

3.8 Deep tank structure

3.8.1 The scantlings of deep tank structure are to be in accordance with the relevant Sections of Part 6.

3.8.2 Above the top of floors, the side shell structure of deep tanks is to be effectively supported by a system of primary framing with web frames, stringers, cross ties and/or perforated flats.

3.8.3 The maximum spacing of side shell transverses in longitudinally framed deep tanks is generally not to exceed 2.5 m in NS1 and NS2 ships, and 1.5 m in NS3 ships.

3.8.4 The maximum spacing of side shell web frames in transversely framed deep tanks is generally not to exceed five frame spaces. They are to extend from the tank top to the level of the lowest deck above the design waterline.

3.8.5 The maximum spacing of horizontal stringers is generally not to exceed 3.0 m.

3.8.6 Where decks terminate at deep tanks suitable scarfing arrangements are to be arranged and the side shell supported by a stringer at deck level. The stringer can be either fully effective or acting as part of a grillage. Bulkhead stiffeners are to be supported at the deck level against tripping.

3.8.7 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side. The bulkhead may be intact or perforated as desired. If intact, the scantlings are to comply with the requirements of Part 6 for tank boundary bulkheads. If perforated, they are to comply with the requirements of Part 6 for wash plates. Where brackets from horizontal girders on the boundary bulkheads terminate at the centreline bulkhead, adequate support and continuity are to be maintained.

3.8.8 The thickness of any longitudinal bulkheads may be required to be increased to ensure compliance with the shear strength requirements of Part 6. In the case of a centreline or perforated wing bulkhead, the proportion of the total shear force absorbed by the bulkhead will be specially considered.

3.8.9 The thickness of plating of wash bulkheads may also be required to be increased to take account of shear buckling.

3.8.10 Where longitudinal wash bulkheads support bottom transverses, the lower section of the bulkhead is to be kept free of non-essential openings for a depth equal to 1.75 times the depth of the transverses. The plating is to be assessed for local buckling requirements.

Section 4

Bulkhead arrangements

4.1 General

4.1.1 Watertight bulkheads for NS2 and NS3 ships are, in general, to extend to the uppermost continuous deck, and their construction is to be in accordance with Pt 6, Ch 3.9. In the larger multidecked NS1 ships (e.g., Aircraft Carriers) the watertight bulkheads are generally to extend to the lowest continuous vertical limit of weathertightness determined by 1.3.
4.1.2 Where permitted by the stability and subdivision standard, certain openings below the deck described in 4.1.1 may be allowed, see Vol 1, Pt 1, Ch 2.1.1.9. In all cases these openings must be kept to a minimum and provided with means of closing to watertight standards.

4.1.3 The number of openings in watertight bulkheads is to be reduced to the minimum compatible with the design and proper working of the ship. Where openings are permitted in bulkheads they are to be provided with suitable closing devices in accordance with Ch 4.4.

4.1.4 Bulkheads forming the boundaries to citadels and zones as defined in Pt 4, Ch 1.7, other than watertight bulkheads, are usually specified to be gastight. See also 4.7. Where specified, LR can assess the gastight integrity of defined gastight boundaries, see Pt 6, Ch 6.6.8.

4.1.5 Pipe or cable runs through watertight bulkheads are to be kept to a minimum and are to be fitted with suitable watertight glands of a type approved and pressure tested for the maximum head of water indicated by any required damage stability calculations.

4.1.6 The specified subdivision and stability standard(s) may require all bulkhead penetrations to be of a nominated standard.

4.1.7 Heat-sensitive materials are not to be used in pipe or cable runs which penetrate watertight bulkheads, where deterioration of such systems in the event of fire would impair the watertight integrity of the deck.

4.1.8 Partial or main bulkheads are to be located beneath the ends of superstructures and deckhouses and masts and heavy items of equipment such as weapon systems to support and transmit the static and dynamic forces into the hull structure. They are to be of sufficient strength and rigidity to carry the concentrated loads imposed on them and maintain alignment where necessary.

4.2 Number and disposition of watertight bulkheads

4.2.1 In general, the number and disposition of bulkheads are to be arranged to suit the requirements for subdivision, floodability and damage stability, and are to be in accordance with the specified subdivision and stability standard(s).

4.2.2 Main transverse watertight bulkheads are to be spaced at reasonably uniform intervals. Where non-uniform spacing is unavoidable and the length of a compartment is unusually large, the transverse strength of the ship is to be maintained by fitting of web frames, increased framing, etc. Details of the proposed arrangements are to be submitted.

4.2.3 All ships are to have a collision bulkhead, an after peak bulkhead and a watertight bulkhead at each end of all main and auxiliary machinery spaces. Additional watertight bulkheads are to be fitted so that the total number of bulkheads is at least in accordance with Table 2.4.1.

4.2.4 Proposals to dispense with one or more of these bulkheads will be considered, subject to suitable structural compensation, if they interfere with the operational requirements.

4.2.5 A main transverse bulkhead is to be located at the position where the ship sues during docking.

4.3 Collision bulkheads

4.3.1 The collision bulkhead is to be positioned as detailed in Table 2.4.2. However, consideration will be given to proposals for the collision bulkhead to be positioned slightly further aft on an arrangement (b) ship, but not more than 0.08LR from the fore end of LR provided that the application is accompanied by calculations showing that flooding of the space forward of the collision bulkhead will not result in any part of the bulkhead deck becoming submerged, or any unacceptable loss of stability. The length LR is as defined in Table 2.4.1.

4.3.2 For ships with pronounced rake of stem, the position of the collision bulkhead will be specially considered.

4.3.3 No accesses or ventilation ducts are to be fitted in collision bulkheads. In designs where it would be impracticable to arrange access to the fore peak other than through the collision bulkhead, access may be permitted if specified. Where accesses are provided, the openings are to be as small as practicable and positioned as far above the design waterline as possible, in any event, no lower than the damage control deck. Access is to be by manholes with bolts spaced at a watertight pitch.

4.3.4 Pipe runs or cable runs are only to be fitted in the collision bulkhead if specified in the subdivision and stability standard(s).

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<th>Length, LR, in metres</th>
<th>Total number of bulkheads</th>
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<th>Machinery aft</th>
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<tr>
<td>LR &gt; 190</td>
<td></td>
<td>To be considered individually</td>
<td></td>
</tr>
</tbody>
</table>

NOTE
With after peak bulkhead forming after boundary of machinery space.

Table 2.4.1 Minimum number of bulkheads
4.4  Aft peak bulkhead

4.4.1  NS1 and, where practicable, NS2 ships, are to have an aft peak bulkhead generally enclosing the sterntube and rudder trunk in a watertight compartment. In twin screw ships where the bossing ends forward of the aft peak bulkhead, the sterntubes are to be enclosed in suitable watertight spaces inside or aft of the shaft tunnels. The stern gland is to be situated in a watertight shaft tunnel or other watertight spaces inside or aft of the shaft tunnels. The stern gland is to be weathertight over its complete length.

4.6  Watertight recesses, flats, openings and loading ramps

4.6.1  Watertight recesses in bulkheads are to be avoided whenever possible.

4.6.2  Where watertight bulkhead stiffeners are cut in way of watertight doors in the lower part of a bulkhead, the opening is to be suitably framed and reinforced. Where stiffeners are not cut but the spacing between the stiffeners is increased on account of watertight doors, the stiffeners at the sides of the doorways are to be increased in depth and strength so that the efficiency is at least equal to that of the unperforated bulkhead, without taking the stiffness of the door frame into consideration.

4.6.3  In collision bulkheads, any recesses or steps in the bulkhead are to fall within the limits of bulkhead positions given in 4.3.1. If a step occurs above the virtual limit of watertight integrity the deck need also only be to weathertight standards in way of the step, unless the step forms the crown of a tank, in which case the requirements for deep tank structures are to be complied with.

4.6.4  In ships fitted with bow doors, in which a sloping loading ramp forms part of the collision bulkhead above the virtual limit of watertight integrity, that part of the ramp which is more than 2,30 m above the virtual limit of watertight integrity may extend forward of the minimum limit specified in Table 2.4.2. Such a ramp is to be weathertight over its complete length.

4.7  Gastight bulkheads

4.7.1  Where an assessment of gastight integrity is required the scantlings of gastight bulkheads are to be in accordance with Part 6.

4.7.2  Where bulkheads are required to be gastight and where it is proposed to pierce such bulkheads for the passage of cables, pipes, vent trunking, etc., gastight glands are to be provided to maintain the gastight integrity.

4.8  Tank bulkheads

4.8.1  For bulkheads in way of partially filled compartments or tanks, sloshing forces may be required to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

4.8.2  The scantlings of deep tank bulkheads are to be in accordance with Part 6.

4.8.3  Air and sounding pipes are to comply with the requirements of Pt 3, Ch 4, 7.
4.9 **Cofferdams**

4.9.1 Tanks carrying oil fuel or lubricating oil are to be separated by cofferdams from those carrying fresh water. Cofferdams are to be fitted between freshwater tanks and black or grey water tanks.

4.9.2 Lubricating oil tanks are also to be separated by cofferdams from those carrying oil fuel unless:

(a) Common boundaries of lubricating oil and oil fuel tanks have full penetration welds.

(b) The tanks are arranged such that the oil fuel tanks are not generally subjected to a head of oil in excess of that in the adjacent lubricating oil tanks.

4.9.3 If oil fuel tanks are necessarily located within or adjacent to the machinery spaces, their arrangement is to be such as to avoid direct exposure of the bottom from rising heat resulting from a machinery or hazardous space fire.

4.9.4 Adequate access is to be provided to all parts of the cofferdams for future maintenance, surveys and repairs. The edges of openings are to be smooth.

4.10 **Watertight tunnels and passageways**

4.10.1 Stern tubes are to be enclosed in watertight spaces of moderate volume. In addition, arrangements are to be made to minimise the danger of water penetrating into the ship in case of damage to the stern tube. Normally the stern gland is to be situated in a watertight shaft tunnel or other watertight space separate from the stern tube compartment and of such volume that, if flooded by leakage through the stern gland, the vertical limit of watertight integrity, see 1.3, will not be submerged.

4.11 **Means of escape**

4.11.1 The arrangement of the hull is to be such that all under deck compartments are as accessible as practicable and provided with a satisfactory means of escape in accordance with a specified standard(s). Access and escape hatches to the machinery and tanks are not to be obstructed by deck coverings or furniture.

4.12 **Carriage of low flash point fuels**

4.12.1 For ships having oil fuel with a flash point below 60°C the arrangement for the storage, distribution and utilisation of the oil fuel are to be such that the safety of the ship and persons on board is preserved, having regard to the fire and explosion hazards. See Vol 2, Pt 7, Ch 3.2.

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**Section 5**

**Fore and aft end arrangements**

5.1 **General**

5.1.1 In general the main hull structural arrangements as defined in 3.3 are to extend as far forward and aft as possible.

5.1.2 The requirements of this Section apply to the fore and aft ends and relate to structure situated in the region forward of 0.7 \( L_R \) and aft of 0.3 \( L_R \) respectively.

5.1.3 Certain ships will require additional strengthening for bottom forward slamming and bow flare slamming. The scantlings of the hull structure forward are to be determined from Part 6, using the loads specified in Pt 5, Ch 3.3.

5.1.4 Where the stern overhang is significant, or large masses are placed on the stern, the strength of the aft end structure will be specially considered, see Ch 5.10.4.

5.2 **Structural continuity**

5.2.1 The Rules provide for both longitudinal and transverse framing systems.

5.2.2 Where the shell, deck and inner bottom are longitudinally framed in the midship region, this system of framing is to be carried forward and aft as far as possible.

5.2.3 End connections of longitudinals to bulkheads are to provide adequate fixity, lateral support and as far as practicable, direct continuity of longitudinal strength, see also Section 3.

5.2.4 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes.

5.2.5 Where longitudinal framing terminates and is replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover. Where a forecastle is fitted extending forward from 0.85 \( L_R \), longitudinal framing at the upper deck and topsides is generally to be continued forward of the aft bulkhead of this superstructure.

5.2.6 Where a superstructure or poop is fitted extending forward of 0.15 \( L_R \), longitudinal framing at the upper deck and topsides is generally to be continued aft of the forward bulkhead of this superstructure.

5.2.7 The forecastle side plating may be a continuation of the side shell plating or fitted as a separate assembly. The side plating is to be stiffened by side frames effectively connected to the deck structure. Deep webs are to be fitted to ensure overall rigidity.

5.2.8 Forecasts and bulwarks are to be constructed in accordance with the scantlings indicated in Pt 6, Ch 3.11.
5.3 Minimum bow height and extent of forecastle

5.3.1 The requirements regarding minimum bow height given in 5.3.2 are to be complied with. Only in exceptional circumstances and in specialist ships will any relaxation be given to this requirement where it interferes with the safe operation of the vessel. In such cases, due consideration is to be given to the clearing of seawater from the forecastle deck. The effects on strength and stability are also to be considered.

5.3.2 All sea-going ships are to be fitted with forecastles, or increased sheer on the upper deck or equivalent, such that the distance from the waterline design draught to the top of the exposed deck at side at the F.P. is not less than:

\[ H_b = \left( \frac{L_R}{100} \right)^2 \times \left( 2.08 + 0.609 C_b - 1.603 C_{C_{\text{in}}/C_{\text{out}}} - 0.0129 \left( \frac{L_R}{d_t} \right)^2 \right) \]

where:
- \( C_b \) = block coefficient
- \( L_R \) = Rule Length, in metres
- \( H_b \) = minimum bow height, in mm
- \( d_t \) = draught at 85 per cent of the depth, \( D \), see Ch 1.5.2.10
- \( C_{C_{\text{in}}/C_{\text{out}}} \) = waterplane area coefficient forward of midships
- \( A_{\text{ref}}/[(L_R/2) \times B] \) = waterplane area
- \( B \) = moulded breadth, in metres
- \( A_{\text{ref}} \) = is the forward waterplane area at draught \( d_t \), in \( m^2 \).

5.3.3 Ships shall have additional reserve of buoyancy in the fore end region to ensure sufficient longitudinal righting energy to recover from bow immersion in a seaway and be designed to prevent the excessive shipping of green seas.

5.3.4 Ships which are designed to suit exceptional operational requirements, restricted in their service to service area SA4, or of novel configuration will be specially considered on the basis of the Rules.

5.3.5 Where the bow height required in 5.3.2 is obtained by increased sheer, the shear shall extend for at least 15 per cent of the length of the ship measured abaft the forward end of \( L_R \). Where it is obtained by fitting a forecastle, the forecastle shall extend from the stem to a point at least \( 0.07 L_R \) abaft the forward end of \( L_R \).

5.4 Bow crumple zone

5.4.1 In general the bow crumple zone is that space forward of the collision bulkhead. Embarked personnel or crew accommodation and the carriage of fuel, hazardous materials and other oils is not permitted in the bow crumple zone.

5.5 Deck structure

5.5.1 The scantlings of the deck structure are to comply with Pt 6, Ch 3.10.

5.5.2 The deck plating thickness and supporting structure are to be suitably reinforced in way of anchor windlass, other deck machinery, and in way of cranes, masts or derrick posts, RAS stump masts, and weapon launching positions, etc.

5.5.3 Where large openings are arranged at lower decks near the side shell, it may be necessary to increase the adjacent deck structure to ensure effective support for side framing.

5.5.4 In NS1 and NS2 ships, on decks aft of the after cut-up, deep beams are generally to be fitted in way of web frames. Deck girders are generally to be spaced not more than 3.0 m apart and integrated with the primary structure forward.

5.5.5 Requirements for the arrangement and geometry of deck openings are given in 3.1 and 3.7. The scantlings of any inserts required are to be in accordance with Part 6.

5.6 Shell envelope plating and framing

5.6.1 The scantlings of bar keels in the forward end are to be the same as that required in the midship region, see Table 3.2.1 in Pt 6, Ch 3.

5.6.2 The thickness and width of plate keels in the forward region are to be the same as that required in the midship region.

5.6.3 The scantlings of plate stems are to be determined from Pt 6, Ch 3.5. Plate stems are to be supported by horizontal diaphragms positioned in line with the side stringers or perforated flats with intermediate breasthook diaphragms. Diaphragms are to be spaced not more than 1.5 m apart, measured along the stem. Where the stem plate radius is large, a centreline stiffener or web will be required.

5.6.4 The thickness of side shell and sheerstrake plating in the forward region is to be not less than the values required by Pt 6, Ch 3.5, but may be required to be increased locally on account of high shear forces, in accordance with Pt 6, Ch 4.3.2.

5.6.5 The shell plating may be required to be increased in thickness locally in way of openings such as hawse pipes and sonar domes, where fitted.

5.6.6 The shell plating is to be increased in thickness locally in way of a bulbous bow, see 5.10.

5.6.7 Sea inlet and other openings are to be in accordance with 3.3.6.

5.6.8 The bottom longitudinals are to be continuous in way of both watertight and non-watertight floors.

5.6.9 Where the shape of the after hull is such that there are large flat areas, particularly in the vicinity of the propellers, additional primary supports for the secondary stiffening may be required. Their extent and scantlings will be specially considered.
5.7  Single and double bottom structure

5.7.1  The general requirements of 3.5 and 3.6 apply.

5.7.2  The minimum depth of centre girder forward is generally to be the same as that required in the midship region.

5.7.3  Where the height of the double bottom varies, structural continuity is to be maintained. An inner bottom where fitted is to be gradually sloped over an adequate longitudinal extent. Knuckles in the plating are to be arranged close to plate floors. Otherwise, suitable scarfing arrangements are to be made.

5.7.4  For ships of full form, in fore peak and deep tank spaces, the floors and bottom transverses are to be supported by a centreline girder or a centreline wash bulkhead. In other cases the centreline girder is to be carried as far forward as practicable. The floor panels and the upper edges of the floors and centreline girder are to be suitably stiffened.

5.7.5  In aft peak spaces, floors are to be arranged at every frame. For details and scantlings, see Pt 6, Ch 3,7.

5.7.6  Provision is to be made for the free passage of water and air from all parts of single or double bottoms as required by 3.1.17 to 3.1.21.

5.8  Fore peak structure

5.8.1  The requirements given in this Section apply to the arrangement of primary structure supporting the fore peak side shell and bulbous bow, the arrangement of wash bulkheads and perforated flats. The scantlings of structure in the fore peak is to be in accordance with the relevant Sections of Part 6.

5.8.2  The bottom of the peak space is generally to be transversely framed. Longitudinally framed bottom structure will be specially considered.

5.8.3  Above the floors, transverse side framing is to be supported by horizontal side stringers, cross ties and/or perforated flats.

5.8.4  Suitable transverses or deep beams are to be arranged at the top of the tank to provide end rigidity to the side transverses.

5.8.5  Wash bulkheads are to have an area of perforations not less than five per cent nor more than 10 per cent of the area of the bulkhead. The plating is to be suitably stiffened in way of openings. Stiffeners are to be bracketed at top and bottom.

5.9  Aft peak structure

5.9.1  The scantlings of aft peak structure are to be as required by the relevant sections of Part 6. The plating thickness is to be increased locally in way of the stern tube gland.

5.9.2  Floors are to be arranged at every frame space and are to be carried to a suitable height, and at least to above the stern tube, where fitted. Floors are to be adequately stiffened. In way of propeller shaft brackets, rudder post or rudder horn, the floors are generally to be carried to the top of the space and are to be of increased thickness. The extent and amount of the increase will be specially considered, account being taken of the arrangements proposed.

5.9.3  Above the floors, transverse side framing is to be supported by horizontal stringers, cross ties and/or perforated flats.

5.9.4  Suitable transverses or deep beams are to be arranged at the top of the tank to provide end rigidity to the side transverses.

5.9.5  A centreline wash bulkhead is to be arranged in the upper part of the aft peak space. Additional wash bulkheads are to be fitted port and starboard where the width of the tank exceeds 20 m.

5.9.6  The plating is to be suitably stiffened in way of openings, and the arrangement of openings is to be such as to maintain adequate shear rigidity.

5.9.7  The position and height of the after peak bulkhead are to be in accordance with the requirements of 4.4.

5.9.8  Centre and side girders where fitted are to be bracketed to the transom framing members by substantial knees. Hard spots are to be avoided in way of the end connections and care is to be taken to ensure that the stiffening member to which the transom knee is attached can satisfactorily carry the load.

5.10  Bulbous bows

5.10.1  Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure.

5.10.2  At the fore end of the bulb the structure is generally to be supported by horizontal diaphragm plates spaced generally 1,0 m apart in conjunction with a deep centreline web.

5.10.3  In general, vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing.

5.10.4  In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is generally to be fitted.

5.10.5  In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or substantial web frames spaced about five frame spaces apart are generally to be fitted.
5.10.6 The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness is to be the same as that required for plated stems.

Section 6
Machinery space arrangements

6.1 General

6.1.1 Requirements particular to machinery spaces, including protected machinery casings and engine seatings only, are given in this Section. For other scantlings and arrangement requirements, see the relevant Section in this Chapter.

6.1.2 Requirements for the scantlings of structure in machinery spaces are to be in accordance with the relevant sub-Sections of Pt 6, Ch 3,13.

6.1.3 In addition, the requirements of Vol 2, Pt 1, Ch 3,5.1.4 to 5.1.6 are to be complied with.

6.2 Structural configuration

6.2.1 Requirements are given for ships constructed using either a transverse or longitudinal framing system, or a combination of the two.

6.2.2 Machinery space stiffening is generally to be arranged in the same manner as structure immediately forward and aft of the space. For NS1 and NS2 ships this will generally be longitudinal. Machinery spaces adjacent to the aft peak bulkhead may be constructed using a transverse framing system or a combination of longitudinal and transverse.

6.3 Structural continuity

6.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt discontinuities where structure which contributes to the main longitudinal strength of the ship is omitted in way of a machinery space.

6.3.2 Where the longitudinal framing terminates and is replaced by transverse framing, a suitable scarfing arrangement of the longitudinal framing is to be arranged.

6.4 Deck structure

6.4.1 The corners of machinery space openings are to be of suitable shape and design to minimise stress concentrations.

6.4.2 Where a transverse framing system is adopted, deck beams are to be supported by a suitable arrangement of longitudinal girders in association with pillars or pillar bulkheads. Deep beams are to be arranged in way of the ends of engine casings and also in line with side web frames where fitted.

6.4.3 Where a longitudinal framing system is adopted, deck longitudinals are to be supported by deck transverses in association with pillars or pillar bulkheads. The maximum spacing of transverses is given in 6.5.2. Deck transverses are to be in line with side transverses or web frames.

6.4.4 Machinery casings are to be supported in accordance with the requirements of 6.7.

6.4.5 The scantlings of lower decks or flats are generally to be as given in Pt 6, Ch 3,10. However, in way of concentrated loads such as those from boiler bearers or heavy auxiliary machinery, etc., the scantlings of deck structure will be specially considered, taking account of the actual loading.

6.4.6 In way of machinery space openings, etc., particularly towards the aft end, decks or flats are to have sufficient strength where they are intended to provide effective primary support to side framing, webs or transverses.

6.4.7 Where decks terminate at a machinery space bulkhead, suitable scarfing arrangements are to be arranged. The side shell of the machinery space is generally to be supported by a stringer at deck level. The stringer can be either fully effective or acting as part of a grillage. Bulkhead stiffeners at the deck level are to be supported against tripping.

6.4.8 Machinery space bulkheads with no supporting decks are to have suitable primary stiffening similar to that provided for the side shell in 6.5.

6.5 Side shell structure

6.5.1 The side shell structure of machinery spaces is to be effectively supported by a system of primary framing with web frames and stringers. General requirements for web frames are given in this Section for both longitudinal and transverse framing systems.

6.5.2 The maximum spacing of side shell transverses in longitudinally framed machinery spaces is generally not to exceed 2,5 m in NS1 and NS2 ships, and 1,5 m in NS3 ships.

6.5.3 The maximum spacing of side shell web frames in transversely framed machinery spaces is generally not to exceed five frame spaces. They are to extend from the tank top to the level of the lowest deck above the design waterline.

6.5.4 The maximum spacing of stringers is generally not to exceed 3,0 m.
6.6 Double and single bottom structure

6.6.1 For the required extent of double bottom structure, see 3.6.

6.6.2 In the bottom structure sufficient fore and aft girders are to be arranged in way of the main machinery to effectively distribute its weight and to ensure adequate rigidity of the structure. In midship machinery spaces these girders are to extend for the full length of the space and are to be carried aft to support the foremost shaft tunnel bearing. This extension beyond the after bulkhead of the machinery space is to be for at least three transverse frame spaces, aft of which the girders are to scarf into the structure. Forward of the forward machinery space bulkhead, the girders are to be tapered off over three frame spaces and effectively scarfed into the structure. In machinery spaces in the aft end of the ship the girders are to be carried as far aft as practicable and the ends effectively supported by web frames or transverses. Care is to be taken to avoid any abrupt changes or discontinuities.

6.6.3 Where, in NS3 ships, the bottom is transversely framed, plate floors are to be fitted at every frame in the machinery space and under the main machinery, rafts, seatings and thrust bearing.

6.6.4 Where the bottom is longitudinally framed, plate floors are to be fitted at a maximum spacing of 2.5 m in NS1 and NS2 ships, and 1.5 m in NS3 ships in the machinery space under the main machinery, rafts, seatings and thrust bearing.

6.6.5 The minimum depth of the centre girder and its thickness are to be at least the same as required in way of other spaces amidships. Where the height of inner bottom in the machinery spaces differs from that in adjacent spaces, continuity of longitudinal material is to be maintained. In ships with a double bottom it is to be achieved by sloping the inner bottom over an adequate longitudinal extent. The knuckles in the plating are to be arranged close to plate floors.

6.6.6 Margin plates and drainage wells are to be provided as necessary and will be subject to special consideration.

6.6.7 Suitable arrangements are to be made to provide free passage of water from all parts of the bilge to the pump suction. General requirements are given in 3.1.17 to 21.

6.6.8 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with 6.8.

6.6.9 Where practicable side girders outboard of the engines are to be fitted and are to line up with the side girders in adjacent spaces.

6.7 Machinery casings

6.7.1 The scantlings and arrangements of exposed casings protecting machinery openings are to be in accordance with Pt 6, Ch 3,11.

6.7.2 Where casing sides act as girders supporting decks over, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if necessary. Particular care is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

6.7.3 Machinery casings are to be supported by a suitable arrangement of deep beams or transverses and longitudinal girders in association with pillars or pillar bulkheads. In way of particularly large machinery casing openings, cross ties may be required, and these are to be arranged in line with deep beams or transverses. Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably reinforced.

6.7.4 Casing bulkheads are to be made gastight and the access doors are to be of a gastight self-closing type.

6.8 Integral fuel tanks

6.8.1 The scantlings of deep tank bulkheads are to be in accordance with Pt 6, Ch 3,9.

6.8.2 Oil fuel tanks situated within the machinery space are generally to comply with the requirements given in Part 6.

6.9 Machinery seatings

6.9.1 Requirements on the scantlings of structure for machinery seatings is given in Pt 6, Ch 3,13.

6.9.2 This Section applies to machinery or machinery raft seatings that are directly supported by the ship's hull. They are to be effectively secured to the hull and to be of adequate scantlings to resist the various gravitational, thrust, torque, dynamic and vibratory forces which may be imposed on them. Due attention is to be paid to the stiffness requirements of the machinery or raft supported.

6.9.3 Seatings are to be of substantial construction and efficiently supported by transverse and horizontal brackets or gusset plates. These should generally be arranged in line with plate floors and girders in a double bottom or with suitable deep beams or transverses and girders at upper decks. Where applicable seats are to be designed to ensure proper alignment with gearing and allow for thermal expansion effects.

6.9.4 In general seats are not to be arranged in way of breaks or recesses in the bottom structure.

6.9.5 Main machinery or raft holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders. When this cannot be achieved, additional floors are to be fitted.

6.9.6 Auxiliary machinery is to be secured on seating of adequate scantlings, so arranged as to distribute the loadings evenly into the supporting structure.
Section 7

Superstructures, deckhouses, bulwarks, sponsons and appendages

7.1 General

7.1.1 Superstructures, deckhouses, forecastles and bulwarks are to be constructed in accordance with the scantlings indicated in Pt 6, Ch 3,11.

7.1.2 For requirements relating to companionways, doors, accesses and skylights, see Chapter 4.

7.1.3 Requirements for machinery casings are given in 6.7.

7.1.4 For closing arrangements and outfit the requirements are given in Chapter 4.

7.2 Definitions

7.2.1 The term ‘house’ is used to include both superstructures and deckhouses.

7.2.2 The lowest, or first tier of a house, is normally that which is directly situated on the deck to which \( D \), is measured. The second tier is the next tier above the lowest tier and so on.

7.3 Structural requirements

7.3.1 The plating and supporting structure are to be suitably reinforced in way of localised areas of high stress such as corners of openings, cranes, masts, equipment, fittings and other heavy or vibrating loads.

7.3.2 Structures subject to concentrated loads are to be suitably reinforced. Where a concentration of loading on one side of a stiffener may occur, such as pillars out of line, the stiffener is to be adequately stiffened against torsion.

7.3.3 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

7.3.4 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

7.3.5 Transverse rigidity is to be maintained throughout the length of the house by means of web frames, bulkheads or partial bulkheads. Particular care is to be paid when an upper tier is wider than its supporting tier and when significant loads are carried on the house top.

7.3.6 Web frames or partial bulkheads are to be fitted in line with bulkheads or deep primary stiffeners below.

7.3.7 Special attention is to be given to the connection of the erection to the deck in order to provide an adequate load distribution and avoid stress concentrations. The house stiffening is to align with main hull stiffening wherever possible.

7.3.8 Where aluminium erections are arranged above a steel hull, details of the arrangements in way of the bimetallic connections are to be submitted.

7.3.9 Adequate support under the ends of houses is to be provided in the form of webs, pillars and diaphragms or bulkheads in conjunction with reinforced deck beams. At the corners of houses and in way of supporting structures attention is to be given to the connection to the decks and inserts or equivalent arrangements should generally be fitted.

7.4 Openings

7.4.1 All openings are to be substantially framed and have well rounded corners. Arrangements are to be made to minimise the effect of discontinuities in houses. Continuous coamings or girders are to be fitted below and above doors and similar openings. House tops are to be strengthened in way of davits and cranes.

7.4.2 Particular care is to be paid to the effectiveness of end bulkheads and the upper deck stiffening in way when large openings are fitted.

7.4.3 Special care is to be taken to minimise the size and number of openings in the sides or longitudinal bulkheads of houses which end within \( 0.25L_R \) to \( 0.75L_R \). Account is to be taken of the high vertical shear loading which can occur in these areas.

7.4.4 Windows, ventilators and other superstructure openings are to be suitably framed and mullions will in general be required.

7.5 Effective structure

7.5.1 For ships where \( L_R \) exceeds 40 m or for designs where the superstructure is designed to absorb global loads the effectiveness of superstructures to carry these loads is to be determined. The effectiveness may be assessed in accordance with Pt 6, Ch 4,2.5.

7.5.2 When large openings or a large number of smaller openings are cut in the superstructure sides, reducing the capability to transmit shear force between decks, an assessment of structural efficiency may be required. The scantlings of the side structure in way of these areas may also be required to be increased.

7.6 Sponsons and appendages

7.6.1 Primary structure supporting sponsons is to be effectively integrated into the main hull structure. This is to be achieved by extending the primary framing system or by suitable scarfing the sponson primary structure over at least five frame spaces.
8.3.3 Where pillars support eccentric loads, or are subjected to lateral pressures, they are to be suitably strengthened for the additional bending moment imposed upon them.

8.3.4 Doublers are generally to be fitted on decks and inner bottoms, other than within tanks where doublers are not allowed. Brackets or insert plates may be used instead of doublers.

8.3.5 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Holes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided, and where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

8.4 Pillars in tanks

8.4.1 In no circumstances are pillars to pass through tanks. Where loads are to be transmitted through tanks, pillars within the tanks are to be carefully aligned with the external pillars. The tensile stress in the pillar and its end connections is not to exceed 108 N/mm² at the tank test pressure. Such pillars are in general to be of built sections and end brackets may be required.

8.5 Fire aspects

8.5.1 Pillars and pillar bulkheads are to be suitably protected against fire, and capable of resisting fire damage. They are not to be constructed of aluminium.
Ship Control Systems

Section
1 General
2 Rudders
3 Stabiliser arrangements
4 Rudder horns and appendages
5 Fixed and steering nozzles, bow and stern thrust units, ducted propellers
6 Water jet propulsion systems

Section 1

General

1.1 Application

1.1.1 This Chapter applies to all of the ships detailed in the Rules, and requirements are given for rudders, stabilisers, and appendages, nozzles, steering gear, bow and stern thrust unit structure and water jet propulsion systems. For podded propulsion systems, see Vol 2, Pt 4, Ch 4.

1.2 General

1.2.1 The following symbols and definitions are applicable to this Chapter, unless otherwise stated:

\[
\sigma_o = \text{minimum yield stress or 0.5 per cent proof stress of the material, in N/mm}^2\text{ and is not to be taken greater than } 0.7 \sigma_u \text{ or } 450 \text{ N/mm}^2, \text{ whichever is the lesser}\]

where

\[
\sigma_u = \text{ultimate tensile strength of the material, in N/mm}^2.
\]

1.3 Navigation in ice

1.3.1 Where an ice class notation is to be included in the class of a ship, the requirements of Pt 5, Ch 2.4 are to be complied with.

1.4 Materials

1.4.1 The requirements for materials are contained in the Rules for the Manufacture, Testing and Certification of Materials (hereinafter referred to as the Rules for Materials).

1.4.2 Rudder stocks, pintles, coupling flange bolts, keys and cast parts of rudders are assumed to be made of rolled, forged or cast carbon manganese steel in accordance with the Rules for Materials. Where other materials are proposed the scantlings will require to be specially considered on the basis of the Rules.

1.4.3 For rudder stocks, pintles, keys and bolts the minimum yield stress is not to be less than 200 N/mm². The following requirements are based on a material’s yield stress of 235 N/mm². If material is used having a yield stress differing from 235 N/mm² the material factor is to be determined as follows:

\[
K_o = \left(\frac{\sigma_o}{235}\right)^m
\]

where

\[
m = 0.75 \text{ for } \sigma_o > 235 \text{ N/mm}^2 \\
m = 1.0 \text{ for } \sigma_o \leq 235 \text{ N/mm}^2
\]

\[
\sigma_o \text{ is as defined in 1.2.1.}
\]

1.4.4 In order to avoid excessive edge pressures in way of bearings, rudder stock deformations should be kept to a minimum. Where significant reductions in rudder stock diameter due to the application of steels with yield strengths exceeding 235 N/mm² are proposed, final acceptance may require the evaluation of the rudder stock deformations.

Section 2

Rudders

2.1 General

2.1.1 The scantlings of the rudder stock are to be not less than those required by 2.14, 2.15 and 2.16 as appropriate.

2.1.2 For rudders having an increased diameter of rudder stock, see Fig. 3.2.1, the increased diameter is to be maintained to a point as far as practicable above the top of the lowest bearing. This diameter may then be tapered to the diameter required in way of the tiller. The length of the taper is to be at least three times the reduction in radius. Particular care is to be taken to avoid the formation of a notch at the upper end of the taper.

2.1.3 Sudden changes of section or sharp corners in way of the rudder coupling, jumping collars and shoulders for rudder carriers, are to be avoided.

2.2 Definition and symbols

2.2.1 Definitions and symbols for use throughout this Section are indicated in the appropriate tables.

2.3 Direct calculations

2.3.1 Where the rudder is of a novel design, high aspect ratio or the speed of the ship exceeds 45 knots the scantlings of the rudder and rudder stock are to be determined by direct calculation methods incorporating model test results and structural analysis, where considered necessary by Lloyd’s Register (hereinafter referred to as ‘LR’).
2.4 Equivalents

2.4.1 Alternative methods of determining the loads will be specially considered, provided that they are based on model tests, full scale measurements or generally accepted theories. In such cases, full details of the methods used are to be provided when plans are submitted for appraisal.

2.5 Rudder arrangements

2.5.1 Rudders considered are the types shown in Fig. 3.2.1, of double plate or single plate construction, constructed from steel. Other rudder types and materials will be subject to special consideration.

2.6 Rudder profile coefficient, $K_2$

2.6.1 The rudder profile coefficient, $K_2$, for use in the determination of rudder force and rudder torque is to be as indicated in Table 3.2.1.

<table>
<thead>
<tr>
<th>Design criteria (see Fig. 3.2.2)</th>
<th>$K_2$ ahead condition</th>
<th>$K_2$ astern condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal profile</td>
<td>1.0</td>
<td>0.97</td>
</tr>
<tr>
<td>Hollow profile</td>
<td>1.25</td>
<td>1.12</td>
</tr>
<tr>
<td>High lift profile</td>
<td>1.7</td>
<td>To be specifically considered</td>
</tr>
</tbody>
</table>

Symbols

$K_2 = \text{rudder profile coefficient for use in 2.11.1}$

NOTE Where a rudder is behind a fixed nozzle, the value of $K_2$, given above, is to be multiplied by 1.3.

2.7 Rudder angle coefficient, $K_3$

2.7.1 The rudder angle coefficient, $K_3$, for use in the determination of rudder force and rudder torque is to be as indicated in Table 3.2.2.

<table>
<thead>
<tr>
<th>Rudder angle</th>
<th>$2 \times 35^\circ$</th>
<th>$2 \times 45^\circ$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_3$</td>
<td>1.0</td>
<td>1.23</td>
</tr>
</tbody>
</table>

Symbols

$K_3 = \text{rudder coefficient. Intermediate values may be obtained by interpolation}$

2.8 Rudder position coefficient, $K_4$

2.8.1 The rudder position coefficient, $K_4$, for use in the determination of rudder force and rudder torque is to be as indicated in Table 3.2.3.
2.9 Rudder speed coefficient, $K_5$

2.9.1 The rudder speed coefficient, $K_5$, for use in the determination of rudder force and rudder torque is to be as indicated in Table 3.2.4.

2.10 Centre of pressure

2.10.1 The position of the centre of pressure for use in the determination of the rudder torque is to be as indicated in Table 3.2.5.

2.11 Rudder force, $F_R$

2.11.1 The rudder force, $F_R$, for use in the determination of the rudder scantlings is not to be taken less than that determined from the following formula:

$$F_R = 0.132K_1K_2K_3K_4K_5A_RV^2 \text{ kN}$$

where

$$F_R = \text{rudder force, in kN}$$

$K_1$ is a factor depending on the aspect ratio $\lambda$ of the rudder area

$$\lambda = \frac{y_R^2}{A_R}$$

$y_R$ is the mean height of the rudder area, in metres. Mean breadth and mean height of rudder are to be determined from Fig. 3.2.3

$A_R$ = area of rudder blade, in m$^2$

Symbol $K_5$ rudder speed coefficient for use in 2.11.1

2.12 Symbols

$V$ = maximum design speed for short-term high power operations, in knots. When the speed is less than 8 knots, $V$ is to be replaced by the expression:

$$V_{min} = \frac{(V + 16)}{3} \text{ knots}$$

For the astern condition the maximum astern speed, $V_A$, is to be used. $V_A \geq 0.5V$ knots.

Table 3.2.3 Rudder position coefficient, $K_4$

<table>
<thead>
<tr>
<th>Design criteria</th>
<th>$K_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahead condition</td>
<td>0.8</td>
</tr>
<tr>
<td>Rudder out of propeller slipstream</td>
<td>0.8</td>
</tr>
<tr>
<td>Rudder in propeller slipstream</td>
<td>1.0</td>
</tr>
<tr>
<td>Rudder behind fixed propeller nozzle</td>
<td>1.15</td>
</tr>
</tbody>
</table>

Table 3.2.4 Rudder speed coefficient, $K_5$

<table>
<thead>
<tr>
<th>Design criteria</th>
<th>$K_5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ships with $V \sqrt{L/W_L} &lt; 3.0$</td>
<td>1.00</td>
</tr>
<tr>
<td>Ships with $V \sqrt{L/W_L} \geq 3.0$</td>
<td>$(1.12 - 0.005V^3)$</td>
</tr>
</tbody>
</table>

Table 3.2.5 Position of centre of pressure

<table>
<thead>
<tr>
<th>Design criteria</th>
<th>Value of $x_{PF}$ and $x_{PA}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectangular rudders;</td>
<td></td>
</tr>
<tr>
<td>(a) Ahead condition</td>
<td>$x_{PF} = (0.33e_l y_R - x_A)$, but not less than 0.12$y_R$</td>
</tr>
<tr>
<td>(b) Astern condition</td>
<td>$x_{PA} = (x_A - 0.25x_B)$, but not less than 0.12$y_R$</td>
</tr>
<tr>
<td>Non-rectangular rudders;</td>
<td></td>
</tr>
<tr>
<td>(a) Ahead condition</td>
<td>$x_{PF}$ and $x_{PA}$ are to be calculated from geometric form (see Note)</td>
</tr>
<tr>
<td>(b) Astern condition</td>
<td>but not less than: $0.12A_R y_R$</td>
</tr>
</tbody>
</table>

NOTE

For rectangular strips the centre of pressure is to be assumed to be located as follows:

(a) 0.33$e_l y_R$ abaft leading edge of strip for ahead condition.

(b) 0.25$y_R$ from aft edge of strip for astern condition.
2.12 Rudder torque, $Q_R$

2.12.1 The rudder torque, $Q_R$, for rudders without cut-outs in the ahead condition may be determined from the following formula:

$$Q_R = F_R x_{PF} \text{ kNm}$$

where

$F_R = \text{rudder force, in kN}$

$x_{PF} = \text{horizontal distance from the centreline of the rudder pintles or axle, to the centre of pressure in the ahead condition, in metres, see Table 3.2.5.}$

2.12.2 The rudder torque, $Q_R$, for rudders without cut-outs in the astern condition may be determined from the following formula:

$$Q_R = F_R x_{PA} \text{ kNm}$$

where

$x_{PA} = \text{horizontal distance from the centreline of the rudder pintles or axle, to the centre of pressure in the astern condition, in metres, see Table 3.2.5.}$

$F_R = \text{rudder force, in kN.}$

2.12.3 For rudders with cut-outs the rudder area, $A_R$, used in the derivation of the rudder torque may be divided into two rectangular or trapezoidal parts with areas $A_1$ and $A_2$, so that $A_R = A_1 + A_2$, see Fig. 3.2.1.

2.12.4 The rudder torque, $Q_R$, for rudders with cut-outs in the ahead condition may be determined from the following formula:

$$Q_R = Q_1 + Q_2 \text{ kNm}$$

where

$Q_1 = F_{R1} x_{PF1} \text{ kNm}$

$Q_2 = F_{R2} x_{PF2} \text{ kNm}$

$F_{R1} = \frac{A_1}{A_R} \text{ kN}$

$F_{R2} = \frac{A_2}{A_R} \text{ kN}$

$F_{RF} = \text{rudder force in the ahead condition determined from 2.2.1, in kN}$

$x_{PF1} = b_{R1} (\alpha - k_1), \text{ in metres}$

$x_{PF2} = b_{R2} (\alpha - k_2), \text{ in metres}$

$\alpha = \text{as given in Table 3.2.6 for the ahead condition}$

$k_1 = \frac{A_1}{A_1}$

$k_2 = \frac{A_2}{A_2}$

$A_{1f}, A_{2f}$ are shown in Fig. 3.2.4.

2.12.5 The rudder torque, $Q_R$, for rudders with cut-outs in the astern condition may be determined from the following formula:

$$Q_R = Q_1 + Q_2 \text{ kNm}$$

where

$Q_1 = F_{R1} x_{PA1} \text{ kNm}$

$Q_2 = F_{R2} x_{PA2} \text{ kNm}$

$F_{R1} = \frac{A_1}{A_R} \text{ kN}$

$F_{R2} = \frac{A_2}{A_R} \text{ kN}$

$F_{RA} = \text{rudder force in the astern condition determined from 2.2.1, in kN}$

$x_{PA1} = b_{R1} (\alpha - k_1), \text{ in metres}$

$x_{PA2} = b_{R2} (\alpha - k_2), \text{ in metres}$

$\alpha = \text{as given in Table 3.2.6 for the astern condition}$

$k_1 = \frac{A_1}{A_1}$

$k_2 = \frac{A_2}{A_2}$

$A_{1f}, A_{2f}$ are shown in Fig. 3.2.4.

### Table 3.2.6 Coefficient, $\alpha$

<table>
<thead>
<tr>
<th>Condition</th>
<th>Behind fixed structure (see Note)</th>
<th>Not behind a fixed structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahead</td>
<td>0.25</td>
<td>0.33</td>
</tr>
<tr>
<td>Astern</td>
<td>0.55</td>
<td>0.66</td>
</tr>
</tbody>
</table>

**NOTE**

For rudder parts behind a fixed structure such as a rudder horn.
2.13 Rudder bending moment, \( M_R \)

2.13.1 For spade rudders, Type (b) in Fig. 3.2.1 the bending moment, \( M_R \), may be determined from the following formula:

\[
M_R = F_R \left( y_1 + \frac{y_3 \left( 2x_l + x_u \right)}{3 \left( x_l + x_u \right)} \right) \quad \text{kNm}
\]

where

- \( F_R \) is as given in 2.11.1
- \( y_1 \), \( y_3 \), \( x_l \) and \( x_u \) are rudder dimensions, in metres, see Fig. 3.2.5.

2.13.2 For rudders supported by a rudder horn, Type (a) in Fig. 3.2.1 the bending moment, \( M_R \), may be determined from the following formula:

\[
M_R = 0.125 F_R \left( y_1 + y_2 \right) \quad \text{kNm}
\]

where

- \( F_R \) is as given in 2.11.1
- \( y_2 \) is a rudder dimension, in metres, see Fig. 3.2.6.

2.13.3 For semi-spade/mariner rudders, Type (c) in Fig. 3.2.1, the bending moment, \( M_R \), may be determined from the following formula:

\[
M_R = F_R \frac{h_R}{10 \left( 1 + \frac{b_R^2}{A_R} \right)} \quad \text{kNm}
\]

where

- \( F_R \) = rudder force determined from 2.2.1, in kN
- \( h_R \) = mean height of rudder, in metres, see Fig. 3.2.3
- \( b_R \) = mean breadth of rudder, in metres, see Fig. 3.2.3.

2.14 Rudder stock diameter in way of the tiller, \( d_{su} \)

2.14.1 The torsional stress in the rudder stock, \( \tau_t \), in way of the tiller is not to exceed that determined from the following:

\[
\tau_t = 68K_o \quad \text{N/mm}^2
\]
2.14.2 The rudder stock diameter in way of the tiller, $d_{su}$, is to be not less than that determined from the formula:

$$d_{su} = 42 \sqrt[3]{\frac{Q_R}{K_0}} \text{ mm}$$

where

- $Q_R = $ rudder torque (in the appropriate condition), in kNm, as given in 2.12
- $K_0 = $ material factor, as defined in 1.4.3.

2.15 Rudder stock diameter $d_s$

2.15.1 For a rudder stock subjected to combined torque and bending, the equivalent stress in the rudder stock is not to exceed that determined from the following:

$$\sigma_e = 118K_o \text{ N/mm}^2$$

The equivalent stress is to be determined by the formula:

$$\sigma_e = \sqrt{\sigma_b^2 + \frac{3}{2} \tau_t^2} \text{ N/mm}^2$$

where

- $\sigma_b = $ bending stress:
  $$\sigma_b = 10200 \times 10^3 \text{ N/mm}^2$$
- $\tau_t = $ torsional stress:
  $$\tau_t = 5100 \times 10^3 \text{ N/mm}^2$$

2.15.2 The basic rudder stock diameter, $d_s$, at and below the lowest bearing is not to be less than that determined from the following:

$$d_s = d_{su} \sqrt[6]{1 + \frac{4}{3} \left( \frac{M_R}{Q_R} \right)^2} \text{ mm}$$

where

- $d_{su} = $ diameter of the rudder stock in way of the tiller, in mm
- $M_R = $ rudder bending moment, kNm, see 2.13
- $Q_R = $ rudder torque (in the appropriate condition), in kNm, as given in 2.12.

2.16 Rudder stock (tubular)

2.16.1 Tubular rudder stock scantlings are to be not less than that necessary to provide the equivalent strength of a solid stock as required by 2.14.2 and 2.15.2 as appropriate, and can be calculated from the following formula:

$$d_e = \sqrt[6]{\frac{d_1^4 - d_2^4}{d_1}} \text{ mm}$$

where

- $d_e = $ the diameter of the equivalent solid rudder stock, in mm
- $d_1, d_2 = $ external and internal diameters, respectively of the tubular stock, in mm.

2.17 Single plate rudders

2.17.1 The scantlings of a single plate rudder are to be not less than required by Table 3.2.7.

### Table 3.2.7 Single plate rudder construction

<table>
<thead>
<tr>
<th>Item</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blade thickness</td>
<td>$t_B = 0.0015Vs + 2.5 \text{ mm}$ with a minimum of 10 mm</td>
</tr>
<tr>
<td>Arms</td>
<td>Spacing ≤ 1000 mm</td>
</tr>
<tr>
<td></td>
<td>$Z_A = 0.0005V^2x_a^2 \text{ s cm}^3$</td>
</tr>
<tr>
<td>Mainpiece</td>
<td>Diameter = $d_s \text{ mm}$</td>
</tr>
<tr>
<td></td>
<td>For spade rudders, the lower third may taper down to 0.75$d_s \text{ mm}$</td>
</tr>
</tbody>
</table>

2.17.2 Rudder arms are to be efficiently attached to the mainpiece.

2.18 Double plate rudders

2.18.1 The scantlings of a double plated rudder are to be not less than required by Table 3.2.8.

2.18.2 In way of rudder couplings and heel pintles the plating thickness is to be suitably increased.

2.18.3 Adequate hand or access holes are to be arranged in the rudder plating in way of pintles as required and the rudder plating is to be reinforced locally in way of these openings. Continuity of the modulus of the rudder mainpiece is to be maintained in way of the openings.

2.18.4 Connection of rudder side plating to vertical and horizontal webs, where internal access for welding is not practicable, is to be by means of slot welds on to flat bars on the webs. The slots are to have a minimum length of 75 mm and in general, a minimum width of twice the side plating thickness. The ends of the slots are to be rounded. The space between the slots is not to exceed 150 mm and welding is to be based on a weld factor of 0.44.

2.18.5 On semi-spade/mariner type rudders the following items are to be complied with:

(a) The main vertical web forming the mainpiece is to be continuous over the full depth of the rudder.

(b) The thickness of the main vertical web is to be not less than two times the thickness required by Table 3.2.8(5) from the top of the rudder to the lower pintle. The thickness is to be not less than required by Table 3.2.8(5) from the lower pintle to approximately a point midway between the lower pintle and bottom of the rudder. Below this the thickness, $t_2$, is to be not less than the thickness required by Table 3.2.8(2). See Fig. 3.2.7.
(c) Where an additional continuous main vertical web is arranged to form an efficient box mainpiece structure, the thickness of each web is to be not less than that required by Table 3.2.8(5) from the top of the rudder to approximately a point midway between the lower pintle and bottom of the rudder. Below this thickness, \( t_2 \), is not to be less than that required by Table 3.2.8(2).

(d) The internal radius, \( r \), of the cut-out for the rudder pintle is to be as large as practicable. See Fig. 3.2.7.

(e) To reduce the notch effect at the corners of the cut-out for the lower pintle, an insert plate 1.6 times the Rule thickness of the side plating is to be fitted. The insert plate is to extend aft of the main vertical web and to have well rounded corners.

2.19 Cast metal rudders

2.19.1 Where rudders are cast, the mechanical and chemical properties of the metal are to be submitted for approval. If the rudder stock is cast integral with the rudder blade, abrupt changes of section and sharp corners are to be avoided.

### Table 3.2.8 Double plated rudder construction

<table>
<thead>
<tr>
<th>Item</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Side plating</td>
<td>( t = 0.0224 \beta \sqrt{\frac{P_R}{10k}} + 2.5 \text{ mm} )</td>
</tr>
<tr>
<td>(2) Webs – vertical and horizontal</td>
<td>As (1) above</td>
</tr>
<tr>
<td>(3) Top and bottom plates</td>
<td>As (1) above using ( s = \text{maximum rudder width, in mm, at top or bottom, but not less than 900 mm.} )</td>
</tr>
<tr>
<td>(4) Nose plates</td>
<td>( t_N \geq 1.25t \text{ from (1) above} )</td>
</tr>
<tr>
<td>(5) Mainpiece – fabricated rectangular</td>
<td>Breadth and width ( \geq d_s ) \n[ t_M = (8.5 + 0.56 \sqrt{d_s}) \text{ mm} ] \nMinimum fore and aft extent of side plating = 0.2( x_B ) \nStress due to bending, see Table 3.2.10</td>
</tr>
<tr>
<td>(6) Mainpiece – tubular</td>
<td>Inside diameter ( \geq d_s ) \n( t_M ) as for (5) above \nSide plating as for (1) above \nBending stress as for (5) above</td>
</tr>
<tr>
<td>(7) Testing</td>
<td>Pressure ( 2.45 \text{ m head and rudder should normally be tested while laid on its side} ) \nLeak (air pressure) ( 0.02 \text{ N/mm}^2 ) and arrangements made to ensure that no pressure in excess of 0.03 N/mm(^2) can be applied</td>
</tr>
</tbody>
</table>

#### Symbols

| \( \beta = A_a (1 - 0.25A_a) \) |
| \( A_a = \) panel aspect ratio, but is not to be taken as greater than 2.0 |
| \( t = \) thickness, in mm |
| \( s = \) spacing, in mm, of the webs, arms or stiffeners, but is not to exceed 900 mm |
| \( d_s = \) basic stock diameter, given by 2.15.2, in mm |
| \( t_N = \) thickness, in mm, of nose plate |
| \( t_M = \) thickness, in mm, of side plating and vertical webs forming mainpiece |
| \( x_B = \) breadth of rudder, in metres, on centreline of stock |
| \( P_R = \) rudder pressure |
| \( = 10T + \frac{F_R}{A_R} \text{ kN/m}^2 \) |
| \( T = \) is as detailed in Ch 1,5.2.9 |
| \( F_R = \) rudder force, in kN, given by 2.11 |
| \( A_R = \) area of rudder blade, in m\(^2\), given in 2.11.1 |

2.20 Rudder stock and bearings

2.20.1 Bearings are to comply with the requirements of Table 3.2.9. The fitting of bearings is to be carried out in accordance with the manufacturer’s recommendations to ensure that they remain secure under all foreseeable operating conditions.

2.21 Bearings

2.21.1 Bearings are to be of approved materials and effectively secured to prevent rotational and axial movement.

2.21.2 Synthetic rudder stock bearing materials are to be of a type approved by LR.

2.21.3 Where it is proposed to use stainless steel bearings for rudder stocks, the chemical composition is to be submitted for approval.
When stainless steel bearings are used, arrangements to ensure an adequate supply of sea-water to the bearing are to be provided.

When the rudder stock or liner is grade 316L austenitic stainless steel, it is recommended that gunmetal, lignum vitae or a synthetic bearing material be used in the bush. If a stainless steel is used in the bush, it is to be of a different grade and with an adequate hardness difference. The use of a ferritic/austenitic duplex structure stainless steel is recommended for the bush, but 17 per cent to 30 per cent chromium stainless steels are also suitable.

---

**Table 3.2.9  Bearing requirements**

<table>
<thead>
<tr>
<th>Item</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing Length</td>
<td>Depth $Z_B$, in mm</td>
</tr>
<tr>
<td></td>
<td>$1.5d_s \geq Z_B \geq 1.0d_s$</td>
</tr>
<tr>
<td>Main bearing wall thickness</td>
<td>The lesser of $0.2d_s$ or 100 mm (see Note 1)</td>
</tr>
<tr>
<td>Bearing pressure (on the projected area, where the projected area is to be taken as the length x diameter)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bearing material</td>
</tr>
<tr>
<td></td>
<td>Metal</td>
</tr>
<tr>
<td></td>
<td>Synthetic</td>
</tr>
<tr>
<td>Clearance</td>
<td>Bearing material</td>
</tr>
<tr>
<td></td>
<td>Metal (see Note 4)</td>
</tr>
<tr>
<td></td>
<td>Synthetic (see Note 5)</td>
</tr>
<tr>
<td></td>
<td>but not less than 1.5</td>
</tr>
</tbody>
</table>

**Symbols**

$d_s$ = stock diameter, given by 2.15.2, in mm

**NOTES**

1. Where web stiffening is fitted on the bearing, a reduction in wall thickness will be considered.
2. Proposals for higher pressures or other materials will be specially considered on the basis of satisfactory test results.
3. Value of proposed minimum clearance is to be indicated on plans submitted for approval.
4. For bearings which are pressure lubricated the clearance must be restricted to enable the pressure to be maintained.
5. If non-metallic bearing material is applied, the bearing clearance is to be specially determined considering the material’s swelling and thermal expansion properties. This clearance is not to be taken less than 1.5 on bearing diameter unless a smaller clearance is supported by the manufacturer’s recommendation and there is documented evidence of satisfactory service history with a reduced clearance.

---

Fig. 3.2.7  Main vertical web thickness

$t_1 = \text{Table 3.2.8(5)}$

$t_2 = \text{Table 3.2.8(2)}$

$t_1 = \text{Table 3.2.8(5)}$

$t_2 = \text{Table 3.2.8(2)}$
2.23 Special attention is to be paid to the fit of the pintle taper into its socket. To facilitate removal of the pintles, it is recommended that the taper is to be not less than half the maximum value given in Table 3.2.11.

2.23.4 The distance between the lowest rudder stock bearing and the upper pintle is to be as short as possible.

2.23.5 Where liners are fitted to pintles, they are to be shrunk on or otherwise efficiently secured. If liners are to be shrunk on, the shrinkage allowance is to be indicated on the plans. Where liners are formed by stainless steel weld deposit, the pintles are to be of weldable quality steel and details of the procedure are to be submitted.

2.23.6 Where an *IWS (In-water Survey) notation is to be assigned, see 2.40.

2.23.7 The bottom pintle on semi-spade (Mariner) type rudders are:
(a) if inserted into their sockets from below, to be keyed to the rudder or sternframe as appropriate or to be hydraulically assembled, with the nut adequately locked, or
(b) if inserted into their sockets from above, to be provided with an appropriate locking device, the nut being adequately secured.

2.24 Bolted couplings

2.24.1 Rudder coupling design is to be in accordance with Table 3.2.12.

2.24.2 Where coupling bolts are required they are to be fitted bolts. Suitable arrangements are to be made to lock the nuts.

---

**Table 3.2.10 Permissible stresses for rudder blade scantlings**

<table>
<thead>
<tr>
<th>Item</th>
<th>Permissible stresses, in N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bending stress</td>
</tr>
<tr>
<td>Rudder blades clear of cut-outs, see Fig. 13.2.3</td>
<td>$110K_0$</td>
</tr>
<tr>
<td>Rudder blades in way of cut-outs, see Fig. 13.2.3 and Note</td>
<td>$75K_0$</td>
</tr>
</tbody>
</table>

**Symbols**

$K_0$ is as defined in 1.4.3

**NOTE**

Requirements in way of cut-outs apply to semi-spade/mariner type rudders.

---

**Fig. 3.2.8**

Lower pintle housed above rudder gudgeon
### Table 3.2.11  Pintle requirements

<table>
<thead>
<tr>
<th>Item</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Pintle diameter (measured outside liner if fitted)</td>
<td>[d_{\text{PL}} = \sqrt{\left(\frac{235}{\sigma_0}\right)^m \left(31 + 4.17V \sqrt{A_{\text{PL}}K_2}\right)} \text{ mm}] For single pintle rudders and lower pintle of semi-spade rudders: [A_{\text{PL}} = \frac{A_R C_{\text{CP}}}{C_{\text{PL}}} \text{ m}^2] but for semi-spade rudders need not be taken greater than (A_R) Upper pintle on semi-spade rudders: [A_{\text{PL}} = \left(1 - \frac{C_{\text{CP}}}{C_{\text{PL}}}\right) \text{ m}^2] or (0.35A_R \text{ m}^2) whichever is greater</td>
</tr>
<tr>
<td>(2) Maximum pintle taper</td>
<td>Method of assembly Taper (on diameter)</td>
</tr>
<tr>
<td></td>
<td>Manual assembly, key fitted (pintle ≤ 200 mm diameter)</td>
</tr>
<tr>
<td></td>
<td>Manual assembly, key fitted (pintle ≥ 400 mm diameter)</td>
</tr>
<tr>
<td></td>
<td>For keyed and other manually assembled pintles with diameters between 200 mm and 400 mm, the taper is to be obtained by interpolation.</td>
</tr>
<tr>
<td></td>
<td>Hydraulic assembly, dry fit</td>
</tr>
<tr>
<td></td>
<td>Hydraulic assembly, oil injection</td>
</tr>
<tr>
<td>(3) Bearing length</td>
<td>[Z_{\text{PB}} \geq 1.2d_{\text{PL}} \text{ mm}] May be less for very large pintles if bearing pressure is not greater than that given in (4), but (Z_{\text{PB}}) must be not less than (1.0d_{\text{PL}} \text{ mm})</td>
</tr>
<tr>
<td>(4) Bearing pressure (on projected area)</td>
<td>Bearing material Pressure</td>
</tr>
<tr>
<td></td>
<td>Metal</td>
</tr>
<tr>
<td></td>
<td>Synthetic</td>
</tr>
<tr>
<td></td>
<td>Using force acting on bearing: [P_{\text{PL}} = \frac{A_{\text{PL}}F_R}{A_R} \text{ kN}] (A_{\text{PL}}) as for item (1) (A_R) and (F_R) are as defined in 2.11.1</td>
</tr>
<tr>
<td>(5) Gudgeon thickness in way of pintle (measured outside bush if fitted)</td>
<td>[b_G \geq 0.5d_{\text{PL}} \text{ mm but need not normally exceed 125 mm}]</td>
</tr>
<tr>
<td>(6) Pintle clearance (note should be taken of the manufacturer’s recommended clearances particularly where bush material requires pre-soaking). Value of proposed minimum clearance is to be indicated on plans submitted for approval.</td>
<td>Bearing material Minimum clearance, mm</td>
</tr>
<tr>
<td></td>
<td>Metal</td>
</tr>
<tr>
<td></td>
<td>Synthetic</td>
</tr>
</tbody>
</table>

**Symbols**

- \(d_{\text{PL}}\) = pintle diameter, in mm
- \(K_2\) = rudder profile coefficient, as given in Table 3.2.1
- \(V\) = as defined in 2.11.1 but not less than 10 knots
- \(A_{\text{PL}}\) = rudder area supported by the pintle, in \(\text{m}^2\)
- \(A_R\) = rudder area, in \(\text{m}^2\)
- \(C_{\text{CP}}, C_{\text{PL}}\) = dimensions in metres, as indicated in Fig. 3.2.8
- \(Z_{\text{PB}}\) = pintle bearing length, in mm
- \(P_{\text{PL}}\) = force acting on bearing, in kN
- \(b_G\) = thickness of gudgeon material in way of pintle, in mm
- \(m\) = as defined in 1.4.3
- \(\sigma_0\) = as defined in 1.2.1

**NOTE**

Proposals for higher pressures or other materials will be specially considered on the basis of satisfactory test results.
2.24.3  For rudders with horizontal coupling arrangements the rudder stock should be forged when the stock diameter exceeds 350 mm. Where the stock diameter does not exceed 350 mm the rudder stock may be either forged or fabricated. Where the upper flange is welded to the rudder stock, a full penetration weld is required and its integrity is to be confirmed by non-destructive examination. The flange material is to be from the same welding materials group as the stock. Such rudder stocks are to be subjected to a furnace post-weld heat treatment (PWHT) after completion of all welding operations. For carbon or carbon manganese steels, the PWHT temperature is not to be less than 600°C.

2.24.4  For a spade rudder the fillet radius between the rudder stock and the flange is to conform to the requirements of Fig. 3.2.10. Where space permits between the upper face of the flange and the lower rudder stock bearing, it is preferable to use a compound fillet design of the parabolic or Morgenbrod form having similar dimensions to those of Fig. 3.2.10. Alternative arrangements will be specially considered.

2.24.5  The connecting bolts for coupling the rudder to the rudder stock are to be positioned with sufficient clearance to allow the fitting and removal of the bolts and nuts without contacting the palm radius, $R$, see Fig. 3.2.9. The surface forming the palm radius is to be free of hard and sharp corners and is to be machined smooth to the Surveyor’s satisfaction. The surface in way of bolts and nuts is to be machined smooth to the Surveyor’s satisfaction.

2.24.6  For spade rudders fitted with a fabricated rectangular mainpiece, the mainpiece is to be designed with its forward and aft transverse sections at equal distances forward and aft of the rudder stock transverse axis, see Fig. 3.2.9(b).

### Table 3.2.12  Rudder couplings to stock (see continuation)

<table>
<thead>
<tr>
<th>Arrangement</th>
<th>Parameter</th>
<th>Requirement</th>
<th>Horizontal coupling</th>
<th>Vertical coupling</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Bolted couplings (see Note 4)</td>
<td>$n$</td>
<td>$\geq 6$</td>
<td>$\geq 8$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$d_b$</td>
<td>$0.65d_s\sqrt{n}$</td>
<td>$0.81d_s\sqrt{n}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$m$</td>
<td>$0.00071n d_s d_b^2$</td>
<td>$0.00043d_s^3$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$l_f$</td>
<td>$\geq d_b$</td>
<td>$d_b$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\alpha_{max}$ (see Note 2)</td>
<td>$(53.82 - 35.29 K_o) - \frac{d_s^3}{F_R h 10^6} - \left(1.8 - 6.3 \frac{R}{d_s}\right)\frac{h - l_{fa}}{l_{fa}}$</td>
<td>$-$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\alpha_{as built}$ (see Note 2)</td>
<td>$\leq \alpha_{max}$</td>
<td>$-$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$w_f$</td>
<td>$0.67d_b$</td>
<td>$0.67d_b$</td>
<td></td>
</tr>
</tbody>
</table>

(2) Conical couplings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta_t$</td>
<td>$\leq \frac{1}{K_1}$</td>
</tr>
<tr>
<td>$l_t$</td>
<td>$\geq 1.5d_s$</td>
</tr>
<tr>
<td>$\sigma_{GM}$</td>
<td>$P_R \theta_t d_{STM} + 4Q_R l_t \left[ K_2 \left( \frac{P_R d_{STM}}{2Q_R} \right)^2 + 1 \right] - \left( \theta_t \frac{\theta_t}{2} \right)^2 $</td>
</tr>
<tr>
<td>$w$</td>
<td>$\frac{9.6 \sigma_{GM} d_{STM} \theta_t}{\theta_t (1 - f_m^2)} \times 10^{-6}$</td>
</tr>
<tr>
<td>$P_u$</td>
<td>Approximately equal to $2.83 \sigma_{GM} l_t d_{STM} \left( K_3 + \frac{\theta_t}{2} \right)$</td>
</tr>
<tr>
<td>$P_o$</td>
<td>Approximately equal to $2.83 \sigma_{GM} l_t d_{STM} \left( K_3 - \frac{\theta_t}{2} \right)$</td>
</tr>
<tr>
<td>$\sigma_o$</td>
<td>$\geq 12.35 \times 10^4 \frac{w \theta_t \sqrt{3 + f_t^2}}{d_{STM}}$</td>
</tr>
</tbody>
</table>
2.25 Conical couplings

2.25.1 Where a rudder stock is connected to a rudder by a keyless fitting, the rudder is to be a good fit on the rudder stock cone. During the fit-up, and before the push-up load is applied, an area of contact of at least 90 per cent of the theoretical area of contact is to be achieved and this is to be evenly distributed. The relationship of the rudder to stock at which this occurs is to be marked and the push-up then measured from that point. The upper edge of the upper mainpiece bore is to have a slight radius. After final fitting of the stock to the rudder, positive means are to be used for locking the securing nut to the stock.

2.25.2 Where a keyed tapered fitting of a rudder stock to a rudder is proposed, a securing nut of adequate proportions is to be provided. After final fitting of the stock to the rudder, positive means are to be used for locking this nut.

2.26 Rudder carrier arrangements

2.26.1 The weight of the rudder is to be supported at the heel pintle or by a carrier attached to the rudder head. The hull structure supporting the carrier bearing is to be adequately strengthened. The plating under all rudder-head bearings or rudder carriers is to be increased in thickness.

2.27 Anti-jump collars

2.27.1 Suitable arrangements are to be provided to prevent the rudder from lifting.

2.27.2 Jumping collars are not to be welded to the rudder stock.

Table 3.2.12  Rudder couplings to stock (continued)

<table>
<thead>
<tr>
<th>Symbols</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n$</td>
<td>number of bolts in coupling</td>
</tr>
<tr>
<td>$d_b$</td>
<td>diameter of coupling bolts, in mm</td>
</tr>
<tr>
<td>$d_{su}$</td>
<td>rudder stock diameters as defined in 2.15 and 2.14 respectively</td>
</tr>
<tr>
<td>$m$</td>
<td>first moment of area of bolts about centre of coupling, in cm$^3$</td>
</tr>
<tr>
<td>$t_f$</td>
<td>thickness of coupling flange, in mm</td>
</tr>
<tr>
<td>$w_f$</td>
<td>width of flange material outside the bolt holes, in mm</td>
</tr>
<tr>
<td>$K_o$</td>
<td>rudder stock material factor see 1.4.3</td>
</tr>
<tr>
<td>$h$</td>
<td>vertical distance between the centre of pressure and the centre point of the palm radius, $R$, in metres, see Fig. 3.2.9(a)</td>
</tr>
<tr>
<td>$R$</td>
<td>palm radius between rudder stock and connected flange not smaller than $d_b/10$ in mm</td>
</tr>
<tr>
<td>$d_{tb}$</td>
<td>as built flange thickness, in mm</td>
</tr>
<tr>
<td>$d_{fmax}$</td>
<td>maximum allowable stress concentration factor</td>
</tr>
<tr>
<td>$d_{as}$</td>
<td>stress concentration factor for as built scantlings</td>
</tr>
</tbody>
</table>

$K_1, K_2, K_3 = \text{constants depending on the type of assembly adopted as follows:}$

<table>
<thead>
<tr>
<th>Type</th>
<th>$K_1$</th>
<th>$K_2$</th>
<th>$K_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil injection method with key</td>
<td>15</td>
<td>0.0064</td>
<td>0.025</td>
</tr>
<tr>
<td>Oil injection method without key</td>
<td>15</td>
<td>0.0036</td>
<td>0.025</td>
</tr>
<tr>
<td>Dry fit method with key</td>
<td>12</td>
<td>0.0128</td>
<td>0.170</td>
</tr>
<tr>
<td>Dry fit method without key</td>
<td>12</td>
<td>0.0072</td>
<td>0.170</td>
</tr>
</tbody>
</table>

NOTES
1. Where materials vary for individual components, scantling calculations for such components are to be based on $d_s$ for the relevant material.
2. For spade rudders with horizontal couplings, $t_f$ is not to be less than $0.33d_s$. The mating plate on the rudder is to have the same thickness as the flange on the stock $d_s$.
3. For a twin spade rudder arrangement with single screw where the rudders are within the slipstream of the propeller:
   (a) the thickness of the palm is not to be less than $0.35d_s$.
   (b) where the stock is welded to the palm plate, the stock diameter, $d_s$ is to be increased by 14%.
4. This requirement is applicable only for spade rudders with horizontal couplings, see Fig. 3.2.9.
2.28 Drain plugs

2.28.1 Where rudders are of plated construction, drain plugs are to be provided to ensure that all compartments can be adequately drained. These plugs are to be locked and details of their scantlings, arrangements and position clearly indicated on the rudder plan.

2.29 Corrosion protection

2.29.1 All metalwork is to be suitably protected against corrosion. This may be by coating or, where applicable, by a system of cathodic protection.

2.29.2 Metalwork is to be suitably cleaned before the application of any coating. Where appropriate, blast cleaning or other equally effective means is to be employed for this purpose.

2.30 Dissimilar materials

2.30.1 Where materials vary for individual components, they are to be compatible to avoid galvanic corrosion. Scantling calculations for the components are to be based on $d_s$ for the relevant material, see 2.15.
2.31 Internal coatings

2.31.1 Internal surfaces of the rudder are to be efficiently coated or the rudder is to be filled with foam plastics. Where it is intended to fill the rudder with plastic foam, details of the foam are to be submitted for consideration.

2.32 Pressure testing

2.32.1 For testing of rudders, see Part 6.

2.33 Tiller arms, quadrants

2.33.1 Tillers and quadrants are to comply with the requirements of Vol 2, Pt 6, Ch 1.

2.33.2 The steering gear is to be mounted on a seat and adequately secured.

2.34 Connecting bars

2.34.1 Connecting bars are to comply with the requirements of Vol 2, Pt 6, Ch 1.

2.35 Keys and keyways

2.35.1 Where the tiller or quadrant is bolted, a key having an effective cross-sectional area in shear of not less than 0.25d_{su} mm^2 is to be fitted. The thickness of the key is to be not less than d_{su}/6 mm. Alternatively, the rudder stock may be machined to a square section in lieu of fitting a key. d_{su} is as defined in 2.14.

2.35.2 Keyways are to extend over the full depth of the tiller boss.

2.35.3 Keyways in the rudder stock are to have rounded ends and the corners at the base of the keyway are to be radiused.

2.36 Stopping arrangements

2.36.1 Suitable rudder stops are to be provided to limit the rudder angle to the desired level port and starboard. These stops are to be of substantial construction and efficiently connected to the supporting structure.

2.37 Novel designs

2.37.1 Where rudders are of a novel design they may be specially considered on the basis of the Rules. Alternatively, the calculations are to be submitted for consideration.

2.38 Rudder tube arrangements

2.38.1 The rudder tube construction is to be of steel.

2.39 Watertight gland

2.39.1 In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided. Rudder trunk boundaries where exposed to the sea are to have a corrosion protection coating applied in accordance with the manufacturer’s instructions.

2.39.2 Where the top of the rudder tube is significantly higher than the deepest load waterline a lesser arrangement of watertightness, such as ‘O’ rings may be accepted.

2.39.3 The watertight gland body may be formed by the top of the fabricated or cast rudder tube; the gland packing being retained against the top bearing or a check in the wall of the rudder tube and is compressed by a gland packet which may be of the flange type, screwed cap or other suitable arrangement.

2.39.4 Alternative arrangements utilising lip seals or ‘O’ rings either in isolation or in combination with one or other of the alternative seal arrangements will be the subject of special consideration.

2.40 In-water Survey requirements

2.40.1 Where in-water surveys are required, notation is to be assigned, (see Pt 1, Ch 2,4.5.5), means are to be provided for ascertaining the rudder pintle and bush clearances and for verifying the security of the pintles in their sockets with the ship afloat.
Section 3

Stabiliser arrangements

3.1 General

3.1.1 This Section details the requirements for fin stabilisers, stabiliser tanks and bilge keel and fins.

3.1.2 The effectiveness of the fin stabilisers are outwith the scope of classification; however their scantlings, arrangements, foundations, supporting structure and watertight integrity are to be examined.

3.1.3 Engineering systems are to comply with the appropriate requirements indicated in Volume 2, as applicable.

3.1.4 The general structure of the fin stabiliser is to comply with the Rule requirements for rudders.

3.1.5 Fin stabilisers are to be contained between watertight bulkheads.

3.1.6 For non-retractable type stabilisers, the watertight bulkheads forming the forward and aft extent of the compartment are to be arranged not less than one third of the root chord length, \( C \), from the fore and aft most extents of the stabiliser, see Fig. 3.3.1. This requirement exists in order to ensure limited flooding in the event of hull damage in way of the fin. Alternate arrangements which are considered to be equivalent to the Rule requirements will be accepted.

3.1.7 For retractable type stabilisers, the watertight bulkheads forming the forward and aft extent of the compartment are to be arranged not less than the total length of the stabiliser (measured from the extreme end of the shaft to the blade tip) from the centreline of the stabiliser shaft.

3.1.8 For non-retractable type stabilisers, a separate watertight box surrounding the shell entry point may be required if the stabiliser is located adjacent to a critical compartment. No stabiliser box is needed if the compartment which it is in has adequate pumping arrangements and the ship has at least a one compartment flooded damage capability.

3.1.9 Where a watertight box surrounding the shell entry point is required, it is to extend longitudinally not less than the minimum bulkhead positions defined in 3.1.6 and vertically to ensure complete enclosure of the machinery and allow adequate inspection, see Fig. 3.3.1.

3.1.10 For both retractable and non-retractable type stabilisers the compartment in which the stabilisers are fitted is to contain a water ingress detector and alarm.

3.1.11 Fin stabiliser systems are, in general, not to extend beyond the extreme waterline breadth, \( B_{WL} \), of the hull or below the horizontal line of keel. However, for retractable fins, alternative arrangements may be specially considered. Where the stabiliser fin extends beyond the extreme moulded beam of the hull in the active mode, the side shell is to be permanently marked indicating the fore and aft extent of the stabiliser, when deployed. It is recommended that an appropriate symbol be placed on the hull side between the marks.

3.1.12 The shell plating in way of retractable stabilisers is to comply with the requirements of 3.2. However, the longitudinal extent of the insert is to be such that it extends beyond around the hull opening in the fore/aft direction by not less than 25 per cent of the root chord length of the foil. In all other directions the extent of the insert shall be 1.25 times the root chord length of the foil over all operational lengths.

3.1.13 The scantlings of internal watertight bulkheads and stiffening for fixed installations are to be specified by the designer/builder and/or fin unit manufacturer, but in no case are to be less than the scantlings for double bottoms as defined in Pt 6, Ch 3. Suitable access is to be provided to allow for maintenance and inspection purposes.
Ship Control Systems

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Section 3

3.1.14 The scantlings and sealing arrangements for the pedestal and bearings will be specially considered, subject to the designer/builder submitting the following:
(a) Detailed structural calculations for the proposed foundation and adjacent supporting structure.
(b) A detailed finite element analysis, if carried out.
(c) Calculations demonstrating that the effect of damage to the stabiliser arrangement arising from the high speed impact, grounding, fouling, etc. will not compromise the structural and watertight integrity of the ship.
(d) Maximum torque, bending moments and bearing loads expected for the proposed design.
(e) The stabiliser fin stock material, together with its ultimate tensile shear strength values (N/mm²).

3.1.15 Fin bearing materials are to be of an approved type.

3.1.16 Where retractable stabilisers are fitted, position indicators are to be provided on the bridge and at auxiliary steering positions.

3.1.17 Where the fin stabiliser is of a novel design, high aspect ratio or the speed of the ship exceeds 45 knots, and the anticipated loads are likely to be significant, the scantlings of the fin and fin stock are to be determined by direct calculation methods incorporating model test results and structural analysis, where considered necessary by LR.

3.2 Fin stabilisers

3.2.1 The stabiliser machinery and surrounding structure is to be adequately supported and stiffened. Where cyclic bending stresses are induced in the structure which are likely to reduce the fatigue life the maximum stress is not to exceed 39,0 N/mm² in mild steel. Where other materials are used for the supporting structure the limiting stress values will be specially considered.

3.2.2 The fin box into which the stabilisers are fitted is to have a perimeter plating with thickness not less than the surrounding Rule shell plating plus 2 mm, and is to be stiffened to the same standard as the adjacent hull structure. Ships constructed from materials other than steel will be specially considered.

3.2.3 Insert plates are to be fitted in way of stabilisers. The thickness of the insert is to be at least 50 per cent greater than the bottom shell thickness in way and is to extend over an area 1,25 times the stabiliser root chord length, covering all operational angles. In addition, for retractable stabilisers, the insert is to extend beyond the shell opening for a distance of not less than 25 per cent of the length of the root chord.

3.2.4 The thickness of plating in way of retractable foil recesses is to be not less than the bottom shell thickness plus 2 mm. Internal stiffening is to comply with the requirements of Ch 3,4, as applicable.

3.3 Centre of pressure

3.3.1 The position of the centre of pressure for use in the determination of the fin torque is to be as indicated in Table 3.3.1.

Table 3.3.1 Position of centre of pressure

<table>
<thead>
<tr>
<th>Design criteria</th>
<th>Value of $x_{PF}$ and $x_{PA}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectangular fins:</td>
<td></td>
</tr>
<tr>
<td>(a) Ahead condition</td>
<td>$x_{PF} = (0.33x_B - x_L)$, but not less than $0.12x_B$</td>
</tr>
<tr>
<td>(b) Astern condition</td>
<td>$x_{PA} = (x_A - 0.25x_B)$, but not less than $0.12x_B$</td>
</tr>
<tr>
<td>Non-rectangular fins:</td>
<td></td>
</tr>
<tr>
<td>(a) Ahead condition</td>
<td>$x_{PF}$ as calculated from geometric form</td>
</tr>
<tr>
<td>(b) Astern condition</td>
<td>$x_{PA}$ (see Note) but not less than: $0.12A_F/y_F$</td>
</tr>
</tbody>
</table>

Symbols

- $x_{PF}$ = horizontal distance from the centreline of the fin stock, to the centre of pressure in the ahead condition, in metres
- $x_{PA}$ = horizontal distance from the centreline of the fin stock, to the centre of pressure in the astern condition, in metres
- $x_B$ = breadth of fin, in metres
- $y_F$ = depth of fin at centreline of stock, in metres
- $A_F$ = fin area, in m²
- $x_L$ and $x_A$ = horizontal distances from leading and after edges, respectively, of the fin to the centreline of the fin stock, in metres
- $x_B$ = horizontal length of any rectangular strip of fin geometric form, in metres

NOTE
For rectangular strips the centre of pressure is to be assumed to be located as follows:
(a) $0.33x_B$ abaft leading edge of strip for ahead condition.
(b) $0.25x_B$ from aft edge of strip for astern condition.

3.4 Fin force, $F_F$

3.4.1 The fin force, $F_F$, in kN, for use in the determination of the fin scantlings is to be submitted. For the astern condition the maximum astern speed, $V_A$, is to be used. In no case is the astern speed to be taken less than that determined from the following: $V_A \geq 0.5V$ knots.

3.5 Fin torque, $Q_F$

3.5.1 The fin torque, $Q_F$, for the ahead condition may be determined from the following formula:

$$Q_F = F_F x_{PF} \text{ kNm}$$

where

$\ x_{PF}$ = horizontal distance from the centreline of the fin stock, to the centre of pressure in the ahead condition.
3.8 Fin stock diameter, \( d_F \)

3.8.1 For a fin stock subjected to combined torque and bending, the equivalent stress in the fin stock is not to exceed that determined from the following:

\[
\sigma_e \leq 118 K_o \text{ N/mm}^2
\]

where

\[ K_o = \text{material factor, as defined in 1.4.3.} \]

The equivalent stress is to be determined by the formula:

\[
\sigma_e = \frac{\sigma_b^2 + 3 \tau_t^2}{2}
\]

Bending stress:

\[ \sigma_b = 10200 \times 10^3 \text{ N/mm}^2 \]

Torsional stress:

\[ \tau_t = 5100 \times 10^3 \text{ N/mm}^2 \]

3.8.2 The basic fin stock diameter, \( d_F \), at and below the lowest bearing is not to be less than that determined from the following:

\[
d_F = \frac{d_{Fu}}{6} \text{ mm}
\]

where

\[ d_{Fu} = \text{diameter of the fin stock in way of the tiller, in mm} \]

\[ M_F = \text{fin bending moment, kNm, see 3.6} \]

\[ Q_F = \text{fin torque (in the appropriate condition), in kNm, as given in 3.5.} \]

3.9 Fin plating

3.9.1 The thickness of the fin side plating is not to be less than that determined from the following:

\[
t = 0.0224 s \beta \sqrt{\frac{P_F}{110K_o} + 2.5 \text{ mm}}
\]

where

\[ s = \text{stiffener spacing, in mm} \]

\[ \beta = \text{panel aspect ratio correction factor} \]

\[ = A_R (1 - 0.25 \rho_R) \text{ for } A_R \leq 2 \]

\[ = 1 \text{ for } A_R > 2 \]

\[ A_R = \text{panel aspect ratio} \]

\[ = \text{panel length/panel breadth} \]

\[ P_F = \text{fin pressure, in kN/m}^2 \]

\[ = 10T + \frac{F_F}{A_F} \text{ kN/mm}^2 \]

\[ T = \text{maximum draught, in metres} \]

\[ F_F = \text{fin force, in kN, see 3.4} \]

\[ A_F = \text{fin area, in m}^2 \]

\[ K_o = \text{material factor, as defined in 1.4.3.} \]

3.9.2 The thickness of the nose plates is not to be less than \( 1.25 \) times the thickness of the fin side plating. The thickness of web plates is not to be less than \( 70 \) per cent the thickness of the fin side plating, or \( 6 \) mm, whichever is the greater.

3.9.3 Alternative materials and methods for fin stabilisers will be specially considered.
3.10 Stabiliser tanks

3.10.1 The general structure of the tank is to comply with the Rule requirements for deep tanks. Sloshing forces in the tank structure are to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

3.11 Bilge keels and fins

3.11.1 It is recommended that bilge keels are not fitted forward of 0.7L_{R} on ships intended to navigate in ice conditions.

3.11.2 Bilge keels are to be gradually tapered at the ends and arranged to finish in way of a suitable internal stiffening member. The taper is to have a length to depth ratio of at least three to one.

3.11.3 A plan of the bilge keels is to be submitted for approval of material grades, welded connections and detail design.

3.11.4 The scantlings and attachment to the hull plating for steel ships is to be in accordance with Pt 6, Ch 6.5.11.

3.12 Novel features

3.12.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

4.2 Propeller boss

4.2.1 The thickness of the propeller boss is to be not less than:

\[ 0.1d_{TS} + 56 \text{ but need not exceed } 0.3d_{TS} \]

where \( d_{TS} \) = diameter of tailshaft in mm, see Fig. 3.4.1.

4.3 Rudder horns

4.3.1 The requirements for the scantlings and arrangements of rudder horns will be subject to special consideration and may require to be determined by direct calculations.

4.4 Shaft bossing

4.4.1 Where the propeller shafting is enclosed in bossings extending back to the bearings supporting the propellers, the aft end of the bossings and the bearings are to be supported by substantially constructed boss end castings or fabrications. These are to be designed to transmit the loading from the shafting efficiently into the ship's internal structure.

4.4.2 For shaft bossings attached to shaft brackets, the length of the boss is to be adequate to accommodate the aftermost bearing and to allow for proper connection of the shaft brackets.

4.4.3 Cast steel supports are to be suitably radiused where they enter the main hull to line up with the boss plating radius. Where the hull sections are narrow, the two arms are generally to be connected to each other within the ship. The arms are to be strengthened at intervals by webs.

4.4.4 Fabricated supports are to be carefully designed to avoid or reduce the effect of hard spots. Continuity of the arms into the ship is to be maintained, and they are to be attached to substantial floor plates or other structure. The connection of the arms to the bearing boss is to be by full penetration welding.
4.4.5 The scantlings of supports will be specially considered. In the case of certain high powered ships, direct calculations may be required.

4.4.6 The boss plating is generally to be radiused into the shell plating and supported at the aft end by diaphragms at every frame. These diaphragms are to be suitably stiffened and connected to floors or a suitable arrangement of main and deep web frames. At the forward end, the main frames may be shaped to fit the bossing, but deep webs are generally to be fitted not more than four frame spaces apart.

4.5 Shaft brackets

4.5.1 The scantlings of the arms of shaft brackets, based on a breadth to thickness ratio of about five, are to be determined from 4.6.1 or 4.7.2 as appropriate.

4.5.2 Where the propeller shafting is exposed to the sea for some distance clear of the main hull, it is generally to be supported adjacent to the propeller by independent brackets having two arms. In very small ships the use of single arm brackets will be considered.

4.5.3 Fabricated brackets are to be designed to avoid or reduce the effect of hard spots and ensure a satisfactory connection to the hull structure. The connection of the arms to the bearing boss is to be by full penetration welding.

4.5.4 Bracket arms are in general to be carried through the shell plating, they are to be attached to floors or girders of increased thickness. The shell plating is to be increased in thickness and connected to the arms by full penetration welding.

4.5.5 In the case of certain high powered ships direct calculations may be required.

4.5.6 For shaft brackets having hollow section arms, the cross-sectional areas at the root and the boss should be not less than that required for a solid arm which satisfies the Rule section modulus having the proportions stated in 4.5.1.

4.5.7 The length of the shaft bracket boss, \( l_b \), is to be sufficient to support the length of the required bearing. In general \( l_b \) is not to be less than \( 4d_t \), where \( d_t \) is the Rule diameter of the screwshaft, in mm, see Vol 2, Pt 3, Ch 2, 4.4. Proposals for a reduction in the required shaft bracket boss length will be considered in conjunction with details of the bearing material, allowable bearing operating pressure and installation arrangements, see Vol 2, Pt 3, Ch 2, 4.16.2. However in no case is \( l_b \) to be less than the greater of:

- (a) \( 2d_t \);
- (b) that recommended by the bearing manufacturer;
- (c) as required by 4.4.2.

4.5.8 Where the shaft and the shaft bracket boss are of the same material, the thickness of the shaft bracket boss is not to be less than \( d_t/4 \). Where the shaft and the shaft bracket boss are of dissimilar materials, the thickness, of the boss, \( t_b \), is to be not less than:

\[
t_b = 0.75d_t \left( \frac{3}{4} f_1 - 0.667 \right) \text{ mm}
\]

\( f_1 = \sigma_S/\sigma_B \) but not less than 0.825

\( \sigma_S = \) ultimate tensile strength of the shaft material, in N/mm\(^2\)

\( \sigma_B = \) ultimate tensile strength of the boss material, in N/mm\(^2\).

4.5.9 The design of the shaft brackets with regard to disturbance of the hydrodynamic flow into the propeller and rudders is out with the scope of classification.

4.6 Single arm shaft brackets (‘P’ brackets)

4.6.1 Single arm shaft brackets are to have a section modulus, \( Z_{xx} \), at the palm of not less than that determined from the formula:

\[
Z_{xx} = \frac{a_s d_{up}^2 f}{45000} \text{ cm}^3
\]

where

\( a_s = \) the length of the arm to be measured from the centre of the section at the palm to the centreline of the shaft boss, in mm, see Fig. 3.4.2

\( d_{up} = \) the Rule diameter for an unprotected screwshaft, in mm, as given in Vol 2, Pt 3, Ch 2 using \( A = 1.0 \)

\( f = \frac{400}{\sigma_u} \)

\( \sigma_u = \) ultimate tensile strength of arm material, in N/mm\(^2\)

The cross-sectional area of the bracket at the boss is to be not less than 60 per cent of the area of the bracket at the palm.
4.6.2 For single arm shaft brackets a vibration analysis may be required if deemed necessary by LR.

4.7 Double arm shaft brackets (‘A’ – brackets)

4.7.1 The angle between the arms for double arm shaft brackets is to be generally not less than 50°. Proposals for the angle between the arms to be less than 50° will be specially considered with supporting calculations to be submitted by the designers.

4.7.2 The arms of double arm shaft brackets are to have a section modulus, $Z_{xx}$, of not less than that determined from the formula:

$$Z_{xx} = 0.45n^3 \text{ cm}^3$$

where $n$ = the minimum thickness, in cm, of a hydrofoil section obtained from:

$$n = \frac{d_{up}}{2000} \sqrt{1 + \left(1 + \left(0.0112 \frac{d_{up}}{f}\right)^2\right)} \text{ cm}$$

$d_{up}$ and $f$ are as given in 4.6.1.

4.8 Intermediate shaft brackets

4.8.1 The length and thickness of the shaft bracket boss are to be as required by 4.5.7 or 4.5.8 as appropriate. The scantlings of the arms will be specially considered on the basis of the Rules.

4.9 Attachment of shaft brackets by welding

4.9.1 Fabricated supports are to be carefully designed to avoid or reduce the effect of hard spots. Continuity of the arms into the ship is to be maintained, and they are to be attached to substantial floor plates or other structure. The connection of the arms to the bearing boss is to be by full penetration welding.

4.10 Attachment of shaft brackets by bolting

4.10.1 The bottom shell thickness in way of the double arm propeller bracket palms is to be increased by 50 per cent. The bottom shell thickness in way of single arm propeller brackets palms is to be doubled in thickness. The insert plates are to be additionally supported by substantial floor plates or other structure.

4.10.2 Where shaft brackets are attached by bolts, they are to be provided with substantial palms securely attached to the hull structure which is to be adequately stiffened in way. Where bolts are used, the nuts are to be suitably locked.

4.10.3 The bracket palms may be bolted directly onto the shell using a suitable bedding compound. The palms may be bolted onto suitable shims or chocking compound, of an approved type, to facilitate alignment.

4.10.4 Where brackets are bolted onto resin chocks, plans indicating the following information are to be submitted for approval:

(a) The thrust and torque loads, where applicable, that will be applied to the chocked item.
(b) The torque load to be applied to the bracket mounting bolts.
(c) The material of the bracket mounting bolts.
(d) The number, thread size, shank diameter and length of the mounting bolts.

4.10.5 The minimum thickness of a resin chock is to be 12 mm.

4.10.6 The bracket palms are to have well radiused corners, and the faying surface to be dressed smooth. The palm thickness in way of the bolts is to be not less than the propeller bracket boss thickness from 4.5.7 or 4.5.8 as appropriate.

4.10.7 The diameter of the propeller bracket mounting bolts is to be not less than:

$$d_b = \sqrt[3]{\frac{Z_{xx}}{8.75 \pi n h x 10^{-5}}} \text{ mm}$$

subject to $d_{b\text{min}} \geq t_b \text{ mm}$

where $Z_{xx}$ = the section modulus of the bracket arm determined from 4.6.1 or 4.7.2, cm$^3$, as appropriate

$n$ = the number of bolts in each row

$h$ = the distance between rows of bolts, mm

$d_b$ = the bolt diameter in the same material as the propeller bracket, mm

$t_b$ = the propeller bracket boss thickness, mm.

4.10.8 Where the shaft bracket and the shaft bracket mounting bolts are of dissimilar materials (which are galvanically compatible), the diameter of the propeller bracket mounting bolts, as determined from 4.10.7, is to be modified in proportion to the square root of the yield strengths of the materials.

Fig. 3.4.3 Double arm shaft bracket (bolted attachment)
particular materials. The corrected bolt diameter of the dissimilar material is to be not less than the propeller bracket boss thickness.

4.10.9 The propeller bracket palms are to have fitted bolts, and suitable arrangements provided to lock the nuts.

4.10.10 A washer plate is to be provided, generally of equal dimensions to the bracket palm with thickness \( t_b/6 \) mm, subject to a minimum of 3 mm.

4.11 Alignment of shaft brackets

4.11.1 Particular care is to be paid to the alignment of shaft brackets to minimise vibration and cyclic loadings being transmitted from the propulsion shafting and propellers into the hull structure.

4.11.2 Alignment of bolted shaft brackets may be by means of suitable metallic shims or chocking resin of an approved type, see 4.10.2 and 4.10.3.

4.11.3 The alignment of shaft brackets connected by welding or bonding may be facilitated by boring of the bracket boss after attachment of the shaft bracket and sterntube.

4.12 Sterntubes

4.12.1 The sterntube scantlings are to be individually considered.

4.12.2 The bottom shell, in way of the sterntube, is to be additionally reinforced by means of an insert plate to increase the bottom shell thickness by 50 per cent.

4.12.3 The sterntube should in general be connected to the shell by welding. Bolted arrangements will be specially considered.

4.12.4 Where sterntubes are to be retained by bolting they are to be provided with a substantial flange securely attached to the hull structure. Where bolts are used, the nuts are to be suitably locked.

4.12.5 Where sterntubes are to be welded to hull insert plates full penetration welding is required.

4.12.6 Where sterntubes are to be installed using a resin system, of an approved type, the requirements of Pt 6, Ch 6 are to be complied with.

4.12.7 The region where the shafting enters the ship, and the bearing in way, is to be adequately supported by floors or deep webs.

4.12.8 The shaft bearings are to be secured against rotation within the sterntube.

4.12.9 A suitable gland arrangement is to be provided at the inboard end of sterntubes.

4.13 Skegs

4.13.1 Skegs are to be efficiently integrated into the adjacent hull structure and their design is to facilitate this.

4.13.2 The scantlings of skegs are to be sufficient to withstand any docking forces imposed upon them.

4.14 Propeller hull clearances

4.14.1 Recommended minimum clearances between the propeller and the sternframe, rudder or hull are given in Table 3.4.1. These are the minimum distances considered desirable in order to expect reasonable levels of propeller excited vibration. Attention is drawn to the importance of the local hull form characteristics, shaft power, water flow characteristics into the propeller disc and cavitation when considering the recommended clearances.

**Table 3.4.1 Recommended minimum propeller hull clearances**

<table>
<thead>
<tr>
<th>Number of blades</th>
<th>Hull clearances for twin screw, in metres, see Fig. 3.4.4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>e</td>
</tr>
<tr>
<td>3</td>
<td>1.20K dp</td>
</tr>
<tr>
<td>4</td>
<td>1,00K dp</td>
</tr>
<tr>
<td>5</td>
<td>0,85K dp</td>
</tr>
<tr>
<td>6</td>
<td>0,75K dp</td>
</tr>
<tr>
<td>Minimum value</td>
<td>3 and 4 blades, 0,20dp; 5 and 6 blades, 0,16dp</td>
</tr>
</tbody>
</table>

**Symbols**

\[
L_R = \left(0.1 + \frac{L_R}{3050}\right) \left(3.48C_B P_s \frac{L_R}{P_s} + 0.3\right)
\]

\[
t_R = \text{thickness of rudder, in metres measured at} 0.7R_p \text{ above the shaft centreline}
\]

\[
P_s = \text{designed power on one shaft, in kW}
\]

\[
R_p = \text{propeller radius, in metres}
\]

\[
d_p = \text{propeller diameter, in metres}
\]

**NOTE**

The above recommended minimum clearances also apply to semi-spade type rudders.
Section 5
Fixed and steering nozzles, bow and stern thrust units, ducted propellers

5.1 General

5.1.1 The requirements for scantlings for fixed and steering nozzles are given, for guidance only, in 5.2 to 5.4 and Table 3.5.1.

5.1.2 The requirements, in general, apply to nozzles with a numeral not greater than 200, see Table 3.5.1. Nozzles exceeding this value will be specially considered.

5.2 Nozzle structure

5.2.1 For basic scantlings of the structure, see Table 3.5.1, in association with Fig. 3.5.1.

5.2.2 The shroud plating in way of the propeller tips is to be carried well forward and aft of this position, due allowance being made on steering nozzles for the rotation of the nozzle in relation to the propeller.

5.2.3 Fore and aft webs are to be fitted between the inner and outer skins of the nozzle. Both sides of the headbox and pintle support structure are to be connected to fore and aft webs of increased thickness. For thicknesses, see Table 3.5.1.

5.2.4 The transverse strength of the nozzle is to be maintained by the fitting of ring webs. Two ring webs are to be fitted in nozzles not exceeding 2,5 m diameter. Nozzles between 2,5 and 3,0 m in diameter are generally to have two full ring webs and a half-depth web supporting the flare plating. The number of ring webs is to be increased as necessary on nozzles exceeding 3,0 m in diameter. Where ring webs are increased in thickness in way of the headbox and pintle support structure in accordance with Table 3.5.1, the increased thickness is to be maintained to the adjacent fore and aft web.

5.2.5 Local stiffening is to be fitted in way of the top and bottom supports which are to be integrated with the webs and ring webs. Continuity of bending strength is to be maintained in these regions.

5.2.6 Fin plating thickness is to be not less than the cone plating, and the fin is to be adequately reinforced. Solid fins are to be not less than 25 mm thick.

5.2.7 Care is to be taken in the manufacture of the nozzle to ensure its internal preservation and watertightness. The preservation and testing are to be as required for rudders, see Part 6.

5.3 Nozzle stock and solepiece

5.3.1 Stresses, derived using the maximum side load on the nozzle and fin acting at the assumed centre of pressure, are not to exceed the values given in Table 3.5.1, in both the ahead and astern conditions.

5.4 Ancillary items

5.4.1 The diameter of pintles and the diameter and first moment of area about the stock axis of coupling bolts are to be derived from 2.23 and 2.24 respectively.

5.4.2 Suitable arrangements are to be provided to prevent the steering nozzle from lifting.

5.5 Steering gear and allied systems

5.5.1 For the requirements of steering gear, see Vol 2, Pt 6, Ch 1.
5.6 Thruster unit wall thickness

5.6.1 The wall thickness of the unit is, in general, to be in accordance with the manufacturer’s practice, but is to be not less than the thickness of the adjacent shell plating plus 10 per cent or 2 mm whichever is the greater, subject to a minimum of 7 mm.

5.7 Thruster unit installation details

5.7.1 The tunnel tube is to be fitted either between a pair of deep floors or bulkheads extending to above the design waterline or in a separate watertight compartment.

5.7.2 The shell plating thickness is to be locally increased by 50 per cent in way of tunnel thruster connections.

5.7.3 For welded tube connections the welding is to be by full penetration welding.

5.7.4 The tunnel tube is to be framed to the same standard as the surrounding shell plating.

5.7.5 The unit is to be adequately supported and stiffened.

5.8 Propeller ducting

5.8.1 Where propellers are fitted within ducts/tunnels the plating thickness in way of the blades is to be increased by 50 per cent.

5.8.2 The tunnel wall in way of the propeller blades is to be additionally stiffened.

5.9 Surface drive mountings

5.9.1 Transoms through which surface drive systems pass and which are required to carry thrust, significant weight, torque, moment, etc., are to be adequately reinforced.

5.9.2 The thickness of transom plating in way is to be increased by 50 per cent or as advised by the drive manufacturer, whichever is the greater.

5.9.3 Steering rams are to be mounted on suitably reinforced areas of plating supported by additional internal stiffening, details of which are to be submitted for consideration.

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**Table 3.5.1 Nozzle construction requirements**

<table>
<thead>
<tr>
<th>Item</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Nozzle numeral</td>
<td>$N_N = 0,01P d_P$</td>
</tr>
<tr>
<td>(2) Shroud plating in way of propeller blade tips</td>
<td>For $N_N \leq 63$ $t_s = (11 + 0,1N_N)$ mm &lt;br&gt; For $N_N &gt; 63$ $t_s = (14 + 0,052N_N)$ mm</td>
</tr>
<tr>
<td>(3) Shroud plating clear of blade tips, flare and cone plating, wall thickness of leading and trailing edge members</td>
<td>$t_p = (t_s - 7)$ mm but not less than 8 mm</td>
</tr>
<tr>
<td>(4) Webs and ring webs</td>
<td>As item (3) except in way of headbox and pintle support where $t_W = (t_s + 4)$ mm</td>
</tr>
<tr>
<td>(5) Nozzle stock</td>
<td>Combined stresses in stock at lower bearing $\leq 92,7 \text{ N/mm}^2$&lt;br&gt;Torsional stress in upper stock $\leq 62,0 \text{ N/mm}^2$</td>
</tr>
<tr>
<td>(6) Solepiece and strut</td>
<td>Bending stresses not to exceed $70,0 \text{ N/mm}^2$</td>
</tr>
</tbody>
</table>

**Symbols**

- $N_N$ = a numeral dependent on the nozzle requirements
- $P$ = power transmitted to the propellers, in kW
- $d_P$ = diameter of the propeller, in metres
- $t_s$ = thickness of shroud plating in way of propeller tips, in mm
- $t_p$ = thickness of plating, in mm
- $t_W$ = thickness of webs and ring webs in way of headbox and pintle support, in mm

**NOTE**

Thicknesses given are for carbon steel. Reductions in thickness will be considered for certain stainless steels.
5.10 Novel features

5.10.1 Where the Rules do not specifically define the requirements for novel features, then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

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Section 6

Water jet propulsion systems

6.1 Construction

6.1.1 The requirements for the construction and installation of water jet units apply irrespective of rated power.

6.1.2 Water jet ducts may be fabricated as an integral part of the hull structure, or as a bolted in unit. In either case, detailed plans indicating dimensions, scantlings and materials of construction of the following are to be submitted in triplicate.

(a) Arrangement of the system including intended method of attachment to the hull and building-in, geometry of tunnel, shell opening, method of stiffening, reinforcement, etc.

(b) Shaft sealing arrangements.

(c) Details of any shafting support or guide vanes used in the water jet system.

(d) Details and arrangements of inspection ports, their closing appliances and sealing arrangement, etc.

(e) Details and arrangements of protection gratings and their attachments.

6.1.3 When submitting the plans requested in 6.1.2, details of the designers’ loadings and their positions of application in the hull are to be submitted. These are to include maximum applied thrust, moments and tunnel pressures for which approval is sought.

6.1.4 All materials used in construction are to be manufactured and tested in accordance with the Rules for Materials.

6.1.5 Steels are to be of suitable grades in accordance with the requirements of Pt 6, Ch 6.

6.1.6 Irrespective of the material used, the strength and supporting structure of all tunnels are to be examined by direct calculation procedures which are to be submitted. In no case are the scantlings to be taken as less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radius ed corners.

6.1.7 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of the guard are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

6.1.8 The inlet profile of the tunnel is to be so designed as to provide a smooth uptake of water over the range of craft operating trims and avoid significant separation of the flow into the rotating machinery.

6.1.9 Single or multiple water jet unit installations having a total rated power in excess of 500 kW are to be contained within their own watertight compartment. Other arrangements for maintaining watertight integrity may be specially considered depending on the size and installation layout.

6.1.10 For details of machinery requirements, see Vol 2, Pt 4, Ch 2.

6.2 Water jet propulsion systems – Installation

6.2.1 Standard units built for ‘off the shelf’ supply and which include the duct are to be installed strictly in accordance with the manufacturer’s instructions, see also 6.1.4.

6.2.2 Integral water jet ducts are to be constructed in accordance with the manufacturer’s requirements and the relevant plans submitted as required by 6.1.

6.2.3 Where load is transmitted into the transom and/or bottom shell, the thickness of the plating adjacent to the jet unit is to be increased. The increase in thickness is to be not less than 50 per cent of the calculated transom and bottom plating thicknesses respectively or 8 mm, whichever is the greater. Such reinforcement is to extend beyond the surrounding stiffening structure.

6.2.4 For ‘bolted in’ units, hull receiving rings are to be of a material compatible with the hull. Scantlings of the receiving rings are to be as required by the jet unit manufacturer and suitably edge prepared prior to welding in place. The receiving ring is to be installed using an approved welding procedure. Where a manufacturer’s specification is not provided, full details are to be submitted.

6.2.5 Bolt sizes and spacings are to be specified by the manufacturer, and are to be of suitable marine grade, insulated as appropriate and locked by suitable means.

6.2.6 Where studs are proposed for the receiving ring(s), the remaining thickness below the depth of blind tap is to be not less than the bottom shell plating thickness plus 2 mm. Bottoms of all blind taps are to be free of sharp corners.

6.2.7 The use of approved alignment resins may be considered where accurate seating and faying surfaces are required. Details are to be submitted for consideration and approval.

6.2.8 Where a water jet unit forms an integral part of the hull structure, such units are to be installed using an approved weld procedure and in accordance with the manufacturer’s instructions. Materials to be welded are to be of compatible specifications.
6.2.9 Water jet units transmitting thrust into the transom structure are to be supported by a system of radial, athwartship and vertical stiffening. Drawings are to be accompanied by a set of detailed structural calculations. Where complex installations are proposed, a finite element model may be submitted in lieu of direct calculations.

6.2.10 Water jet units transmitting thrust to a bottom shell connection or intermediate tunnel connection are to be supported by additional stiffening, the details of which are to be submitted.
1.1.5 The requirements for closing appliances in this Chapter are suitable for weathertight arrangements. When closing appliances are designed to comply with the requirements for CBRN Defence, they will be considered as being equivalent to the weathertight requirements of this Chapter.

Section 2
Hatches and miscellaneous openings on the weather deck

2.1 Hatch covers

2.1.1 The hatch covers on the weather decks of all ships are to be steel plated, stiffened by webs or stiffeners, hinged and secured by clamping devices. Weathertightness is to be achieved by means of gaskets. The means of securing are to be such that weathertightness can be maintained in any sea condition. Where toggles are fitted, their diameter and spacing are to be in accordance with ISO standards or equivalent.

2.1.2 Consideration should be given to positioning weathertight or gastight hatches on lower decks in accordance with a specified standard for CBRN purposes.

2.1.3 The scantlings of covers are not to be less than the rule thickness for the deck at that point. Where other materials are used, equivalent scantlings are to be provided. The scantlings apply basically to rectangular covers, with the stiffening members arranged primarily in one direction and carrying a uniformly distributed load. The covers are assumed to be simply supported. Where covers are stiffened by a grillage formation, and also where point loads are applied to any type of cover, the scantlings are to be determined from direct calculations.

2.1.4 In the case of flush hatch covers or of covers on coamings of lesser height than required by 2.3.1, their scantlings, the securing and sealing arrangements and the drainage of gutterways will be specially considered.

2.1.5 Where hatchways are trunked through one or more lower decks, and hatchway beams and covers are dispensed with at the intermediate decks, the hatchway beams, coamings and covers immediately below the trunk are to be adequately strengthened. Plans are to be submitted for approval.

2.1.6 Small hatches, including escape hatches, are to be situated clear of RADHAZ areas and RAS stores receiving areas and storing routes. Small hatches and their securing devices are to be easily operable by one person. Where necessary, counterbalance weights, springs or other equivalent mechanisms are to be provided to assist the user in opening and closing the hatch. Any mechanism fitted is to be designed so as not to present a hazard to persons using the hatch. Failure of the mechanism is not to prevent the operation of the hatch.
2.1.7 Where portable plates are required in decks for unshipping machinery, or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced deck or the surrounding structure is suitably compensated. Portable plates are to be secured by gaskets and closely spaced bolts at a pitch not exceeding five diameters or equivalent naval standard.

2.2 Hatch coamings

2.2.1 The height of coamings above the upper surface of the weather deck, measured above sheathing if fitted, is to be not less than 300 mm. For exposed decks immediately above the design draft, e.g., quarter decks and well decks, coaming heights are to be no less than 600 mm. Coaming of a height no less than 450 mm may be provided if the hatch cover is kept closed and a small access hatch is provided in the hatch cover.

2.2.2 The height of coamings of hatchways closed by steel covers fitted with gaskets and clamping devices are to be as specified in 2.2.1, but may be reduced, or the coamings may be omitted entirely, if the safety of the ship is not thereby impaired in any sea condition. Special attention will be given in such cases to the scantlings of the covers, to their gasketing and securing arrangements and to the drainage of recesses in the deck.

2.2.3 The height of coamings may be required to be increased on ships where this is shown to be necessary by the stability and watertight subdivision calculations required by Ch 2.1.3.

2.2.4 Vertical coamings are to have a thickness, \( t \), in mm not less than the greater of the following:

\[
(a) \quad t = 0.008H_c \sqrt{K} + 1.0 \text{ mm}
\]

\[
(b) \quad \text{Rule thickness of the deck in the position fitted}
\]

where

\[
H_c = \text{the coaming height}
\]

\[
k = \text{local strength steel factor, see Pt 6, Ch 5.}
\]

2.2.5 Vertical coamings are to be stiffened at their upper edge by a substantial rolled or fabricated section. Additional support is to be arranged as necessary.

2.3 Manholes and flush escape hatches

2.3.1 Manholes are to be closed by substantial covers capable of being made watertight. The covers are to be permanently attached.

2.3.2 Flush escape hatches are to be closed by substantial watertight covers capable of being opened and closed from either side unless specified otherwise for hatches that provide access to high security areas such as magazines or to prevent access from open decks. The covers are to be permanently attached.

2.4 Hatchways within enclosed superstructures or lower decks

2.4.1 The requirements of this Section are to be complied with where it is necessary to maintain the watertight envelope.

2.4.2 Access hatches within a superstructure or deckhouse need not be provided with means for closing if all openings in the surrounding bulkheads have watertight closing appliances.

2.5 Openings on the tops and sides of enclosed structures on the weather deck

2.5.1 Openings on the tops and sides of enclosed structures on the weather deck up to a height of 2.5 m are to be watertight. In the forward 0.25LW the height should be taken to 5 m. The height of openings may be required to be increased where this is shown necessary by the stability and watertight subdivision calculation required by Pt 1, Ch 2.1.1. The weather deck as defined in Ch 1.5.4.2 may be stepped or recessed for the purpose of this Chapter. Special consideration will be given to the position of the weather deck of NS1 ship types.

2.6 Magazine blow out plates

2.6.1 Where blow out plates are required they are to be secured by sealing arrangements adequate to meet the watertightness and operational requirements. They are to be of an equivalent strength to the deck in which they are fitted.

2.6.2 Blow out plates are to be permanently attached.

### Section 3

**Doors and accesses on weather decks**

3.1 General

3.1.1 Access openings in:

(a) superstructure bulkheads;

(b) deckhouses protecting openings leading into enclosed superstructures or to spaces below the weather deck; and

(c) deckhouse on a deckhouse protecting an opening leading to a space below the weather deck, are to be fitted with doors of steel or other equivalent material, permanently and strongly attached to the bulkhead and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead, and watertight when closed. The doors are to be gasketed and secured watertight by means of clamping devices or equivalent arrangements, permanently attached to the bulkhead or to the door. Doors are generally to open outwards.
and are to be capable of being operated and secured from both sides. The sill heights are to be as required by 3.1.3 and 3.1.4.

3.1.2 Fixed lights in doors are to comply with the requirements for side scuttles lights as given in 6.1. Hinged steel deadlights may be external.

3.1.3 The height of doorway sills above the weather deck sheathing, if fitted, is to be not less than 300 mm.

3.1.4 For exposed decks immediately above the design draught, e.g. quarter decks and well decks, sill heights are to be no less than 450 mm.

3.1.5 When the closing appliances of openings in superstructures and deckhouses do not comply with 3.1.1, interior deck openings are to be treated as if exposed on the weather deck.

3.1.6 The height of door sills may be required to be increased on ships where this is shown to be necessary by the stability and watertight subdivision calculations required by Ch 2,1.2.

3.1.7 Where portable plates are required for unshipping machinery, or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced bulkhead and are secured by gaskets and close spaced bolts at a pitch not exceeding five diameters or equivalent naval standard.

3.1.8 The sill heights of accesses closed by covers which are secured by closely spaced bolts or otherwise kept permanently closed at sea will be specially considered.

3.1.9 Special consideration will be given to access on the weatherdeck where for operational purposes it is not possible to provide a sill meeting 3.1.3 or 3.1.4.

3.2 Magazine blow out plates

3.2.1 Where blow out plates are required, they are to be secured by sealing arrangements adequate to meet the weathertightness and operational requirements. They are to be of an equivalent strength to the deck in which they are fitted.

3.2.2 Blow out plates are to be permanently attached.

3.2.3 Fixed lights in doors are to comply with the requirements for side scuttles lights as given in 6.1. Hinged steel deadlights may be external.

3.3.3 The height of doorway sills above the weather deck sheathing, if fitted, is to be not less than 300 mm.

3.3.4 For exposed decks immediately above the design draught, e.g. quarter decks and well decks, sill heights are to be no less than 450 mm.

3.3.5 When the closing appliances of openings in superstructures and deckhouses do not comply with 3.3.1, interior deck openings are to be treated as if exposed on the weather deck.

3.3.6 The height of door sills may be required to be increased on ships where this is shown to be necessary by the stability and watertight subdivision calculations required by Ch 2,1.2.

3.3.7 Where portable plates are required for unshipping machinery, or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced bulkhead and are secured by gaskets and close spaced bolts at a pitch not exceeding five diameters or equivalent naval standard.

3.3.8 The sill heights of accesses closed by covers which are secured by closely spaced bolts or otherwise kept permanently closed at sea will be specially considered.

3.3.9 Special consideration will be given to access on the weatherdeck where for operational purposes it is not possible to provide a sill meeting 3.3.3 or 3.3.4.

4 Watertight doors and hatches in watertight subdivision boundaries

4.1 General

4.1.1 Watertight doors and hatches are to be designed in accordance with a recognised Standard. They are to be manufactured under LR Survey and surveyed during installation. They are to be tested in accordance with the LR survey procedures, operated under working conditions and tested in place, see Pt 6, Ch 6.

4.1.2 Doors and hatches are to be of equivalent strength to the unpierced subdivision. They are to be approved for the maximum head of water indicated by the approved damage stability calculations.

4.1.3 Where watertight doors of the sliding type are permitted by the subdivision and stability standard, they are to be capable of being operated by efficient hand-operated gear, both at the door itself and from an accessible position above the vertical limit of watertight integrity. Means are to be provided at the remote operating position to indicate whether the door is open or closed. The time necessary for the complete closure of the door, when operating by hand gear, is not to exceed 90 seconds with the ship in the upright position.

4.1.4 Power operated doors are to be capable of being opened and closed locally by both power and efficient hand operated mechanisms in accordance with 4.1.3.

4.1.5 Indicators are to be provided on the bridge, ship command centre or operations room showing whether power operated watertight doors and hatches are open or closed, see Vol 2, Pt 10, Ch 1,19.

4.1.6 Where manually operated hinged watertight doors are fitted, a suitable procedural system is to be implemented to ensure that such doors remain closed when at sea unless specific authorisation is sought.

4.1.7 Watertight doors and hatches are to be capable of being operated from both sides of the watertight division except for access to high security areas such as magazines or to prevent access from open decks.

4.1.8 Sliding watertight doors are to be capable of being operated up to the heel and trim angles specified in the subdivision and stability standard, but not less than 15º heel either way. Consideration is also to be given to the forces which may act on either side of the door as may be experienced when water is flowing through the opening, applying a static head equivalent to a water height of at least 1 m above the sill on the centreline of the door.
Section 5
Side scuttles and windows

5.1 General

5.1.1 Side lights, porthlights and portholes are considered to be side scuttles.

5.1.2 Side scuttles are defined as being round or oval openings with an area not exceeding 0,16 m².

5.1.3 Windows are defined as being rectangular openings generally, and round or oval openings with an area exceeding 0,16 m².

5.1.4 A plan showing the location of side scuttles and windows is to be submitted.

5.1.5 Side scuttles and windows together with their glasses and deadlights if fitted, are to be of an approved design or in accordance with a specified standard(s).

5.1.6 Side scuttles to spaces within enclosed superstructures, or deckhouses on or above the weather deck are to be fitted with efficient, hinged, inside deadlights and capable of being effectively closed and secured watertight.

5.1.7 All side scuttles are to be of the non-opening type.

5.1.8 Windows are not to be fitted below the lowest weather deck or in end bulkheads of superstructures.

5.1.9 If fitted in a deckhouse or superstructures in the forward 0,25 LR, windows are to be provided with strong, hinged, steel, weatherlight storm covers. However, if there is an opening leading below deck, this opening is to be treated as being on an exposed deck and is to be protected as required by 2.2.1.

5.1.10 Side scuttles and windows set inboard from the shell on the weather deck, protecting direct access below, are either to be provided with strong permanently attached deadlights or, where they are accessible, strong permanently attached external steel storm covers instead of internal deadlights.

5.1.11 Side lights and windows set inboard from the shell on the weather deck, not protecting direct access below, do not require deadlights or storm covers.

5.1.12 Cabin bulkheads and doors are considered to provide effective protection between side scuttles or windows and access below.

5.1.13 Where windows are permitted in an exposed bulkhead on the weather deck in the forward 0,25 LR, strong external storm covers which may be portable and stored adjacent are to be provided.

5.1.14 Where the bridge is on, or not more than 5,0 m above, the weather deck in lieu of storm covers being provided for the bridge windows, a weatherlight cover, fitted to a coaming of not less than 230 mm in height around the internal stairway opening within the bridge, may be accepted.

If this arrangement is accepted, adequate means of draining the bridge are to be provided.

5.1.15 If necessary, for practical considerations, the storm covers may be in two parts.

5.1.16 Laminated toughened safety glass may also be used for windows but the total thickness will need to be greater than that required for the equivalent sized window using monolithic toughened safety glass. The equivalent thickness of laminated toughened safety glass is to be determined from the following formula:

$$ T_{Li}^2 + T_{L2}^2 + ... T_{Ln}^2 = T_S^2 $$

where

- \( n \) = number of laminates
- \( T_{Li} \) = thickness of glass laminate
- \( T_S \) = Rule thickness of toughened safety glass.

Alternative arrangements that do not meet the above thickness requirement will be specially considered, provided that equivalent strength and bending stiffness to that of a single, thermally toughened pane of thickness \( T_S \) can be demonstrated in a four-point bending test in accordance with EN-ISO 1288-3 or an equivalent recognised National or International Standard, using no fewer than ten samples. The lower limit of the 90 per cent confidence level interval for the laminated pane shall not be less than the same for monolithic toughened safety glass. Small scale punch test or ring-in-ring test methods shall not be used.

5.1.17 Rubber frames are not acceptable for windows.

Section 6
Ventilators

6.1 Application

6.1.1 This Section applies to all ship types and provides requirements for ventilators. Reference should be made to the specified subdivision and stability standard(s).

6.1.2 For requirements regarding down flooding in connection with stability and watertight subdivision, see Ch 2.1.3.

6.2 Protection

6.2.1 In all spaces where mechanical damage is likely, all air and sounding pipes, scuppers and discharges, including their valves, controls and indicators, are to be well protected. This protection is to be of steel or other equivalent material.

6.3 General

6.3.1 Special care is to be taken in the design and positioning of ventilator openings and coamings, particularly in the region of the forward end of superstructures and other points of high stress. The deck plating in way of the coamings is to be efficiently stiffened.
6.3.2 Ventilators from tunnels passing through decks are to have scantlings suitable for withstanding the pressures to which they may be subjected and are to be made watertight.

6.4 Coamings

6.4.1 The scantlings and height of ventilator coamings exposed to the weather are to be not less than required by Table 4.6.1 but the thickness need not exceed that of the adjacent deck or bulkhead plating. In particularly exposed positions, the height of coamings and scantlings may be required to be increased.

6.4.2 The height of ventilator coamings may be required to be increased on ships where this is shown to be necessary by the stability and watertight subdivision calculations required by the specified subdivision and stability standard(s), see Pt 1, Ch 2, 1.1.9. The specified standard may require that satisfactory baffles and drainage arrangements are provided, as in the case of air intakes or exhaust openings for machinery spaces, which may be arranged in the sides of the ship.

6.4.3 Mushroom ventilators closed by a head revolving on a centre spindle (screw-down head) are acceptable, but the diameter is not to exceed 300 mm.

6.4.4 Mushroom ventilators with a fixed head and closed by a screw-down plate (screw-down cover) may be accepted up to a diameter of 750 mm within the forward 0.25 LR.

6.4.5 Wall ventilators (jalousies) may be accepted provided they are capable of being closed weathertight by hinged steel gasketed covers secured by bolts or toggles.

6.4.6 A ventilator head not forming part of the closing arrangements is to be not less than 6.5 mm thick.

6.5 Closing appliances

6.5.1 All ventilator openings are to be provided with efficient weathertight closing appliances of steel or other equivalent material unless the height of the coaming is greater than 2.5 m above the weather deck or 5 m on exposed deck immediately above the design waterline, e.g. quarter decks and well decks.

6.5.2 Where ventilators are proposed to be led overboard through an enclosed lower deck space the closing arrangements are to be submitted for approval. If such ventilators are led overboard more than 4.5 m above the damage control deck, closing appliances may be omitted, provided that satisfactory baffles and drainage arrangements are provided, as in the case of air intakes or exhaust openings for machinery spaces, which may be arranged in the sides of the ship.

6.5.3 Wall ventilators (jalousies) may be accepted provided they are capable of being closed weathertight by hinged steel gasketed covers secured by bolts or toggles.

6.5.4 A ventilator head not forming part of the closing arrangements is to be not less than 6.5 mm thick.

6.6 Machinery spaces

6.6.1 In general, ventilators necessary to supply the machinery space continuously are to have coamings of sufficient height to comply with 6.6.1 without having to fit weathertight closing appliances. Ventilators to emergency generator rooms are to be so positioned that closing appliances are not required.

6.6.2 Where due to ship size and arrangement this is not practicable, lesser heights for machinery space ventilator coamings fitted with weathertight closing appliances may be permitted if specified in combination with other suitable arrangements to ensure uninterrupted, adequate supply of ventilation to these spaces.

Table 4.6.1 Ventilator coaming requirements

<table>
<thead>
<tr>
<th>Feature</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (measured above sheathing if fitted)</td>
<td>(1) ( z_c = 900 \text{ mm} ) for locations defined in Note 2 ( z_c = 760 \text{ mm} ) elsewhere</td>
</tr>
<tr>
<td>Thickness</td>
<td>(2) ( t_c = 5.5 + 0.01 d_v \text{ mm} ) where ( 7.5 \text{ mm} \leq t_c \leq 10.0 \text{ mm} )</td>
</tr>
<tr>
<td>Support</td>
<td>(3) If ( z_c &gt; 900 \text{ mm} ) the coaming is to be specially supported</td>
</tr>
</tbody>
</table>

Symbols:
- \( t_c \) = thickness of coaming, in mm
- \( z_c \) = height of coaming, in mm
- \( d_v \) = internal diameter of coaming, in mm

NOTES
1. Where the height of the ventilator exceeds that given in Item (1), the thickness given by (2) may be gradually reduced, above that height, to a minimum of 6.5 mm. The ventilator is to be adequately stayed.
2. For exposed decks immediately above the design waterline, e.g. quarter decks and well decks.
7.2 Height of air pipes

7.2.1 The height of air pipes from the upper surface of decks exposed to the weather, to the point where water may have access below is normally to be not less than:
- 760 mm on exposed decks immediately above the design draught, e.g., quarter decks and well decks.
- 450 mm measured above deck sheathing, where fitted elsewhere.

7.2.2 Lower heights may be approved in cases where these are essential for the working of the ship, provided that the design and arrangements are otherwise satisfactory. In such cases, efficient, permanently attached closing appliances as required by 7.3.1 are to be of an approved automatic type.

7.2.3 The height of air pipes may be required to be increased on ships where this is shown to be necessary by the stability and watertight subdivision calculations required by Pt 1, Ch 1.1. An increase in height may also be required when air pipes to fuel oil and settling tanks are situated in positions where sea water could be temporarily entrapped, e.g., in recesses in the sides and ends of superstructures or deckhouses, between hatch ends, behind high sections of bulwark, etc. This may entail an increase in tank scantlings, see also Pt 6, Ch 3.

7.2.4 Air pipes are generally to be led to an exposed deck. See also Vol 2, Pt 7, Ch 2.10.4.4.

7.2.5 Where air pipes are led through the side of superstructures, the opening is to be at least 2.3 m above the design waterline.

7.2.6 The minimum wall thickness of air pipes in positions indicated in 7.2.1 is to be:
- 6.0 mm for pipes of 80 mm external diameter or smaller.
- 8.5 mm for pipes of 165 mm external diameter or greater.
Intermediate minimum thicknesses are to be determined by linear interpolation.

7.2.7 Air pipe coaming heights may be reduced on ships assigned a service area notation SA4. Coaming heights are to be as high as practicable, with a minimum height of 300 mm.

7.3 Closing appliances

7.3.1 All openings of air and sounding pipes are to be provided with permanently attached, satisfactory means of closing to prevent the free entry of water (see also 7.2.2 and Vol 2, Pt 7, Ch 2.10.6.2).

7.3.2 Closing appliances are to be of an approved automatic type.

Section 8
Scuppers and sanitary discharges

8.1 General

8.1.1 Scuppers sufficient in number and size to provide effective drainage are to be fitted in all decks.

8.1.2 Scuppers draining weather decks and spaces within superstructures or deckhouses not fitted with efficient watertight doors are to be led overboard.

8.1.3 Where the freeboard is such that the deck edge forming the vertical limit of watertight integrity is immersed when the ship heels 5° or less, scuppers and discharges which drain spaces below this deck, or spaces within intact superstructures or deckhouses on this deck fitted with efficient watertight doors, are to be led to the bilges in the case of scuppers or to suitable sanitary tanks in the case of sanitary discharges. Where the freeboard is such that the deck edge forming the vertical limit of watertight integrity is immersed when the ship heels greater than 5° then they may be led overboard and fitted with means of preventing water from passing inboard in accordance with 8.2.

8.1.4 In ships where an approved fixed pressure water spray fire-extinguishing system is fitted in vehicle, magazines or hangar spaces, deck scuppers of not less than 150 mm diameter are to be provided port and starboard, spaced about 9.0 m apart. Where the design capacity of the drencher system exceeds an application of water at a rate 5 litres per square metre of deck area by 10 per cent or more, the scupper area will require to be increased accordingly. After installation the two adjacent sections with the greatest aggregate drencher capacity are to be tested in operation to ensure that there is no build-up of water on the deck. The mouth of the scupper is to be protected by bars.

8.1.5 Where a sewage system is fitted, the shipside valves on the discharge pipe from the effluent tank(s) and the by-pass system are to comply with 8.2.

8.1.6 The minimum wall thickness of pipes not indicated in 8.2.6 is to be:
- 4.5 mm for pipes of 155 mm external diameter or smaller.
- 6.0 mm for pipes of 230 mm external diameter or greater.
Intermediate minimum thicknesses are to be determined by linear interpolation.

8.1.7 For the use of non-metallic pipe, see Vol 2, Pt 7, Ch 1.11.

8.1.8 Scuppers and discharge pipes should not normally pass through oil fuel tanks. Where scuppers and discharge pipes pass, unavoidably, through oil fuel tanks, and are led through the shell within the tanks, the thickness of the piping should be at least the same thickness as Rule shell plating in way, derived from the appropriate Chapters, but need not exceed 19 mm.

8.1.9 Piping within tanks is to be tested in accordance with the Naval Ship Survey Procedures Manual.
8.1.10 All piping is to be adequately supported.

8.2 Closing appliances

8.2.1 In general, each separate overboard discharge is to be fitted with a screw-down non-return valve capable of being operated from a position always accessible and above the damage control deck. An indicator is to be fitted at the control position showing whether the valve is open or closed. A machinery space, whether manned or unattended (i.e. with UMS notation), is considered accessible. Spaces with access only by bolted manholes are not considered accessible.

8.2.2 Where an approved fire pressure waterspray fire-extinguishing system is provided in an enclosed vehicle space, magazines or hangar spaces, the scupper controls are to be operated from a position above the damage control deck, and outside the space protected by the fire-extinguishing system, and are to be protected from mechanical damage.

8.2.3 Where the vertical distance from the design draught to the inboard end of the discharge pipe exceeds 0.01\( L_R \) the discharge may be fitted with two automatic non-return valves without positive means of closing, instead of the screw-down non-return valve, provided that the inboard valve is always accessible for examination under service conditions.

8.2.4 Where the vertical distance from the design waterline to the inboard end of the discharge pipe exceeds 0.02\( L_R \), a single automatic non-return valve without positive means of closing may be fitted, see Fig. 4.8.1.

\[ F \text{ less than } 0.01L_R \]

- Scupper from enclosed space
- Deck forming the vertical limit of watertight integrity
- One automatic non-return valve on shell operated from above the deck forming the vertical limit of watertight integrity fitted with controls and indicators

\[ F \text{ more than } 0.01L_R \text{ but less than } 0.02L_R \]

- Scupper from enclosed space
- Deck forming the vertical limit of watertight integrity
- Two automatic non-return valves without positive means of closing, one on shell and one always accessible under service conditions

\[ F \text{ more than } 0.02L_R \]

- Scupper from enclosed space
- Deck forming the vertical limit of watertight integrity
- One automatic non-return valve without positive means of closing

ANRV = Automatic non-return valve
ANRV of screw-down type
ANRV F = Positive control valve
\( L_R = \) Length of ship, see Pt 3, Ch 1.5.2.2
\( F = \) Vertical distance between the inboard end of the discharge pipe and deep draught waterline

Fig. 4.8.1 Diagrammatic arrangement of discharge valves
8.2.5 The requirements for non-return valves are applicable only to those discharges which remain open during the normal operation of the ship. For discharges which are closed at sea, a single screw-down valve operated from the weather deck is considered to provide sufficient protection.

8.2.6 Scuppers and discharge pipes originating at any level which penetrate the shell either more than 450 mm below the deck forming the vertical limit of watertight integrity or less than 600 mm above the deep draught waterline, are to be fitted with an automatic non-return valve at the shell. This valve, unless required by 8.1.3, may be omitted provided the piping has a minimum wall thickness of:
- 7,0 mm for pipes of 80 mm external diameter or smaller.
- 10,0 mm for pipes of 180 mm external diameter.
- 12,5 mm for pipes of 220 mm external diameter or greater.

Intermediate minimum thicknesses are to be determined by linear interpolation. Unless required by 8.1.8, the maximum thickness need not exceed 12,5 mm.

8.2.7 The outboard valve is to be mounted directly on the shell and secured in accordance with Vol 2, Pt 7, Ch 1. If this is impracticable, a short distance piece of rigid construction may be introduced between the valve and the shell.

8.2.8 If a valve is required by 8.1.3, this valve should preferably be fitted as close as possible to the point of entry of the pipe into the tank. If fitted below the weather deck, the valve is to be capable of being controlled from an easily accessible position above the weather deck. Local control is also to be arranged, unless the valve is inaccessible. An indicator is to be fitted at the control position showing whether the valve is open or closed.

8.2.9 Valves for maintaining watertight integrity such as ship side valves and their fittings (other than those on scuppers and sanitary discharges), are to comply with the requirements of Vol 2, Pt 7, Ch 1 and Ch 2.

8.3 Rubbish chutes and similar discharges

8.3.1 Rubbish chutes and similar discharges should be constructed of mild steel piping or plating of shell thickness. Other materials will be specially considered. Openings are to be kept clear of the sheerstrake and areas of high stress concentration.

8.3.2 Rubbish chute hoppers are to be provided with a hinged weathertight cover at the inboard end with an interlock so that the discharge flap and hopper cover cannot be open at the same time. The hopper cover is to be secured closed when not in use, and a suitable notice displayed at the control position.

8.3.3 Where the inboard end of the hopper is less than 0,01L_{R} above the design draught, a suitable valve with positive means for closing is to be provided in addition to the cover and flap in an easily accessible position above the design draught. The valve is to be controlled from a position adjacent to the hopper and provided with an open/shut indicator. The valve is to be kept closed when not in use, and a suitable notice displayed at the valve operating position.

8.4 Materials for valves, fittings and pipes

8.4.1 All shell fittings and valves required by 8.2 are to be of steel, bronze or other approved ductile material; ordinary cast iron or similar material is not acceptable. Materials are to satisfy the requirements of the Rules for the Manufacture, Testing and Certification of Materials.

8.4.2 All these items, if made of steel or other approved material with low corrosion resistance, are to be suitably protected against wastage.

8.4.3 The lengths of pipe attached to the shell fittings, elbow pieces or valves are to be of galvanised steel or other equivalent approved material.

Section 9

Bulwarks, guard rails, raised walkways and other means for the protection of crew and embarked personnel

9.1 General requirements

9.1.1 Bulwarks or guard rails are to be provided at the boundaries of exposed decks. Bulwarks or guard rails are to be not less than 1,0 m in height measured above sheathing, and are to be constructed as required by this Section. Consideration will be given to cases where this height would interfere with the normal operation of the ship. Guard rails provided around aircraft operating areas may be of the type which drop outwards with nets, provided access is restricted to essential personnel. Where bulwarks or rails are undesirable, e.g., for radar signature purposes, alternative equivalent arrangements will be required.

9.1.2 The freeing arrangements in bulwarks are to be in accordance with 9.3.

9.1.3 Guard rails fitted on superstructure and exposed decks are to have at least three courses. The opening below the lowest course of guard rails is not to exceed 230 mm. The other courses are to be spaced not more than 380 mm apart. In the case of ships with rounded gunwales, the guard rail supports are to be placed on the flat of the deck. In other locations, guard rails with at least two courses are to be fitted.

9.1.4 Guard rails are to be fitted with fixed, removable or hinged stanchions fitted no more than 1,5 m apart. Removable or hinged stanchions shall be capable of being locked in the upright position.

9.1.5 At least every third stanchion is to be supported by a stay.

9.1.6 Stowage is to be provided for portable stanchions and stays, sited adjacent to where they are to be used.
9.1.7 Where necessary for the normal operation of the ship, steel wire ropes may be accepted in lieu of guard rails. Wires are to be made taut by means of turnbuckles. Chains are only permitted in short lengths in way of access openings.

9.1.8 Satisfactory means for safe passage of personnel, in the form of guard rails, life-lines, handrails, gangways, underdeck passageways or other equivalent arrangements, are to be provided for the protection of the crew and embarked personnel in getting to and from their quarters, the machinery space and all other spaces used in the essential operation of the ship.

9.1.9 A well illuminated and ventilated underdeck passage (with a clear opening at least 0.8 m in width and 2 m in height) is to be provided as close as practicable to the weatherdeck, connecting and providing access to the following locations:

- between superstructures;
- from the forwardmost superstructure to the forward end of the vessel;
- from the aftmost superstructure to the aft end of the vessel.

9.1.10 To assist movement in adverse weather conditions, handrails are to be fitted to bulkheads in passageways and superstructure on weatherdecks.

9.1.11 Handrails are to be fitted at a height of not less than 1 m, measured from the top of the rail to the deck. Handrails should be made of steel tubes of 42.4 mm outside diameter, with a wall thickness of at least 2.6 mm.

9.1.12 Handrails are to be secured by way of supports that are not to be spaced more than 1.5 m apart. The supports are to hold the rails not less than 50 mm from the bulkhead, measured from the inside of the rail to the bulkhead.

9.1.13 Raised walkways which form escape routes or assembly areas, or provide for the transfer of heavy equipment, stores or munitions, are to comply with the requirements of 9.5.

9.1.14 For additional requirements for the safety of embarked persons, see Vol 3, Pt 1, Ch 6.2.4.

9.2 Bulwark construction

9.2.1 Plate bulwarks are to be stiffened by a strong rail section and supported by stays from the deck. The spacing of these stays forward of 0.93L/ref is to be not more than 1.2 m. Elsewhere, bulwark stays are to be not more then 1.83 m apart. Where bulwarks are cut to form a gangway or other opening, stays of increased strength are to be fitted at the ends of the openings. Bulwarks are to be adequately strengthened in way of eyeplates for RAS points, and in way of mooring pipes the plating is to be doubled or increased in thickness and adequately stiffened.

9.2.2 Bulwarks should not be cut for gangway or other openings near the breaks of superstructures, and are also to be arranged to ensure their freedom from main structural stresses. See shell plating in appropriate Chapters.

9.2.3 The section modulus, \( Z \), at the bottom of the bulwark stay is to be not less than:

\[
Z = (33.0 + 0.44L/R) h^2 s \quad \text{cm}^3
\]

where

- \( h \) = height of bulwark from the top of the deck plating to the top of the rail, in metres
- \( s \) = spacing of the stays, in metres, in accordance with 10.2.1
- \( L/R \) = length of ship, in metres (as defined in Ch 1.5.1), but to be not greater than 100 m.

9.2.4 In the calculation of the section modulus, only the material connected to the deck is to be included. The bulb or flange of the stay may be taken into account where connected to the deck, and where, at the ends of the ship, the bulwark plating is connected to the sheerstrake, a width of plating not exceeding 600 mm may also be included. The free edge of the stay is to be stiffened.

9.2.5 Bulwark stays are to be supported by, or to be in line with, suitable underdeck stiffening, which is to be connected by double continuous fillet welds in way of the bulwark stay connection.

9.3 Freeing arrangements

9.3.1 The following requirements are applicable to all ship types.

9.3.2 Where bulwarks on the weather decks or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of large quantities of water by means of freeing ports, and also for draining them.

9.3.3 The minimum freeing area on each side of the ship, for each well on the weather deck is to be derived from the following formulae:

(a) where the length, \( I \), of the bulwark in the well is 20 m or less: area required = 0.7 + 0.035I m\(^2\)

(b) where the length, \( I \), exceeds 20 m, area required = 0.07I m\(^2\)

\( I \) need not be taken greater than 0.7L/R, where L/R is the length of the ship as defined in Ch 1.5.2.

9.3.4 If the average height of the bulwark exceeds 1.2 m or is less than 0.9 m, the freeing area is to be increased or decreased, respectively, by 0.004 m\(^2\) per metre of length of well for each 0.1 m increase or decrease in height respectively.

9.3.5 The minimum freeing area for each well on a superstructure is to be half the area calculated from 9.3.3.

9.3.6 Two-thirds of the freeing port area required is to be provided in the half of the well nearest to the lowest point of the sheer curve.

9.3.7 When the deck has little or no sheer, the freeing area is to be spread along the length of the well.

9.3.8 In ships with no sheer the freeing area as calculated from 9.3.3 is to be increased by 50 per cent. Where the sheer is less than the standard, as given in Table 4.9.1, the percentage is to be obtained by linear interpolation.
9.3.9  Where the length of the well is less than 10 m, or where a deckhouse occupies most of the length, the freeing port area will be specially considered but in general need not exceed 10 per cent of the bulwark area.

9.3.10  Where it is not practical to provide sufficient freeing port area in the bulwark, particularly in small ships, credit can be given for bollard and fairlead openings where these extend to the deck.

9.3.11  Where a deckhouse has a breadth less than 80 per cent of the beam of the ship, or the width of the side passageways exceeds 1.5 m, the arrangement is considered as one well. Where a deckhouse has a breadth equal to or more than 80 per cent of the beam, B, of the ship, or the width of the side passageways does not exceed 1.5 m, or when a screen bulkhead is fitted across the full breadth of the ship, this arrangement is considered as two wells, before and aft of the deckhouse.

9.3.12  Suitable provision is also to be made for the rapid freeing of water from recesses formed by superstructures and deckhouses, etc., in which water may be shipped and trapped. Deck gear is not to be stowed in such a manner as to obstruct unduly the flow of water to freeing ports.

9.3.13  The lower edges of freeing ports are to be as near to the deck as practicable, and should not be more than 100 mm above the deck.

9.3.14  Where freeing ports are more than 230 mm high, vertical bars spaced 230 mm apart may be accepted as an alternative to a horizontal rail to limit the height of the freeing port.

9.3.15  Where shutters are fitted, the pins or bearings are to be of a non-corroding material, with ample clearance to prevent jamming. The hinges are to be within the upper third of the port. Shutters are not to be fitted with securing appliances.

9.3.16  All ships are to have open rails for at least half the length of the exposed part of the weather deck. Alternatively, if a continuous bulwark is fitted, the minimum freeing area is to be at least 33 per cent of the total area of the bulwark. The freeing area is to be placed in the lower part of the bulwark.

9.3.17  In ships having superstructures which are open at either or both ends to wells formed by bulwarks on the open deck, adequate provision for freeing the open spaces are to be provided as follows:

The freeing port area, \( A_w \), for the open well:

\[
A_w = (0.07t_w + A_c) \left( \frac{0.5h_b}{h_w} \right)
\]

The freeing port area, \( A_b \), for the open superstructure:

\[
A_b = (0.07t_b) \left( \frac{b_o}{t_b} \right) \left( 1 - \left( \frac{t_w}{t_b} \right)^2 \right) \left( \frac{0.5h_b}{h_w} \right)
\]

where

- \( t_w \) = the length of the open deck enclosed by bulwarks, in metres
- \( t_b \) = the length of the common space within the open superstructure, in metres
- \( l_t = l_y + l_z \) but if 20 m or less then the freeing area is to be calculated in accordance with 9.3.3(a)
- \( S_c \) = sheer correction factor, maximum 1.5 as defined in 9.3.8
- \( b_o \) = breadth of openings in the end bulkhead of the enclosed superstructure, in metres
- \( h_w \) = distance of the well deck above the freeboard deck, in metres
- \( h_b \) = one standard superstructure height
- \( h_o \) = actual height of the bulwark, in metres
- \( A_c \) = bulwark height correction factor taken as:
  - \( = 0 \) for bulwarks between 0.9 and 1.2 m in height
  - \( = 0.004l_w \left( \frac{h_o - 1.2}{1.0} \right) \) m\(^2\)
    for bulwarks of height greater than 1.2 m, and
  - \( = 0.004l_w \left( \frac{h_o - 0.9}{1.0} \right) \) m\(^2\)
    for bulwarks of height less than 0.9 m.

To adjust the freeing port area for the distance of the well deck above the weatherdeck, for decks located more than 0.5\( h_b \) above the weatherdeck, multiply by the factor 0.5\( (h_o/h_w) \).

9.3.18  Where a ship operates for extended periods in a cold weather environment, see Pt 5, Ch 2.4.2.3, closing devices fitted to freeing port arrangements are to remain effective. The arrangement will be specially considered.

9.4  Free flow area

9.4.1  The effectiveness of the freeing port area in bulwarks of vessels not fitted with a continuous deck obstruction, depends on the free flow across the deck.
9.4.2 The free flow area is the net total longitudinal area of the transverse passageways or gaps between hatchways and superstructures or deckhouses, due account being made for any obstructions such as equipment or other fittings. The height of passageways or gaps used in the calculation of the area is the height of the bulwark.

9.5 Walkways

9.5.1 Walkways are to be designed to an agreed specified standard.

9.5.2 Plans are to be submitted showing the proposed scantlings and arrangements of the structure.

9.5.3 The design loads used are to be as given in Pt 5, Ch 3, 5.3.1. Where it is intended that the walkway be used for the transfer or storage of equipment or other substantial items, the design loads are to be agreed considering the loads given in Pt 5, Ch 3, 5.3.1.

9.5.4 For the design of the supporting structure of walkways, the applicable self weight of the walkway structure is to be added to the total load derived in 9.5.3.

Section 10
Lagging and lining of structure

10.1 General

10.1.1 Suspended floors are to be fitted and secured in such a manner as to provide access to the structure and fittings below.

10.2 Removal for access

10.2.1 It is recommended that the cabin fittings and linings against the side of the ship be so fitted as to be capable of being removed when necessary. The method of attachment is not to impair the strength of the structural members.

10.2.2 Removable linings are to be fitted in areas prone to high structural degradation and areas that are critical to the structural integrity of the hull, to permit examination of these areas.

10.2.3 Decorative linings are to be manufactured of materials resistant to secondary fragmentation and combustion.

Section 11
Lifting eyes

11.1 Application

11.1.1 The following Section covers the design appraisal, testing during construction and through-life inspection of lifting eyes, with a permissible loading of 2.5 tonnes or less, installed for the purposes of shipping and unshipping equipment and machinery, and where they do not form part of a lifting appliance. Where the requirements of this Section are complied with the optional notation LE may be assigned.

11.1.2 The Owner is to ensure that the eyes are located in appropriate locations to enable the shipping and unshipping of equipment and machinery.

11.2 Information to be submitted

11.2.1 The following documentation is to be submitted for approval:
- Documentation detailing the range of standard lifting points to be used, see 11.4.

11.2.2 The following information is also to be submitted:
- A register of all equipment and machinery which is required to be shipped or unshipped during service.
- Plans detailing the shipping and unshipping routes by compartment.
- A register of all lifting points specifying the detail type, tally information and test loads.

11.3 Materials

11.3.1 Materials are to be in accordance with an agreed specified standard.

11.4 Lifting points

11.4.1 Lifting eyes are to be manufactured in accordance with an agreed specified standard.

11.4.2 A range of standard lifting point detail designs are to be selected. The range of detail types is to be appropriate for the weight of equipment and machinery which is required to be shipped or unshipped and the method of transfer which is to be used. When considering the weight of equipment and machinery the weight of the lifting gear is to be included.

11.4.3 Each standard lifting point detail is to have the following information defined:
- Permissible loading – Vertical lift.
- Permissible loading – Along eye-plate 45 degrees lift (where applicable).
- Permissible loading – Across eye-plate 45 degrees lift (where applicable).
- Material of construction.
- Method of attachment to the ship's structure.
- Method of use.
- Manufacturer's test loads.
11.4.4 The safe working load (SWL) for each of the standard detail designs is to be validated by calculation. The design load to be applied is as follows:
- \(2 \times \text{SWL}\) for the vertical lift case.
- \(1.5 \times \text{SWL}\) for the 45 degree lift case.
The permissible stresses in Table 4.11.1 are not to be exceeded.

Table 4.11.1 Permissible stresses

<table>
<thead>
<tr>
<th>Stress Type</th>
<th>Permissible Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bending and direct stress</td>
<td>(0.8\sigma_0)</td>
</tr>
<tr>
<td>Shear stress</td>
<td>(0.5\sigma_0)</td>
</tr>
<tr>
<td>Combined stress</td>
<td>(0.9\sigma_0)</td>
</tr>
</tbody>
</table>

\(\sigma_0\) = specified yield stress of the material, in N/mm²

11.4.5 The weld stresses are also to be validated by calculation and confirmed as acceptable. For this purpose a factor of 0.7 is to be used.

11.5 Supporting structure

11.5.1 Lifting points are to be located at the intersection of structural members wherever possible.

11.5.2 The strength of the supporting structure is to be validated by calculation.

11.5.3 Where double tallying is used, see 11.6.2, the unused direction is to be checked at an angle of 45 degrees for a load 0.25 times the SWL.

11.6 Tallying

11.6.1 Each lifting point is to have a tally displayed which clearly defines the permissible methods of use and the permissible loading associated with each method.

11.6.2 In general, a lifting point will have a single tally all round capability or single tally vertical lift only. A double tally is only to be used where the supporting structure would be required to be strengthened to provide all round capability but where the planned method of use does not require all-round capability.

11.7 Testing

11.7.1 Each lifting eye is to be supplied with a Manufacturer’s Test Certificate. A vertical lift and 45 degree lift test are to be carried out. The test load is to be \(2 \times \text{SWL}\) for the vertical lift arrangement and \(1.5 \times \text{SWL}\) for the 45 degree lift arrangement.

11.7.2 Once installed on board the ship, each lifting eye is to be load tested to \(2 \times \text{SWL}\) in the vertical direction. Documentation detailing the test loads and testing arrangement used is to be submitted to LR.

11.7.3 The weld attachment to the ship’s structure of each lifting eye is to be visually inspected by a Surveyor. Where requested, Magnetic Particle Inspection is also to be carried out and the results are to be submitted to LR.

11.8 Inspection during service

11.8.1 A maintenance and inspection regime is to be developed in accordance with a recognised Standard (e.g., Merchant Shipping and Fishing Vessels (Lifting Operations and Lifting Equipment) Regulations 2006), documented and confirmed as being implemented by the attending Surveyor. As a minimum the procedure is to:
- Define the Standard or applicable legalisation which is used to define a Responsible Person;
- Nominate an appropriate Responsible Person or persons;
- Detail any training which the Responsible Person is to receive;
- Detail any qualifications which the Responsible Person is to hold;
- State that lifting points are to be inspected by a Responsible Person prior to and after use;
- Mandate that a record is kept of when each lifting point was last inspected and by whom;
- Authorise the Responsible Person to request that the lifting eye is to be load tested in accordance with 11.7.2 upon inspection;
- Authorise the Responsible Person to remove the item from service should they consider it appropriate to do so.
Section 1
General

1.1 Application
1.1.1 The anchoring equipment specified in this Section is suitable for ships designed for unrestricted service.

1.2 Definitions
1.2.1 The definitions for use throughout this Chapter are as indicated in the appropriate Section.

1.3 Character of classification
1.3.1 For classification purposes the character figure 1, or the character letter E, is to be assigned.

1.3.2 To entitle a ship to the character 1 in its classification symbol, equipment in accordance with the requirements of Sections 4, 5, 6, 8 and 9 is to be provided. The regulations governing the assignment of the character figure 1 for equipment are given in Pt 1, Ch 2.

1.3.3 Where Lloyd’s Register (hereinafter referred to as ‘LR’) has agreed that anchoring and mooring equipment, as defined in 1.3.2, need not be fitted in view of the particular service of the ship, the character letter E will be assigned. See also Pt 1, Ch 2.

1.3.4 For ships intended to be operated only in suitable areas or conditions, other than those included in this Section, which have been agreed by LR, (as defined in Pt 1, Ch 2.3.6) equipment differing from these requirements may be approved if considered suitable for the particular service on which the ship is to be engaged.

Section 2
Equipment Number

2.1 Equipment Number calculation
2.1.1 The anchoring and mooring equipment specified in this Section is based on an ‘Equipment Number’ which is to be calculated as follows:

\[
\text{Equipment Number} = \Delta^{2/3} + 2.5A_t + A/10
\]

where

- \(A\) = area, in m\(^2\), in profile view, of the hull, superstructures, houses, masts, etc. above the design draught which are within the Rule length of the vessel and also have a breadth greater than \(B/4\). See also 2.1.2

- \(A_t\) = transverse projected area, in m\(^2\), of the hull and of all superstructures, houses, masts, etc., above the design draught

- \(\Delta\) = displacement, in tonnes, of the ship at its deep draft waterline.

2.1.2 Screens and bulwarks more than 1.5 m in height are to be regarded as parts of houses when determining \(A\). Where a screen or bulwark is of varying height, the portion to be included is to be that length the height of which exceeds 1.5 m.

2.1.3 For ships which have a complex above water transverse profile due to the presence of large plated masts, mast trees, large radar equipment, etc., the equipment number may need to be specially considered.

2.2 Novel ship design
2.2.1 Where a ship is of unusual form and proportions the requirement for equipment will be individually considered on the basis of the Rules.

Section 3
Service area factors

3.1 General
3.1.1 For details of the service areas referred to in this Section, see Pt 5, Ch 2.2.2.

3.2 Service Areas SA1, SA2, SA3, SA4, SAR
3.2.1 For ships designed to operate in any service area, the equipment is to be in accordance with the requirements of Tables 5.4.1 and 5.6.1.
Anchoring, Mooring, Towing, Berthing,
Launching, Recovery and Docking

Section 4
Anchors

4.1 General

4.1.1 The Rules are based on the use of high holding power (HHP) type anchors.

4.1.2 When ordinary holding power anchors are used as bower anchors, the mass given in Table 5.4.1 is to be increased by 33 per cent.

4.1.3 Where it is proposed to fit other types of anchor, the mass will be specially considered.

4.1.4 Ships are to be provided with the number of anchors specified in Table 5.4.1 which must be ready for immediate use. Where this is impractical, see 9.3.4, special consideration may be given to only having one anchor ready for immediate use.

4.1.5 Where there is a high degree of redundancy in propulsion and steering and where the engine can be brought to readiness quickly, consideration may be given to the fitting of a single anchor where Table 5.4.1 requires the fitting of two anchors.

4.1.6 Anchors are to be of an approved design. The design of all anchor heads is to be such as to minimise stress concentrations, and in particular, the radii on all parts of cast anchor heads are to be as large as possible, especially where there is considerable change of section.

4.1.7 Anchors which must be specially laid the right way up, or which require the fluke angle or profile to be adjusted for varying types of sea bed, will not generally be approved for normal ship use, but may be accepted for offshore units, floating cranes, etc. In such cases suitable tests may be required.

4.1.8 Where kedge anchors are specified, they are to be in accordance with Table 5.6.1.

4.2 Manufacture and testing of anchors

4.2.1 The requirements for the manufacture, testing and certification of anchors are contained in Chapter 10 of the Rules for the Manufacture, Testing and Certification of Materials (hereinafter referred to as the Rules for Materials).

4.3 Anchor stowage

4.3.1 Anchors are generally to be housed in suitable hawse pipes, or stowed in dedicated chocks on deck.

4.3.2 Hawse pipes and anchor pockets are to be in accordance with 8.3. Alternatively, roller fairleads of suitable design may be fitted. Where hawse pipes are not fitted, alternative arrangements will be specially considered.

4.4 High Holding Power (HHP) type anchors

4.4.1 Anchors of designs for which approval is sought as high holding power anchors are to be tested in accordance with Chapter 10 of the Rules for Materials.

4.5 Super High Holding Power (SHHP) type anchors

4.5.1 Proposals to use anchors of the SHHP type will be subject to special consideration.

4.5.2 Final acceptance will be dependent upon satisfactory strength and performance tests.

4.5.3 Anchors of designs for which approval is sought as super high holding power anchors are to be tested at sea to show that they have holding powers of at least four times those of approved standard stockless anchors of the same mass.

4.6 Tolerances

4.6.1 The mass of each bower anchor given in Table 5.4.1 is for anchors of equal mass. The masses of individual anchors may vary by ±7 per cent of the masses given in the Table, provided that the total mass of the anchors is not less than would have been required for anchors of equal mass.

4.6.2 The mass of the head, including pins and fittings, of an ordinary stockless anchor is to be not less than 60 per cent of the total mass of the anchor.

4.6.3 When stocked bower or kedge anchors are to be used, the mass ‘ex stock’ is to be not less than 80 per cent of the mass given in Table 5.4.1 for ordinary stockless bower anchors and Table 5.6.1 for kedge anchors. The mass of the stock is to be 25 per cent of the total mass of the anchor, including the shackle, etc., but excluding the stock.

4.7 Identification

4.7.1 Identification of anchors which have been tested is to be in accordance with Chapter 10 of the Rules for Materials.
Table 5.4.1 Equipment – HHP Bower anchors and chain cables

<table>
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<tr>
<th>Equipment number</th>
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<th>Equipment Letter</th>
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<td>Total length, in metres</td>
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5.4 Cable clench

5.4.1 Provision is to be made for securing the inboard ends of the cables to the structure. This attachment should have a working strength of not less than 63.7 kN or 10 per cent of the breaking strength of the chain cable, whichever is the greater, and the structure to which it is attached is to be adequate for this load. Attention is drawn to the advantages of arranging that the cable may be slipped from an accessible position outside the chain cable locker. The proposed arrangement for slipping the chain cable, if constructed outside the chain locker, must be made watertight.

5.5 Cable stopping and release arrangements

5.5.1 It is recommended that suitable bow chain stoppers be provided. The scantlings of these chain stoppers are outside the scope of the Rules, however the structure in way is to be designed with due regard to the applied loading. Support under chain stopping arrangements is to be to the satisfaction of the Surveyor.

5.6 Cable locker

5.6.1 Adequate storage is to be provided to accommodate the full length of anchor cable.

5.6.2 The chain locker is to be of a capacity and depth adequate to provide an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. Chain or spurling pipes are to be of suitable size and provided with chafing lips. The port and starboard cables are to be separated by a division in the locker.

5.6.3 Chain lockers fitted abaft the collision bulkhead are to be weathertight and the space to be efficiently drained.

6.1 Mooring ropes

6.1.1 Ships under 90 m require mooring lines as specified in Table 5.6.1.

6.1.2 The lengths of individual mooring lines in Table 5.6.1 may be reduced by up to seven per cent of the Table length, provided that the total length of mooring lines is not less than would have resulted had all lines been of equal length. Proposals to fit individual mooring lines of reduced length to suit the particular service will be specially considered.
Anchoring, Mooring, Towing, Berthing, Launching, Recovery and Docking  
Volume 1, Part 3, Chapter 5  
Section 6  

RULES AND REGULATIONS FOR THE CLASSIFICATION OF NAVAL SHIPS, January 2015

Table 5.6.1 Equipment – Kedge anchors, wires and mooring lines

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NOTES
1. The rope used for kedge anchor wire is to be constructed of not less than 72 wires, made up into six strands.
2. Steel wire and fibre ropes used for mooring lines and kedge anchors are to meet the requirements of Ch 10,6 and 7 of the Rules for Materials respectively.
3. Wire ropes for mooring lines used in association with mooring winches (on which the rope is stored on the winch drum) are to be of suitable construction.
4. Irrespective of strength requirements, no fibre rope is to be less than 20 mm diameter.
6.1.3 Ships 90 m and over in length do not require mooring lines as a classification item. It is recommended, however, that the sum of the strengths of all the mooring lines supplied to such ships should be not less than the Rule breaking load of one anchor cable as required by Table 5.4.1, based on Grade U2 chain. On ships regularly using exposed berths, twice the above total strength of mooring ropes is desirable.

6.1.4 It is recommended that not less than four mooring lines be carried on ships exceeding 90 m in length, and not less than six mooring lines on ships exceeding 180 m in length. The length of mooring lines should be not less than 200 m, or the length of the ship, whichever is the lesser.

6.1.5 For ease of handling, fibre ropes should be not less than 20 mm diameter. All ropes having breaking strengths in excess of 736,0 kN and used in normal mooring operations are to be handled by, and stored on, suitably designed winches. Alternative methods of storing should give due consideration to the difficulties experienced in manually handling ropes having breaking strengths in excess of 490,0 kN.

6.2 Materials

6.2.1 Mooring lines may be of steel wire rope, natural fibre or synthetic fibre. The diameter, construction and specification of wire or natural fibre mooring lines are to comply with the requirements of Chapter 10 of the Rules for Materials. Where it is proposed to use synthetic fibre ropes, the size and construction will be specially considered.

6.2.2 The design loads applied to deck fittings by 6.6 relate to conventional fibre ropes (i.e. polypropylene, polyester and nylon). If other materials are used, i.e. HMPE, consideration should be given to the elongation properties and therefore the design load applied to deck fittings.

6.2.3 Wire rope mooring lines used in association with winches (on which the rope is stored on the winch drum) are to be of suitable construction.

6.3 Testing and certification

6.3.1 Mooring ropes are to be tested and certified in accordance with Chapter 10 of the Rules for Materials.

6.4 Bollards, fairleads and bull rings

6.4.1 Means are to be provided to enable mooring lines to be adequately secured on board ship.

6.4.2 It is recommended that the total number of suitably placed bollards on either side of the ship and/or the total brake holding power of mooring winches should be capable of holding not less than 1.5 times the sum of the maximum breaking strengths of the mooring lines required or recommended.

6.4.3 Bollards, fairleads and bull rings are to be located on longitudinals, beams and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the mooring load. Other equivalent arrangements (Panama chocks, etc.) will be considered providing the strength is confirmed as adequate for the intended use.

6.4.4 It is recommended that shipboard fittings are selected in accordance with an Industry standard (e.g. ISO3913 Shipbuilding Welded Steel Bollards) accepted by the Society. When the shipboard fitting is not selected from an accepted Industry standard, the design load used to assess its strength and its attachment to the ship is to be in accordance with 6.6.3 and the design is to be submitted for approval.

6.4.5 The SWL of each shipboard fitting is not to exceed 80 per cent of the design load as per 6.6.3. It is to be marked (by weld bead or equivalent) on the deck fittings used for mooring. The SWL with its intended use is to be noted in the mooring arrangement plan or other information available on board for the guidance of the Master. These requirements for SWL apply for a single post basis (no more than one turn of one cable). The arrangement plan is to explicitly prohibit the use of mooring lines outside of their intended function.

6.5 Mooring winches

6.5.1 Mooring winches where provided are to be suitable for the intended purpose.

6.5.2 Mooring winches are to be fitted with drum brakes, the strength of which is sufficient to prevent unreeeling of the mooring line when the rope tension is equal to 80 per cent of the breaking strength of the rope as fitted on the first layer on the winch drum.

6.6 Support structure of deck fittings

6.6.1 Plans are to be of sufficient detail for plan approval purposes. Plans covering the following items are to be submitted for approval:

- Strong points, bollards and fairleads, see 6.4.4.
- Support structure and foundations of towing equipment.

6.6.2 A mooring arrangements plan is to be submitted for information and is to include the following in respect of each shipboard fitting:

- Location on the ship.
- Fitting type.
- Safe working load (SWL).
- Purpose of fitting (mooring/harbour towing/escort towing).
- Manner of applying towing or mooring line load, including limiting fleet angles.

A mooring arrangement plan is to be provided on board the ship for the guidance of the Master.
6.6.3 The design load to be applied to the supporting structure of mooring fittings is to be 1.25 times the minimum breaking strength of the mooring line according to Table 5.6.1 for the ship's corresponding equipment number.

6.6.4 The design load to be applied to the supporting structure of winches is to be 1.25 times the rated maximum holding power of the winch or the rated maximum pull power, whichever is greater.

6.6.5 The design load to be applied according to the arrangement shown on the mooring arrangement plan. The point of action of the force on the fitting is to be taken as the point of attachment of the mooring line or towline or at a change in its direction. The total design load applied to a fitting need not be more than twice the design load, see Fig. 5.7.1.

6.6.6 The reinforced members (carling) beneath shipboard fittings are to be effectively arranged for any variation of direction (horizontally and vertically) of the mooring forces (which is to be not less than the design load) acting through the arrangement of connection to the shipboard fittings. Other arrangements will be specially considered, provided that the strength is confirmed as adequate for the service.

6.6.7 The stresses in shipboard fittings associated with mooring are not to exceed the specified minimum yield stress of the material in bending and 60 per cent of the specified minimum yield stress of the material in shear considering the design load.

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Section 7

Towing arrangements

7.1 Definition

7.1.1 Towing can be defined as either receiving motive assistance from, or rendering it to, another vessel.

7.2 Application

7.2.1 The towing arrangements specified in this Section are applicable to NS1, NS2 and NS3 category ships carrying the corresponding optional towing arrangement notation.

7.2.2 The strength of strong points, fittings and machinery are to be proof tested unless type approved.

7.2.3 In general, ships complying with the requirements of this Section will be eligible to be classed with the notation TA1, TA2 or TA3.

7.2.4 TA1 This notation will be assigned when an appraisal has been made of the towing arrangements and strength performance of the supporting structures in accordance with the Rules. This notation recognises weather conditions less severe than TA1, see Tables 5.7.2 and 5.7.3.

7.2.5 TA2 This notation will be assigned when an appraisal has been made of the towing arrangements and strength performance of the supporting structures in accordance with the Rules. This notation recognises weather conditions less severe than TA1, see Tables 5.7.2 and 5.7.3.

7.2.6 TA3 This notation will be assigned when an appraisal has been made of the towing arrangements and strength performance of the supporting structures in accordance with the Rules. This notation recognises the least severe weather conditions, see Tables 5.7.2 and 5.7.3.

7.2.7 These three levels of towing arrangements in 7.2.4 to 7.2.6 recognise towing a ship of similar displacement at 6 knots in defined environmental conditions (see Table 5.7.3) and are appropriate for the weather conditions found in the equivalent service areas, i.e., TA1 corresponds to the weather conditions found with service area notation SA1.

7.2.8 Where alternative requirements to the breaking load of the towing hawser required by Pt 3, Ch 5, 7.6.1 are specified have been complied with, the ship will be entitled to the notation TA(NS). These alternative requirements are to be clearly defined and referenced in the Certificate of Class. The load specified in the alternative is to replace the BL value given by the expression in 7.6.1.

7.2.9 Where the towline complies with the strength requirements of Table 5.7.1 as applicable to merchant ships for the related equipment number, the ship will be entitled to the assignment of the TA(S) notation. The breaking load specified in Table 5.7.1 is to replace the BL value given by the expression in 7.6.1.

7.2.10 Towing operations are to be in accordance with the towing, mooring and arrangements plan or equivalent information which is required to be placed on board. See 7.4.

7.3 Materials

7.3.1 Towing hawsers and towing pennants can be of steel wire rope, natural fibre or synthetic fibre. The diameter, construction and specification of steel wire or fibre towlines are to comply with Chapter 10 of the Rules for Materials. Where synthetic fibre ropes are used the size and construction will be specially considered.

7.3.2 Where a length of chafing chain is included in the arrangement it is to comply with Chapter 10 of the Rules for Materials.

7.3.3 The design loads applied to deck fittings by this Section relate to conventional fibre ropes (i.e. polypropylene, polyester and nylon). Consideration should be given to the elongation properties of the actual line used.

7.3.4 Wire ropes used in association with winches (on which the rope is stored on the winch drum) are to be of suitable construction.
7.4 Information required

7.4.1 Plans are to be of sufficient detail for plan approval purposes. Plans covering the following items are to be submitted for approval:
- Strong points, bollards and fairleads, see 7.5.7.
- Support structure and foundations of towing equipment.

7.4.2 The towing arrangement plan is to be submitted for information. It is to include the following in respect of each shipboard fitting:
- Location on the ship.
- Fitting type.
- Safe working load (SWL).
- Manner of applying towing line load, including limiting fleet angles.

The towing arrangement plan is to be provided on board the ship for the guidance of the Master.

7.5 Towing arrangements

7.5.1 A towing arrangement is to be provided at both the fore and aft end of the ship.

7.5.2 The fixed towing equipment is to comprise a securing arrangement which is a strong point and may be in the form of a stopper, bracket, deck clench or towing slip. A fairlead, rollers or other appropriate towline guides as necessary are to be included in the arrangement.

7.5.3 Loose towing equipment is to comprise a towing hawser and a towing pennant. The towing pennant may comprise a length of chafing chain. In the absence of a length of chafing chain suitable arrangements (e.g. a low friction sheath) are to be provided.

<table>
<thead>
<tr>
<th>Table 5.7.1</th>
<th>Equipment – Minimum length and breaking strength of towlines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment number</td>
<td></td>
</tr>
<tr>
<td>Exceeding Not Exceeding</td>
<td>Equipment Letter</td>
</tr>
<tr>
<td>50</td>
<td>70</td>
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<tr>
<td>70</td>
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<table>
<thead>
<tr>
<th>Table 5.7.2</th>
<th>Design weather factors</th>
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<tbody>
<tr>
<td>Applicable notation</td>
<td>Wind speed coefficient, $C_{\text{MW}}$</td>
</tr>
<tr>
<td>TA1</td>
<td>0.0150</td>
</tr>
<tr>
<td>TA2</td>
<td>0.0129</td>
</tr>
<tr>
<td>TA3</td>
<td>0.0108</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 5.7.3</th>
<th>Environmental conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beaufort Scale</td>
<td>Equivalent mean wind speed (knots)</td>
</tr>
<tr>
<td>1–4</td>
<td>1–16</td>
</tr>
<tr>
<td>5</td>
<td>17–21</td>
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<tr>
<td>6</td>
<td>22–27</td>
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<tr>
<td>7</td>
<td>28–33</td>
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<td>8</td>
<td>34–40</td>
</tr>
<tr>
<td>9</td>
<td>41–47</td>
</tr>
<tr>
<td>10+</td>
<td>48+</td>
</tr>
</tbody>
</table>
7.5.4 Fairleads and guides are to be designed so as to prevent excessive bending stress in the towing hawser, towing pennant or chafing chain, whichever is applicable. The bending ratio of the guides bearing surface to the diameter of the applicable towline element is not to be less than 7 to 1. For fibre rope towing hawsers and towing pennants the bending ratio is to comply with the rope manufacturer's specification.

7.5.5 The fairlead or guide is to have an opening large enough to allow the passage of the largest element of the loose towing equipment.

7.5.6 The fairlead or guide is to be fitted as close to the deck as practicable and in a position so that the tow will be approximately parallel to the deck when under tension between the strong point and the guide.

7.5.7 The selection of shipboard fittings is to be made by the shipyard in accordance with an acceptable National or International standard. If the shipboard fitting is not selected from an acceptable National or International standard then the design load used to assess its strength and its attachment to the ship is to be in accordance with the design load given in 7.6.3. The design is to be submitted for approval. Any weld, bolt or equivalent device connecting the shipboard fitting to the supporting structure is part of the shipboard fitting and is subject to the National or International standard applicable to that shipboard fitting.

7.5.8 Deck fittings and strong points are to be located on longitudinals, beams and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the towing load. Other equivalent arrangements will be considered, providing the strength is confirmed as adequate for the intended use.

7.5.9 To avoid chafing, the arrangement is to be designed so that no element of the loose towing equipment, when under tension, is to contact with the ship's hull at any point other than those specified as a securing arrangement, fairlead or guide. The final point of contact of the towline with the ship is to be positioned as close as practicable to the centre line so as to reduce the adverse effect on manoeuvrability.

7.5.10 The chafing arrangement is to extend a minimum of 3 m outboard of the fairlead or guide when in the deployed position and 2 m inboard.

7.5.11 The loose towing equipment is to be located as near as practicable to the strong point and is to be designed to be capable of being rigged and deployed in the absence of power. It is recommended that extra loose gear meeting the requirements of this Section be carried on board to provide for redundancy.

7.5.12 The minimum length of the towing hawser is to be as given in Table 5.7.1.

7.5.13 Irrespective of strength requirements, no fibre rope is to be less than 20 mm in diameter.

7.5.14 The SWL of each shipboard fitting is to be clearly marked, by weld bead or equivalent, on each of the fittings used for towing, see 7.6.10.

7.6 Strength requirements for towing arrangements

7.6.1 The minimum Breaking Load (hereinafter referred to as BL) of the towing hawser, in tonnes, is not to be less than that calculated below:

\[ BL = (0.03\Delta^{2/3} + (C_{mw},A_t)) \cdot K \]

where

- \( \Delta \) = displacement, in tonnes, to the deep draught waterline
- \( C_{mw} \) = wind speed coefficient, which is to be taken from Table 5.7.2 for the relevant notation
- \( K \) = weather factor, which is to be taken from Table 5.7.2 for the relevant notation
- \( A_t \) = transverse projected area, in m\(^2\), of the hull and of all superstructures, houses, masts, etc., above the design draught.

7.6.2 The strength of other loose towing equipment, e.g. links, shackles rings and chafing chain is to be determined on the basis of a design load equal to 1,25 times the BL of the towing hawser.

7.6.3 The strength of shipboard fittings and their supporting structure is to be determined on the basis of a design load equal to 1,25 times the BL of the towing hawser. The design load is to be applied through the towline according to the arrangement shown on the towing arrangement plan. The point of action of the force on the fitting is to be taken as the point of attachment of the mooring line or towline or at a change in its direction. The total design load applied to a fitting need not be more than twice the design load, see Fig. 5.7.1.

7.6.4 The stress in all loose and fixed towing equipment constructed of steel, and its supporting structure, is not to exceed the specified minimum yield stress of the material in bending and 60 per cent of the specified minimum yield stress of the material in shear. Special consideration will be given if the vessel and/or towing equipment is not constructed of steel.
7.6.5 The reinforced members (carling) beneath shipboard fittings are to be effectively arranged for any variation of direction (horizontally and vertically) of the towing forces (which is to be not less than the design load) acting through the arrangement of connection to the shipboard fittings. Other arrangements will be specially considered provided that the strength is confirmed as adequate for the service.

7.6.6 For the assessment of fairleads and their supporting structure, due consideration is to be given to lateral loads. The strength of the fairlead is to be sufficient for all angles of towing load up to 90° horizontally from the ship’s centreline and 30° vertically from the horizontal plane.

7.6.7 For the assessment of a strong point and its supporting structure, the applied load is to be in the direction that the towing pennant or towing hawser will take up during normal deployment. It is also to be applied at the maximum height possible above the deck for that specific type of strong point.

7.6.8 The structural arrangements of strong points, bollards and fairleads are to be such that continuity will be ensured. Abrupt changes in section; sharp corners and other points of stress concentration are to be avoided.

7.6.9 Strong points are to be fitted in way of a transverse or longitudinal deck girder or beam to facilitate efficient distribution of the towing load.

7.6.10 The SWL of each towing arrangement component is to be no greater than 80 per cent of the design load applied.

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Section 8

Windlass and capstan design and testing

8.1 General

8.1.1 A windlass, capstan or winch of sufficient power and suitable for the size of anchor cable is to be fitted to the ship. Where Owners require equipment significantly in excess of Rule requirements, it is their responsibility to specify increased windlass power.

8.1.2 The windlass seating to be designed to loads no less than the maximum pull developed by the windlass.

8.1.3 Windlasses may be hand or power operated, subject to the requirements of 8.2.3.

8.1.4 Where steel wire rope is used in lieu of chain cable, a suitable winch with sufficient drum capacity to store the length of wire rope fitted is to be provided.

8.1.5 The windlass, anchoring capstans and winches are to be of types approved by LR.

8.1.6 On ships equipped with anchors having a mass of over 50 kg, windlass(es) of sufficient power and suitable for the type and size of chain cable are to be fitted. Arrangements with anchor davits will be specially considered.

8.1.7 The design of the windlass is to be such that the following requirements or equivalent arrangements will minimise the probability of the chain locker or forecastle being flooded in bad weather:

(a) a weathertight connection can be made between the windlass bedplate, or its equivalent, and the upper end of the chain pipe, and

(b) access to the chain pipe is adequate to permit the fitting of a cover or seal, of sufficient strength and proper design, over the chain pipe while the ship is at sea.

8.2 Windlass design

8.2.1 The following performance criteria are to be used as a design basis for the windlass:

(a) The windlass is to have sufficient power to exert a continuous duty pull over a period of 30 minutes of:

(i) For specified design anchorage depths up to 82.5 m:

<table>
<thead>
<tr>
<th>Cable grade</th>
<th>Duty pull, P, in N</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1</td>
<td>37,5d_c^2</td>
</tr>
<tr>
<td>U2</td>
<td>42,5d_c^2</td>
</tr>
<tr>
<td>U3</td>
<td>47,5d_c^2</td>
</tr>
</tbody>
</table>

(ii) For specified design anchorage depths greater than 82.5 m:

\[ P_1 = P + (D_a - 82.5) 0.27d_c^2 \] N

where \( d_c \) is the chain diameter, in mm, \( D_a \) is the design anchorage depth, in metres, \( P \) is the duty pull for anchorage depth up to 82.5 m and \( P_1 \) is the duty pull for the anchorage depths greater than 82.5 m.

(b) The windlass is to have sufficient power to exert, over a period of at least two minutes, a pull equal to the greater of:

(i) short term pull: 1.5 times the continuous duty pull as defined in 8.2.1(a).

(ii) anchor breakout pull:

\[ 12.18W_a + \frac{7.0L_c \cdot d_c^2}{100} \] N

where

\( L_c \) is the total length of chain cable on board, in metres, as given by Table 5.4.1

\( W_a \) is the mass of bower anchor (kg) as given in Table 5.4.1.
In the absence of a chain stopper, the windlass, with its braking system in action and in conditions simulating those likely to occur in service, is to be able to withstand, without permanent deformation or brake slip, a load, applied to the cable, given by:

\[ K_b d_c^2 (44 - 0.08 d_c) \quad \text{N} \]

where

- \( K_b \) is given in Table 5.8.1
- \( d_c \) is the cable diameter

The performance criteria are to be verified by means of shop tests in the case of windlasses manufactured on an individual basis. Windlasses manufactured under LR's Type Approval Scheme for Marine Engineering Equipment will not require shop testing on an individual basis.

Where a chain stopper is fitted, the windlass braking system is to have sufficient brake capacity to ensure safe stopping when paying out the anchor and chain. It is the Master's responsibility to ensure that the chain stopper is in use when riding at anchor. At clearly visible locations on the bridge and adjacent to the windlass control position the following notice is to be displayed:

"The brake is rated to permit controlled descent of the anchor and chain only. The chain stopper is to be used at all times whilst riding at anchor."

8.2.2 Windlass performance characteristics specified in 8.2.1 and 8.3.2 are based on the following assumptions:
(a) One cable lifter only is connected to the drive shaft.
(b) Continuous duty and short term pulls are measured at the cable lifter.
(c) Brake tests are carried out with the brakes fully applied and the cable lifter declutched.
(d) The probability of declutching a cable lifter from the motor with its brake in the off position is minimised.
(e) Hawse pipe efficiency assumed to be 70 per cent.

8.2.3 Hand-operated winches are only acceptable if the effort required at the handle does not exceed 150 N for raising one anchor at a speed of not less than 2 m/min and making about thirty turns of the handle per minute.

8.2.4 Winches suitable for operation by hand as well as by external power are to be so constructed that the power drive cannot activate the hand drive.

8.2.5 Calculations for torque transmitting components are to be based on 1500 hours of operation with a nominal load spectrum factor of 1.0. Alternatively, unlimited hours with a nominal load spectrum factor of 0.8 can be applied.

8.2.6 Where the available input torque exceeds the torque required for anchor breakout then torque overload protection is to be fitted.

8.2.7 An arrangement to release the anchor and chain in the event of windlass power failure is to be provided.

8.2.8 The maximum stress from load cases stated in Table 5.8.2 is not to exceed the limits stated in Table 5.8.3.

Table 5.8.1 Values of \( K_b \)

<table>
<thead>
<tr>
<th>Cable grade</th>
<th>Windlass used in conjunction with chain stopper</th>
<th>Chain stopper not fitted</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1</td>
<td>4.41</td>
<td>4.02</td>
</tr>
<tr>
<td>U2</td>
<td>6.18</td>
<td>6.00</td>
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<tr>
<td>U3</td>
<td>8.93</td>
<td>8.75</td>
</tr>
</tbody>
</table>

8.2.9 Design load cases for windlass and chainstopper

<table>
<thead>
<tr>
<th>Load case</th>
<th>Condition</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Continuous pull</td>
<td>See 8.2.1(a)</td>
</tr>
<tr>
<td>2</td>
<td>Overload pull</td>
<td>See 8.2.1(b)</td>
</tr>
<tr>
<td>3</td>
<td>Brake holding load</td>
<td>See 8.2.1(c)</td>
</tr>
</tbody>
</table>

Table 5.8.3 Permissible stress for design load cases

<table>
<thead>
<tr>
<th>Stress</th>
<th>Load case</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 and 2</td>
</tr>
<tr>
<td>Tension</td>
<td>0.8Y</td>
</tr>
<tr>
<td>Compression or bending</td>
<td>0.8Y</td>
</tr>
<tr>
<td>Shear</td>
<td>0.7Y</td>
</tr>
<tr>
<td>Combined</td>
<td>0.85Y</td>
</tr>
</tbody>
</table>

NOTES
1. Where a component is subjected to axial tensile, axial compressive, bending or shear stress, \( F_c \) is to be calculated in the normal manner.
2. Where a component is subjected to a combination of co-existent stresses, \( F_c \) is the combined stress which is to be calculated as follows:

\[ F_c = \sqrt{1.25 f_t + f_{bt}} \]

Combined bending and tension
\[ F_c = f_t + f_{bc} \]
Combined bending and compression
\[ F_c = \sqrt{(1.25 f_t + f_{bt})^2 + 3 f_{bc}^2} \]
Combined bending, compression and shear

where

- \( f_t \) is the calculated axial tensile stress
- \( f_{bt} \) is the calculated maximum tensile stress due to bending about both principal axes
- \( f_{bc} \) is the calculated maximum compressive stress due to bending about both principal axes
- \( f_{q} \) is the specified 0.2 per cent proof stress for the material
8.2.9 The following criteria are to be used for gearing design:
(a) Torque is to be based on the performance criteria specified in 8.2.1.
(b) The use of an equivalent torque, $T_{eq}$, for dynamic strength calculations is acceptable but the derivation is to be submitted to LR for consideration.
(c) The application factor for dynamic strength calculation, $K_A$, is to be 1.15.
(d) Calculations are to be based on 1500 hours of operation.
(e) The static torque is to be $1.5 \times T_n$ where $T_n$ is the nominal torque.
(f) The minimum factors of safety for load capacity of spur and helical gears, as derived using ISO 6336 or a relevant National or International Standard acceptable to LR, are to be 1.5 for bending stress and 0.6 for contact stress.

8.2.10 Keyways are to be designed to a relevant National or International Standard acceptable to LR.

8.2.11 The maximum stress in brake components is not to exceed the permissible stress stated in Table 5.8.3.

8.3 Control arrangements

8.3.1 All control devices are to be capable of being controlled from readily accessible positions and protected against unintentional operation.

8.3.2 The maximum travel of the levers is not to exceed 600 mm if movable in one direction only, or 300 mm to either side from a central position if movable in both directions.

8.3.3 Wherever practical, the lever is to move in the direction of the intended movement. If this cannot be achieved, it is to move towards the right when hauling and towards the left when paying out.

8.3.4 For lever-operated brakes, the brake is to engage when the lever is pulled and disengage when the lever is pushed. The physical effort on the brake for the operator is not to exceed 160 N.

8.3.5 For pedal-operated brakes, the maximum travel is not to exceed 250 mm and the physical effort for the operator is not to exceed 320 N.

8.3.6 The handwheel or crankhandle is to actuate the brake when turned clockwise and release it when turned counterclockwise. The physical effort for the operator is not to exceed 250 N for speed regulation and 500 N at any moment.

8.3.7 When not provided with automatic sequential control, separate push-buttons are to be provided for each direction of operation.

8.3.8 The push-buttons are to actuate the machinery when depressed and stop and effectively brake the machinery when released.

8.3.9 The above mentioned individual push-buttons may be replaced by two ‘start’ and ‘stop’ push-buttons.

8.3.10 Control systems for windlasses are to comply with the requirements of Vol 2, Pt 9, Ch 7.4.

8.3.11 Windlass motors are to be protected against overload, overspeed and overpressure using appropriate safety techniques suitable for the intended installation.

8.4 Maintenance arrangements

8.4.1 Access is to be provided for inspection of reduction gears, bearings, brakes, etc.

8.4.2 Accessible manual lubrication points, including nipples, are to be provided for both for oil and grease, as applicable.

8.4.3 Gear-boxes are to be provided with adequate access arrangements for monitoring and replacing oil.

8.5 Protection arrangements

8.5.1 Where applicable, moving parts of windlass machinery are to be provided with suitable railings and/or guards to prevent injury to personnel.

8.5.2 Protection is to be provided for preventing persons from coming into contact with surfaces having temperatures over 50°C.

8.5.3 Steel surfaces not protected by lubricant are to be protected by a coating, in accordance with the requirements of a relevant National or International Standard acceptable to LR.

8.5.4 For arrangements of power transmission systems and relief requirements, see Vol 2, Pt 7, Ch 5,11.1.2.

8.6 Marking and identification

8.6.1 Controls are to be permanently marked for identification, unless their functions are readily apparent. If required, instructions are to be permanently marked and readily visible.

8.7 Tests and trials

8.7.1 Where shop testing is not possible and Type Approval has not been obtained, calculations demonstrating compliance with 8.2.1 are to be submitted together with detailed plans and an arrangement plan showing the following components:
- Shafting.
- Gearing.
- Brakes.
- Clutches.
8.7.2 During trials on board the ship the windlass is to be shown to be capable of:
(a) for all specified design anchorage depths: raising the anchor from a depth of 82.5 m to a depth of 27.5 m at a mean speed of 9 m/min.
(b) for specified design anchorage depths greater than 82.5 m, in addition to (a): raising the anchor from the specified design anchorage depth to a depth of 82.5 m at a mean speed of 3 m/min.
Following trials, the ship will be eligible to be assigned a descriptive note ‘Specified design anchorage depth. . . metres’ which will be entered in column 6 of the Register Book.

8.8 Seating

8.8.1 The windlass is to be efficiently bedded and secured to the deck. The thickness of the deck in way of the windlass is to be increased, and adequate stiffening is to be provided, to the Surveyor’s satisfaction. The structural design integrity of the bedplate is the responsibility of the Builder and windlass manufacturer.

Section 9 Structural details

9.1 General

9.1.1 An easy lead of the cables from the windlass to the anchors and chain lockers is to be arranged. Where cables pass over or through stoppers, these stoppers are to be manufactured from ductile material and be designed to minimise the probability of damage to, or snagging of, the cable. They are to be capable of withstanding without permanent deformation a load equal to 80 per cent of the Rule breaking load of the cable passing over them.

9.2 Bulbous bow and wave piercing bow arrangements

9.2.1 The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness is to be the same as that required for plated stems by Part 6.

9.3 Hawse pipes and anchor recesses

9.3.1 Hawse pipes, bow rollers and other deck gear, of adequate size and construction, are to be provided for handling and securing the anchors and are to be efficiently attached to the structure and arranged to give an easy lead to the cable.

9.3.2 The hawse pipes are to be of sufficient size and thickness with a minimum diameter not less than 12 times the diameter of the chain cable. The arrangement is to give an easy lead for the cable to the windlass.

9.3.3 Hawse pipes and anchor pockets are to be of ample thickness and of a suitable size and form to house the anchors efficiently, preventing, as much as practicable, slackening of the cable or movements of the anchor being caused by wave action. The shell plating and framing in way of the hawse pipes are to be reinforced as necessary, see 9.5.1. Substantial chafing lips are to be provided at shell and deck. These are to have sufficiently large, radiused faces to minimise the probability of cable links being subjected to high bending stresses. Alternatively, roller fairleads of suitable design may be fitted. Where unpocketed rollers are used, it is recommended that the roller diameter be not less than eleven times the chain diameter. Where hawse pipes are not fitted, alternative arrangements will be specially considered.

9.3.4 The lines of the bow are to be taken into consideration when siting the anchor recesses for conventional bower anchors. Sufficient clearance of the flukes from the hull is to be maintained over the whole of the anchor run, above and below the water, considering the flukes in the most critical position. If a bow sonar dome is fitted, consideration is to be given to the positioning of the anchor recesses to reduce the possibility of the anchor chain rubbing on the dome when the anchor is in the deployed position.

9.4 Spurling pipes

9.4.1 Satisfactory means are to be provided to prevent inadvertent flooding of chain lockers.

9.5 Local reinforcement

9.5.1 The thickness of shell plating determined in accordance with the Rule requirements is to be increased locally by not less than 50 per cent in way of hawse pipes.

Section 10 Launch and recovery, berthing and dry-docking arrangements

10.1 Berthing loads

10.1.1 To resist loads imposed by tugs and berthing operations all structure within a 1.0 m strip centred 1.0 m above the deep waterline. It should be able to withstand the following pressure $P_D$:

$$P_D = \left( \frac{g \Delta}{800} \right) \text{ kN/m}$$

where

$\Delta$ = deep displacement, in tonnes.

10.1.2 If $L_R > 200$ m, or the ship is able to have significantly different loading conditions, the strip is to be taken from 1.5 m above the light waterline to 2.5 m above the deep waterline.
10.1.3 Ships with markings to indicate location of internal structure designed specifically for berthing purposes will be specially considered.

10.2 Dry-docking arrangements

10.2.1 Dry-docking arrangements are not explicitly covered in the Rules, see Ch 1.1.4.1. These requirements are intended to address the loads imposed on the vessel during dry-docking.

10.3 Dry-docking plan

10.3.1 In accordance with Pt 6, Ch 1.2.2.6 a dry-docking plan is to be submitted as a supporting document. Consideration should be given throughout the design of a vessel to producing a dry-docking plan. The dry-docking plan should include, but not be limited to, the following information:
- The permissible locations of dock furniture;
- Maintenance and withdrawal envelopes;
- The arrangement of underwater fittings and openings.

The dry-docking plan should take into account multiple likely docking arrangements for maintenance and through-life support.

10.4 Dry-docking loads

10.4.1 Dry-docking a ship on blocks potentially imposes high vertical loads on the keel. For ships where the Rule length, \( L_R \), exceeds 50 m, the strength of the keel and bottom structure is to be assessed.

10.4.2 Methods, other than those described here, for demonstrating that the strength of the keel and bottom structure is sufficient to withstand the loads imposed by dry-docking may be considered. Such methods are to be agreed with LR prior to the analysis being conducted.

10.4.3 For each dry-docking arrangement the stress and buckling behaviour of the bottom structure in way of the proposed dock blocks is to be assessed. The acceptance criteria given in Table 5.10.1 are not to be exceeded.

10.4.4 Where it is anticipated that there will be more than one typical dry-docking loading condition, the bottom structure is to be assessed for a representative number of loading conditions.

10.4.5 It is recommended that the block load distribution be derived by direct calculation using a full ship finite element model, constructed generally in accordance with the ShipRight SDA procedure for passenger ships. Where the dry-docking load distribution, \( F_{DL} \), as defined in 10.4.6 becomes negative at any point, the block load distribution is to be derived by such direct calculations. The model is to be supported on grounded spring elements representing the proposed dry-docking arrangements. The spring element stiffness in the model should be representative of the combined block and capping stiffness. A sensitivity assessment should be carried out to ascertain the structural response to the spring constant used.

10.4.6 The following equation may be used to calculate the dry-docking load distribution, \( F_{DL} \), between main transverse bulkheads acting on a keel block:

\[
F_{DL} = \left( \frac{W_c f_{bhd}}{(n - 1) L_{kb}} \right) + \frac{W_{oh}}{n}
\]

where:
- \( F_{DL} \) = dry-docking load distribution acting on a keel block, in kN/m
- \( W_c \) = section weight between main transverse bulkheads, in kN
- \( f_{bhd} \) = 2, for the keel blocks located adjacent to a main transverse bulkhead
- \( f_{bhd} \) = 1, elsewhere
- \( n \) = number of keel blocks between main transverse bulkheads
- \( L_{kb} \) = nominal keel block length, in metres
- \( W_{oh} \) = weight increase per unit length due to an overhang, if applicable, see 10.4.8.

10.4.7 For ships with an after end cut-up or significant rake of stem where there is considerable overhang, it may be assumed that the increase in load due to the overhang will extend a distance equal to twice the length of the overhang and will be distributed parabolically, see Fig. 5.10.1.

10.4.8 The increase in weight per unit length to be added due to an overhang, see 10.4.6, is to be determined from the following equation:

\[
W_{oh} = \frac{k d l L_o}{L_G} \text{ kN/m}
\]

where:
- \( W_{oh} \) = additional weight per unit length due to overhang, in kN/m
- \( W_o \) = weight of overhang, in kN
- \( k_d l \) = \( 1.5 + 2.25 \frac{L_G}{L_o} \left( \frac{x}{L_o} \right)^2 - \left( 4.5 + 6 \frac{L_G}{L_o} \left( \frac{x}{L_o} \right) + 3 \frac{L_G}{L_o} \right) + 3 \frac{L_G}{L_o} \)
- \( x \) = distance from the overhang, measured in metres from the mid-point of the last keel block
- \( L_G \) = length of overhang, in metres
- \( L_o \) = horizontal distance measured from the mid-point of the last keel block to the centre of gravity of the overhang, in metres.
10.4.9 When an overlap of the forward and aft overhang correction curves occurs, both curves are to be included. This will increase the possibility that blocks amidships will become unloaded, see 10.4.5.

10.5 Launching loads

10.5.1 In accordance with Pt 6, Ch 1.2.2.6 a dry-docking plan is to be submitted as a supporting document. Consideration should be given throughout the design of a vessel to producing a dry-docking plan. The dry-docking plan should include, but not be limited to, the following information:

- The permissible locations of dock furniture;
- Maintenance and withdrawal envelopes;
- The arrangement of underwater fittings and openings.

The dry-docking plan should take into account multiple likely docking arrangements for maintenance and through-life support.

10.5.2 The global strength of the hull girder is to be adequate under the loads imposed by launching, in particular for NS1 ships.
Section

1 General
2 Structural Design Assessment
3 Fatigue Design Assessment
4 Construction Monitoring
5 Ship Event Analysis
6 Enhanced Scantlings
7 Protective coatings
8 Hull Condition Monitoring
9 Ship Emergency Response Service

Section 1
General

1.1 Application
1.1.1 This Chapter is applicable to all ship types and components and the requirements are to be applied in conjunction with the relevant Chapters of Part 6.

1.2 Classification notations
1.2.1 In addition to the hull class notations defined in Pt 1, Ch 2, ships complying with the requirements of this Chapter will be eligible to be assigned the additional optional class notations defined in Pt 1, Ch 2.

1.3 Information and plans required to be submitted
1.3.1 The information and plans required to be submitted are as specified in the Pt 6, Ch 1.2.2, applicable to the particular ship type and in this Chapter where related to particular items and notations.

Section 2
Structural Design Assessment

2.1 Structural Design Assessment notation – SDA
2.1.1 Where scantlings are primarily examined using finite element methods for both the overall and detailed structural capability of the ship using Lloyd’s Register (hereinafter referred to as ‘LR’) approved procedures, the notation SDA (Structural Design Assessment) may be assigned and will be entered in the Register Book.

Section 3
Fatigue Design Assessment

3.1 Fatigue Design Assessment notation – FDA
3.1.1 Where the fatigue capability of the ship has been assessed using LR approved procedures, the notation FDA (Fatigue Design Assessment) may be assigned and will be entered in the Register Book.

Section 4
Construction Monitoring

4.1 Construction Monitoring notation – CM
4.1.1 The Construction Monitoring (CM) notation may be assigned if extended controls on structural alignment, fit-up and workmanship standards are applied to critical areas, as identified during the design of the ship. Construction Monitoring is applied primarily to verify the quality of workmanship required to improve the fatigue resistance of critical details, though other construction quality requirements can be specified in the CM plan.

4.1.2 The fatigue life of structural details can be adversely affected by a variety of factors, including workmanship defects. Criteria for workmanship defects can be considered in the CM plan. The most common factors that impact on fatigue are:
(a) Misalignment of structural members; i.e., poor fit-up;
(b) Welding defects;
(c) Materials defects;
(d) Stress concentrations resulting from incorrect geometry of structure, inadequate plate edge finish or generally poor manufacturing;
(e) Erroneous cut-outs due to inappropriate routing of systems;
(f) Discontinuity of structural members.

4.2 Identification of critical areas
4.2.1 A critical area is generally a structurally significant item or structural joint that has been subjected to an enhanced calculation or assessment. As a consequence, the performance of the item or joint will be influenced by the workmanship and fit-up in the building yard. In some areas, where there are high cyclic stresses, an enhanced workmanship and alignment standard is required in order to achieve the specified design hull fatigue life.

4.2.2 Critical areas will be identified by LR from the following assessments:
(a) Structural Design Assessment (SDA), specified in Section 2;
(b) Fatigue Design Assessment (FDA), specified in Section 3. The CM notation is mandatory if the SDA or FDA notations are applied.
4.2.3 Critical areas may also be identified by LR from one of the following optional assessments. In general, these will be associated with reinforcement and alignment of specific critical joints; they will not be associated with general deformation criteria:

(a) Extreme Strength Assessment (ESA), specified in Pt 6, Ch 4.3;
(b) Residual Strength Assessment (RSA), specified in Pt 6, Ch 4.4;
(c) Whipping Assessment (WH), specified in Pt 4, Ch 2.6.

4.2.4 In addition, critical areas may be identified by the designer, Naval Administration or Owner from one of the following:

(a) Known areas of high stress identified by structural engineers;
(b) Areas that have experienced failure on similar ships in service;
(c) Structures with specific alignment requirements; e.g., masts, shaft brackets.

4.2.5 The critical areas, locations and assessment criteria are to be detailed in the Construction Monitoring plan. The plan should also contain templates to be used to record specific alignment requirements. The CM plan may be supported by a high-stress key plan identifying critical regions on the ship.

4.2.6 Development of the CM plan is the responsibility of the designer; LR will identify the critical locations to be subject to monitoring, following appraisal of the assessments identified in 4.2.2 and 4.2.3 above. In general, areas with stress ranges greater than \( \sigma_{ws} \), see Pt 6, Ch 4.2.2.3, and areas where general or detailed fatigue analysis has been undertaken will be listed in the appraisal documentation. LR may develop the CM plan on behalf of the designer, if so requested.

4.2.7 It is recommended that the areas for Construction Monitoring be identified and the criteria developed in a workshop with the Owner, Naval Administration, Builder and LR.

4.3 Construction monitoring criteria

4.3.1 Critical areas are to be assigned an alignment criterion, as given in 4.3.2 to 4.3.4, based on the significance of the item and requirement from which it was derived. LR will review and agree the criterion assigned before construction commences.

4.3.2 Normal alignment is assigned to structure which requires an enhanced level of survey above the normal survey requirement but does not require enhanced levels of alignment above the agreed production standard, such as the Naval Survey Guidance for Steel Ships:

(a) Structure will be inspected by the Builder, before welding, for compliance with the general shipbuilding tolerances laid down in the agreed production standard.
(b) A representative sample of alignment measurements will be undertaken by LR during the survey to confirm compliance with the agreed production standard.

(c) Where there are non-compliances, the relevant shipyard department will be requested by LR to undertake full measurements and to produce a report for review by LR which details the non-compliances.

4.3.3 Enhanced alignment is assigned where critical areas have enhanced alignment requirements to maintain structural performance:

(a) The relevant shipyard department will be required to provide a report, based on templates in the CM plan, detailing the achieved alignment at each location.
(b) LR will review the alignment report and request check measurements as necessary to confirm the results.
(c) The maximum allowable misalignment between the interconnection of structural members is to be 15 per cent of the thinner of the members being connected. This alignment criterion is to be applied where longitudinally effective structure is butted; e.g., plating at ring butts, longitudinal butts, see Fig. 6.4.1.
(d) For all cruciform joints, the maximum allowable misalignment between the interconnection of structural members is to be 20 per cent of the thinner of the members being connected. This alignment criterion is to be applied where there is alignment through a thickness; e.g., intercostal longitudinal bulkheads through a transverse bulkhead, bilge keel plate alignment with internal structure through shell plating, see Fig. 6.4.2.

4.3.4 Specific alignment is assigned where there are specific alignment criteria identified by the designer which need to be verified by LR:

(a) the relevant shipyard department will be required to provide a report detailing the achieved alignment at each location;
(b) LR will review the alignment report and request check measurements as necessary to confirm the results;
(c) the alignment criteria and templates, where appropriate, are to be defined by the designer for each critical area defined.
4.3.5 Close-up inspection is assigned to structure which has no specific alignment requirement but requires an increased level of inspection; for example, to verify correct plate thickness or maximum permitted plate deformation. Close-up inspection may be required to verify a particular or unusual structural feature:

(a) Structure will be subject to an enhanced close-up visual inspection by LR Surveyor(s).

(b) Dry surveys should identify where units or compartments contain construction monitoring points. These are to be identified by the Builder as a specific witness point.

4.3.6 Non-destructive examination, in addition to the general levels of NDE required in Pt 6, Ch 6, may be specified by the designer for critical areas, which LR will verify:

(a) The relevant shipyard department will be required to undertake the additional NDE required at each location and record the results.

(b) LR will review and audit the NDE measurements as necessary to confirm the results.

4.4 Construction Monitoring survey

4.4.1 Construction Monitoring is a process for monitoring workmanship standards and alignment in critical areas. It is the Builder’s responsibility to carry out the necessary checks and document the results for relevant critical locations, irrespective of the Surveyor(s) attendance at hold points. Shipyard personnel are responsible for the inspection and recording of all CM requirements, in accordance with the approved CM plan.

4.4.2 LR will provide third party inspection to confirm that the critical areas to be covered by CM conform to the required/agreed standards based on check inspections and audit activities. Where LR undertakes a CM inspection to verify the implementation of the CM plan, it will cover:

(a) weld specification in terms of type, size and finish/treatment including:

(i) fit-up and alignment before commencement of welding;

(ii) alignment after application of first root run;

(iii) back gouging;

(b) the continuity of structural members, where required;

(c) plate edge radius and roughness;

(d) joints for radius and tapering;

(e) openings and penetrations for radius corners.

(b) LR will review and audit the NDE measurements as necessary to confirm the results.

4.4.3 LR will review all of the specific CM records, as defined in 4.3, and in a few cases request that measurements be presented. It is not intended that the attending Surveyor(s) witness each stage of the fabrication process for every critical area, except during the early stages of construction whilst the process is being established.

4.4.4 CM activities will generally be undertaken in conjunction with routine dry surveys required for all construction units. A few specific CM items require measurement by the shipyard; these are described as Enhanced or Specific Alignment.

4.4.5 Non-compliances will not be permitted in the critical areas identified within the CM plan. Where defects are identified within defined critical sections, LR is to agree the remedial action to be taken with the Shipbuilder before rectification is commenced.

4.4.6 On satisfactory completion of all surveys and measurements, LR Surveyor(s) will recommend the assignment of the CM notation.

Section 5

Ship Event Analysis

5.1 Ship Event Analysis – Class notations SEA(HSS-n), SEA(VDR), SEA(VDR-n)

5.1.1 At the Owner’s request, and in order to enhance safety and awareness on board during ship operation, provisions can be made for the following systems:

(a) A hull surveillance system that monitors the hull girder stresses and motions of the ship and warns the ship’s personnel that these levels or the frequency and magnitude of slamming motions are approaching a level where corrective action is advisable.

(b) A voyage data recorder system that can record the ship’s control, navigational, operational and hull response information. This information is recorded and stored in a protective containment unit to enable the analysis of any marine or other incidents.

5.1.2 Where a hull surveillance system is fitted the class notation SEA(HSS-n) will be assigned. Where a voyage data recorder system is fitted the class notation SEA(VDR) or SEA(VDR-n) will be assigned. The extension -n signifies the number of fitted strain gauges connected to the system. The appropriate class notation(s) will be entered in column 6 of the Register Book, see also Pt 1, Ch 2,3.10.4 of the Rules for Naval Ships.
Section 6

Enhanced Scantlings

6.1 Enhanced Scantlings – ES

6.1.1 Where scantlings in excess of the approved Rule requirement are fitted at defined locations as a corrosion margin or for other purposes as specified by the Owner, a notation, ES, 'Enhanced Scantlings', will be assigned. It will be accompanied by a list giving items to which the enhancement has been applied and the increase in scantling. For example, the item 'bottom shell (strakes A, B, C, D) + 2' will indicate that an extra 2 mm has been fitted to the bottom shell of the ship for the particular strakes listed, see also Pt 6, Ch 6.2.10. In addition, the plans submitted for approval are to contain the enhanced scantling, together with the nominal thickness less the enhancement, adjacent and in brackets.

Section 7

Protective coatings

7.1 General

7.1.1 It is recommended for all ship types that all salt-water spaces having boundaries formed by the hull envelope have a corrosion protection coating applied.

7.1.2 It is recommended that consideration be given to the effective corrosion protection of other internal spaces and external areas by the use of a suitable protective coating system.

7.2 Protective Coating in Water Ballast Tanks – PCWBT

7.2.1 If the Owner so wishes, a notation, PCWBT ‘Protective Coating in Water Ballast Tanks’, will be entered in the Register Book to indicate that the ship’s water ballast tanks are coated and that the coating remains efficient and well maintained. If the coatings have broken down, particularly at more critical areas, and no effort is being made to maintain the coatings, then this notation will be placed in parentheses, i.e., (PCWBT). In either case the date of the last survey will be placed in parentheses after the notation.

Section 8

Hull Condition Monitoring

8.1 Hull Condition Monitoring – HCM

8.1.1 Where an Owner adopts the LR Hull Condition Monitoring Scheme the notation HCM, ‘Hull Condition Monitoring’ will be entered in the Register Book.

8.1.2 This notation will indicate that a computer software system for on-board recording of ship surveys is available aboard ship.

Section 9

Ship Emergency Response Service

9.1 Ship Emergency Response Service – SERS

9.1.1 This service, offered by LR, provides a rapid computer assisted analysis of a damaged ship’s stability and damaged longitudinal strength in the event of a casualty to the ship.

9.1.2 Where an Owner adopts this service, the notation SERS, ‘Ship is registered with LR’s Ship Emergency Response Service’, will be entered in the Register Book.

7.3 ShipRight ACS notations

7.3.1 The Anti-Corrosion System notation, ShipRight ACS (B), will be assigned to Naval vessels, at the Owner’s request, when protective coating systems have been applied to water ballast tanks during construction, in accordance with the ShipRight Anti-Corrosion System Notations for Naval Ships procedure.