RULES FOR BUILDING AND CLASSING STEEL VESSELS

PART 9 : VESSELS FOR TRADE IN INLAND WATERWAYS
       C : HULL DESIGN AND CONSTRUCTION

DECEMBER 2013

INTERNATIONAL REGISTER OF SHIPPING
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SECTION 1 GENERAL

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1.1. Application

1.1.1. In Part 9C, the rule requirements are made for determination of the minimum hull scantlings of all types of inland waterway displacement vessels whose length is limited to 135 m and having normal hull form, speed and proportion. The rule requirements are made for vessels which are of welded steel construction. These requirements are to be integrated in addition to the rules specified in Part 9 E. These rules are applicable for any individual vessel type, depending on the additional class notations assigned to the vessels.

1.1.2. The rules given in the Part 9 C are based on the assumption that the significant wave height in inland condition is less than 2 m.

1.2. Definitions

1.2.1. Symbols

The following symbols are used:

i. \( L \) = Length of the ship in 'm'.
   The distance \( L \) is measured on the summer load waterline from the fore side of the stem to the axis of the rudder stock. \( L \) should not to be less than 96%, and need not to be greater than 97%, of the extreme length on the summer load waterline. For ships with unusual stern and bow arrangement, the length \( L \) will be considered separately.

ii. F.P. = The point at which the summer load waterline intersects with the fore side of the stem. For ships with unusual bow arrangements, the position of the F.P. will be considered separately.

iii. A.P. = The after perpendicular is the perpendicular at the after end of the length \( L \).

iv. M.P. = The middle of the length \( L \).

v. \( L_F \) = Length of the ship as defined in the International Convention on Load Lines:

vi. \( B_D \) = Moulded breadth in 'm', horizontal distance from outside of frame to outside of frame measured at the broadest part of the hull.

vii. \( D_m \) = is the vertical distance measured from the baseline to the moulded deckline at the uppermost continuous deck.

viii. \( D_F \) = The moulded depth is the vertical distance in 'm' measured from the top of the keel to the top of the freeboard deck beam at side.

The ships having rounded gunwales, the moulded depth shall be measured to the point of intersection of the moulded lines of deck and sides, the lines extending as though the gunwale were of angular design. When the freeboard deck is stepped and the raised part of the deck extends over the point at which the moulded depth is determined, the moulded depth \( D_F \), must shall be measured to a line of reference extending from the lower part of the deck along a line parallel with the raised part.

ix. \( T_{ms} \) = Mean moulded summer draught in 'm'.

x. \( \Delta_m \) = Moulded displacement in ‘t’ in salt water (Density (\( \rho \)) = 1.025 t/m³) on draught \( T \).

xi. \( C_B \) = Block coefficient,
   \[ \frac{\Delta}{(\rho \ast L \ast B_D \ast T)} \]

xii. \( C_{BF} \) = Block coefficient as defined in the International Convention of Load Lines:
   \[ \frac{\nabla}{(L_F \ast B_D \ast T_F)} \]

xiii. \( V \) = Volume of the moulded displacement, excluding bossings, taken at the moulded draught \( T_F \).

xiv. \( T_F \) = 85% of the least moulded depth \( D_F \).

xv. \( V_{SS} \) = Maximum service speed in knots, defined as the greatest speed which the ship is designed to maintain in service at her deepest seagoing draught.
xvi. \( g = \text{acceleration due to gravity} = 9.806 \, \text{m/s}^2 \).

xvii. \( k = \text{Material factor depending on material strength group. See Chapter 2.} \)

xviii. \( f_1 = \text{allowable stress factor (see table Chapter 2 Sec 2, Table 2.2.2)} \)

xix. \( t_c = \text{Corrosion addition as (Chapter 2 Sec 6) as relevant.} \)

xx. \( E = \text{Modulus of elasticity of the material,} \)
\( = 2.06 \times 10^5 \, \text{N/mm}^2 \text{ for steel.} \)
\( = 0.69 \times 10^5 \, \text{N/mm}^2 \text{ for aluminum alloy.} \)

xxi. \( C_W = \text{Wave load coefficient given below} \)

---

**Figure 1.1.1:**

1.2.2. Terms

i. **Moulded deck line, rounded sheer strake, sheer stroke, and stringer plate** are as defined in Figure.1.1.2

---

**Figure 1.1.2: Deck corners**

ii. **Freeboard:** The distance measured vertically downward amidships from the upper edge of the deck to the upper edge of the related load line
iii. **The freeboard deck:** The uppermost complete deck exposed to weather and sea, which has permanent means of closing all openings in the weather part thereof, and below which all openings in the sides of the ship are fitted with permanent means of watertight closing. The freeboard deck is defined in Regulation 3 of the 1966 International Convention on Load Lines, as amended.

iv. **Strength deck:** Uppermost continuous deck of the vessel. When a superstructure deck is located within 0.4 L amidships and has a continuous length equal to or greater than \(3\left(\frac{H}{2} + H_{ud}\right)\) (m) it is to be considered as the strength deck instead of the covered part of the uppermost continuous deck.

Where,
\[
H_{ud} = \text{Height in m between the uppermost continuous deck and the superstructure deck.}
\]

On special consideration any other deck maybe considered as strength deck provided they are proved to be effective.

v. **Double bottom structure** is defined as shell plating with stiffeners below the top of inner bottom, see Figure 1.1.2 and other elements like stiffeners below and including the inner bottom plating.

Note: sloping hopper tank side is to be regarded as longitudinal bulkhead.

vi. **Single bottom structure** is defined as shell plating with stiffeners and girders below the upper turn of bilge or the top of bottom girders, whichever is the highest.

vii. **Side structure** is defined as shell plating with stiffeners and girders between the bottom structure and the uppermost deck at side.
viii. **Deck structure**: Deck plating with stiffeners, girders and supporting pillars is a deck structure.

ix. **Bulkhead structure**: Transverse or longitudinal bulkhead plating with stiffeners and girders is a bulkhead structure

*Watertight bulkhead* is a collective term for transverse and longitudinal bulkheads required according to Chapter 6 Section 4.

*Cargo hold bulkhead*: A boundary bulkhead for cargo hold.

*Tank bulkhead*: A boundary bulkhead in tank for liquid cargo, ballast or bunker.

*Wash bulkhead*: A perforated or partial bulkhead in tank.

x. **Forepeak and Afterpeak**: The areas forward of collision bulkhead and aft of after peak bulkhead, respectively.

xi. **Superstructure**

a. A decked structure on the freeboard deck, extending from side to side of the ship or with the side plating not being inboard of the shell plating more than 4 per cent of the breadth ($B$) is called a superstructure. A raised quarter deck may be considered as superstructure.

b. An enclosed superstructure is a structure with:

   - Enclosing bulkheads of efficient construction.
   - Adequate compensation for access openings is provided.
   - Efficient Weathertight means of closing are provided for all openings on sides and ends of the superstructure.

A bridge or poop shall not be regarded as enclosed unless access is provided for the crew starting from any point on the uppermost complete exposed deck or higher to reach machinery and other working spaces inside these superstructures by alternate means which are available at all times when bulkhead openings are closed.

A. The height of superstructure: the least vertical height measured at side from the top of the superstructure deck beams to the top of the freeboard deck beams.
d. Length of a superstructure ($L_{SS}$): The mean length of the part of the superstructure which lies within the length ($L$).

e. Along forward superstructure: An enclosed forward superstructure with length $L_{SS}$ equal to or greater than 0.25 $L$.

xii. A flush deck ship is one which has no superstructure on the freeboard deck.

xiii. Girder is a collective term for primary supporting members, usually supporting stiffeners. Other terms used are:
- Floor (a bottom transverse girder)
- Stringer (a horizontal girder).

xiv. Stiffener is a collective term for a secondary supporting member. Other terms used are:
- Frame
- Bottom longitudinal
- Inner bottom longitudinal
- Reversed frame (inner bottom transverse stiffener)
- Side longitudinal
- Beam
- Deck longitudinal
- Bulkhead longitudinal.

Figure 1.1.6

xv. Supporting structure. Strengthening of the vessel structure, e.g. a deck, in order to accommodate loads and moments from a heavy or loaded object.

xvi. Foundation. A device transferring loads from a heavy or loaded object to the vessel structure.
## SECTION 2 DOCUMENTATION

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2.1. Plans and particulars

2.1.1. The following plans shall be submitted for approval:

i) Midship section with calculation for section modulus, Transverse sections, Longitudinal sections, Shell expansion, Decks and profiles, Single bottoms, Double bottoms, Pillar arrangements and Framing plan.¹

ii) Watertight subdivision bulkheads and Watertight tunnels.²

iii) Fore part structure.³

iv) Transverse thruster, if any, general arrangement, tunnel structure, connections of thruster with tunnel and hull structures.

v) Aft part structure.⁴

vi) Machinery space structures and foundations of propulsion machinery.⁵Plummer blocks, Boilers, Generators and other major Auxiliary engines.

vii) Superstructures and deckhouses and machinery space casing.⁶ & fire safety and Life Saving Appliances plan.

viii) Hatch covers, if any⁷

ix) Movable decks and ramps, if any

x) Windows and side scuttles, arrangements and details

xi) Scuppers and sanitary discharges

xii) Bulwarks and freeing ports.⁸

xiii) Rudder ⁹

xiv) Sternframe or sternpost, sterntube, shaft tunnels, Propeller shaft boss and brackets ⁹

xv) Hawse pipes

xvi) Plan of outer doors and hatchways

xvii) Plan of manholes

xviii) Plan of access to and escape from spaces

xix) Plan of ventilation.¹⁰

xx) Plan of watertight doors and scheme of relevant manoeuvring device.¹¹

xxi) Equipments and accessories.¹²

xxii) Steering gear arrangement and its foundations,

xxiii) Pumping and flooding arrangements,

xxiv) Masts, Derrick posts and booms with their strength calculations,

xxv) Cargo handling gear arrangements,

xxvi) Welding procedures,

xxvii) Loading arrangements of vessel

¹ The plans should also contain the following information.

- Class characteristics.
- Main dimensions.
- Maximum draught
- Block coefficient for the length between perpendiculars at the maximum draught
- Frame spacing
- Contractual service speed
- Density of cargoes
- Setting pressure of safety relief valves, if any
- Assumed loading and unloading procedure
- Design loads on decks and double bottom
- Steel grades
- Location and height of air vent outlets of various compartments
- Corrosion protection
- Openings in decks and shell and relevant compensations
- Boundaries of flat areas in bottom and sides
- Details of structural reinforcements and/or discontinuities
- Details related to welding
2. Openings and their closing appliances, if any
3. Location and height of air vent outlets of various compartments.
4. Location and height of air vent outlets of various compartments.
5. Type, power and r.p.m. of propulsion machinery. Mass and centre of gravity of machinery and boilers, if any. Mass of liquids contained in the engine room.
6. Extension and mechanical properties of the aluminium alloy used (where applicable).
7. Design loads on hatch covers. Sealing and securing arrangements, type and position of locking bolts. Distance of hatch covers from the load waterline and from the fore end.
8. Arrangement and dimensions of bulwarks and freeing ports on the main deck and superstructure deck.
9. Maximum ahead service speed [When other steering or propulsion systems are used (e.g. steering nozzles or azimuth propulsion systems,) the plans containing the relevant arrangement and structural scantlings are to be submitted]
10. Use of spaces
11. Manoeuvring devices, Electrical diagrams of power control and position indication circuits
   General arrangement of the vessel,
   Specification of the vessel,
   Lines plan and Hydrostatic curves,
   Load line calculations
   Other plans and documents deemed necessary by the Society.
CHAPTER 2 MATERIALS, WELDING & TESTING

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1.1. General

1.1.1. Characteristics of materials

The characteristics of the materials to be used in the construction of ships are to conform to the applicable requirements of Part 2. Some other characteristics in the materials used may be accepted, provided their specification viz. manufacture, mechanical properties, chemical composition, weldability, etc. is submitted for approval to IRS.

1.2. Testing of materials

Material testing is also to be conducted in compliance with the applicable requirements of Part 2.

1.3. Manufacturing processes

The requisites of this Section take for granted that welding along with other cold or hot manufacturing processes are executed in conformation to current duly appropriate working practice and the applicable requisites of Part 2. Specifically:

- Welding processes and parent material are to be approved within the limits affirmed for the specified type of material for which they are proposed
- Before welding, specific preheating may be required
- Welding or other hot or cold manufacturing processes may need to be followed by an appropriate heat treatment.
## SECTION 2 STEELS FOR HULL STRUCTURE

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<td>2.6</td>
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2.1. Application

2.1.1. The characteristics of the materials currently used in the ship construction are to comply with the rules and requirements given in Table 2.2.1.

2.1.2. IRS considers higher strength steels other than those indicated in Table 2.2.1 on a case-by-case basis.

2.1.3. When on a ship, steels with a minimum guaranteed yield stress $R_{eH}$ other than 235 N/mm$^2$ are used; hull scantlings are to be determined by taking into consideration the material factor $k$ defined in [2.3].

2.1.4. Part 2 mentions characteristics of Materials and Weldings with specified through thickness properties.

2.2. Information to be kept on board

2.2.1. A plan indicating the material types and grades adopted for the hull structures is to be kept on board. Where steels other than those indicated in Table 2.2.1 are used, their chemical and mechanical properties, as well as any workmanship recommendations or requirements along with the above plan are to be available on board.

2.2.2. It is also suggested that a plan indicating the hull structures built with normal strength steel of grades D or E is kept on board.

<table>
<thead>
<tr>
<th>Steel grades</th>
<th>Minimum yield stress $R_{eH}$ in</th>
<th>Ultimate minimum tensile</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-B-D-E t≤100mm</td>
<td>235</td>
<td>400-520</td>
</tr>
<tr>
<td>AH32-DH32-EH32 t≤100mm</td>
<td>315</td>
<td>440-590</td>
</tr>
<tr>
<td></td>
<td>FH32 t≤50mm</td>
<td></td>
</tr>
<tr>
<td>AH36-DH36-EH36 t≤100mm</td>
<td>355</td>
<td>490-620</td>
</tr>
<tr>
<td></td>
<td>FH36 t≤50mm</td>
<td></td>
</tr>
<tr>
<td>AH40-DH40-EH40 FH40 t≤50mm</td>
<td>390</td>
<td>510-650</td>
</tr>
</tbody>
</table>

Notes: Refer Part 2

2.3. Material factor $k$

2.3.1. General

The material factor $k$ has the values defined in Table 2.2.2, as a function of the minimum guaranteed yield stress $R_{eH}$, unless otherwise specified. For intermediate values of $R_{eH}$, $k$ may be obtained by linear interpolation. IRS considers steels with a yield stress lower than 235 N/mm$^2$ or greater than 390 N/mm$^2$ on a case-by-case basis.
### Grades of steel

#### 2.4.1. General

The steel grades to be used for the various structural members, for the purpose of selection, are divided into categories (SECONDARY, PRIMARY and SPECIAL), as described in Table 2.2.3.

For the various categories of structural members, Table 2.2.3 also clearly specifies the classes (I, II and III) of the materials to be used.

#### 2.4.2. A steel grade not lower than that indicated in Table 2.2.4 is acceptable to the Society for use as construction materials for vessels and that also takes into account the material class and structural member gross thickness.

#### 2.4.3. For strength members not covered in Table 2.2.3, grade A/AH may be used.

#### 2.4.4. The steel grade is to match up to the as-fitted gross thickness when its gross thickness attained is greater than the net thickness required by the Rule.

#### 2.4.5. IRS considers the steel grades of plates or sections of gross thickness greater than the limiting thicknesses in Table 2.2.1 on a case-by-case basis.

#### 2.4.6. In a particular case, such as in [2.4.7], with respect to stress distribution along the hull girder, the classes required within 0.4L amidships may be extended beyond that zone, on a case-by-case basis.

#### 2.4.7. The material classes for the sheer strake, strength deck plating and the upper strake of longitudinal bulkheads within 0.4L amidships are to be maintained for sufficient length across the poop front and at the after ends of the bridge, where fitted.

#### 2.4.8. Rolled products used for welded attachments in way of hull plating, such as gutter bars and bilge keels, are to be of the same grade as that used for the hull plating. Where it is required to weld attachments to the sheer strake or stringer plate, attention is to be paid to the suitable choice of material and design, the workmanship and welding and the lack of prejudicial undercuts and notches, specially to any free edges of the material.

#### 2.4.9. In the case of grade D plates and grade DH plates with a nominal thickness equal to or greater than 36 mm or 31 mm respectively, IRS may, on a case by case basis, need that the impact test are performed on each original "rolled unit", where the above plates:

- Either to be placed in positions where high local stresses may occur, for instance, at breaks of poop and bridge, or in way of large openings on the strength deck and on the bottom, including relevant doublings, or are to be subjected to considerable cold working.
2.4.10. IRS may require, on a case by case basis, in the case of full penetration welded joints located in positions where high local stresses may occur perpendicular to the continuous plating, the use of rolled products having sufficient ductile properties in the through thickness direction, so as to avert the risk of lamellar tearing (Z type steel, see Part 2 Chapter 2 Sec 7).

2.4.11. IRS may require, in highly stressed areas, that plates of gross thickness greater than 20 mm are of grade D/DH or E/EH.

2.4.12. For some uses, grade B steel with controlled toughness at 0°C may be required for plates of gross thickness less than 25 mm.
### IRS Rules for Building and Classing Steel Vessels

#### Table 2.2.3: Application of material classes and grades

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<th>Structural member category</th>
<th>Material class or grade</th>
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<tbody>
<tr>
<td></td>
<td>Within 0.4L amidships</td>
</tr>
<tr>
<td><strong>SECONDARY:</strong></td>
<td>I</td>
</tr>
<tr>
<td>- Longitudinal bulkhead strakes, other than that belonging to the Primary category</td>
<td></td>
</tr>
<tr>
<td>- Deck plating exposed to weather, other than that belonging to the Primary or Special category</td>
<td></td>
</tr>
<tr>
<td>- Side plating</td>
<td></td>
</tr>
<tr>
<td><strong>PRIMARY:</strong></td>
<td>II</td>
</tr>
<tr>
<td>- Bottom plating (including keel plate)</td>
<td></td>
</tr>
<tr>
<td>- Strength deck plating, excluding that belonging to the Special category</td>
<td></td>
</tr>
<tr>
<td>- Continuous longitudinal members above strength deck, excluding hatch coamings</td>
<td></td>
</tr>
<tr>
<td>- Uppermost strake in longitudinal bulkhead</td>
<td></td>
</tr>
<tr>
<td>- Vertical strake (hatch side girder) and upper most sloped strake in top wing tank</td>
<td></td>
</tr>
<tr>
<td><strong>SPECIAL:</strong></td>
<td>III</td>
</tr>
<tr>
<td>- Sheer strake at strength deck (6)</td>
<td></td>
</tr>
<tr>
<td>- Stringer plate in strength deck (6)</td>
<td></td>
</tr>
<tr>
<td>- Deck strake at longitudinal bulkhead (1)(6)</td>
<td></td>
</tr>
<tr>
<td>- Strength deck plating at outboard corners of cargo hatch openings in container carriers and other ships with similar hatch opening configuration (2)</td>
<td></td>
</tr>
<tr>
<td>- Strength deck plating at corners of cargo hatch openings in bulk carriers, ore carriers, combination carriers and other ships with similar hatch opening configuration (3)</td>
<td></td>
</tr>
<tr>
<td>- Bilge strake (4) (6)</td>
<td></td>
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<tr>
<td>- Longitudinal hatch coamings of length greater than 0.15L (5)</td>
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<td>- End brackets and deckhouse transition of longitudinal cargo hatch coamings (5)</td>
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</tr>
</tbody>
</table>

**Notes:**

1. Excluding deck plating in way of inner-skin bulkhead of double hull ships.
2. To be not less than class III within the length of the cargo region.
3. To be not less than class III within 0.6L amidships and class II within the remaining length of the cargo region.
4. May be of class II in ships with a double bottom over the full breadth and with length less than 150 metres.
5. To be not less than grade D/DH.
6. Single strakes required to be of class III or of grade E/EH and within 0.4L amidships are to have breadths not less than (800+5L) mm, but not necessarily greater than 1800 mm, unless limited by the geometry of the ship design.

**Note 1:** Plating materials for stem frames, rudders, rudder horns and shaft brackets are generally to be of grades not lower than those corresponding to class II. For rudder and rudder body plates subjected to stress concentrations (e.g. in way of lower support of semi-spade rudders or at upper part of spade rudders) class III is to be applied.

**Note 2:** Bedplates of seats for propulsion and auxiliary engines inserted in the inner bottom are to be of class I. In other cases, the steel may generally be of grade A. Different grades may be required by RINA on a case-by-case basis.

**Note 3:** Plating at corners of large hatch openings on decks located below the strength deck, in the case of hatches of holds for refrigerated cargoes, and insert plates at corners of large openings on side shell plating are generally to be of class III.
Table 2.2.4: Material grade requirements for classes I, II and III

<table>
<thead>
<tr>
<th>Gross thickness, in mm</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NSS</td>
<td>HSS</td>
<td>NSS</td>
</tr>
<tr>
<td>t &lt; 15</td>
<td>A</td>
<td>AH</td>
<td>A</td>
</tr>
<tr>
<td>15 &lt; t &lt; 20</td>
<td>A</td>
<td>AH</td>
<td>A</td>
</tr>
<tr>
<td>20 &lt; t &lt; 25</td>
<td>A</td>
<td>AH</td>
<td>B</td>
</tr>
<tr>
<td>25 &lt; t &lt; 30</td>
<td>A</td>
<td>AH</td>
<td>D</td>
</tr>
<tr>
<td>30 &lt; t &lt; 35</td>
<td>B</td>
<td>AH</td>
<td>D</td>
</tr>
<tr>
<td>35 &lt; t &lt; 40</td>
<td>B</td>
<td>AH</td>
<td>D</td>
</tr>
<tr>
<td>40 &lt; t &lt; 50</td>
<td>D</td>
<td>AH</td>
<td>E</td>
</tr>
</tbody>
</table>

Note 1: “NSS” and “HSS” mean, “Normal Strength Steel” and “Higher Strength Steel” respectively.

2.5. Grades of steel for structures exposed to low air temperatures

2.5.1. For ships proposed to operate in low air temperatures areas (-20°C or below), e.g. during regular service in winter seasons to Arctic or Antarctic waters, the materials used in exposed structures are to be selected based on the design temperature $t_D$, that is taken as defined in [2.5.2].

2.5.2. The lowest mean daily average air temperature in the area of operation is taken as the design temperature $t_D$, where:
- Mean: Statistical mean over observation period (of minimum 20 years)
- Average: Average during one night and day
- Lowest: Lowest during a year

Figure 2.2.1 illustrates the temperature definition.

The lowest value within the period of operation is applicable for seasonally restricted service.
2.5.3. For the purpose of the selection of steel grades to be used for the structural members above the lowest ballast waterline and exposed to air, the latter are divided into categories (SECONDARY, PRIMARY and SPECIAL), as indicated in Table 2.2.5. Table 2.2.5 also specifies the classes (I, II and III) of the materials to be used for the various categories of structural members.

For non-exposed structures and structures below the lowest ballast waterline, see [2.4].

2.5.4. Materials may not be of a lower grade than that indicated in Table 2.2.8 to Table 2.2.10 depending on the material class, structural member gross thickness and design temperature \( t_D \). IRS will consider materials for design temperatures \( t_D < -55^\circ C \) especially on a special case basis.

2.5.5. Single strakes are required to be of class III or of grade E/EH of FH to have widths not less than \((800+5L)\) mm, but not essentially greater than 1800 mm.
2.2.5: Application of material classes and grades for structures exposed to low air temperatures

<table>
<thead>
<tr>
<th>Structural member category</th>
<th>Material Class</th>
<th>Within 0.4L amidships</th>
<th>Outside 0.4L amidships</th>
</tr>
</thead>
<tbody>
<tr>
<td>SECONDARY:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deck plating exposed to weather (in general)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side plating above TB (1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transverse bulkheads above TB (1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRIMARY:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength deck plating (2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous longitudinal members above strength deck (excluding longitudinal hatch coamings of ships equal to or greater than 90 m in length)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longitudinal bulkhead above TB (1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topside tank bulkhead above TB (1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPECIAL:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sheer strake at strength deck</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stringer plate in strength deck</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deck strake at longitudinal bulkhead (3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous longitudinal hatch coamings of ships equal to or greater than 90 m in length (4)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) TB is the draught in light ballast condition, defined in Ch 5, Sec 1, [2.4.3].
(2) Plating at corners of large hatch openings to be considered on a case by case basis. Class III or grade E/EH to be applied in positions where high local stresses may occur.
(3) In ships with breadth exceeding 70 metres at least three deck strakes to be class III.
(4) To be not less than grade D/DH.

Note 1: Plating materials for stern frames, rudder horns, rudders and shaft brackets are to be of grades not lower than those corresponding to the material classes in [2.4].

2.6. Grades of steel within refrigerated spaces

2.6.1. When the design temperatures is below 0°C, in case of structural members within or adjacent to refrigerated spaces, the materials are to be of grade not lower than those given in Table 9, depending on the design temperature and the gross thickness and category of structural member (as defined in Table 2.2.3).

2.6.2. Unless a temperature gradient calculation is done to assess the design temperature and the steel grade in the structural members of the refrigerated spaces, the assumed temperatures are specified under:

- Temperature of the space on the uninsulated side, for plating insulated on one side only, either with uninsulated stiffening members (i.e. fitted on the uninsulated side of plating) or with insulated stiffening members (i.e. fitted on the insulated side of plating)
- Mean value of temperatures in the adjoining spaces, for plating insulated on both sides, with insulated stiffening members, when the temperature difference between the adjacent spaces is normally not greater than 10 °C (IRS considers and establishes the temperature value when the temperature difference between the adjoining spaces is greater than 10°C, on a case by case basis)
The temperature in the non-refrigerated spaces is to be conventionally taken equal to 0°C in the case of non-refrigerated spaces flanking refrigerated spaces.

2.6.3. IRS will consider situations other than those given in [2.6.1] and [2.6.2] above or special arrangements on a case by case basis.

2.6.4. Irrespective of the provisions of Table 2.2.9, [2.6.1] and [2.6.2], steel having grades lower than those required in [2.4], Table 2.2.3 and Table 2.2.4, in relation to the class and gross thickness of the structural member considered, may not be used.

### Table 2.2.6: Material grade requirements for class I at low temperatures

<table>
<thead>
<tr>
<th>Gross thickness, in mm</th>
<th>-20°C / -25°C</th>
<th>-26°C / -35°C</th>
<th>-36°C / -45°C</th>
<th>-46°C / -55°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NSS</td>
<td>HSS</td>
<td>NSS</td>
<td>HSS</td>
</tr>
<tr>
<td>t ≤ 10</td>
<td>A</td>
<td>AH</td>
<td>B</td>
<td>AH</td>
</tr>
<tr>
<td>10 &lt; t ≤ 15</td>
<td>B</td>
<td>AH</td>
<td>D</td>
<td>DH</td>
</tr>
<tr>
<td>15 &lt; t ≤ 20</td>
<td>B</td>
<td>AH</td>
<td>D</td>
<td>DH</td>
</tr>
<tr>
<td>20 &lt; t ≤ 25</td>
<td>D</td>
<td>DH</td>
<td>D</td>
<td>DH</td>
</tr>
<tr>
<td>25 &lt; t ≤ 30</td>
<td>D</td>
<td>DH</td>
<td>D</td>
<td>DH</td>
</tr>
<tr>
<td>30 &lt; t ≤ 35</td>
<td>D</td>
<td>DH</td>
<td>D</td>
<td>DH</td>
</tr>
<tr>
<td>35 &lt; t ≤ 45</td>
<td>D</td>
<td>DH</td>
<td>E</td>
<td>EH</td>
</tr>
<tr>
<td>45 &lt; t ≤ 50</td>
<td>E</td>
<td>EH</td>
<td>E</td>
<td>EH</td>
</tr>
</tbody>
</table>

**Note 1:** “NSS” and “HSS” mean, respectively, “Normal Strength Steel” and “Higher Strength Steel”.

**Note 2:** “φ” = not applicable.

### Table 2.2.7: Material grade requirements for class II at low temperatures

<table>
<thead>
<tr>
<th>Gross thickness, in mm</th>
<th>-20°C / -25°C</th>
<th>-26°C / -35°C</th>
<th>-36°C / -45°C</th>
<th>-46°C / -55°C</th>
<th>HSS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NSS</td>
<td>HSS</td>
<td>NSS</td>
<td>HSS</td>
<td>NSS</td>
</tr>
<tr>
<td>t ≤ 10</td>
<td>B</td>
<td>AH</td>
<td>D</td>
<td>DH</td>
<td>D</td>
</tr>
<tr>
<td>10 &lt; t ≤ 20</td>
<td>D</td>
<td>DH</td>
<td>D</td>
<td>DH</td>
<td>E</td>
</tr>
<tr>
<td>20 &lt; t ≤ 30</td>
<td>D</td>
<td>DH</td>
<td>E</td>
<td>EH</td>
<td>E</td>
</tr>
<tr>
<td>30 &lt; t ≤ 40</td>
<td>E</td>
<td>EH</td>
<td>E</td>
<td>EH</td>
<td>φ</td>
</tr>
<tr>
<td>40 &lt; t ≤ 45</td>
<td>E</td>
<td>EH</td>
<td>φ</td>
<td>FH</td>
<td>φ</td>
</tr>
<tr>
<td>45 &lt; t ≤ 50</td>
<td>E</td>
<td>EH</td>
<td>φ</td>
<td>FH</td>
<td>φ</td>
</tr>
</tbody>
</table>

**Note 1:** “NSS” and “HSS” mean, respectively, “Normal Strength Steel” and “Higher Strength Steel”.

**Note 2:** “φ” = not applicable.
Table 2.2.8: Material grade requirements for class III at low temperatures

<table>
<thead>
<tr>
<th>Gross thickness, in mm</th>
<th>-20°C / -25°C</th>
<th>-26°C / -35°C</th>
<th>-36°C / -45°C</th>
<th>-46°C / -55°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NSS HSS</td>
<td>NSS HSS</td>
<td>NSS HSS</td>
<td>NSS HSS</td>
</tr>
<tr>
<td>t ≤ 10</td>
<td>D DH</td>
<td>D DH</td>
<td>E EH</td>
<td>E EH</td>
</tr>
<tr>
<td>10 &lt; t ≤ 20</td>
<td>D DH</td>
<td>E EH</td>
<td>E EH</td>
<td>φ FH</td>
</tr>
<tr>
<td>20 &lt; t ≤ 25</td>
<td>E EH</td>
<td>E EH</td>
<td>φ FH</td>
<td>φ FH</td>
</tr>
<tr>
<td>25 &lt; t ≤ 30</td>
<td>E EH</td>
<td>E EH</td>
<td>φ FH</td>
<td>φ FH</td>
</tr>
<tr>
<td>30 &lt; t ≤ 35</td>
<td>E EH</td>
<td>φ FH</td>
<td>φ FH</td>
<td>φ FH</td>
</tr>
<tr>
<td>35 &lt; t ≤ 40</td>
<td>E EH</td>
<td>φ FH</td>
<td>φ FH</td>
<td>φ FH</td>
</tr>
<tr>
<td>40 &lt; t ≤ 50</td>
<td>φ FH</td>
<td>φ FH</td>
<td>φ</td>
<td>φ</td>
</tr>
</tbody>
</table>

Note 1: “NSS” and “HSS” mean, respectively, “Normal Strength Steel” and “Higher Strength Steel”.
Note 2: “φ” = not applicable.

Table 2.2.9: Material grade requirements for members within or adjacent to refrigerated spaces

<table>
<thead>
<tr>
<th>Design temperature, in °C</th>
<th>Gross thickness, in mm</th>
<th>Structural member category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Secondary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B / AH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B / AH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D / DH</td>
</tr>
<tr>
<td>-10 ≤ t₀ &lt; 0</td>
<td>t ≤ 20</td>
<td>B / AH</td>
</tr>
<tr>
<td></td>
<td>20 &lt; t ≤ 25</td>
<td>B / AH</td>
</tr>
<tr>
<td></td>
<td>t &gt; 25</td>
<td>D / DH</td>
</tr>
<tr>
<td>-25 ≤ t₀ &lt; -10</td>
<td>t ≤ 15</td>
<td>B / AH</td>
</tr>
<tr>
<td></td>
<td>15 &lt; t ≤ 25</td>
<td>D / DH</td>
</tr>
<tr>
<td></td>
<td>t &gt; 25</td>
<td>E / EH</td>
</tr>
<tr>
<td>-40 ≤ t₀ &lt; -25</td>
<td>t ≤ 25</td>
<td>D / DH</td>
</tr>
<tr>
<td></td>
<td>t &gt; 25</td>
<td>E / EH</td>
</tr>
</tbody>
</table>
SECTION 3 STEELS FOR FORGING AND CASTING

Contents

3.1. General ........................................................................................................................................ 30
3.2. Steels for forging .......................................................................................................................... 30
3.3. Steels for casting .......................................................................................................................... 30
3.1. General

3.1.1. Mechanical and chemical properties of steels for forging and casting to be used for structural members are to comply with the applicable requirements of Part 2.

3.1.2. Steels of structural members intended to be welded are to have mechanical and chemical properties deemed appropriate for this purpose by IRS on a case by case basis.

3.1.3. The steels used are to be tested in accordance with the applicable requirements of Part 2.

3.2. Steels for forging

3.2.1. For the purpose of testing, which is to be carried out in accordance with the applicable requirements of Part 2, the materials for forging are assigned to Steel Forging for Machinery and Equipment (see Part 2, Chapter 3, Sec 3).

3.2.2. Rolled bars may be accepted in lieu of forged products, after consideration by IRS on a case-by-case basis. In such case, compliance with the provisions of Part 2, Chapter 2, relevant to the quality and testing of rolled parts accepted in lieu of forged parts, may be required.

3.3. Steels for casting

3.3.1. In general, cast parts intended for stern frames, stems, rudders, parts of steering gear and deck machinery may be made of C and C-Mn weldable steels of quality 1, having tensile strength $R_m = 400 \text{ N/mm}^2$ or $440 \text{ N/mm}^2$, in terms with the applicable requisites of Part 2, Chapter 2, Section 5 and Part 2, Chapter 3, Section 2. Quality 2 steels of the above types may be required to make items which may be subjected to high stresses.

3.3.2. For the purpose of testing, which is to be done as per the provisions of Part 2, Chapter 9, the materials for casting are assigned to class, irrespective of their quality.

3.3.3. IRS considers the welding of cast parts to main plating that contributes to hull strength members on a case-by-case basis.

For such castings, IRS may require additional properties and tests, in particular, impact properties which are suitable to those steel platings on which the cast parts are to be welded and non-destructive examinations be done.

3.3.4. Non-destructive examination of heavily stressed cast parts of steering gear, particularly those intended to form a welded assembly and rotors or tillers mounted without key, are to be conducted to check their internal structure.
SECTION 4 ALUMINIUM ALLOY STRUCTURES

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4.3. Influence of welding on mechanical characteristics ............................................................... 32
4.4. Material factor k ............................................................................................................................ 32
4.1. General

4.1.1. The characteristics of marine aluminium alloys are to conform to the requisites of Part 2, Chapter 6. Generally, series 5000 aluminium-magnesium alloys or series 6000 aluminium-magnesium-silicon alloys are to be used (see Part 2, Chapter 6, Section 4).

4.1.2. IRS defines the alloys that are to be employed in the case of marine structures subjected to low service temperatures or are proposed for other specific applications, and in each case also states the acceptability conditions and requirements.

4.2. Extruded plating

4.2.1. Extrusions with built-in stiffeners and plating, referred to as extruded plating, may be used.

4.2.2. In general, the application is limited to decks, superstructures, bulkheads and deckhouses. IRS may allow other uses on a case-by-case basis.

4.2.3. Preferably, the extruded plating is to be oriented so that the stiffeners are parallel to the direction of main stresses.

4.2.4. Special attention is to be given to the connections between extruded plating and primary members.

4.3. Influence of welding on mechanical characteristics

4.3.1. Welding heat input locally lowers the mechanical strength of aluminium alloys hardened by work hardening (series 5000 other than condition 0 or H111) or by heat treatment (series 6000).

4.3.2. Subsequently, where required, a drop in the mechanical characteristics of welded structures with respect to those of the parent material is to be considered in the heat-affected zone. On each side of the weld axis, the heat-affected zone may be taken to an extent of 25 mm.

4.3.3. Aluminium alloys of series 5000 in 0 condition (annealed) or in H111 condition (annealed flattened) are not subject to a drop in mechanical strength in the welded areas.

4.3.4. Aluminium alloys of series 5000 other than condition 0 or H111 are subject to a drop in mechanical strength in the welded areas.

4.3.5. Normally, the mechanical characteristics to consider are those of condition 0 or H111. Higher mechanical characteristics may be taken into consideration, provided they are suitably justified.

4.3.6. Aluminium alloys of series 6000 are subject to a drop in mechanical strength in the close proximity of the welded areas. Normally, the supplier indicates the required mechanical characteristics to be considered.

4.4. Material factor k

4.4.1. The material factor k for aluminium alloys is to be attained from the underlying formula:

\[ k = \frac{235}{\eta \cdot R_{P0.2}}. \]

where:
\( \eta \) : Joint coefficient for the welded assembly, corresponding to the aluminium alloy considered, given in Table 2.5.1
$R_{p0.2}$: Minimum guaranteed yield stress, in N/mm$^2$, of the parent material in delivery condition.

4.4.2. In the case of welding of two different aluminium alloys, the material factor $k$ to be considered for the scantlings is the greater material factor of the aluminium alloys of the assembly.
SECTION 5 OTHER MATERIALS AND PRODUCTS

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5.1. **General**

5.1.1. Other products and materials such as parts made of iron castings, where permitted by the Society, and also the products made of copper and copper alloys, chain cables, rivets, anchors, cranes, derricks, masts, derrick posts, accessories and wire ropes are to conform to the applicable requisites of Part 2.

5.1.2. IRS considers the use of plastics or other special materials not covered by these Rules on a case-by-case basis. IRS states the requirements for the acceptance of the materials concerned in such cases.

5.1.3. As per the applicable rules and requirements of Part 2, materials used in the welding process are to conform to.

5.2. **Iron cast parts**

5.2.1. As a rule, the use of malleable iron, grey iron or spheroidal graphite iron cast parts combined with ferritic/perlitic structure is permitted only to manufacture low stressed elements of less or secondary importance.

5.2.2. Ordinary iron cast parts may not be used for windows or side scuttles while IRS may consider use of high grade iron cast parts of an appropriate type on a case by case basis.

---

**Table 2.5.1: Joint coefficient for aluminium alloys**

<table>
<thead>
<tr>
<th>Aluminium alloy</th>
<th>( \eta )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alloys without work-hardening treatment (series 5000 in annealed condition 0 or annealed flattened condition H111)</td>
<td>1</td>
</tr>
<tr>
<td>Alloys hardened by work hardening (series 5000 other than condition 0 or H111)</td>
<td>( R'p0.2/Rp0.2 )</td>
</tr>
<tr>
<td>Alloys hardened by heat treatment (series 6000) (1)</td>
<td>( R'p0.2/Rp0.2 )</td>
</tr>
</tbody>
</table>

(1) When no information is available, coefficient \( \eta \) is to be taken equal to the metallurgical efficiency coefficient \( \beta \) defined in Tab 11.

**Note 1:**

\( R'p0.2 \): Minimum guaranteed yield stress, in N/mm\(^2\), of material in welded condition (see Section 4 [4.3]).
Table 2.5.2: Aluminium alloys Metallurgical efficiency coefficient $\beta$

<table>
<thead>
<tr>
<th>Aluminium alloy</th>
<th>Temper condition</th>
<th>Gross thickness. in mm</th>
<th>$\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>6005 A (Open sections)</td>
<td>T5 or T6</td>
<td>$t \leq 6$</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$t &gt; 6$</td>
<td>0.4</td>
</tr>
<tr>
<td>6005 A (Closed sections)</td>
<td>T5 or T6</td>
<td>All</td>
<td>0.5</td>
</tr>
<tr>
<td>6061 (Sections)</td>
<td>T6</td>
<td>All</td>
<td>0.53</td>
</tr>
<tr>
<td>6082 (Sections)</td>
<td>T6</td>
<td>All</td>
<td>0.45</td>
</tr>
</tbody>
</table>
## SECTION 6 CORROSION ALLOWANCE

### Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
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<td>6.1</td>
<td>Corrosion Additions for Steel Ships</td>
<td>38</td>
</tr>
<tr>
<td>6.2</td>
<td>Corrosion protection</td>
<td>39</td>
</tr>
</tbody>
</table>
6.1 Corrosion Additions for Steel Ships

6.1.1. General

As specified in 6.1.2, the scantlings of the steel structures are to be increased by corrosion additions in tanks for cargo oil and/or water ballast. In the following, a collective term, cargo oil, will be used for liquid cargoes which may be carried by oil carriers.

6.1.2. Corrosion additions

6.1.2.1. Stiffeners, plates and girders in tanks for water ballast and/or cargo oil and of holds in dry bulk cargo carriers are to be given a corrosion addition $t_c$, as stated in Table 2.6.1.

<table>
<thead>
<tr>
<th>Internal members and plate boundary between spaces of the given category</th>
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1) The term ballast tank also includes combined ballast and cargo oil tanks, but not cargo oil tanks which may carry water ballast according to MARPOL 73/78 Annex I Reg. 18.

2) The figure in brackets refers to non-horizontal surfaces.

3) Other category space denotes the hull exterior and all spaces other than water ballast and cargo oil tanks and holds of dry bulk cargo carriers.

4) Hold of dry bulk cargo carriers refers to the cargo holds, including ballast holds, of vessels with class notations Bulk Carrier and Ore Carrier. The figure in brackets refers to webs and bracket plates in lower part of main frames in bulk carrier holds.

6.1.2.2. It is assumed that an effective coating or an equivalent protection system is used to protect tanks for ballast water only.

6.1.2.3. The requisites to section modulus of stiffeners in tanks for cargo oil or ballast tanks, given in relevant chapters, is to be multiplied by a factor:

$w_c = 1 + 0.05 (t_{cw} + t_{cf})$ for flanged sections

$= 1 + 0.06 t_{cw}$ for bulbs

$t_{cw}$ = corrosion addition $t_c$ with respect to the profile flange.
6.2  Corrosion protection

6.2.1  Cementing or equivalent protective coating

The internal structures of compartments of double bottoms located under the boiler room which are not used for fuel oil are to be adequately protected by a thick cement composition or other protective material accepted by IRS.

A similar procedure is to be applied to lateral bilges, double bottom and bottom in single bottom hulls, except for tankers, and it may be extended by thick cement, cement washing or equivalent coating to all double bottoms and tanks not intended for fuel oil.

It is recommended that narrow spaces are filled with a composition of cement mixed with low density material, particularly at the ends of the ships where maintenance would be impracticable due to their inaccessibility.

6.2.2  Painting

In general, all the metallic parts are to be protected against corrosion by means of a coating of recognized efficiency and adhesion, to be applied in at least two coats. Painting is not required for internal surfaces of spaces intended for fuel oil or mineral or vegetable oils. Where internal tanks are intended for fresh water, painting may be replaced by the application of at least two coats of cement wash. Tanks carrying drinking water are to be treated by cement washing unless they are protected by special paints of recognized efficiency. Before the paint is applied, mill scale is to be removed from the external shell plating. The use of aluminium paint is not permitted in cargo tanks, slop tanks, cargo pump rooms, cofferdams and any other space where cargo gases may accumulate.

Other painting schemes for protection of marine structures as approved by the Society may be used for corrosion

Corrosion Control

Sacrificial anodes protection system with due approval of the Society is to be fitted for Ballast tanks, cofferdams.
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7.1. Pressure tests

7.1.1. General

As per the procedures given in [7.1.2], tanks supposed to carry liquids; cofferdams and double bottoms are to be hydraulically tested. Alternatively, as per the procedure given in [7.1.3], in lieu of hydraulic test, the above compartments may be subjected to a leak test using air, when, in the view of IRS, the latter is considered vital in relation to the construction techniques and the welding procedure adopted by the shipyard. In such cases, IRS may require some of the tanks, cofferdams or double bottoms to be subjected to a hydraulic test. Cargo tanks of tankers and similar may also be subjected to a leak test using air, apart from cargo tanks proposed for hazardous chemicals, which are always to be subjected to a hydraulic test for all tanks, and cargo tanks intended for liquefied gases, to which the special requirements of Section I apply.

In all cases, bulkheads separating cargo tanks from cofferdams, pump rooms, machinery spaces or segregated ballast tanks are to be subjected to a hydraulic test.

Peak tank bulkheads not flanking tanks are to be tested by filling the peak tanks with water to the level of the full load waterline. The chain locker, where arranged aft of the collision bulk-head, is to be filled with water for testing. Pressure tests are to be executed prior to application of cement or final painting and after all bulkhead and deck penetrations, air vents, sounding pipes etc. are fitted. A “Pressure test plan” is to be submitted to IRS for approval giving indications relating to test procedures for the various compartments.

7.1.2. Hydraulic test

The value of the test head is to be the highest of the values stated in (a), (b) and (c):

a) The value corresponding to the top of the overflow pipe;
b) The value corresponding to a point located at a height h, in m, above the tank top, h being the higher of the values obtained by the following formulae:
   \[ h = 1 + 0.05 \cdot (L - 50) \cdot r' \]
   \[ h = 100 \cdot p_{PV}, \text{ where } L \text{ is to be taken not less than 50 m and not surpassing 80 m, } p_{PV} \text{ is as defined in Chapter 1, Section 5, and } r' \text{ either as in Part 4 or equal to 1.44, whichever is the lesser}; \]
c) The value corresponding to \( r \) metres above the top of the trunk or the hatchway coaming, for tanks with trunks or deep tanks also intended for the carriage of liquids, respectively.

However, in the case of deep tanks intended for water ballast only, the test head may be restricted to the upper edge of the hatch or manhole coaming and the weather tightness of the hatch cover, in way of the gasket, may be validated via hose testing as specified in [7.2].

The test head of tanks independent of the hull structure is to be taken equal to that corresponding to the top of the over-flow pipe, but is, in any case, to be not less than 1 m. Hydraulic testing is in general required to be carried out before any type of protective coating is applied to the structures. IRS may, however, allow the testing to take place after the application of the coating, subject to the compartment passing a careful inspection of all welded connections. Whenever possible, hydraulic testing is to be carried out on the building berth or in dock.
7.1.3. Leak test using air

Weathertightness is to be validated by applying a soapy water solution to the welded connections. It is suggested that the air pressure in the tank is initially raised, with due care, to 0.02 N/mm² and then lowered to 0.015 N/mm², before inspection. The test pressure is to be substantiated by means of two master pressure gauges and a U-tube; the latter is to have a cross-section larger than that of the pipe supplying air such as to act as a relief.

The leak test using air is normally done prior to application of any preservative coating. However, at the discretion of the IRS and subject to careful visual inspection, permission may be granted for the test to be done after the application of the coating, particularly, in way of welds made by automatic welding processes. In this case, as a rule, specific non-destructive tests will be required with procedures to be defined in all individual cases.

7.2. Hose tests

7.2.1. Weathertight and watertight closing appliances

All weathertight and watertight closing appliances are to be subjected to hose testing, which are not hydrostatically tested, at a pressure not less than 0.2 N/mm² at the bore of the nozzle, the latter being held at approximately 2 m from the testing point.

7.2.2. Subdivision watertight bulkheads, shaft tunnels and recesses

On completion, subdivision watertight bulkheads, recesses and shaft tunnels, if any, including any watertight doors, are to be tested by a jet of water having a pressure of not less than 0.2 N/mm² at the bore of the nozzle, the latter being held at approximately 2 m from the testing point.

7.2.3. Shell and deck plating

Shell and deck plating riveted seams, if any, for which water tightness is required and which are not hydrostatically tested are to be tested by a jet of water having a pressure of not less than 0.2 N/mm² at the bore of the nozzle, the latter being held about 2 m from the testing point.

7.3. Testing of watertight doors

7.3.1. General

Generally, prior to installation on board, watertight doors of subdivision bulkheads are to be hydraulically tested ashore with a head corresponding to the maximum head to which they may be subjected. In exceptional cases, IRS may allow the test to be executed after installation on board, using a procedure that is established in each individual case.
CHAPTER 3 DESIGN PRINCIPLES

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## SECTION 1 SUBDIVISION AND ARRANGEMENT

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1.1 General

The hull is to be further divided into watertight compartments.

1.2 Definitions

1.2.1. Symbols:

- \( L_F \) = Length of the ship as defined in International Convention on Load Line see Chapter 1 Section 1 [1.2]
- \( P_F \) = perpendicular coinciding with the fore side of the stem on the waterline on which \( L_F \) is measured.

For ships with unconventional stem curvatures, e.g. a bulbous bow overhanging the waterline, the position of \( P_F \) will be specially considered.

- \( H_{SS} \) = height of superstructure in m
- \( D_F \) = moulded depth of the freeboard deck see Chapter 1 Sec 1[1.2]

1.3 Arrangement of transverse watertight bulkheads

1.3.1. The following transverse, watertight bulkheads are to be fitted in all ships:

- An afterpeak bulkhead.
- A collision bulkhead.
- Two bulkheads constituting the boundaries of the machinery space in vessels with machinery amidships, and when machinery is aft the one bulkhead forward of the former.
- When vessels have an electrical propulsion plant, both the generator room and the engine room are to be enclosed by watertight bulk-heads.
- The after peak bulkhead may be considered as the after machinery bulkhead on certain occasions.

1.3.2. For ships not required to comply with subdivision regulations, and when particular transverse connections for structural purposes are not required, unless equivalent safety is otherwise ensured, at least the following transverse bulk-heads are to be provided and carried up to the deck or, where the deck is not provided, to the uppermost edge of the plating:

- A collision bulkhead constructed between \( 0.04L \) and \( 0.04L + 2m \) aft of the forward perpendicular, where \( L \) is the length defined in Chapter 1 Sec 1 [1.2.1]. A distance from the collision bulk-head to the forward perpendicular greater than the maximum specified above will be accepted, provided that in such cases, flooding of the space forward of the collision bulkhead, subdivision and stability calculations in both the full load departure condition and the arrival condition complies with national and IRS Rules.
- A bulkhead should in the aft part of the ship. It should be fitted at an appropriate distance from the stern. The configuration of the ship's after extremity should be considered when designing the bulkhead. Ships which are of more than 25 m in overall length, the two transverse bulkheads should contain the machinery space, including the working spaces which form part of it.
- When damage stability is to be met, additional transverse bulkheads can be provided in order to have longitudinal compartments having dimensions to ensure the minimum stability requirements when flooded. Additional transverse bulkheads may be fitted according to the service of the ship and to satisfy strength requirements.

1.3.3. The total number of watertight transverse bulkheads for ships with no longitudinal bulkheads in the cargo region is not to be less than given in Table 1.1.1.
### 1.3.4. Additional bulkheads

Additional transverse bulkheads may be recommended in order to ensure an efficient support to the topside structure inside the cargo space of single hull open deck vessels. Transverse bulkheads are to be fitted in the side tanks in way of watertight floors, in the cargo space of double hull vessels.

Additional bulkheads maybe required to be fitted for meeting damage stability criteria of the vessel.

### 1.3.5. Stern Tube

The stern tube and the rudder trunk is to be located in watertight compartment by the after peak bulkhead. IRS may on a case by case basis approve other measures to minimize the danger of water penetrating into the vessel in the case of damage to stern tube or rudder trunk.

The stern tubes are to be enclosed in watertight spaces of moderate volume for vessels less than 40 m where the after peak bulkhead is not provided in way of the stern tube stuffing box.

### 1.3.6. Tank Bulkheads

The number and location of transverse and longitudinal watertight bulkheads in vessels intended for the carriage of liquid cargoes (tankers and similar) are to have transverse and longitudinal bulkheads which will comply with the stability requirements to which the vessel is subjected.

When liquid compartments extend over the full breadth of the vessel at least one longitudinal bulkhead is to be fitted, whether watertight or not, where the mean compartment breadth is at least equal to \(2B_D/3\), where \(B_D\) is the vessel breadth defined in Chapter 1, Section 1, [1.2]. If the bulkhead is perforated, the total area of the holes is generally to be about 5% of the total area of the bulkhead.

### 1.3.7. The number of watertight bulkheads may be brought down after special assessment of the arrangement and strength. The actual number of watertight bulkheads satisfying the national requirements will be entered in the Register of vessels classed with IRS.

### 1.4 Openings in watertight bulkheads

#### 1.4.1. Collision bulkheads

Openings are not to be provided in the collision bulkhead below the bulkhead deck. The number of openings in the collision bulkhead above the bulkhead deck is to be kept to the minimum compatible with the design and proper working of the vessel. All such openings are to be fitted with means of closing to weather tight standards.

Collision bulkhead should not have doors or manholes below the bulkhead deck.
Collision bulkhead is not to have bilge cock or similar devices. Unless otherwise justified not more than two pipes may pass through the collision bulkhead below the bulkhead deck. Pipes so fitted should have suitable watertight closing valves operable from above the bulkhead deck. Valve chests are to be secured at the bulkhead inside the fore peak. These valves may be located on the after side of the collision bulkhead and should be easily accessible and they are not to be fitted in cargo spaces.

1.4.2. Bulkheads other than collision bulkheads

Bulkheads other than the collision bulkhead may have openings below the bulkhead deck; provided they are essential as per the design and proper working of the vessel and they are also to be provided with water-tight doors having strength such as to withstand the head of water to which they may be subjected.

1.5 Cofferdams and compartments forward of the collision bulkhead

1.5.1. Adjacent tanks or double bottoms, hereafter generically referred to as "tanks", intended for the carriage of different liquids among the following:

i) fuel oil,
ii) lubricating oil,
iii) vegetable oil and other similar,
iv) drinking water, washing and boiler feed water, are to be separated by a cofferdam.
v) Liquid foams for fire extinguishing

1.5.2. Cofferdams are generally required between tanks intended for the carriage of fuel oil or lubricating oil and adjacent tanks intended for the carriage of liquid foam for fire-extinguishing.

1.5.3. Cofferdams which separate fuel oil tanks from adjacent lubricating oil tanks and such tanks from adjacent tanks meant to carry liquid foam for fire-extinguishing or fresh water or boiler feed water may not be required when found impracticable or unreasonable by IRS in relation to the characteristics and dimensions of the spaces containing said tanks, provided that:

i) the thickness of common boundary plates of adjacent tanks is increased, with respect to the Rule thickness, by 2 mm in the case of tanks carrying fresh water or boiler feed water, and by 1 mm in all other cases;
ii) the sum of the throats of the weld fillets at the edges of said plates is not less than the thickness of the plates themselves;
iii) the hydrostatic test is carried out with a head increased by 1 m with respect to the Rule head.

1.5.4. When the inner bottom plating is subjected to the head of fuel oil contained therein a cofferdam between fuel oil double bottom and a tank immediately above is required.

1.5.5. In a corner to corner situation, tanks are not considered to be adjacent. Adjacent tanks which are not separated by cofferdams should have adequate dimensions to ensure easy inspection.

1.5.6. Spaces meant to carry flammable liquids are to be separated from accommodation and service spaces by cofferdam. When accommodation and service spaces are located immediately above such spaces, the cofferdam may be avoided only when the deck is not provided with access openings and is coated with a layer of fire retardant material recognized as suitable by IRS.
1.5.7. The cofferdam may also be avoided when such spaces are adjacent to a passageway, subject to the requirements as stated herein above in [1.5.1] for fuel oil or lubricating oil tanks.

1.5.8. All cofferdams required in [1.5] are to be constructed so as to enable easy inspection and adequate ventilation.

1.5.9. For oil tankers combination carriers, gas carriers and chemical tankers, the specific requirements of Part E are also to be applicable.

**Freeboard, Bow height and Reserve of buoyancy.**

International Load Line Convention’s stipulations for minimum freeboard bow height shear and reserve buoyancy for intended use of the vessel are to be considered as per requirements of the national authority.

1.6 Ventilation requirement

1.6.1 Accommodation spaces, service spaces, machinery spaces cofferdams and, in general, cargo spaces are to be provided with natural or mechanical ventilation. Machinery spaces should be provided with mechanical ventilation.

1.6.2 Proper ventilation is to be provided for machinery spaces so as to ensure that, when machinery or boilers are operating at full power and in all weather conditions including heavy weather, a sufficient supply of air is maintained for the whole period of operation of the machinery.

1.6.3 The air supply is to be obtained through openings so located that weathertight closing devices are not required.

1.6.4 For oil tankers and combination carriers, gas carriers and chemical tankers the specific requirements of Part E are also to apply.

1.7 Access arrangements

1.7.1. Double bottom

i) Inner bottom manholes

Inner bottom manholes should have a minimum dimension of 0.40 m x 0.40 m. Number and location of the manholes should be so arranged so as to provide convenient access to any part of the double bottom. Manholes on the inner bottom are to be closed by watertight plate covers. When the watertight plate covers are secured by bolts, doubler plates are to be fitted on it. When there is no ceiling, covers are to be adequately protected from damage by the cargo.

ii) Floor and girder manholes

Access to double bottom is to be ensured by means of manholes in floors and girders. The size of manholes and lightening holes in floors and girders are generally to be less than 50 per cent of the local height of the double bottom. When manholes of greater size are required, edge reinforcement by means of flat bar rings or other suitable stiffeners may be required. Manholes may not be cut into the continuous centerline girder or floors and girders below pillars, except where allowed by the Society on a case by case basis.

Access opening on bulkheads located below the freeboard deck and are intended for use during voyage of the vessel are to have watertight doors closable from freeboard deck or
place above the deck. The protected closing device for these doors should have easy access.

Access openings on collision bulkheads above freeboard deck are fitted with watertight doors. Minimum number of opening is to be considered during the design for the normal operation of the vessel.

Access to cargo holds
Permanent or removable means of access stowed on board are to be provided for, proper maintenance and survey of cargo holds.

1.7.2. Access to tanks

If Tanks and subdivisions of tanks have length more than 35 m, they are to be fitted with at least two access hatch-ways and ladders, as far apart as practicable longitudinally. If tanks are less than 35 m in length they are to be served by at least one access hatchway and ladder.

Access hatchway should have sufficient dimensions so as to allow a person wearing a self-contained breathing apparatus to ascend or descend the ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the tank. In no case is the clear opening to be less than 0.36 m² and its width 0.50 m.

1.7.3. Access within Tanks

i) Wash bulkheads in tanks
When one or more wash bulkheads are present in a tank, they are to have openings so arranged as to facilitate the access of persons wearing breathing apparatus or carrying a stretcher with a patient.

ii) Manholes
At locations where manholes are present, access is to be facilitated by means of steps and hand grips with platform landings on each side.

1.7.4. Access to side tanks

If stringer plates have openings which provides access to side tanks, they are to be arranged clear of the hatch corners and shall be of even-deck design, without obstacles causing stumbling. In order to ensure the continuity of the strength, they are to be cut smooth along a well-rounded design and are to be strengthened by thick plates, by doubling plates or by other equivalent structure.

1.8 Accommodation arrangements

1.8.1 Accommodation spaces are to be located abaft the collision bulkhead and, as far as is practical, above the bulkhead deck.

1.8.2 The floor forward should not be more than 1.20 m below the maximum draught level. Requirements may be waived for spaces which are no permanently manned.

1.8.3 Access to accommodation spaces is to be easy and completely safe.

1.8.4 As a rule, living rooms and galleys are to be accessible from the deck through a passageway.

1.8.5 Transverse watertight bulkheads are not required if the front part is capable of withstanding a load at least equal to 2.5 times the load foreseen for the collision bulkhead of a ship for inland waterway service having the same draught.
1.9 **Steering gear compartment**
The steering gear compartment shall be easily accessed, and as far as practicable, separated from other machinery spaces. (SOLAS Ch. II-1/29.13.1)

1.10 **Navigation bridge design**
All round an proper visibility should be taken into consideration while design of the navigation bridge for voyage conditions. Reference is made to SOLAS Ch.V Reg.22.

1.11 **Oil fuel tank protection**
Oil fuel tank design is to meet requirements for protection of fuel tank onboard. Reference is made to MARPOL Annex I Reg. 12A.
SECTION 2 STRUCTURE DESIGN PRINCIPLES

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2.1. Loading conditions

2.1.1. Lightship

The vessel is assumed empty (without supplies and ballast) for non-propelled cargo type. For self-propelled cargo and passenger type, the light standard loading conditions are:

- supplies: 100 %
- ballast: 50 %.

2.1.2. Fully loaded vessel

The vessel is considered to be homogeneously loaded when it is non-propelled cargo type, at its maximum draught, without supplies or ballast. For self-propelled cargo type, the vessel is considered to be homogeneously loaded at its maximum draught with 10 % of supplies (and without ballast). For passenger type, the vessel is considered to be homogeneously located at its maximum draught with all crews, passengers and provisions onboard, 100% of supplies and without ballast.

2.1.3. Transitory conditions

i) General

Transitory standard conditions are listed in items [ ii) to iv)] For non-propelled cargo type, the vessel is assumed without supplies nor ballast. For self-propelled cargo type, the vessel without ballast is assumed to carry following amount of supplies:

- in hogging condition: 100 % of supplies
- in sagging condition: 10 % of supplies

ii) Loading/unloading in two runs

Loading and unloading are performed uniformly in two runs of almost equal masses. For self-propelled vessels, the first loading/unloading run is carried out from the aft end of the cargo space, progressing to the fore end, the second run being performed from the fore end towards the aft end. For non-propelled vessels, the two loading/unloading runs can be carried out from either the aft end or the fore end, progressing towards the opposite end.

iii) Loading/unloading in one run

Loading and unloading are performed uniformly in one run, starting from the aft end of the cargo space, for self-propelled vessels, and from any end of cargo space for non-propelled vessels.

iv) Loading/unloading for liquid cargoes

Loading and unloading for liquid cargoes are assumed to be performed in two runs [see ii) above], unless otherwise specified.

2.1.4. Non-homogeneous loading conditions

If requested, in addition to design bending moments occurring in standard loading conditions described in [2.1.3 (ii)], the hull girder loads may be determined, by direct calculation, in any non-homogeneous loading conditions approved by IRS. Static loads for the vessel are derived by designer or shipbuilder at different voyage and loading conditions or standard conditions for ordinary ships indicated in the rules.
Unless otherwise stated, ship’s cargo and ballasting conditions are assumed to be symmetric about the centerline of the vessel. For unsymmetrical cargo or ballast loading, the effect of which is to be specially considered in design. Dynamic loads will depend on long term distribution of motions to be experienced by the vessel during her operational life. The dynamic loads considered and included in the relevant formulas.

2.2. Hull girder strength

A minimum longitudinal strength standard determined by the section modulus at bottom and deck is essential for the hull girder cross-section.

2.3. Transverse strength

2.3.1. The overall or local transverse strength need to be specially considered. In such cases the ship is understood to have an angle of heel less than 30 degrees. No additional dynamic loads need not be considered. Normally acceptable stress levels will be:

\[ \sigma = f^2 \cdot f^1 \text{N/mm}^2 \text{for structural members without longitudinal bending stresses} \]

\[ \tau = 90 / k \text{N/mm}^2 \]

\[ k = \text{material factor given in Chapter 2, [2.3.1].} \]

2.4. Plate strength

For plating exposed to lateral pressure the thickness requirement is usually given by:

\[ t = \frac{\gamma_c \sqrt{p_{ltm}}}{\sigma} + t_c \]

\[ c_f = \text{correction factor for aspect ratio of plate field} \]

\[ = 1.21 - 0.538(s/l) + (0.0441)(s/l)^2 \]

\[ s = \text{stiffener spacing in m} \]

\[ p_{ltm} = \text{maximum lateral pressure in kN/m}^2 \]

\[ \sigma = \text{allowable local stress in N/mm}^2 \text{for mild steel} \]

\[ t_0, k = \text{as given in relevant chapters} \]

\[ k = \text{material factor given in Chapter 2 Section 2, [2.1.3]} \]

2.5. Stiffeners, local bending and shear strength

For stiffeners subjected to lateral pressure, the section modulus necessities is generally given as function of bending moments and nominal allowable bending stress as follows:

\[ Z = S_f 1000l_m \gamma s p_{lt} / m \sigma \]

Where:

\[ S_f = 1.1, \gamma = (l - 0.2s) \]

\[ p_{lt} = \text{lateral pressure in kN/m}^2 \]

\[ l_m = \text{length of the member in m as defined in Figure 3.3.1} \]

\[ s = \text{spacing in m} \]
\[ m = \text{bending moment factor} \]
\[ w_k = \text{section modulus corrosion factor in tanks as given in Ch.2, [2.6.2]} \]
\[ \sigma = \text{allowable stress in N/mm}^2 \text{ for mild steel} \]
\[ k = \text{material factor given in Chapter 2, Section 2, [2.1.3.]} \]

The \( m \)-value has been directly taken from general elastic bending theory for elastic deflections. In Table 3.2.1 \( m \)-values are given for some defined load and boundary conditions.

**Table 3.2.1: Values of \( m \) and \( k \)**

<table>
<thead>
<tr>
<th>Load and boundary conditions</th>
<th>Bending moment and shear force factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positions</td>
<td>1</td>
</tr>
<tr>
<td>------------------------------</td>
<td>---</td>
</tr>
<tr>
<td>1 Support</td>
<td></td>
</tr>
<tr>
<td>2 Field</td>
<td></td>
</tr>
<tr>
<td>3 Support</td>
<td></td>
</tr>
<tr>
<td>( m_1 ) ( k_s_1 )</td>
<td>12.0</td>
</tr>
<tr>
<td>( 0.50 )</td>
<td>-</td>
</tr>
<tr>
<td>( 0.38 )</td>
<td>-</td>
</tr>
<tr>
<td>( 0.50 )</td>
<td>-</td>
</tr>
<tr>
<td>( 0.30 )</td>
<td>15.0</td>
</tr>
<tr>
<td>( 0.20 )</td>
<td>-</td>
</tr>
<tr>
<td>( 0.33 )</td>
<td>-</td>
</tr>
</tbody>
</table>

The effective shear area necessities are given as a function of boundary conditions and nominal allowable shear stress as follows:

\[ A_s = \frac{10Q}{\tau f^1} + A_k \]

\( Q = k_s P \)

\( Q = \text{expected shear force in kN} \)

\( P_t = \text{total load force on the member in kN} \)

\( k_s = \text{shear force factor} \)

\( \tau = 90 \text{ N/mm}^2 \text{ for mild steel in general} \)

\( k = \text{material factor given in Chapter 2, Section 2, [2.3.1]} \)

\( A_K = \text{corrosion addition area for the effective shear area. } A_K \text{ may be obtained by adding the corrosion addition } t_c \text{ to the net web thickness or increasing the web height correspondingly.} \)

The \( k_s \)-value is derived directly from general elastic beam theory. In Table 3.2.1 \( k_s \)-values are given for some defined load and boundary conditions.
2.6. **Girders, local bending and shear strength**

Strength formulas for girders are limited to simple girders. The boundary conditions and the nominal allowable stresses are given in a similar way as for stiffeners. For girder systems the stress pattern is understood to be obtained by direct calculations. The loadings and bending stresses are to conform with the values given in the relevant sections of the rule.

Acceptable shear stresses = 90 N/mm²

2.7. **Buckling strength**

Necessities for stability of local strength members for buckling are given in Chapter 10.

2.8. **Impact strength**

Ships having small draught at F.P. should be strengthened to defend against slamming. Requirements for which are given in bottom structures forward. The draught, upon which the slamming strength is based, will be mentioned in the appendix to the classification certificate.

2.9. **Vibrations**

The rules do not cover any requirements to prevent harmful vibrations in global or local structural elements.

2.10. **Miscellaneous strength requirements**

Requisites for scantlings of foundations, minimum plate thickness and other necessities not concerning relevant load and strength parameters may reveal criteria other than those specified by these parameters. Such necessities may have been developed from experience or may represent simplifications considered suitable by the IRS.
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<td>58</td>
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</tbody>
</table>
3.1. Definition of span for stiffeners and girders

The effective span of a stiffener (I) or girder (S) is also related to the design of the end connections in relation to nearby structures. Unless otherwise mentioned the span points at each end of the member, between which the span is measured, is in general to be determined as shown in Figure 3.3.1 and Figure 3.3.2. If the adjoining structure is found ineffective to support the bracket, or when the end bracket does not fulfill with requirements in this section and is fitted for stiffening of supporting structures, the span point shall be defined by the intersection of the line defined by the stiffener face plate and the end support structure.
3.2. **End connections of stiffeners**

3.2.1. All types of stiffeners (longitudinal, beams, frames, bulkhead stiffeners) are generally to be connected at their ends. However in special cases, snipped ends may be allowed, [see 3.2.4]. For the various types of connections (with brackets, bracket less, snipped ends) the general requirements are given below. Special requirements for specific structures are given in subsequent sections.

3.2.2. The arm lengths of brackets for stiffeners not taking part in longitudinal strength may normally be taken as:

\[
a = c \sqrt{\frac{Z}{(t - t_C)}}
\]

- \(c = 1.25\) for brackets with flange or edge stiffener
- \(c = 1.0\) for brackets without flange or edge stiffener
- \(Z\) = rule section modulus in cm³ of stiffener
- \(t_{bk}\) = thickness of bracket in mm

Net thickness of bracket is not to be less than

\[
t_{bk} = c \sqrt{\frac{Z}{k}}
\]

\(t_c\) = as given in Ch.2 [6.1], but need not be taken greater than 1.5 mm.

In no case shall the arm length, \(a\), be taken less than \((1 + \frac{1}{sin \phi}) h\), where \(\phi\) represents the angle between the stiffeners connected by the bracket, and \(h\) the depth of the lowest of the connected stiffeners. In addition the height of the bracket, \(h_b\), see [Figure 3.3.3 and 3.3.4], shall not be less than \(h\).
Brackets are to be arranged with flange or edge stiffener if free lengths exceed 50 \((t_b - t_c)\) except when the depth of the bracket, which is the distance from the root to the edge is less than 22 \((t_b - t_c)\).

The connection between stiffener and bracket should be designed so that the effective section modulus is not reduced to a value less than required for the stiffener.

3.2.3. Bracket less end connections may be applied for longitudinal and other stiffeners running constantly through girders (web frames, transverses, stringer, bulkheads, etc.), provided enough connection area is arranged for. For longitudinal, see special requirements in Chapter 5 Sec.2 and 4.

3.2.4. Stiffeners with snipped ends may be fitted in compartments and tanks in which dynamic loads are small and where vibrations are considered to be of small importance, provided the thickness of plating supported by the stiffener is not less than:

\[
t_p = \frac{1.25\sqrt{(l_{st} - 0.25s)p_{st} + \tau}}{t_p}
\]

- \(l_{st}\) = stiffener span in m
- \(s\) = stiffener spacing in m
- \(p_{st}\) = pressure on stiffener in kN/m²

3.3. End connections of girders

3.3.1. Ends of single girders or connections between girders forming ring systems shall be provided with brackets under normal circumstances. Brackets are to be radiused or well-rounded at their toes. The free edge of the brackets is to be arranged with flange or edge stiffener. Scantlings and details of girder and connections are given below. Bracket less connections may be applied provided enough support of the adjoining free flanges is arranged.

3.3.2. The thickness of brackets on girders shall not be less than that of the girder web plate.

3.3.3. The arm length and depth of girder web may in general be taken as:

\[
a = \frac{50\sqrt{Z}}{(t_{bk} - t_c)}
\]

- \(Z\) = Rule section modulus in cm³ of the strength member to which the bracket is connected
- \(t_{bk}\) = thickness of bracket in mm
- \(t_c\) = as given in Chapter 2 Sec 6 [6.1], but need not be taken greater than 1.5 mm
- \(w_c\) = section modulus corrosion factor as given in Chapter 2 Section 2 [6.1.]

3.3.4. Flanges on girder brackets are to have a cross-sectional area not less than:

\[
A = l_{br}t_{bk} \text{ (cm²)}
\]

- \(l_{br}\) = length of free edge of brackets in m
- \(t_{bk}\) = thickness of brackets in mm.

3.3.5. At the cross joint the thickness of the web plate of bracket less connection (see Figure.3.3.4) is not to be less than the greater of:

\[
t_3 = k_3\left(\frac{\sigma_1A_1}{h_2}\right) - t_2\left(\frac{\tau_2}{100}\right) \text{ (mm)}
\]

\[
t_3 = k_3\left(\frac{\sigma_2A_2}{h_1}\right) - t_2\left(\frac{T_1}{100}\right)
\]
3.4. Effective flange of girders

3.4.1. The section modulus of the girder is to be taken in accordance with particulars as given in the following. When applicable structural modeling in connection with direct stress analysis is to be conducted on the same particulars.

Note: Such structural modeling will not reveal the stress distribution at local flange cut-outs or at supports with variable stiffness over the flange width.

3.4.2. The effective plate flange area is defined as the cross-sectional area of plating within the effective flange width. Continuous stiffeners within the effective flange may be included. The effective flange width be is determined by the following formula:

\[ b_x = C \cdot b_{pf} \]

\[ C = \text{as given in Table 3.3.1} \]

<table>
<thead>
<tr>
<th>a/b</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>≥7</th>
</tr>
</thead>
<tbody>
<tr>
<td>C(r≥6)</td>
<td>0.00</td>
<td>0.38</td>
<td>0.67</td>
<td>0.84</td>
<td>0.93</td>
<td>0.97</td>
<td>0.99</td>
<td>1</td>
</tr>
<tr>
<td>C(r=5)</td>
<td>0.00</td>
<td>0.33</td>
<td>0.58</td>
<td>0.73</td>
<td>0.84</td>
<td>0.89</td>
<td>0.92</td>
<td>0.93</td>
</tr>
<tr>
<td>C(r=4)</td>
<td>0.00</td>
<td>0.27</td>
<td>0.49</td>
<td>0.63</td>
<td>0.74</td>
<td>0.81</td>
<td>0.85</td>
<td>0.87</td>
</tr>
<tr>
<td>C(r≤3)</td>
<td>0.00</td>
<td>0.22</td>
<td>0.4</td>
<td>0.52</td>
<td>0.65</td>
<td>0.73</td>
<td>0.78</td>
<td>0.8</td>
</tr>
</tbody>
</table>

\[ a = \text{distance between points of zero bending moments, see Figure.3.3.5} \]
\[ S_{gr} = \text{span of girder} \]
\[ b_{pf} = \text{plate flange width taken as the sum of half spans of adjacent stiffeners, see Figure.3.3.4} \]
\[ r = \text{number of stiffeners along girder span} \]

Figure 3.3.4: Bracketless joint

\[ A_1, A_2 = \text{flange area in cm}^2 \text{ of girder 1 and 2} \]
\[ \sigma_1, \sigma_2 = \text{bending stresses in N/mm}^2 \text{ in girder 1 and 2} \]
\[ \tau_1, \tau_2 = \text{shear stresses in N/mm}^2 \text{ in webs of girder 1 and 2} \]
\[ h_1, h_2 = \text{height in mm of girder 1 and 2} \]
\[ k_3 = \text{material factor for corner plate} \]
\[ k_3 = \text{Corresponds to the material factor given in Chapter 2, Section 2 [2.3.]} \]
3.3.5: Effective flange

If plate flanges has corrugations parallel to the girder, the effective width is as given in [3.4.2.] If the corrugations are perpendicular to the direction of the girder, the plate flange is considered not effective unless otherwise demonstrated.

3.5. Effective web of girders

3.5.1. The web area of a girder is to be taken in accordance with particulars as given below. Structural modeling in association with direct stress analysis is to be done based on the same particulars when applicable.

3.5.2. Holes in girders are generally acknowledged provided the shear stress level is acceptable and the buckling strength is adequate. Holes are to be kept well clear of end of brackets, pillars, crossties and locations where shear stresses are high.

3.5.3. For normal girders the effective web area is to be taken as:

\[ A_w = 0.01 h_n t_w \text{ (cm}^2) \]

\[ h_n = \text{net girder height in mm after deduction of cut-outs in the cross-section considered} \]

\[ = h_{n1} + h_{n2} \]

\[ t_w = \text{web thickness in mm, } t_c \text{ not included.} \]
If an opening is positioned at a distance less than $h_w/3$ from the cross-section considered, $h_n$ is to be taken as the smaller of the net height and the net distance through the opening. See Figure.3.3.6

### 3.6. Stiffening of girders

#### 3.6.1. Girders are generally provided with tripping brackets and web stiffeners to achieve sufficient lateral and web panel stability. The requirements provided below are for achieving a satisfactory stiffening standard. However, the stiffening system may be modified based on direct stress analysis and stability calculations as per accepted methods.

#### 3.6.2. The web plates of girders are to be stiffened where:

- $h_w > 75 \ t_w$ (mm)
- $t_w$ web thickness in mm, $t_c$ not included
- with stiffeners of maximum spacing:
  - $s = 60 \ t_w$ (mm)
  - within 20 percent of the span from each end of the girder and where high shear stresses.
- Elsewhere stiffeners are required where:
  - $h_w > 90 \ t_w$ (mm)
  - with stiffeners of maximum spacing: $s = 90 \ t_w$ (mm)

#### 3.6.3. If the mean shear stress exceeds 60 N/mm$^2$ the web plate is to be specifically stiffened at openings. Stiffeners should be fitted along free edges of the openings parallel to the vertical and horizontal axis of the opening. If the shortest axis is less than 400 mm and in both directions if length of both axes is less than 300 mm in both directions, stiffeners may be not required in one direction. Edge reinforcement may be used as an alternative to stiffeners.

#### 3.6.4. Generally the spacing $S_T$ of tripping brackets is not to surpass the values given in Table 3.3.2 valid for girders with symmetrical face plates. For others the spacing will be considered specially.

<table>
<thead>
<tr>
<th>Girder Type</th>
<th>$S_T$ (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transverse girders</td>
<td>0.02 $b_f$ 1</td>
</tr>
<tr>
<td>Vertical girders</td>
<td>maximum 6</td>
</tr>
<tr>
<td>Longitudinal girders outside 0.5L amidships</td>
<td>0.014 $b_f$ 2</td>
</tr>
<tr>
<td>Longitudinal girders within 0.5 L amidships</td>
<td>maximum 4</td>
</tr>
</tbody>
</table>

*b_f* = flange breadth in mm

$S_T$ = distance between transverse girders in m.

1 For girders in tanks and machinery spaces $S_T$ is not to exceed 0.014 $b_f$

2 If the web of a strength member forms an angle with the perpendicular to the ship's side of more than 10°, $S_T$ is not to exceed 0.007 $b_f$. 

#### 3.6.5. Tripping brackets on girders are to be stiffened by a flange or stiffener along the free edge if the length of the edge goes beyond:

- $0.06 \ t_t$ (m)

$t_t$ = thickness in mm of tripping bracket, $t_c$ not included.

The area of the stiffening is not to be less than:
$10 \ell_t (\text{cm}^2)$

$\ell_t =$ length in m of free edge.

The tripping bracket is to have a smooth transition to adjacent longitudinal or stiffeners exposed to large longitudinal stresses.

Tripping brackets when fitted should conform to the requirements in [3.6.4], and are further to be fitted near the toe of bracket, near rounded corner of girder frames and in line with any cross ties. The tripping bracket is to be fitted in line with longitudinal or stiffeners, and is to extend the whole height of the web plate. The arm length of brackets along the longitudinal or stiffeners, is not to be less than 40 percent of the depth of the web plate, the depth of the longitudinal or stiffener deducted. The requirement may be modified for deep transverses.

3.6.6. Hatch end beams supporting hatch side coamings are to have tripping brackets situated in the centreline and between the hatch side coaming and the ship's side.

3.6.7. The minimum thickness of tripping brackets and stiffeners is given in Chapter 5 covering the various local structures.

### 3.7. Properties of sections in relation to rule requirements

3.7.1. The geometric properties (moment of inertia $I$ and section modulus $Z$) of stiffeners and girders may be calculated straight from the given dimensions in connection with the effective plate flange (for girders, see 3.4), or obtained from published tables and curves.

3.7.2. The necessity for standard section modulus is valid about an axis parallel to the plate flange. For profiles with web plate angle $\alpha$ from the perpendicular to the flange greater than 15°, the requirement for standard section modulus may be determined by multiplying the rule requirement by $1 / \cos \alpha$.

3.7.3. Where several members in a group with some variation in requirement are selected as equal, the section modulus may be taken as the average of each individual requirement in the group. However, the requirement for the group is not to be taken less than 90 percent of the largest individual requirement.

3.7.4. For stiffeners and girders in tanks and in cargo holds of dry bulk cargo carriers, corrosion additions corresponding to the requirements given in Chapter 2 Section 6, [6.1] are to be applied. For built up sections the appropriate $t_c$-value may be added to the web and flange thicknesses after fulfillment of the net modulus requirement. For rolled sections the net section modulus requirement may be multiplied by a corrosion factor $w_c$ as given in Chapter 2, Section 6 [6.1.]

### 3.8. Continuity of local strength members

3.8.1. It is important to maintain structural continuity throughout.

3.8.2. The junctions of primary supporting members of unequal stiffness are made structurally continuous by fitting well rounded brackets. Unsupported plating need not have brackets. Either local plating reinforcement is to be provided at the toe of the bracket or they are to extend to the nearest stiffener.

3.8.3. Deck pillars are to be located in line with pillars above or below wherever possible.

3.8.4. Below decks and platforms, strong transverses are to be fitted between verticals and pillars, so that rigid continuous frame structures are formed.
3.9. Welding of outfitting details to hull

3.9.1. Connections of outfitting details to the hull are generally, to be such that stress concentrations are reduced and the high stressed parts are not welded as far as possible. Connections are to have smooth transitions and proper alignment with the hull structural elements. Terminations are to be properly supported.

3.9.2. Edge of openings and other areas with high stresses and toe of brackets are to be kept clear of equipment particulars such as clips for piping, support of ladders, valves, anodes etc. Connections to top flange of girders and stiffeners are to be avoided if not well smoothened. Supporting of outfitting are to be welded to the stiffener web wherever possible.

3.9.3. All materials welded to the hull shell structure are to be of marine quality steel, or equivalent, preferably with the same strength group as the hull structure to which the item is welded.

3.9.4. Gutterway bars on strength deck are to be arranged with expansion joints unless the height/thickness ratio complies with the formula:

\[ \frac{h}{t} < \frac{2}{3} \sqrt{\frac{E}{\sigma_F}} \]

Where:
- \( E \) as given in Chapter 1, Section 1, [1.2]
- \( \sigma_F \) = minimum upper yield stress of material in N/mm². May be taken as 235 N/mm² for normal strength of mild steel.

For welding of deck fittings to a rounded sheer strake, see also Chapter 5 Section 2, [2.4.6].

3.10. Cold formed plating

3.10.1. For important structural members, like corrugated bulkheads and hopper knuckles, the inside bending radius in cold formed plating is not to be less than 4.5 times the plate thickness for carbon-manganese steels and 2 times the plate thickness for austenitic- and ferritic-austenitic (duplex) stainless steels, corresponding to 10 percent and 20 percent theoretical deformation, respectively.

3.10.2. The allowable inside bending radius of carbon–manganese steel radius may be brought down below 4.5 times the plate thickness providing the following additional requirements are complied with:

a) The steel is killed and fine grain treated.

b) The material is impact tested in the strain-aged condition and meets the requirements stated herein. The deformation is to be equal to the maximum deformation to be applied during production, calculated by the formula \( t_{pl}/(2R + t_{pl}) \), where \( t_{pl} \) is the thickness of the plate material and \( R \) is the bending radius. Ageing is to be carried out at 250°C for 30 minutes. The average impact energy after strain ageing is to be at least 27 J at 20°C.

c) 100 percent visual inspection of the deformed area is to be done. Moreover random check by magnetic particle testing also to be done. The bending radius is in no case to be less than 2 times the plate thickness.
CHAPTER 4 LONGITUDINAL STRENGTH

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SECTION 1 GENERAL

Contents

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1.1. Introduction

This section describes the requirements pertaining to the longitudinal hull girder scantlings with respect to bending. The rules apply mainly to the ships with large block coefficient and low Froude number. For the ships with openings in ship side/deck, the collective effects of vertical and horizontal bending of the hull girder may have to be considered separately. For example, the effect of torsion needs to be considered when a ship is having large deck openings. The details for the special cases mentioned above will be dealt in detail in the relevant section.

1.2. Definitions

1.2.1. Symbols

\[ L, B_D, D, T, C_B, \text{ see Chapter 1, [1.2]} \]

\[ C_w = 0.32 + (0.0824L) \text{ for } L \leq 100 \]
\[ = 5.99 + (0.0193L) \text{ for } 100 < L \ll 130 \]

\[ M_{wh} = \text{Vertical Wave Bending Moment (Hogging) in kN-m as given in Chapter 4 Sec 2, [2.2].} \]

\[ M_{ws} = \text{Vertical Wave Bending Moment (Sagging) in kNm as given in Chapter 4 Sec 2, [2.1].} \]

1.2.2. Terms: Loading manual is a document which describes:

- The loading conditions on which the design of the ship has been structured, including allowable limits of Stillwater bending moment, shear force and shear force correction
- The results of calculations of still water bending moments, shear forces and, where applicable, limitations due to torsional and lateral loads
- The allowable local loadings for the structure (hatch covers, decks, double bottom, etc.).

Unless otherwise stated a loading computer system is a system, which is digital, which can be easily and quickly ascertained that, at specified read-out points, the still water bending moments, shear forces, and the still water torsional moments and lateral loads, in any loading or ballast condition will not go beyond the specified permitted values.

An operation manual is always to be given for the loading computer system. Single point loading computer systems are not acceptable.

**Category I Ships**: Ships with large deck openings where combined stresses due to vertical and horizontal hull girder bending and torsional and lateral loads have to be considered. Ships liable to carry non-homogeneous loadings, where the cargo and/or ballast may not be distributed evenly. Ships less than 120 m in length, when their design takes into account uneven distribution of cargo or ballast, belong to Category II.

**Chemical tankers and gas carriers.**

**Category II Ships**: Ships with arrangement giving small possibilities for variation in the distribution of cargo and ballast, and ships on regular and fixed trading pattern where the loading manual gives sufficient guidance, and in addition the exception given under Category I.
SECTION 2 VERTICAL BENDING MOMENTS

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2.1 Vertical bending moment

The vertical hull bending moment \( M \) in sagging and hogging conditions, to be considered in the ultimate strength check for the hull girder, is to be obtained in KNm, in intact, flooded and harbour conditions as follows:

\[
M_v = M_s + M_w
\]

Where:

- \( M_s \) = Vertical still water bending moment
- \( M_w \) = Vertical wave bending moment.

Still water wave banding moment can be defined as:

\[
M_{sw} = 0.11C_wL^2B_D D_f (C_B + 0.7) \quad \text{(for sagging condition)}
\]

\[
M_{hw} = 0.19C_wD_f L^2B_D C_B \quad \text{(for hogging condition)}
\]

For the calculation of midship section, the distribution factor \( D_f \) is taken as 1.0.

In general, for the calculation of the wave bending moment at any transverse section, the factor \( D_f \) can be obtained by linear interpolation as given in table 4.2.1

<table>
<thead>
<tr>
<th>Hull transverse location</th>
<th>( D_f )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 0 \leq x/L \leq 0.4 )</td>
<td>( 2.5 \times x/L )</td>
</tr>
<tr>
<td>( 0.4 &lt; x/L \leq 0.65 )</td>
<td>1</td>
</tr>
<tr>
<td>( 0.65 &lt; x/L \leq 1 )</td>
<td>( 2.86(1 - x/L) )</td>
</tr>
</tbody>
</table>

Note:

For ships with large deck openings (total width of hatch openings in one transverse section greater than 65 percent of the ship’s breadth or length of hatch opening beyond 75 percent of hold length) the longitudinal strength including torsion may be required to be considered as given in the subsequent section. For ships with block coefficient < 0.7, the longitudinal/local strength outside of the midship region may, subject to special consideration in each case,
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3.1. **Section modulus**

3.1.1. The requirements for section modulus within 0.4 L amidships about the transverse neutral axis based on cargo and ballast conditions are given by:

\[ Z = (M_s + M_w \sigma_w) \text{(cm}^3) \]

\[ \sigma_w = \text{as defined in Chapter 2, Section 2 [2.3.1].} \]

3.1.2. The unrestricted service wave bending moments may be reduced by 30 percent when still water bending moments calculated for harbour and sheltered water conditions (enclosed fjords, lakes, rivers) are inserted in the formula in [3.1.1] above.

3.1.3. According to Chapter 10, the buckling strength of longitudinally compressed structures is to be checked.

3.1.4. The midship section modulus about the transverse neutral axis is not to be less than:

\[ Z_0 = C_w B_D \left(C_B + 0.7\right) \text{cm}^3 \]

\[ C_w = \text{as defined in Chapter 4, Section 4 [1.2.1].} \]

\[ C_B \text{ is in this case not to be taken less than 0.50. For ships with restricted service, } C_w \text{ may be reduced as given in the subsequent sections.} \]

For range of navigation, see Part 9-A Chapter 2 Sec 2 [2.9].

3.1.5. As a basis for the section modulus calculation, the following sectional area of the deck may give an estimated section modulus:

\[ A_{SD} = C_B B_D L \]

\[ A_{SD} = \text{total sectional area of deck plating including deck longitudinal outside line of hatches, and the sheer strake plating, the width of which being limited to the Rule value.} \]

3.2. **Midship section particulars**

3.2.1. During the calculation of the moment of inertia and section modulus, only effective sectional area is to be taken.

3.2.2. The effective sectional area = The area of the continuous longitudinal strength members – the area of the openings

3.2.3. For the multi hatch way athwartships, the net area should be multiplied by a factor of 0.6 unless otherwise stated or justified by direct calculations.

3.2.4. The main strength members included in the hull girder calculations such as longitudinal bulkhead, side shell etc. are to be extended continuously through the cargo region and sufficiently far towards the forward and aft ends of the ship.

3.2.5. The followings are not included in the net section

i. Superstructure

ii. Deckhouse

iii. Bulwarks

iv. Hatch side coamings

3.2.6. In case of openings on the ship sides, the shear area of the section under consideration should be treated specially.
Generally the section modulus at deck is referred to the moulded deckline at side. For ships having a continuous trunk, long hatch side coamings or other continuous strength members above deck taking part in the longitudinal strength, the section modulus is to be referred to a point at a distance \( z \) above the neutral axis:

The midship section modulus \( Z \) at deck or bottom about the transverse neutral axis is to be obtained as follows:

\[
Z = \frac{1}{100} \frac{1}{z} \text{[cm}^3]\]

Where:

\( z = \) the vertical distance [m] from the horizontal neutral axis upto the strength deck at side or the base line, as relevant.

However, in case of ships where continuous trunks or longitudinal hatch coamings are to be included in the section modulus calculation as per Sec.3.1.1, the distance \( z \) for calculation of modulus at deck is to be taken as the greater of the following:

\[
z = z_1 (0.9 + 0.2 \frac{y}{b})
\]

where \( z_1 \) is the vertical distance from the neutral axis to the top of the continuous strength member, \( y \) is the horizontal distance from top of the continuous strength member to the ship's centre. \( y \) and \( z_1 \) are to be measured to the point giving the greatest value of \( z \).

\( z \) is not to be taken less than the distance from the neutral axis to the moulded deck line at side.

3.2.8. Large transition brackets are to be fitted at ends of effective continuous longitudinal strength members in deck and bottom region.

3.2.9. If the section modulus of midship section at deck as built is based on use of high strength steel the shipside plating should be made of the same high strength steel for a distance \( h_{ht} \) below the deck:

\[
h_{ht} = \frac{z_d (k - 1)}{k}
\]

where \( z_d \) is the distance from deck to neutral axis of the midship section, \( k \) is the material factor given in Chapter 2, Section 2 [2.3.1]
SECTION 4 OPENINGS IN LONGITUDINAL STRENGTH MEMBERS

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4.1. Positions

4.1.1. Bilge plate openings are to be kept clear of the bilge keel, the keel plate is not to have opening unless otherwise stated. Openings in bilge plate within 0.5 L amidships are to be avoided as far as possible.

4.1.2. Openings in strength deck are as far as feasible to be located well clear of ship's side and hatch corners.

4.2. Effect of openings

4.2.1. The effects of openings are assumed to have longitudinal extensions as shown by the shaded areas in Fig.4.4.1, i.e. inside tangents at an angle of 30° to each other. Example for transverse section III:

\[ b_{III} = b' + b'' + b''' \]

4.3. Hatchway corners

4.3.1. Strength deck openings are to have streamlined or rounded shape corners.

4.3.2. For corners with rounded shape the radius is not to be less than:

\[ r = 0.025 B_D \text{(m)} \]

Where:

\[ r \leq 0.1 \text{, } b = \text{breadth of opening in m.} \]

For local reinforcement of deck plating at circular corners, see Chapter 5 Sec 3.

4.3.3. In case the corners are given a streamlined shape as far as Fig.4.4.2 and Table 4.4.1 with the ordinate an equal to \( r \) given in 4.3.2, the deck plating need not be reinforced.

---

**Fig 4.4.1 effect of openings**
4.3.4. Streamlined shape may be required for very long hatches if large cut-outs are taken at deck/shipside corners.

In addition strengthening of the deck plating may be considered.

4.3.5. Alternative hatch corner designs (e.g. key hole) may be acknowledged subject to special consideration in each case.

4.4. Miscellaneous

4.4.1. Edges of openings are to be smooth. Machine flame cut openings with smooth edges may be accepted. Small holes are to be drilled. Hatch corners in special cases might be needed to be ground smooth. Welds to the deck plating within the curved hatch corner region are as far as possible to be avoided.

4.4.2. Studs for securing small hatch covers are to be fastened to the top of a coaming or a ring of suitable thickness welded to the deck. The studs are not to penetrate the deck plating.

4.4.3. Special considered will be given to the design of the hatch corners for ships with very large hatch openings («open» ships), where added local stresses occur in the hatch corner area.

### Table 4.4.1 Ordinates of streamlined corner

<table>
<thead>
<tr>
<th>Point</th>
<th>Abscissa x</th>
<th>Ordinate y</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>1.793 a</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1.381 a</td>
<td>0.002 a</td>
</tr>
<tr>
<td>3</td>
<td>0.987 a</td>
<td>0.021 a</td>
</tr>
<tr>
<td>4</td>
<td>0.802 a</td>
<td>0.044 a</td>
</tr>
<tr>
<td>5</td>
<td>0.631 a</td>
<td>0.079 a</td>
</tr>
<tr>
<td>6</td>
<td>0.467 a</td>
<td>0.131 a</td>
</tr>
<tr>
<td>7</td>
<td>0.339 a</td>
<td>0.201 a</td>
</tr>
<tr>
<td>8</td>
<td>0.224 a</td>
<td>0.293 a</td>
</tr>
<tr>
<td>9</td>
<td>0.132 a</td>
<td>0.408 a</td>
</tr>
<tr>
<td>10</td>
<td>0.065 a</td>
<td>0.548 a</td>
</tr>
<tr>
<td>11</td>
<td>0.022 a</td>
<td>0.712 a</td>
</tr>
<tr>
<td>12</td>
<td>0.002 a</td>
<td>0.899 a</td>
</tr>
<tr>
<td>13</td>
<td>0</td>
<td>1.000 a</td>
</tr>
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SECTION 5 LOADING GUIDANCE INFORMATION

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5.1. **General**

5.1.1. All ships covered by Reg. 10 of the Load Line Convention are to be provided with an approved loading manual.

5.1.2. Compliance with the requirements of this subsection will fulfill the Reg. 10(1) of the Load Line Convention for all ships with length 65 m and above.

5.1.3. For category II ships with length less than 90 m and where the deadweight does not go beyond 30 percent of the maximum displacement; a loading manual considering longitudinal strength is not required.

5.1.4. All ships of category I (see Chapter 4, Sec 1, [1.2.]) are in addition to the loading manual to be provided with a loading instrument approved and certified for calculation and control of hull strength in accordance with the requirements given in Pt.6 Ch.9.

5.2. **Conditions of approval of loading manuals**

5.2.1. The approved loading manual is subjected to the final data of the ship. The manual is to comprise the conditions of design loading and ballast conditions upon which the approval of the hull scantlings is based, see Chapter 4, Sec 2 [2.1].

Possible specifications are:
- load specifications for cargo decks
- Draught limitations (in ballast etc.)
- Restrictions to GM-value.
- cargo density and filling heights for cargo tanks
- cargo mass and cargo angle of repose restrictions

The manual for loading must be made in a language which is understood by the users. Incase this language is not English a translation into English is to be added. A new approved loading manual is to be issued in case of alterations leads to changes in the main data of the ship.
## CHAPTER 5 HULL SCANTLINGS

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### SECTION 1 BOTTOM STRUCTURES

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1.1. General

1.1.1 General

The formulas in this section are for bottom structures. Direct stress calculations as outlined in Chapter 5, Section 1 [1.5] will be considered as alternative basis for the scantlings.

1.1.2 Definitions

\[ t_{pl} = \text{rule thickness in mm of plating} \]
\[ c_f = \text{correction factor of aspect ratio for plate field see Chapter 3 Section 2, [2.4]} \]
\[ Z_r = \text{rule section modulus in cm}^3 \text{ of stiffeners and simple girders} \]
\[ s = \text{stiffener spacing in m, measured along the plating} \]
\[ l_{st} = \text{stiffener span in m, measured along the top flange of the member. For definition of span point, see Chapter 5, [1.3.1]. For curved stiffeners may be taken as the cord length} \]
\[ w_c = \text{section modulus corrosion factor in cargo oil and ballast tanks, Chapter 2, [6.1]} \]
\[ \sigma = \text{nominal allowable bending stress in N/mm}^2 \text{ due to lateral pressure} \]
\[ Z_B = \text{midship section modulus in cm}^3 \text{ as built at bottom} \]
\[ Z_R = \text{rule midship section modulus in cm}^3 \text{ as given in Chapter 3, [3.1]} \]

Fig 5.1.1: Longitudinal connections

1.1.3 Structural arrangement details

1.1.3.1. When the bottom or inner bottom is longitudinally stiffened, the following arrangements of longitudinal connections will normally be accepted (see Fig.5.1.1):
1.1.3.2. The longitudinals are normally to be continuous through transverse members within 0.5 L amidships.
1.1.3.3. In Ships with length less than 50m, the longitudinal maybe welded against the floors and in larger ships outside 0.5L
1.1.3.4. Abrupt ending of the bilge keel and the flat bar to which it is attached is not accepted. Ends are to be tapered to internal stiffening.
1.1.3.5. Weld connections are to conform to the general requirements stated in Chapter 2. Section 7
1.1.3.6. For end connections of stiffeners and girders, see Chapter 3Section 3,[3.2]
1.1.4 Bottom arrangement

1.1.4.1. A double bottom shall be fitted which should extend from the collision bulkhead to the afterpeak bulkhead for passenger vessels and cargo vessels (except tankers), if it is found that it does not hamper the proper working of the ship.

1.1.4.2. The inner bottom shall be properly arranged so that it provides adequate protection for the bottom of the turn of bilge.

1.1.4.3. Precaution should be taken to avoid unnecessary extension of depth in small wells constructed in double bottom in connection with drainage arrangement of holds. A well extending to the outer bottom may, however, be permitted if the arrangement gives protection equivalent to that afforded by a double bottom complying with this regulation. In no case shall the vertical distance from the bottom of such a well to a plane coinciding with the keel line be less than 500 mm.

1.1.4.4. Double bottoms are to be avoided in watertight compartments used exclusively for the carriage of goods. However the safety of the ship in the event of bottom damage should not be impaired.

1.1.4.5. Any part of the ship that is not fitted with a double bottom in accordance with [1.1.4.1] and [1.4.4.4] shall be capable of with-standing bottom damage. Ref. SOLAS Reg.II-1/9.8.

1.2. Design loads

1.2.1. Generally applicable local loads on bottom structures are given here. In connection with the various local structures, reference is made to this section, indicating the relevant loads in each case.

A. Outer bottom:

   Sea pressure:
   \[ P_1 = P_E \]

B. Internal Loads

   i. Boundaries Of tanks
   \[ P_2 = \rho_w g h_s \]
   
   Where \( h_s \) is the distance from the point of application to the tank top.

   ii. Pressure inside the tank
   \[ P_3 = \rho_w g \left( h_s + 0.5g \cdot \frac{b}{L} \right) \]

   Where, \( \alpha \) is the correction factor proportional to the velocity of the fluid in the direction of positive x-axis.

C. Cargo Holding

   \[ P_4 = 10\left( \frac{G}{V_{sc}} \right) h \left( 1 + 0.55 \cdot \frac{c_w}{\sqrt{T}} \right) \]

   Where \( G \) = mass of the solid cargo
   \( V_{sc} \) = volume of the solid cargo

   Minimum Pressure
   \[ P_5 = 10T \]

   \[ P_E = \frac{g \cdot R \cdot z}{2} \left[ 1 - 0.8 \frac{(r-x)^2}{r^2} + (0.005) \frac{(r-x)^2}{r} \right] + \rho_w g z + \frac{2B_1}{c_w + \gamma} \left( V_s / \sqrt{gD} \right) \text{ kN/m}^2 \]
g = Acceleration due to gravity = 9.81 m/s²

\( h_1 \) = Wave height in m

\( \gamma_c \) = correction factor = 0.8 * \( h_1 \) if \( h_1 >= 2 \), else 1.0

T = Draught of the vessel

\( z \) = load point in z direction (downward positive)

\( \rho_w \) = density of water

\( C_B \) = block co-efficient

\( y \) = load point in y direction

\( B_i/2 \) = Half Breadth of the vessel.

\( V_s \) = Speed of vessel in knots

L = length of the vessel

Note:
If arrangements for the prevention of over pumping of ballast tanks are done \( \Delta p_{dyn} \) may be taken as zero.

Total loads on double bottom: In connection with direct stress calculations on double bottom structures, total loads are to be taken as differences between internal and external pressures. These loads are specified in [1.5.1].

1.3. Plating's & stiffeners

1.3.1 Keel plate and garboard strake

1.3.1.1 The keel plate or garboard strake is to extend over the complete length of the ship.

The breadth is not to be less than:

\[ b = 800 + 5L \text{ mm} \]

1.3.1.2 The thickness is not to be less than:

\[ t = 7.0 + 0.05L + t_c \text{ mm} \]

The thickness is in no case to be less than that of the adjacent bottom plate.

1.3.2 Bottom and bilge plating

1.3.2.1 The thickness requirement corresponding to lateral pressure is given by:

\[ t_{req} = \frac{\gamma_c f \sqrt{p}}{\sqrt{\sigma}} + t_c \]

\( p = p_1 \) to \( p_5 \) whichever is applicable, see [1.2.1]

\( \sigma \) = as given in Table 5.1.2.

\( c_i \) = see chapter 3 Sec 2, [2.4]
Table 5.1.2: Values of $\sigma$

<table>
<thead>
<tr>
<th></th>
<th>Allowable stress $\sigma$ 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transverse stiffening:</td>
<td>60 ($Z_b/Z_r$) maximum 120 within 0.4 L 160 within 0.1 L from the perpendiculare</td>
</tr>
<tr>
<td>Longitudinal stiffening:</td>
<td>120 within 0.4 L 160 within 0.1 L from the perpendiculare</td>
</tr>
</tbody>
</table>

1) Between specified regions the $\sigma$-value may be varied linearly.

1.3.2.2 The thickness is not to be less than:

$$t = 5.0 + 0.04L + t_c \text{ (mm)}$$

1.3.2.3 The thickness of the bilge plate should always be greater than the adjacent side shell or bottom thickness.

1.3.2.4 Buckling strength requirements given in Part 9C, Chapter 10 are also to be conformed with.

1.3.2.5 If the bilge plate is not stiffened or has only one stiffener inside the curved plate, the thickness is not to be less than:

1.15 times the thickness obtained from [1.3.2.1]

Fig 5.1.2: Bilge without longitudinal stiffening

1.3.3 Inner bottom plating

1.3.3.1 The thickness requirement corresponding to lateral pressure is given by:

$$t_{ipb} = \frac{\gamma_c f_s \sqrt{p}}{\sqrt{\sigma}} + t_c$$

$p = p_{t-p_{5}}$ whichever is relevant, as given in [1.2.1]

$\sigma = 0.9*11 * R_{ef}$(Refer Chapter 2 [2.3])

= 160 within 0.1 L from the perpendiculare.

120 /k

Between specified regions the $\sigma$-value may be varied linearly.

$c_f$ = see chapter 3 Sec 2, [2.4]
1.3.3.2 The thickness is not to be less than:

\[ t = t_0 + 0.03 L + t_c \text{ (mm)} \]

- \( t_0 = 7.0 \) in holds below dry cargo hatchway opening if ceiling is not fitted
- \( = 6.0 \) elsewhere in holds if ceiling is not fitted
- \( = 5.0 \) in holds if ceiling is fitted
- \( = 5.0 \) in void spaces, machinery spaces and tanks

1.3.4 Floors and longitudinal girders

1.3.4.1. The thickness requirement of floors and longitudinal girders forming boundaries of double bottom tanks is given by:

\[ t_{trg} = \frac{ycf s\sqrt{p}}{\sqrt{\sigma}} + t_c \]

- \( p = p_1 - p_5 \) whichever is relevant, as given in 1.2.1
- \( \sigma = 130 \) within \( 0.4L \) for longitudinal girder
- \( = 160 \) within \( 0.1L \) from perpendiculars
- \( = 160 \) for floors.
- \( = 120/k \) for sea chest boundaries (including top and partial bulkheads)

Between specified regions the \( \sigma \)-value may be varied linearly.

\( c_f = \) see chapter 3 Sec 2, [2.4]

1.3.4.2. The thickness of longitudinal girders, floors, supporting plates and brackets is not to be less than:

\[ t = 6 + \alpha L + t_c \text{ (mm)} \]

- \( \alpha = 0.045 \) for centre girder
- \( = 0.025 \) for other girders.
- \( = 0.055 \) for sea chest boundaries (including top and partial bulkheads)

1.3.5 Transverse frames

1.3.5.1 The section modulus requirement of bottom and inner bottom frames is given by:

\[ Z_{bf} = 0.63 I_{w} s p w_c \text{ (cm}^3) \]

- \( p = p_1 - p_5 \) whichever is relevant, as given in 1.2.1.

1.3.5.2 Struts fitted between bottom and inner bottom frames are in general not to be considered as effective supports for the frames.

1.3.5.3 The requirement given in [1.3.5.1] however, may be reduced after special consideration. Span reduction of 35% maybe accepted when the strut is at the middle length of the span and the and when the bottom and inner bottom frames have the same scantlings.

1.3.5.4 The thickness of web and flange is not to be less than the larger of:

\[ t_{tf-wb/ft} = 4.5 + \alpha + t_c \text{ (mm)} \]

- \( \alpha = 0.016 \) L
- \( h_w = \) web height in mm
- \( g = 75 \) for flanged profile webs
1.3.6 Bottom longitudinal

1.3.6.1. The section modulus requirement is given by:

\[ Z = \frac{8312^2 spwc}{\sigma} \text{ (cm}^3) \]

\( p = p_1 \) to \( p_5 \) as given in 1.2.1

\( \sigma = 95 \) within 0.4 L when \( Z_b = Z_R \)

\( = 160 \) within 0.4 L when \( Z_b \geq 2 Z_R \)

\( = 160 \) within 0.1 L from the perpendiculars.

1.3.6.2. Between specified regions the \( \sigma \)-value may be varied linearly.

The thickness of web and flange is not to be less than the larger of:

\[ t = 4.5 + \alpha + tk \text{ (mm)} \]

\( = 1.5 + (h_w)/g + t_c \)

\( \alpha = 0.016 \text{ L} \)

\( h_w = \) web height in mm

\( g = 75 \) for flanged profile webs

41 for bulb profiles

22 for flat bar profiles.

1.3.6.3. Struts present between bottom and inner bottom longitudinal will not be considered as effective supports for the longitudinals. Span reduction of 35% maybe accepted when the strut is at the middle length of the span and the and when the bottom and inner bottom frames have the same scantlings.

1.3.6.4. A longitudinal is to be fitted at the bottom where the curvature of the bilge plate starts.

1.3.7 Inner bottom longitudinal

1.3.7.1 The section modulus requirement is given by:

\[ Z_{ibl} = \frac{8312^2 spwc}{\sigma} \text{ (cm}^3) \]

\( p = p_1 \) to \( p_5 \) whichever is relevant, as given in [1.2.1]

\( = p_1 \) for sea chest boundaries (including top and partial bulkheads).

\( \sigma = 140 \) within 0.4 L for longitudinal stiffeners

\( = 160 \) within 0.1 L from perpendiculars

\( = 160 \) for other stiffeners.

\( = 120 \) for sea chest boundaries (including top and partial bulkheads)

Between specified regions the \( \sigma \)-value may be varied linearly
1.3.8 Stiffening of floors and girders

1.3.8.1 Stiffeners in accordance with the requirement in [1.3.8.1] are assumed to have end connections. When Z is increased by 40%, however, stiffeners other than longitudinals may be snipped at ends if the thickness of plating supported by the stiffener is not less than:

\[ t_{sf} = 1.25 \sqrt{(l_s - .05s) + p + t_c} \text{ (mm)} \]

1.3.8.2 The thickness of web and flange is not to be less than the larger of:

\[ t_{fl, wb/ft} = 4.5 + \alpha + t_c \text{ (mm)} \]

\[ = 1.5 + \frac{h_w}{g} + t_c \]

\[ \alpha = 0.016 L \]
\[ h_w = \text{web height in mm} \]
\[ g = 75 \text{ for flanged profile webs} \]
\[ = 41 \text{ for bulb profiles} \]
\[ = 22 \text{ for flat bar profiles.} \]

1.3.8.3 The longitudinal girders are to be stiffened at every transverse frame.

1.3.8.4 The longitudinal girders are to be satisfactorily stiffened against buckling.

1.4. Arrangement of double bottom

1.4.1 General

1.4.1.1 Where a double bottom is required to be fitted the inner bottom shall be continued out to the ship side in such a manner as to protect the bottom to the turn of bilge. Such protection will be deemed satisfactory if the inner bottom is not lower at any part than a plane parallel with the keel line and which is located not less than a vertical distance h measured from the keel line, as calculated by the formula:

\[ h = \frac{1000 \cdot B_D}{20} \text{ (mm)}, \text{minimum 760 mm} \]

The height, h, need not be taken more than 2000 mm.
The height is to be sufficient to give good access to all parts of the double bottom. For ships with a great rise of floors, the minimum height may have to be increased after special consideration.

In the engine room, the height of the tank top above the keel should be 45% and 30% greater than the required centre. Girder height, respectively, with and without a sump in way of the main engine.

1.4.2 Double bottom with transverse framing

1.4.2.1 Side girders are to be fitted so that the distance between the side girders and the centre girder or the margin plate or between the side girders themselves does not exceed 4 m. In the engine room additional side girders are normally to be fitted.

1.4.2.2 Under the main engine, girders extending from the bottom to the top plate of the engine seating are to be fitted. The height of the girders is not to be less than that of the floors. If the engine is bolted directly to the inner bottom, the thickness of the plating in way of the engine is to be at least twice the rule thickness of inner bottom plating given in Chapter 5, Section 1, [1.3.3] of this part.

1.4.2.3 Engine holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders.
The thickness of the top plate of seating for main engine and reduction gear should preferably not be less than:

\[ t_{top} = \begin{align*}
25 \text{ mm} & \text{ for } P_s \leq 1000 \text{ kW} \\
30 \text{ mm} & \text{ for } 1000 < P_s \leq 1750 \text{ kW} \\
35 \text{ mm} & \text{ for } 1750 < P_s \leq 2500 \text{ kW} \\
40 \text{ mm} & \text{ for } 2500 < P_s \leq 3500 \text{ kW} \\
45 \text{ mm} & \text{ for } P_s > 3500 \text{ kW}
\end{align*} \]

\( P_s \) = maximum continuous output of propulsion machinery.

The thickness of the engine girders should preferably not be less than 40 per cent of the recommended top plate thickness.

**1.4.2.4** The floor spacing is normally not to be greater than given in Table 5.1.3. In the engine room floors are to be fitted at every frame. In way of thrust bearing and below pillars, additional strengthening is to be provided.

<table>
<thead>
<tr>
<th>Draught in m</th>
<th>Under deep tanks 1)</th>
<th>Clear of deep tanks and machinery space 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T ≤ 2</td>
<td>Every 4th frame</td>
<td>Every 6th frame</td>
</tr>
<tr>
<td>2 &lt; T ≤ 5.4</td>
<td>Every 3rd frame</td>
<td>Every 5th frame</td>
</tr>
<tr>
<td>5.4 &lt; T ≤ 8.1</td>
<td>Every 3rd frame</td>
<td>Every 4th frame</td>
</tr>
<tr>
<td>T &gt; 8.1</td>
<td>Every 2nd frame</td>
<td>Every 3rd frame</td>
</tr>
</tbody>
</table>

With height greater than 0.7 times the distance between the inner bottom and the main deck. The distance between plate floors is not to exceed 3 m.

**1.4.2.5** Supporting plates for the transverse bottom frames are to be fitted at the centre girder and the margin plate on frames without floors. The breadth is to be at least one frame spacing, and the free edge is to be provided with a flange.

**1.4.3 Double bottom with longitudinal framing**

**1.4.3.1** Side girders are to be fitted so that the distance between the side girders and the center girder or the margin plate or between the side girders themselves does not exceed 5 m. In the engine room additional side girders are normally to be fitted.

**1.4.3.2** Under the main engine, girders extending from the bottom to the top plate of the engine seating are to be fitted. The height of the girders is not to be less than that of the floors. If the engine is bolted directly to the inner bottom, the thickness of the plating in way of the engine is to be at least twice the rule thickness of inner bottom plating given in Chapter 5, Section 1, [1.3.3] of this part. Engine holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders.

**1.4.3.3** The floor spacing is normally not to be greater than 3.6 m. In way of deep tanks with height exceeding 0.7 times the distance between the inner bottom and the main deck, the floor spacing is normally not to exceed 2.5 m. In the engine room, floors are to be fitted at every second side frame. Bracket floors are to be fitted at intermediate frames, extending to the first ordinary side girder outside the engine seating. In way of thrust bearing and below pillars additional strengthening is to be provided.

**1.4.3.4** Supporting plates are to be fitted at the centre girder. The free edge of the supporting plates is to be provided with flange. The breadth of supporting plates is to be given at least one longitudinal spacing. The spacing is normally not to exceed two frame spacing’s. Between supporting plates on the centre girder docking brackets are to be fitted. Alternative arrangements of supporting plates and docking brackets require special consideration of local buckling strength of centre...
PART 9-C  IRS Rules for Building and Classing Steel Vessels

CHAPTER 5  girder/duct keel and local strength of docking longitudinal subject to the forces from docking blocks.

1.5. **Single bottom girders**

1.5.1 **General**

1.5.1.1 The strength of single bottom girders within cargo area should generally be based on direct stress calculations. The calculation should be based on a 2- or 3- dimensional frame analysis with the following loadings: In ships with possibility for uneven loading of cargo it should be assumed that the bottom will be subject to external water pressure equal to:

\[ 10 T + 0.12 L \text{ (kN/m}^2\text{)} \text{ with empty hold.} \]

In ships with even loading the net external load (i.e. sea pressure — partload in hold) on the bottom should not be taken less than:

\[ 5 T + 0.12 L \text{ (kN/m}^2\text{)} \]

The load on bottom in cargo holds intended for liquid with specific gravity greater than 1 t/m\(^3\)will be specially considered.

1.5.1.2 Acceptable stress levels for the calculation will be:

\[ \sigma = 160 \text{ N/mm}^2 \text{ for transverse structural elements} \]

= as given for bottom longitudinals in Section 1, [1.3.6] of this chapter.

= 90 N/mm\(^2\)

1.5.1.3 The strength of single bottom girders outside holds for liquid cargo may also be based on the requirements given in [1.5.2]

1.5.2 **Arrangement of single bottom girders outside holds for liquid cargo.**

1.5.2.1 If direct stress calculations of the single bottom girders are not carried out the following requirements may be applied.

1.5.2.2 The height of centre girder and floors at centre line is not to be less than:

\[ h_{bt-gr/ft} = 250 + 20 B + 50 T \text{ (mm)} \]

1.5.2.3 Floors are to be fitted at every frame.

1.5.2.4 Floors are to be fitted at every frame.

1.5.2.5 A centre line girder is to be fitted.

1.5.2.6 Side girders are normally to have spacing not exceeding 2.5 m. Forward of 0.25 L from F.P. The spacing should not exceed 1.25 m.

1.5.2.7 Side girders are normally to have spacing not exceeding 2.5 m. Forward of 0.25 L from F.P. the spacing should not exceed 1.25 m.

1.5.3 **Scantlings**

1.5.3.1 The flange area of floors and side girders with minimum height in accordance with [1.5.2.1] is normally not to be less than:

3.5 T (cm\(^2\)) in way of cargo holds and 5.0 T (cm\(^2\)) in way of engine room.
When cement is filled to top of floors, the flange may be omitted in cargo holds.

1.5.3.2 Within 0.5 L amidships the centre girder flange area is not to be less than:
   \[ A_{fl} = 0.6 \ L \ (cm^2) \].

1.5.3.3 The flange area of side girders and centre girder outside 0.5 L may be 80% of the value given in [1.5.3.1] and [1.5.3.2].

1.5.3.4 The minimum height of floors anywhere between the engine or gear girders is not to be less than 50% of the height given in [1.5.2.2]. For this reduction the requirement for flange area given in [1.5.3.1] is to be increased by 100% and the web thickness by 50%. For intermediate reduced heights the increase of flange area should be correspondingly.

1.5.3.5 The thickness of web plates, flanges, stiffeners and brackets is not to be less than:
   \[ t_{sb-wb/fl} = 6 + \alpha L + t_c \ (mm) \]
   
   \[ c = 0.045 \] for centre girder
   \[ = 0.025 \] elsewhere
   \[ = 0.015 \] for stiffeners of girders.

   The thickness of girder web plates is in addition not to be less than:
   \[ t_{sgrb} = 15s + t_c \]

   \[ s = \text{spacing of web stiffening in m.} \]

   For thickness of top plate of seating’s for main engine and reduction gear, see [1.3.2.2]

1.5.3.6 Girder flanges are to have a thickness not less than 1/30 of the flange width when the flange is symmetrical, and not less than 1/15 of the flange width when the flange width is asymmetrical. The width is not to be less than 1/20 of the distance between tripping brackets.

1.5.3.7 For stiffening of girders, see Chapter 3 Section 3, [3.6]

1.6. **Peak Tank Girders**

1.6.1 In the after peak of single screw ships, the floors are to have such a height that their upper edge is well above the stern tube.

1.6.2 The thickness of floors is not to be less than:
   \[ t_{ptk-gr} = 6 + 0.025L + t_c \ (mm) \]

1.7. **Special requirements**

1.7.1 Bar keel

   The scantlings are not to be less than:
   - depth: 100 + 1.5 L (mm)
   - thickness: 10 + 0.6 L (mm).

1.7.2 Vertical struts

   Where bottom and inner bottom longitudinals or frames are supported by vertical struts, the sectional area of the strut is not to be less than:
   \[ A_{st} = \alpha l_{st}sT \ (cm^2) \]
\[ \alpha = 0.75 \text{ in way of ballast tanks} \]
\[ = 0.65 \text{ elsewhere} \]
\[ l_{st} = \text{stiffener span in m disregarding the strut.} \]

The moment of inertia of the strut is not to be less than:

\[ I_{st} = 2.5 h_{dB}^2 A_{st} \text{ (cm}^4 \text{)} \]

\[ h_{db} = \text{double bottom height in m}. \]
## SECTION 2 SIDE STRUCTURE SCANTLING

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2.1. General

2.1.1. Introduction
The requirements in this section apply to ship’s side structure.

2.1.2. Definitions

2.1.2.1 Symbols:
- \( L, B, D, T, C \) see Chapter 1, Section 1, [1.2] of this part
- \( t_{\text{pl}} \) = rule thickness in mm of plating
- \( Z_r \) = rule section modulus in cm\(^3\) of stiffeners and girders
- \( c_f \) = correction factor for aspect ratio of plate field see Chapter 3 Sec 2,[2.4]
- \( s \) = stiffener spacing in m, measured along the plating
- \( l_{\text{st}} \) = stiffener span in m, measured along the top flange of the member. For definition of span point, see Chapter 3, Section 3, [3.1] of this part. For curved stiffeners may be taken as the cord length.
- \( S \) = girder span in m
- \( w_c \) = section modulus corrosion factor in tanks, see Chapter 2, Section 2 [6.1.2.1] of this part.
- \( \sigma \) = nominal allowable bending stress in N/mm\(^2\) due to lateral pressure
- \( p_d \) = design pressure in kN/m\(^2\) as given in B
- \( Z_A \) = midship section modulus in cm\(^3\) as built at deck or bottom respectively
- \( Z_R \) = rule midship section modulus in cm\(^3\) as given in Chapter 4, Section 3, [3.1] of this part.

2.1.2.2 The load point where the design pressure is to be calculated is defined for various strength members as follows:

- for plates: Midpoint of horizontally stiffened plate field. Half of the stiffener spacing above the lower support of vertically stiffened plate field, or at lower edge of plate when the thickness is changed within the plate field.
- for stiffeners: Midpoint of span. When the pressure is not varied linearly over the span, the design pressure is to be taken as the greater of:
  - \( p_m \), \( p_a \) and \( p_b \) are calculated pressures at the midpoint and at each end respectively, see Fig.5.2.1.
  \[ p_m \leq p_a + \frac{p_b}{2} \]
- for girders: Midpoint of load area.

2.1.3. Structural arrangement and details

2.1.3.1 Within 0.5 \( L \) amidships, in the areas 0.15 \( D \) above the bottom and 0.15 \( D \) below the strength deck, the continuity of side longitudinal is to be as required for bottom and deck longitudinal, respectively.

2.1.3.2 Weld connections are to satisfy the general requirements given in Chapter 2 Section 7.

2.1.3.3 For end connections of stiffeners and girders, see Chapter 3 Section 3, 3.3.
2.2. Design Loads

2.2.1 Local loads on side structures

2.2.2.1 Generally applicable local loads on side structures are given in Table 5.2.1. In connection with the various local structures, reference is made to this table, indicating the relevant loads in each case.

<table>
<thead>
<tr>
<th>Load type</th>
<th>p (kN/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea pressure below summer load waterline</td>
<td>Refer to Chapter 5, Section 1.2.1-A</td>
</tr>
<tr>
<td>Sea pressure above summer load waterline</td>
<td></td>
</tr>
<tr>
<td>Ballast, bunker or liquid cargo in side tanks in genera¹²³</td>
<td>Refer to Chapter 5, Section 1.2.1-B</td>
</tr>
</tbody>
</table>

¹ For ships with service restrictions, p₂ and the last term in p₁ may be reduced by 25%
² p₁ is to be applied for 25% of length of tank measured from the tank ends.
³ For partly filled tanks, see also Sec.4.4.2

h₀ₚ  = vertical distance in m from the waterline at draught T to the load point
P₀ₚ  = as given in Chapter 5 Section 1.2
k    = 1.3 aft of 0.2 L from F.P.
      = 1.5 within 0.2 L from F.P
L    = ship length
hₕ   = vertical distance in m from load point to top of tank, excluding smaller hatchways
h₀ₕ  = vertical distance in m from the load point to the top of air pipe
ρ    = density of ballast, bunker or liquid cargo in t/m³, normally not to be less than 1.025 (i.e. ρ₀ₕ ≈ 10)
P₀    = 0.3 L – 5 (kN/m²), minimum 10 generally
      = 25 kN/m² in cargo tanks
      = pressure valve opening pressure when exceeding the general value
Bₙₚ  = breadth of tank in m
lₙₚ  = total length of tank in m.
Pₑ    = as given in Chapter 5, Sec 1, [1.2.1] of this part.
Note:
When a ship is designed with VCS notation (high-high level alarm) or provided with equivalent systems to prevent overflow through air pipes, the tank pressure for liquid cargo, based on air pipe height $h_p$, may be omitted.

2.3. Plating and Stiffeners

2.3.1. Side plating, general

2.3.1.1. The thickness requirement corresponding to lateral pressure is given by:

$$t_{spl} = \frac{\gamma c_f s_p \sqrt{p}}{\sqrt{\sigma}} + t_c$$

$p = p_1$ to $p_5$, whichever is relevant, as given in Table 5.2.1
$\sigma =$ as given in Table 5.2.2.
$c_f =$ Chapter 3 Section 2,[2.4]

2.3.1.2. The thickness is not for any region of the ship to be less than:

$$t = 5.0 + \alpha L + t_c \text{ mm}$$

$\alpha = 0.045$ up to 4.6 m above the summer load waterline. For each 2.3 m above this level the $k$-value may be reduced by 0.01 ($\alpha$(minimum) = 0).

$= 0.065$ for plating connected to the stern frame.

2.3.1.3. If the end bulkhead of a superstructure is located within 0.5 L amidships, the side plating should be given a smooth transition to the sheer strake below.

<table>
<thead>
<tr>
<th>Table: 5.2.2: Allowable Stresses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Allowable stress $\sigma$</strong></td>
</tr>
<tr>
<td><strong>Transverse stiffening:</strong></td>
</tr>
<tr>
<td>120 within 0.4 L at neutral axis $Z_A$</td>
</tr>
<tr>
<td>maximum 120 within 0.4 L at deck or bottom</td>
</tr>
<tr>
<td>160 within 0.1 L from the perpendiculars</td>
</tr>
<tr>
<td><strong>Longitudinal stiffening:</strong></td>
</tr>
<tr>
<td>140 within 0.4 L at neutral axis</td>
</tr>
<tr>
<td>120 within 0.4 L at deck or bottom</td>
</tr>
<tr>
<td>160 within 0.1 L from the perpendiculars</td>
</tr>
</tbody>
</table>

1) Between specified regions the $\sigma$-value may be varied linearly.

2.4. Sheer strake at strength deck

2.4.1. The breadth is not to be less than:

$$b = 800 + 5 L \text{ (mm)}$$

2.4.2. The thickness is not to be less than:

$$t_{shs} = \frac{t_1 + t_2}{2} \text{ (mm)}$$

$t_1 =$ required side plating in mm
$t_2 =$ strength deck plating in mm, not to be taken less than $t_1$.

2.4.3. If the superstructure deck is of partial strength the thickness of sheer strake can be increased by 30 percent on each side provided they are within 0.5L amidships deck.
2.4.4. When the radius of curvature is less than 15t, cold rolling and bending of rounded sheer strakes.

2.4.5. Details for hot forming, if used for rounding of sheer strake are to be submitted to the society for the approval. Appropriate heat treatment subsequent to the forming operation will normally be required.

2.4.6. Where the rounded sheer strake forms knuckle at the forward and aft ends line heating maybe may be accepted.

2.4.7. The welding of deck fittings to rounded shear strakes is to be kept to a minimum within 0.6 L amidships. Subject to the surveyor's consent, such welding may be carried out provided:

— when cold formed, the material is of grade NVD or a grade with higher impact toughness
— the material is hot formed in accordance with [2.4.5] above.

The weld joints are to be subjected to magnetic particle inspection. The design of the fittings is to be such as to minimize stress concentrations, with a smooth transition towards deck level.

2.4.8. Where the sheer strake extends above the deck stringer plate, the top edge of the sheer strake is to be kept free from notches and isolated welded fittings, and is to be ground smooth with rounded edges. Drainage openings with smooth transition in the longitudinal direction may be allowed.

2.4.9. Bulwarks are in general not to be welded to the top of the sheer strake within 0.6 L amidships. Such weld connections may, however, be accepted upon special consideration of design (i.e. expansion joints), thickness and material grade.

2.5. Longitudinals

2.5.1. The section modulus requirement is given by:

\[ Z = \frac{83.5 \left[ \frac{1}{s_{st}} / \left(0.1/s_{st}\right) \right] s_{st} p w c}{\sigma} \text{ (cm}^3\text{), minimum 15 cm}^3\]

\[ p = p_1 \text{ to } p_5, \text{ whichever is relevant, as given in Table 5.2.1} \]

\[ \sigma = 95 \text{ at deck or bottom within 0.4 L when } Z_{AW} = Z_R \]

\[ = 160 \text{ at deck or bottom within 0.4 L when } Z_A \geq 2 Z_R \]

\[ = 160 \text{ within 0.25 D above and below the neutral axis} \]

\[ = 160 \text{ within 0.1 L from the perpendiculars.} \]

Between specified regions σ-value may be varied linearly.

2.5.2. The thickness of web and flange is not to be less than the larger of

\[ t_{wb/f1} = 4.5 + \alpha + t_c (\text{mm}) \]

\[ = 1.5 + \frac{h_w}{g} + t_c \]

\[ \alpha = 0.015 \text{ L in general} \]

\[ = 0.016 \text{ L in peaks and in cargo oil tanks and ballast tanks in cargo area} \]

\[ H_w = \text{web height in mm} \]

\[ g = 75 \text{ for flanged profile webs} \]

\[ = 41 \text{ for bulb profiles} \]
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CHAPTER 5 = 22 for flat bar profiles.

2.6.  Main frames

2.6.1.  Main frames are frames located outside the peak tanks, connected to the floors or the double bottom and extending to the lowest deck or stringer on the ship's side.

2.6.2.  The section modulus requirement is given by the greater of:

\[ Z_{mf1} = 0.5 \, l_{st} \cdot s \cdot p \cdot w_c \, (\text{cm}^3) \]

\[ Z_{mf2} = 6.5 \sqrt{L} \, (\text{cm}^3) \]

And,

\[ p = p_1 \text{ to } p_5, \text{ whichever is relevant, as given in Table 5.2.1.} \]

2.6.3.  The thickness of web and flange is not to be less than given in [2.5.2] above.

2.6.4.  The requirement given in [2.6.2] above is based on the assumption that effective brackets are fitted at both ends.

The length of brackets is not to be less than:

- \( 0.12l_f \) for the lower bracket
- \( 0.07l_f \) for the upper bracket.

Where:

\[ l_f = \text{full length of frame including brackets.} \]

The section modulus of frame including bracket is not to be less than:

- \( 2 \, Z \) at lower end
- \( 1.7 \, Z \) at upper end

\[ Z = \text{as given in [2.6.2] above} \]

When the length of the free edge of the bracket is more than 40 times the plate thickness, a flange is to be fitted, the width being at least \( 1/15 \) of the length of the free edge.

2.6.5.  Brackets may be omitted provided the frame is carried through the supporting member and the section modulus is not less than:

\[ 1.5 \, Z \]

\[ Z = \text{as given in [2.6.2] above with total span applied.} \]

2.6.6.  The section modulus for a main frame is not to be less than that for the 'tween deck frame above.

2.6.7.  The inner edge of frames at hatch end beams is to be reinforced to withstand additional bending moments from the deck structure after special consideration.

2.7.  'Tween deck frames and vertical peak frames

2.7.1.  'Tween deck frames are frames between the lowest deck or the lowest stringer on the ship's side and the uppermost superstructure deck between the collision bulkhead and the after peak bulkhead.

2.7.2.  If the lower end of 'tween deck frames is not welded to the bracket or the frame below, the lower end is to be bracketed above the deck. For end connections, see also [3.2] of Chapter 3, Sec 3.

2.7.3.  The section modulus is not to be less than the greater of:

\[ Z_{tdfr1} = 0.55l_{st} \cdot s \cdot p \cdot w_c \]
\[Z_{tdfr2} = \frac{\alpha}{\sqrt{L}}\]

\(\alpha = 6.5\) for peak frames

\(= 4.0\) for 'tween deck frames

\(p = p_{1}\) to \(p_{5}\), whichever is relevant, as given in Table 5.2.1.

2.7.4. The thickness of web and flange is not to be less than given in Chapter 5, Section 2, [2.5]

2.7.5. The requirement for section modulus given in [2.7.3] may be modified as for main frames in [2.6.2] above provided effective brackets as given in Part 9-C Chapter 5, section 2, [2.6.4] are fitted at both ends.

2.8. Girders

2.8.1. General

The web plate thickness and the thickness of flanges, brackets and stiffeners on girders is not to be less than:

\[t_{gwpf1} = 5.0 + \alpha L + t_{c}\] mm

\(\alpha = 0.03\) for peak tank girders

\(= 0.02\) for girders in cargo/ballast tanks in liquid cargo tank areas

\(= 0.01\) for other girders and for stiffeners on girders in general.

\[t = 12s + t_{c}\] mm

The thickness of girder web plates in single skin constructions is in addition not to be less than:

\(s = \) spacing of web stiffening in m.

2.8.2. In the after peak, engine and boiler room, side verticals are normally to be fitted at every 5th frame.

2.8.3. Verticals in the engine room and verticals less than 0.1 \(L\) from the perpendiculare are to have a depth not less than:

\[h = 2LS\] (mm), maximum 200S

2.8.4. Girder flanges are to have a thickness not less than 1/30 of the flange width when the flange is symmetrical, and not less than 1/15 of the flange width when the flange is asymmetrical.

For girders in engine room the total flange width is not to be less than 35 S mm.

2.8.5. Transverse bulkheads or side verticals with deck transverses are to be fitted in the 'tween deck spaces to ensure adequate transverse rigidity.

2.8.6. Vertical peak frames are to be supported by stringers or decks at a vertical distance not exceeding 2.5 m.

2.8.7. The end connections and stiffening of girders are to be arranged as given in Chapter 3 Section 3.

2.9. Simple girders

2.9.1. The section modulus requirement is given by:
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\[ Z_{sgr} = \frac{100 \cdot s^2 \cdot b_{lo} \cdot p_w \cdot c}{\sigma} \text{ (cm}^3\text{)} \]

\( p = p_1 - p_5 \) whichever is relevant as in Table 5.2.1

\( b = \) loading breadth in m

\( \sigma = \) as given in 2.3 for continuous longitudinal girders

\( =160 \alpha \) for other girders.

The above requirements apply about an axis parallel to the ship's side.

2.9.2. The web area requirement (after deduction of cut-outs) at the girder ends is given by:

\[ A = \alpha S b_{lo} + 10 h_{gr} t_c \text{ (cm}^2\text{)} \]

\( \alpha = 0.065 \) for continuous horizontal girders and upper end of vertical girders

\( = 0.085 \) for lower end of vertical girders

\( b_{lo} = \) as given in [2.9.1]

\( h_{gr} = \) girder height in m

\( p = p_{10} - p_5 , \) whichever is relevant, as given in Table 5.2.1.

The web area at the middle of the span is not to be less than 0.5 \( A \).

The above requirements apply when the web plate is perpendicular to the ship's side.

For oblique angles the requirement is to be increased by the factor \( 1/\cos \theta \), where \( \theta \) is the angle between the web plate of the girder and the perpendicular to the ship's side.

2.10. Complex girder systems

2.10.1. In addition to fulfilling the general local requirements given in 100, the main scantlings of girders being parts of a complex system may have to be based on a direct stress analysis.

2.11. Special Requirements

2.11.1 Bar stem

If bar stem is fitted the scantlings are not to be less than:

- width : 90 + 1.2 \( L \) below summer load waterline
  70 + 0.9 \( L \) at the stem head

- thickness : 12 + 0.48 \( L \).

The stem width is to be gradually tapered from the waterline to the stem head.

2.12. Strengthening against bow impact

For vessels with high speed, well rounded bow lines and/or large flare, special strengthening of the bow region is to be considered.
### SECTION 3 DECK STRUCTURES

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3.1. General

3.1.1. Introduction

3.1.1.1. The requisites in this section apply to ship's deck structure.

3.1.2. Definitions

3.1.2.1. Symbols:

- \( L, B, D, T, C, \) see Chapter 1, Sec 1 [1.2] of this part.
- \( Z \) = rule section modulus in cm\(^3\) of stiffeners and simple girders
- \( C_\ell \) = See Chapter 3 Sec 2, [2.4]
- \( s \) = stiffener spacing in m, measured along the plating
- \( l_\ell = \) stiffener span in m, measured along the top flange of the member. For definition of span point, see Chapter 3, Sec 3 [3.1]. For curved stiffeners \( l_\ell \) may be taken as the cord length
- \( S \) = girder span in m. For definition of span point, see Chapter 3, Sec 3 [3.1].
- \( w_c \) = section modulus corrosion factor in tanks, see Chapter 2, Sec 6, [6.1].
- \( \sigma \) = nominal allowable bending stress in N/mm\(^2\) due to lateral pressure
- \( p_d \) = design pressure in kN/m\(^2\)
- \( Z_D \) = midship section modulus in cm\(^3\) as built at deck
- \( Z_R \) = rule midship section modulus in cm\(^3\) as given in Chapter 4, Sec 3, [3.1].

3.1.3. Structural arrangement and details

3.1.3.1. When the strength deck is longitudinally stiffened:

- the longitudinals are normally to be continuous at transverse members within 0.5 \( L \) amidships
- the longitudinals may be cut at transverse members. In that case continuous brackets connecting the ends of the longitudinals are to be fitted
- the longitudinals may be welded against the transverse members in ships with length \( L \leq 50 \) m and in larger ships outside 0.5 \( L \) amidships provided \( Z_D > 2 \) \( Z_R \). Brackets to be fitted.

3.1.3.2. Preferably, transverse beams are to be used in deck areas between hatches. The beams are to be efficiently supported by longitudinal girders. If longitudinals are used, the plate thickness is to be increased so that the required transverse buckling strength is achieved, or transverse buckling stiffeners are to be fitted in intercostal manner. The stiffening of the upper part of a plane transverse bulkhead (or stool tank) is to be such that the required transverse buckling strength is achieved. Transverse beams are to extend to the second deck longitudinal from the hatch side. Where this is impracticable, stiffeners or brackets are to be placed in intercostal manner in extension of beams.

3.1.3.3. If hatch coaming corners with double curvature or hatch corners of streamlined shape are not adopted, the thickness of deck plates in strength deck at hatch cornes is to be increased by 25%. The longitudinal extension of the thicker plating is not to be less than 1.5 \( R \) and not more than 3 \( R \) on both sides of the hatch end. The transverse extension outside line of hatches is to be at least 2 \( R \).
R = corner radius.
For shape and radius of corners in large hatch openings, see Chapter 4, Sec 4 [4.3].

3.1.3.4. The seam between the thicker plating at the hatch corner and the thinner plating in the deck area between the hatches is to be located at least 100 mm inside the point at which the curvature of the hatch corner terminates. If the difference between the deck plate thickness at the hatch corners and in the deck area between hatches is greater than 1/2 of the thickest plate, a transition plate is to be laid between the thick plating and the thin deck area plating. The material strength group of the transition plate is typically to be of an intermediate strength group to that of the connecting plates.

3.1.3.5. Weld connections are to satisfy the general requirements given in Chapter 2 Section 7.

3.1.3.6. For end connections of girders and stiffeners, see Chapter 3, Sec 3.

3.1.4. Construction and initial testing of watertight decks, trunks etc.

3.1.4.1. Watertight decks, trunks, tunnels, duct keels and ventilators are to be of the same strength as watertight bulkheads at corresponding levels (see Table 3.1.1, p[12]). The means for making them watertight, and the arrangements adopted for closing openings in them are to satisfy the requirements of this section and Ch.3 Sec.6. Watertight ventilators and trunks are to be carried at least up to the bulkhead deck in passenger ships and up to the freeboard deck in cargo ships.

3.1.4.2. Where a ventilation trunk passing through a structure penetrates the bulkhead deck, the trunk shall be capable of withstanding the water pressure that may be present within the trunk, after having taken into account the maximum heel angle allowable during intermediate stages of flooding, in accordance with SOLAS Ch. II-1/8.5.

3.1.4.3. Where all or part of the penetration of the bulkhead deck is on the main ro-ro deck, the trunk shall be capable of withstanding impact pressure due to internal water motions (sloshing) of water trapped on the ro-ro deck.

3.1.4.4. In ships constructed before 1 July 1997, the requirements of paragraph 2 shall apply not later than the date of the first periodical survey after 1 July 1997.

3.1.4.5. After completion, a hose or flooding test is to be applied to watertight decks and a hose test to watertight trunks, tunnels and ventilators.

3.2. Design Loads

3.2.1. Local loads on deck structures

3.2.1.1. Generally applicable local loads on deck structures are given in Table 3.1.1 below. In connection with the various local structures, reference is made to this table, indicating the relevant loads in each case.
### Table 5.3.1: Design loads

<table>
<thead>
<tr>
<th>Structure</th>
<th>( P_d (kN/m^2) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather decks 1) 3)</td>
<td>( p_6 = a \left( p_E - (4 + 0.2 K_s) h_0 \right) = \text{minimum } 5.0 )</td>
</tr>
<tr>
<td>Cargo 'tween decks</td>
<td>( p_7 = k g_0 q ) \hspace{1cm} ( p_8 = k</td>
</tr><tr>
<td>ho_0 g_0 H_c )</td>
<td></td>
</tr>
<tr>
<td>Platform deck in machinery spaces</td>
<td>( P_9 = k g_0 1.6 )</td>
</tr>
<tr>
<td>Accommodation decks</td>
<td>( p_{10} = k g_0 0.35 )</td>
</tr>
<tr>
<td>Deck as tank bottom or top in general 2)</td>
<td>( p_{11} = k \rho_w g_0 h_5 ) \hspace{1cm} ( p_{12} = 0.67 \left( \rho g_0 h_p + P_E \right) ) \hspace{1cm} ( p_{13} = p_w g_0 h_s + p_0 ) \hspace{1cm} ( p_{14} = p_w g_0 \left( h_s + 0.3 b \right) ) \hspace{1cm} ( p_{15} = \rho_w g_0 \left( h_s + 0.1 l \right) )</td>
</tr>
<tr>
<td>Top of deckhouse</td>
<td>( p_{16} = 4 )</td>
</tr>
<tr>
<td>Watertight deck submerged in damaged condition 5)</td>
<td>( p_{17} = 10 h_b )</td>
</tr>
</tbody>
</table>

1) On weather decks combination of the design pressures \( p_1 \) and \( p_2 \) may be required for deck cargo with design stowage height less than 2.3 m.
2) For partly filled tanks, see Sec.4, Table 4.1.1
3) For ships with service restrictions, \( p_1 \) may be reduced by 25%.
4) \( p_9 \) and \( p_{10} \) refer to tank sides and ends, respectively. Adjacent structures are to be reinforced accordingly.
5) The strength may be calculated with allowable stresses for plating, stiffeners and girders increased by 60.

\( a = 1.0 \) for weather decks forward of 0.15L from FP, or forward of deckhouse front, whichever is the foremost position.

\( a = 0.8 \) for weather decks elsewhere.

\( p_{dP}, K_s = \) as given in Chapter 5, Sec 1 [1.21]

\( h_{\text{dock}} = \) vertical distance in m from the waterline at draught \( T \) to the deck.

\( T_r = \) rule draught in m, see Chapter 1 Sec.1 [1.2].

\( \alpha = 1.3 \) aft of 0.2 L from F.P.

\( = 1.5 \) forward of 0.2 L.

\( q = \) deck cargo load in t/m² as specified.

Weather decks above cargo holds in dry cargo ships are normally to be designed for a minimum cargo load \( q_{\text{min}} = 1.0 \).

When it is specially stated that no deck cargo is to be carried, the \( q_{\text{min}} \) may be disregarded.

\( \rho_c = \) dry cargo density in t/m³, if not otherwise specified to be taken as 0.7

\( \rho_0 = \) density of ballast, bunker or liquid cargo in t/m³, normally not to be less than 1.025 (i.e. \( \rho g_0 \approx 10 \))

\( H_c = \) stowage height in m of dry cargo. Normally the ‘tweendeck height or height to top of cargo hatchway to be used.

\( h_s = \) vertical distance in m from the load point to top of tank, excluding smaller hatchways.

\( h_p = \) vertical distance in m from the load point to the top of air pipe.
\( h_b = \) vertical distance in meters from the load point to the deepest equilibrium waterline in damaged condition obtained from applicable damage stability calculations. The deepest equilibrium waterline in damaged condition should be indicated on the drawing of the deck in question.

The vertical distance is not to be less than up to the margin line (a line drawn at least 76 mm below the upper surface of the bulkhead at side)

\[ p_0 = 0.3 \, L - 5 \, (kN/m^2), \text{ minimum } 10 \, \text{generally} \]

\[ = 25 \, kN/m^2 \text{ in cargo tanks} \]

\[ = \text{pressure valve opening pressure when exceeding the general value} \]

\( B_{tk} = \) breadth of tank in m

\( l_{tk} = \) total length of tank in m.

\( P_E = \) as given in Chapter 5 Sec.1 [1.2.1].

Guidance note:

When a ship is designed with VCS notation (high-high level alarm) or provided with equivalent systems to prevent overflow through air pipes, the tank pressure for liquid cargo, based on air pipe height \( h_p \), may be omitted.

### 3.3. Plating and stiffeners

#### 3.3.1. Strength deck plating

3.3.1.1. The breadth of stringer plate and strakes in way of possible longitudinal bulkheads which are to be of grade B, D or E is not to be less than:

\[ b_{st, p} = 800 + 5L \, (mm) \]

3.3.1.2. The thickness requirement corresponding to lateral pressure is given by:

\[ t_{dk} = \frac{\gamma_f \sqrt{p}}{\sqrt{\sigma}} + t_c \]

\( c_f = \) correction factor for aspect ratio of plate field

\[ = 1.21 - 0.538(s/l) + (0.0441)(s/l)^2 \]

\( P = p_6 \text{ to } p_{15}, \) whichever is relevant, as given in Table 5.3.1

\( \sigma = \) as given in Table 5.3.2

<table>
<thead>
<tr>
<th>Table 5.3.2: Allowable Stresses</th>
</tr>
</thead>
</table>
| \( \sigma \) (N/mm\(^2\))
| 1) |
| Transverse stiffening | 60 \( Z_D/Z_{Rr} \), maximum 120 within 0.4 L 160 within 0.1 L from the perpendiculars |
| Longitudinal stiffening | 120 within 0.4 L 160 within 0.1 L from the perpendiculars |

1) Between specified regions the \( \sigma \)-value may be varied linearly.
3.3.1.3. The thickness is not to be less than:

\[ t_{sdpt} = t_0 + \alpha L + t_c \text{ (mm)} \]

- \( t_0 = 5.5 \) for unsheathed weather and cargo decks
- \( t_0 = 5.0 \) for accommodation decks and for weather and cargo decks sheathed with wood or an approved composition
- \( \alpha = 0.025 \) in vessels with single continuous deck
- \( \alpha = 0.015 \) in vessels with two continuous decks above 0.7 D from the baseline
- \( \alpha = 0 \) in vessels with more than two continuous decks above 0.7 D from the baseline.

3.3.1.4. If the end bulkhead of a long superstructure is located within 0.5 L amidships, the stringer plate is to be increased in thickness for a length of 3 m on each side of the superstructure end bulkhead. The increase in thickness is to be 20%.

3.3.1.5. The thickness of transversely stiffened strength deck should comply with the requirements to buckling strength as given in Chapter 10.

3.3.2. Plating of decks below or above strength deck

3.3.2.1. The thickness requirement corresponding to lateral pressure is given by the formula in 3.3.1.2 when \( \sigma = 160 \).

3.3.2.2. The thickness of steel decks is not to be less than:

\[ t_{sdk} = t_0 + t_c \text{ (mm)} \]

- \( t_0 \) as given in 3.3.1.3.

3.3.3. Longitudinals

3.3.3.1. The section modulus requirement is given by:

\[ p = p_s \text{ to } p_{15}, \text{ whichever is relevant, as given in Table 5.3.1} \]

- \( \sigma = 95 \) within 0.4 L midship when \( Z_D = Z_R \)
- \( \sigma = 160 \) within 0.4 L midship when \( Z_D \geq 2 Z_R \)
- \( \sigma = 160 \) within 0.1 L from the perpendiculars.

Between the specified regions the \( \sigma \)-value shall be varied linearly.

For definition of other parameters used in the formula, see 3.1.2

3.3.3.2. The thickness of web and flange shall not be less than the larger of:

\[ t_{wb/fl} = 4.5 + \alpha + t_c \text{ (mm)} \]

- \( \alpha = 0.015 \) L in general
- \( \alpha = 0.0155 \) L in peaks and for boundaries of cargo oil tanks and ballast tanks in cargo area
- \( \alpha = 0.5 \) for accommodations decks above strength deck

\( h_w = \) web height in mm

\( g = 75 \) for flanged profile webs

- \( g = 41 \) for bulb profiles
- \( g = 22 \) for flat bar profiles.
PART 9-C
IRS Rules for Building and Classing Steel Vessels
CHAPTER 5

3.3.4. Transverse beams

3.3.4.1. The section modulus requirement is given by:
\[ Z_{tbrm} = 0.63 l^2 s p w_c \text{ (cm}^3\text{)}, \text{ minimum } 15 \text{ cm}^3 \]
\[ p = p_6 \text{ to } p_{15}, \text{ whichever is relevant, as given in Table 5.3.1.} \]

3.3.4.2. The thickness of web and flange is not to be less than given in 3.3.3.2.
3.3.4.3. For end connections, see Chapter 3 Section 3, 3.2.

3.4. Girders

3.4.1. General

3.4.1.1. The thickness of web and flange, brackets and stiffeners on girders is not to be less than:
\[ t_{grwf/ft} = 5.0 + \alpha L + t_c \text{ (mm)} \]
\[ \alpha = 0.035 \text{ for peak tank girders} \]
\[ = 0.025 \text{ for girders in cargo/ballast tanks in liquid cargo tank areas} \]
\[ = 0.015 \text{ for other girders and for stiffeners on girders in general.} \]

The thickness of girder web plates is in addition not to be less than:
\[ t_{grwbpt} = 12s + t_c \text{ (mm)} \]
\[ s = \text{ spacing of web stiffening in m.} \]

3.4.1.2. Longitudinal deck girders above tanks are to be fitted in line with transverse bulkhead verticals. The flange area is to be at least 1/7 of the sectional area of the web plate, and the flange thickness is to be at least 1/30 of the flange width.

3.4.1.3. Deck transverses are to be fitted in the lowest deck in engine room, in line with the side verticals. The depth of the deck transverses is to be at least 50% of the depth of the side verticals, web thickness and face plate scantlings being as for side verticals.

3.4.1.4. The thickness of girder stiffeners and brackets is not to be less than given in 3.4.1.1.

3.4.1.5. The end connections and stiffening of girders are to be arranged as given in Chapter 3 Section 3.

3.4.1.6. The deck flange of the girder is to comply with the requirements to buckling strength as given in Chapter 10

3.4.2. Simple girders

3.4.2.1. The section modulus requirement is given by:
\[ p = p_6 - p_{10} \]
\[ = 1.15 p_{12} \]
\[ = p_{13} - p_{15} \text{ whichever is relevant, as given in Table 5.3.1} \]
\[ b_0 = \text{ loading breadth in m} \]
\[ \sigma = \text{ allowable stress as given in 3.3.3.1 for longitudinal girders} \]
\[ = 160 \text{ for other girders.} \]

3.4.2.2. The web area requirement (after deduction of cut-outs) at the girder ends is given by:
\[ A_{wbr} = 0.06 S b_{lo} p + 10h_{gr} t_c \text{ (cm}^2\text{)} \]
The web area at the middle of the span is not to be less than 0.5 A.

3.4.3. Complex girder systems

3.4.3.1. In addition to fulfilling the general local requirements given in 3.4.1 the main scantlings of deck girders being parts of complex girder systems in holds or tanks for heavy cargo or liquids may have to be based on a direct stress analysis.

3.5. Special Requirements

3.5.1. Transverse strength of deck between hatches

3.5.1.1. In ships with large hatch openings, it is to be examined that the effective deck area between hatches is sufficient to withstand the transverse load acting on the ship's sides. Reinforcement to reduce the additional stresses will be considered in each case.

The effective area is defined as:

- deck plating
- transverse beams
- deck transverses
- hatch end beams (after special consideration).

When calculating the effective area, corrosion additions are to be deducted. The compressive stress is not to exceed 120 N/mm$^2$ or 80% of the critical buckling stress of the deck, bulkhead and stool tank plating. The buckling strength of stiffeners and girders is to be examined.

3.5.2. Strength of deck outside large hatches

3.5.2.1. The strength of deck and ship's side in way of long and wide hatches as given in Chapter 4, as applicable, to be examined by direct calculation of bending moments, torsional moments, shear forces and deflections due to loads caused by the sea and the deck cargo.

3.5.3. Pillars in tanks

3.5.3.1. Hollow pillars are not accepted.

3.5.3.2. Where the hydrostatic pressure may give tensile stresses in the pillars, their sectional area is not to be less than:

\[ A_{sp} = 0.07 A_{dk} p_t \text{ (cm}^2\text{)} \]

\[ A_{dk} = \text{deck area in m}^2 \text{ supported by the pillar} \]
\[ p_t = \text{design pressure} \ p \text{ in kN/m}^2 \text{ giving tensile stress in the pillar.} \]
Doubling plates at ends are not allowed.
SECTION 4 BULKHEAD STRUCTURES

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4.1. General

4.1.1. Introduction

4.1.1.1. The requirements in this section apply to bulkhead structures.

4.1.2. Definitions

4.1.2.1. Symbols:

\( L, B, D, T, C_b \), see Chapter 1, Sec 1 [1.2] of this part.

\( t_{pl} = \) rule thickness in mm of plating

\( Z_t = \) rule section modulus in \( \text{cm}^3 \) of stiffeners and single girders

\( c \) = correction factor for aspect ratio of plate field, see chapter 3 Section 2, [2.4]

\( s = \) stiffener spacing in m, measured along the plating. For corrugations, see 4.1.2.3

\( l_{st} = \) stiffener span in m, measured along the top flange of the member. For definition of span point, see Sec.3. For curved stiffeners \( l \) may be taken as the cord length

\( S = \) girder span in m. For definition of span point, see Chapter 3 Sec.3 [3.1]

\( w_c = \) section modulus corrosion factor in tanks, see Chapter 2, Sec 6, [6.1].

\( = 1.0 \) in other compartments

\( \sigma = \) nominal allowable bending stress in N/mm\(^2 \) due to lateral pressure

\( p_d = \) design pressure in kN/m\(^2 \) as given in 4.2

\( Z_A = \) midship section modulus in \( \text{cm}^3 \) as built at deck or bottom respectively

\( Z_R = \) rule midship section modulus in \( \text{cm}^3 \) as given in Chapter 4, Sec 3, [3.1].

4.1.2.2. The load point where the design pressure is to be calculated is defined for various strength members as follows:

- for plates: Midpoint of horizontally stiffened plate field. Half of the stiffener spacing above the lower support of vertically stiffened plate field, or at lower edge of plate when the thickness is changed within the plate field

- for stiffeners: Midpoint of span. When the pressure is not varied linearly over the span, the design pressure is to be taken as the greater of:

\[
p_m \text{ and } \frac{p_a + p_b}{2}
\]

\( p_m, p_a \) and \( p_b \) are calculated pressures at the midpoint and at each end respectively, see Fig.1. Sec.6

- for girders: Midpoint of load area.

4.1.2.3. For corrugated bulkheads the following definition of spacing applies (see Fig.5.4.1):

\( s = s_1 \) for section modulus calculations

\( = 1.05 s_2 \) or \( 1.05 s_3 \) for plate thickness calculations in general

\( = s_2 \) or \( s_3 \) for plate thickness calculation when 90 degrees corrugations.
4.1.3. Structural arrangement and details

4.1.3.1. Number and location of transverse watertight bulkheads are to be in accordance with the requirements given in Chapter 3.

4.1.3.2. The peak tanks are to have centre line wash bulkheads when the breadth of the tank is greater than 2/3 of the moulded breadth of the ship.

4.1.3.3. The free distance between transverse tank bulkheads is normally not to exceed 10 m. The free distance may be increased to 0.13 L (when L > 77 m) provided the tank structure is strengthened to resist the additional dynamic load p8 in tanks with unrestricted filling heights.

If the free distance exceeds 0.13 L (when L > 77 m) the dynamic load will be specially considered.

4.1.3.4. The free breadth of tanks should normally not exceed 0.56 B. For greater breadths the strength of the tank structure will be specially considered.

4.1.3.5. Within 0.5 L amidships, in the areas 0.15 D above the bottom and 0.15 D below the strength deck, the continuity of bulkhead longitudinals is to be as required for bottom and deck longitudinals respectively.

4.1.3.6. Weld connections are to satisfy the general requirements given in Chapter 2 Section 7.

4.1.3.7. Stern tubes shall be enclosed in a watertight space (or spaces) of moderate volume. In case the stern tube terminates at an aftpeak bulkhead also being a machinery space bulkhead, a pressurized stern tube sealing system may be accepted as an alternative to the watertight enclosure. (SOLAS Ch. II-1).

4.2. Design Loads

4.2.1. Local loads on bulkhead structures

4.2.1.1. Generally applicable local loads on bulkhead structures are given in Table 5.4.1 In connection with the various local structures, reference is made to this table, indicating the relevant loads in each case.
Table 5.4.1: Design Loads

<table>
<thead>
<tr>
<th>Structure</th>
<th>( p_d (\text{kN/m}^2) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watertight bulkheads</td>
<td>( p_{16} = 10h_b )</td>
</tr>
<tr>
<td>Cargo hold bulkheads</td>
<td>Refer to Chapter 5, Section 1.2.1-C</td>
</tr>
<tr>
<td>Tank bulkheads</td>
<td></td>
</tr>
<tr>
<td></td>
<td>general</td>
</tr>
<tr>
<td></td>
<td>Refer to Chapter 5, Section 1.2.1-C</td>
</tr>
<tr>
<td></td>
<td>sides</td>
</tr>
<tr>
<td></td>
<td>Refer to Chapter 5, Section 1.2.1-C</td>
</tr>
<tr>
<td></td>
<td>ends</td>
</tr>
<tr>
<td></td>
<td>( P_{17} = \rho_0 \cdot g_0 (h_b + 0.1h)^2 )</td>
</tr>
<tr>
<td></td>
<td>( p_{22} = \rho \left[ 4 - \left( \frac{l}{200} \right) l_b \right]^2 )</td>
</tr>
</tbody>
</table>

1) For ships with service restrictions, \( p_2 \) and \( p_3 \) may be reduced by 25%.
2) Adjacent ends and sides are to be reinforced for 25% of the breadth and length respectively.
3) When \( l > 0.56B \), \( p_6 \) is to be specially considered.

For dry cargo 'tween decks, \( h_c \) may be taken to the nearest deck above.

\[ A = 1.35 \text{ aft of 0.2 L from F.P.} \]
\[ = 1.55 \text{ within 0.2 L from F.P.} \]

\( h_b \) = vertical distance in metres from the load point to the deepest equilibrium waterline in damaged condition obtained from applicable damage stability calculations. The deepest equilibrium waterline in damaged condition should be indicated on the drawing of the bulkhead in question. The vertical distance is not to be less than up to the margin line (a line drawn at least 76 mm below the upper surface of the bulkhead at side).

\( \rho_c \) = dry cargo density in t/m\(^3\), if not otherwise specified to be taken as 0.7

\( \rho_0 \) = density of ballast, bunker or liquid cargo in t/m\(^3\), normally not to be taken less than 1.025 (i.e. \( \rho_0 = \rho_0 \))

\( \alpha = \sin 2 \tan 2 \left( 45 - 0.5 \delta \right) + \cos 2 \alpha_1 \)

\[ = \cos \alpha_1 \times \text{minimum} \]

\( \alpha_1 \) = angle between panel in question and the horizontal plane in degrees

\( \delta \) = angle of repose of cargo in degrees, not to be taken greater than 20 degrees for light bulk cargo (coal, grain) and not greater than 35 degrees for heavy bulk cargo (ore)

\( h_{ts} \) = vertical distance in m from the load point to the top of tank or hatchway excluding smaller hatchways

\( h_p \) = vertical distance in m from the load point to the top of air pipe

\( h_c \) = vertical distance in m from the load point to the highest point of the hold including hatchway in general.

For sloping and vertical sides and bulkheads, \( h_c \) may be measured to deck level only, unless the hatch coaming is in line with or close to the panel considered.

In dry cargo 'tween decks, \( h_c \) may be taken to the nearest deck above.

\( B_k \) = breadth of tank in m
\( l_t \) = total length of tank in m

\( b \) = free tank length in m

\( p_0 = 0.3 \times L - 5 \) (kN/m\(^2\)), minimum 10 generally

= 25 kN/m\(^2\) in cargo tanks

= pressure valve opening pressure when exceeding the general value.

\( P_E \) = as given in Chapter 5 Section 1, [1.2.1].

Note:

When a ship is designed with VCS notation (high-high level alarm) or provided with equivalent systems to prevent overflow through air pipes, the tank pressure for liquid cargo, based on air pipe height \( h_p \), may be omitted.

4.3. Plating and Stiffeners

4.3.1. Bulkhead plating

4.3.1.1. The thickness requirement corresponding to lateral pressure is given by:

\[
t_{bhd} = \frac{\gamma c f \sqrt{P}}{\sqrt{\sigma}} + t_c
\]

\( c_f \) = correction factor for aspect ratio of plate field

= \( 1.21 - 0.538(s/l) + (0.0441)(s/l)^2 \)

\( p = p_{16} - p_{22} \) whichever is relevant, as given in Table 5.4.1

\( \sigma = \) as given in Table 5.4.2.

Table 5.4.2: Allowable Stresses

<table>
<thead>
<tr>
<th>Structure</th>
<th>( \sigma \text{(N/mm}^2))(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal bulkhead</td>
<td>Transverse stiffening: 140 within 0.4L at neutral axis</td>
</tr>
<tr>
<td></td>
<td>( \frac{Z_A}{Z_R} )</td>
</tr>
<tr>
<td></td>
<td>at deck or bottom: 160 within 0.1L from perpendiculars</td>
</tr>
<tr>
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</table>

1) Between specified regions the \( \sigma \)-value may be varied linearly.
4.3.1.1. The thickness is not to be less than:

\[ t_{\text{min}} = 5.0 + \alpha L + t_c (\text{mm}) \]

\( \alpha = 0.03 \) for longitudinal bulkheads except double skin bulkheads in way of cargo oil tanks and ballast tanks in liquid cargo tank areas

\( \alpha = 0.02 \) in peak tanks and for transverse and double skin longitudinal bulkheads in way of cargo oil tanks and ballast tanks in liquid cargo tank areas

\( \alpha = 0.01 \) for other bulkheads.

4.3.1.2. The thickness of longitudinal bulkhead plating not more than 0.1 D above the bottom or below the strength deck is normally to satisfy the buckling strength requirements given in Chapter 10.

4.3.1.3. The buckling strength of corrugation flanges at the middle length of corrugations is to be controlled according to Chapter 10 taking \( \alpha \) equal to 5.

Usage factors to be applied:

\( = 0.8 \) for cargo tank bulkheads, cargo hold bulkheads when exposed to dry cargo or ballast pressure, and collision bulkheads

\( = 1.0 \) for watertight bulkheads.

Allowable stresses are given by:

\[ \sigma = \eta f (1 - \frac{\sigma_f}{3.7 (t_{ncf})^2} \]

\( t_{ncf} \) = net thickness \((t - t_c)\) of corrugation flange in mm

\( b_{cpl} \) = breadth of corrugation plate in m

\( \sigma_f = 235 \text{ N/mm}^2 \) for mild steel.

4.3.1.4. For plates in aftpeak bulkhead in way of stern tube, increased thickness or doubling may be required.

4.3.1.5. For wash bulkhead plating, requirement for thicknesses may have to be based on the reaction forces imposed on the bulkhead by boundary structures.

4.4. **Longitudinals**

4.4.1. The section modulus requirement for stiffeners and corrugations is given by:

\[ z = \frac{83.25 L_d (s - (s/L)) s P_w e}{\sigma} \text{ cm}^3, \text{ minimum 15cm}^3 \]

\( p \) = whichever is relevant, as given in Table 5.4.1

\( \sigma = 95 \) at deck or bottom within 0.4 L when \( Z_A = Z_R \)

\( = 160 \) at deck or bottom within 0.4 L when \( Z_A \geq 2 Z_R \)

\( = 160 \) within 0.25 D above and below the neutral axis

\( = 160 \) within 0.1 L from the perpendiculars.

Between specified regions \( \sigma \)-value may be varied linearly.
4.4.2. The thickness of web and flange is not to be less than the larger of:

\[ t_{c,bhd-w/b/f1} = 4.5 + \alpha + t_c \text{ (mm)} \]

\[ = 1.5 + \frac{p_w \sqrt{\alpha}}{g} + t_c \]

\( \alpha = 0.01 \text{ L in general} \)

\( = 0.015 \text{ L in peaks and in cargo oil tanks and ballast tanks in cargo area} \)

\( h_w = \text{web height in mm} \)

\( g = 75 \) for flanged profile webs

\( = 41 \) for bulb profiles

\( = 22 \) for flat bar profiles.

4.4.3. Vertical and transverse stiffeners on tank bulkheads and dry bulk cargo bulkheads

4.4.3.1. Transverse bulkheads for ballast and bulk cargo holds are normally built with strength members only in the vertical direction (corrugations or double plane bulkheads), having unsupported spans from deck to inner bottom. The scantlings of such bulkheads are to be based on a special calculation, taking into account the reactions from double bottom and deck structure.

4.4.3.2. The section modulus requirement for simple stiffeners and corrugations is given by:

\[ z = \frac{6.25 l_{st} [l_{st} - (s / l_{st})] sp w_c}{m} \text{ cm}^3 \]

\( p = \text{whichever is relevant, as given in Table 5.4.1} \)

\( m = 7.5 \) for vertical stiffeners simply supported at one or both ends

\( = 10 \) for transverse stiffeners and vertical stiffeners which may be considered fixed at both ends.

4.4.3.3. The thickness of web and flange is not to be less than given in 202.

4.4.3.4. Brackets are normally to be fitted at ends of non-continuous stiffeners. For end connections, see also

4.4.4. Stiffeners on watertight bulkheads and wash bulkheads

4.4.4.1. The section modulus requirement is given by:

\[ z_{bh,bhd} = \frac{1000 l_{st} [l_{st} - (s / l_{st})] sp w_c}{m \sigma} \]

\( p = p_{16} \text{ as given in Table 5.4.1 for watertight bulkheads} \)

\( = p_{17} \text{ for wash bulkheads} \)

\( w_c = \text{corrosion factor, see Chapter 2 Section 6} \)

\( \sigma = 160 \text{ for collision bulkhead} \)

\( = 220 \text{ for other watertight bulkheads} \)

\( m = 16 \text{ for member fixed at both ends} \)

\( = 12 \text{ for member fixed at one end (lower) and simply supported at the other} \)

\( = 8 \text{ for member simply supported at both ends.} \)
The m-value may be adjusted for members with boundary conditions not corresponding to the above specification.

**Guidance note:**
The m-value is based on plastic deformation at fixed supports and is not to be compared with the bending moment factor corresponding to elastic bending.

4.4.4.2. The thickness of web and flange is not to be less than given in 4.4.2.

### 4.5. Girders

#### 4.5.1. General

4.5.1.1. The web plate thickness and the thickness of, flanges brackets and stiffeners are not to be less than:

\[ t_{gwb/ft} = 5.0 + \alpha L + t_c \text{ (mm)} \]

\[ \alpha = 0.035 \text{ for peak tank girders} \]
\[ = 0.025 \text{ for girders in cargo/ballast tanks in liquid cargo tank areas} \]
\[ = 0.015 \text{ for other girders and for stiffeners on girders in general.} \]

The thickness of girder web plates is in addition not to be less than:

\[ t_{gwpt} = 12s + t_c \text{ (mm)} \]

\[ s = \text{spacing of web stiffening in m.} \]

4.5.1.2. The end connections and stiffening of girders are to be arranged as given in Chapter 3 Section 3.

#### 4.5.2. Simple girders

4.5.2.1. The section modulus requirement is given by:

\[ z_{sgr} = \frac{1000l_{st}\{l_{st}(s/l_{st})\}sp_{b_{lo}}w_c}{m\sigma} \text{ (cm}^3\text{)} \]

\[ p = \text{whichever is relevant, as given in Table 5.4.1} \]
\[ b_{lo} = \text{loading breadth in m} \]
\[ \sigma = \text{as given in 4.3.2 for continuous longitudinal girders} \]
\[ = 160 \text{ for other girders.} \]

The allowable stress may be increased by 60 for watertight bulkheads, except the collision bulkhead, when \( p_{16} \) is applied.

4.5.2.2. The web area requirement (after deduction of cut-outs) at the girder ends is given by:

\[ A = \alpha S b_{lo}p + 10h_{gr} t_c \text{ (cm}^2\text{)} \]

\[ p = \text{as given in 4.5.2.1} \]
\[ \alpha = 0.06 \text{ for stringers and upper end of vertical girders} \]
\[ = 0.08 \text{ for lower end of vertical girders.} \]
\[ \alpha \text{ may be reduced by 25% when watertight bulkheads, except collision bulkhead, when } p_{1} \text{ is applied} \]
4.5.3. Complex girder systems

4.5.3.1. In addition to fulfilling the general local requirements given in 100, the main scantlings of bulkhead girders being parts of complex girder systems in holds or tanks for heavy cargo or liquids, may have to be based on a direct stress analysis.

4.6. Special requirements

4.6.1. Shaft tunnels

4.6.1.1. In ships with engine room situated amidships, a watertight shaft tunnel is to be arranged. Openings in the forward end of shaft tunnels are to be fitted with watertight sliding doors capable of being operated from a position above the load waterline.

4.6.1.2. The thickness of curved top plating may be taken as 90% of the requirement to plane plating with the same stiffener spacing.

4.6.1.3. If ceiling is not fitted on top plating under dry cargo hatchway openings, the thickness is to be increased by 2 mm.

4.6.1.4. The shaft tunnel may be omitted in ships with service area notations R2, R3, R4 and RE provided the shafting is otherwise effectively protected. Bearings and stuffing boxes are to be accessible.

4.6.2. Corrugated bulkheads

4.6.2.1. The lower and upper ends of corrugated bulkheads and those boundaries of vertically corrugated bulkheads connected to ship sides and other bulkheads are to have plane parts of sufficient width to support the adjoining structures.

4.6.2.2. Girders on corrugated bulkheads are normally to be arranged in such a way that application of the bulkhead as girder flange is avoided.

4.6.2.3. End connections for corrugated bulkheads terminating at deck or bottom are to be carefully designed. Supporting structure in line with corrugation flanges are to be arranged below an inner bottom.

4.6.3. Supporting bulkheads

4.6.3.1. Bulkheads supporting decks are to be regarded as pillars. The compressive loads and buckling strength are to be calculated as indicated in Chapter 6 assuming:

\[ i = \text{radius of gyration in cm of stiffener with adjoining plate. Width of adjoining plate is to be taken as } 40 \ t, \text{ where } t = \text{plate thickness.} \]

Local buckling strength of adjoining plate and torsional buckling strength of stiffeners are to be checked.

4.6.3.2. Section modulus requirement to stiffeners:

\[ Z_{st} = 212s (\text{cm}^3) \]

4.6.3.3. The distance between stiffeners is not to be greater than 2 frame spacings, and is not to exceed 1.5 m.

4.6.3.4. The plate thickness is not to be less than 7.5 mm in the lowest hold and 6.5 mm in 'tween decks.

4.6.3.5. On corrugated bulkheads, the depth of the corrugations is not to be less than 150 mm in the lower holds and 100 mm in the upper 'tween deck.
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1.1. Introduction

1.1.1. The requirements in this section apply to pillars and supporting bulkheads made of mild steel.

1.2. Definitions

1.2.1. Symbols:

\[ l_{bs} = \text{length in m of pillar or bulkhead stiffener} \]

\[ i = \sqrt{I/A} \]

\[ I = \text{moment of inertia in cm}^4 \text{ about the axis perpendicular to the expected direction of buckling} \]

\[ A = \text{cross-sectional area in cm}^2 \]

When calculating I and A for bulkhead stiffeners, a plate flange with breadth equal to 40 t, where t = thickness of bulkhead, may be included.

\[ P = \text{load in kN acting on the pillar or bulkhead stiffener}. \]

Unless otherwise specified P should be based on the deck loadings given in Chapter 5 Section 3,[3.2].

**Guidance note:**

For round pillars:

\[ i = 0.25\sqrt{(\text{Outer diameter})^2 + (\text{Inner diameter})^2} \]

For square hollow pillars:

\[ i = 0.29\sqrt{(\text{Outer breadth})^2 + (\text{Inner breadth})^2} \]

1.3. Cross sectional area

1.3.1. The requirement to the sectional area is given by:

\[ A_{req} = k_1 P \text{ (cm}^2) \]

\[ k_1 \text{ is given in Fig.6.1.1.} \]
Figure 6.1.1: Values of $k_1$

\[ A = k_1 P \]
\[ P = \text{pillar force in kN} \]

- Below weather deck forward of 0.2L
- Elsewhere

\[ k_1 = 0.16 \left( \frac{L}{L} \right)^2 \]
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2.1. General

2.1.1. Introduction

2.1.1.1. In this section the requirements applicable to superstructure end bulkheads, deckhouse sides and ends and bulwarks are collected. The requirements for sides of superstructures and decks above superstructures and deckhouses are given in Chapter 5 Sec.3 and 4 respectively.

2.1.2. Definitions

2.1.2.1. Symbols:

- \( L_r \) = rule length in m, see Chapter 1 [1.2.1]
- \( B_D \) = rule breadth in m, see Chapter 1 [1.2.1]
- \( C_B \) = rule block coefficient, see Chapter 1 [1.2.1]
- \( t_{pl} \) = rule thickness in mm of plating
- \( Z_r \) = rule section modulus in cm\(^3\) of stiffeners and simple girders
- \( L_1 = L \), but need not be taken greater than 300 m
- \( c_f \) = correction factor for aspect ratio of plate field see Chapter 3 Section 2, [2.4]
- \( s \) = stiffener spacing in m, measured along the plating
- \( l_{st} \) = stiffener span in m, measured along the topflange of the member. For definition of span point, see Chapter 3 Section 3 [3.1]. For curved stiffeners \( l \) may be taken as the cord length
- \( k \) = material factor
- \( \sigma \) = nominal allowable bending stress in N/mm\(^2\) due to lateral pressure
- \( p_d \) = design pressure in kN/m\(^2\) as given in [2.3].

2.1.2.2. Superstructure is defined as a decked structure on the freeboard deck, extending from side to side of the ship or with the side plating not inboard of the shell plating more than 4% of the breadth (B).

2.1.2.3. Deckhouse is defined as a decked structure above the strength deck with the side plating being inboard of the shell plating more than 4% of the breadth (B). Long deckhouse = deckhouse having more than 0.2 L of its length within 0.4 L amidships. Short deckhouse = deckhouse not defined as a long deckhouse.

2.2. Structural Arrangement and Details

2.2.1. Structural continuity

2.2.1.1. In superstructures and deckhouses aft, the front bulkhead is to be in line with a transverse bulkhead in the hull below or be supported by a combination of partial transverse bulkheads, girders and pillars. The after end bulkhead is also to be effectively supported. As far as practicable, exposed sides and internal longitudinal and transverse bulkheads are to be located above tank bulkheads and/or deep girder frames in the hull structure and are to be in line in the various tiers of accommodation. Where such structural arrangement in line is not possible, there is to be other effective support.
2.2.1.2. Sufficient transverse strength is to be provided by means of transverse bulkheads or girder structures.

2.2.1.3. At the break of superstructures, which have no set-in from the ship’s side, the side plating of poop and bridge is to extend beyond the ends of the superstructure, and is to be gradually reduced in height down to the sheer strake. The transition is to be smooth and without local discontinuities. A substantial stiffener is to be fitted at the upper edge of plating, which extends beyond the superstructure. The plating is also to be additionally stiffened.

2.2.1.4. The end bulkheads of long superstructures are to be effectively supported by bulkheads or heavy girders below deck.

2.2.1.5. In long deckhouses, openings in the sides are to have well rounded corners. Horizontal stiffeners are to be fitted at the upper and lower edge of large openings for windows. Openings for doors in the sides are to be substantially stiffened along the edges, and the side plates forming coamings below and above the doors, are to be continuous and extended well beyond the door openings. The thickness is to be increased locally or doubling plates are to be fitted. The connection area between deckhouse corners and deck plating is to be increased locally. Deck girders are to be fitted below long deckhouses in line with deckhouse sides. The girders are to extend three frame spaces forward and aft of the deckhouse ends. The depth of the girders is not to be less than that of the beams plus 100 mm. Girders are to be stiffened at the lower edge. The girder depth at ends may be equal to the depth of the beams.

Note:
Expansion of long deckhouse sides should be taken into account by setting in parts of the sides towards the centre line of the ship.

2.2.1.6. Casings situated within 0.5 L amidships are to be stiffened longitudinally at the strength deck (e.g. at the lower edge of the half beams) to avoid buckling due to longitudinal compression forces.

2.2.2. Connections between steel and aluminium

2.2.2.1. To prevent galvanic corrosion a non-hygroscopic insulation material is to be applied between steel and aluminium when bolted connection.

2.2.2.2. Aluminium plating connected to steel boundary bar at deck is as far as possible to be arranged on the side exposed to moisture.

2.2.2.3. A rolled compound (aluminium/steel) bar may be used in a welded connection after special approval.

2.2.2.4. Direct contact between exposed wooden materials, e.g. deck planking, and aluminium is to be avoided.

2.2.2.5. Bolts with nuts and washers are either to be of stainless steel or cadmium plated or hot galvanized steel. The bolts are to be fitted with sleeves of insulating material. The spacing is normally not to exceed 4 times the bolt diameter.

2.2.2.6. For earthing of insulated aluminium superstructures, see****.

2.2.3. Miscellaneous

2.2.3.1. Companionways situated on exposed decks are to be of steel and efficiently stiffened.

2.2.3.2. Bulwark plates are in general not to be welded to side plating or deck plating. Long bulwarks are to have expansion joints within 0.6 L amidships.

2.2.3.3. Where bulwarks on exposed decks form wells, ample provision is to be made for freeing the decks of water.

2.2.3.4. Weld connections are to satisfy the general requirements given in Chapter 2 Section 7.
2.3. Design Loads

2.3.1. External pressure

2.3.1.1. The design sea pressure for the various end and side structures is given in Table 6.1.1.

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<td>Unprotected front bulkheads</td>
<td></td>
</tr>
<tr>
<td>General</td>
<td>p₁₈ = 5.7a(kCW – h₀)c</td>
</tr>
<tr>
<td>Minimum lowest tier</td>
<td>p₁₉ = 12.5 + 0.05L₁</td>
</tr>
<tr>
<td>Minimum else where</td>
<td>p₂₀ = 6.25 + 0.025L₁</td>
</tr>
<tr>
<td>Unprotected sides in deckhouses</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p₂₁ = Pₑ – (4 + 0.2kₛ)h₀, minimum p₃</td>
</tr>
<tr>
<td>Unprotected aft end bulkheads</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p₂₂ = 0.85p₄, minimum p₃</td>
</tr>
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</table>

1) For ships with service restrictions, p₁ and p₄ may be reduced by 25% CW should not be reduced.
2) The minimum design pressure for sides and aft end of deckhouses 1.7 CW(m) above S.W.L. may be reduced to 2.5 kN/m².

\[
a = 2.0 + \frac{L}{120}
\]

\[
= 1.0 + \frac{L}{120}
\]

\[
= 0.5 + \frac{L}{120}
\]

\[
α = 1.3 - 0.6 \frac{x}{L} \text{ for } \frac{x}{L} > 0.5
\]

\[
α = 0.3 + 1.4 \frac{x}{L} \text{ for } \frac{x}{L} > 0.5
\]

\[
x = \text{longitudinal distance in m from A.P. to the load point}
\]

\[
h₀ = \text{vertical distance in m from the waterline at draught T to the load point}
\]

\[
c = 0.3 + 0.7 \frac{b₁}{B₁}
\]

b₁ = breadth of deckhouse at position considered

B₁ = maximum breadth of ship on the weather deck at position considered

is not to be taken less than 0.25.

For unprotected parts of machinery casings c is not to be taken less than 1.0.

C_W = wave coefficient as given in Chapter 4 Section 1, [1.2]

p₄₈₇₇ kₛ = as given in Chapter 5 Section 1

2.4. Scantlings

2.4.1. End bulkheads of superstructures and deckhouses, and exposed sides in deckhouses

2.4.1.1. The thickness requirement for plating corresponding to lateral external pressure is given by:
\[ t_{ssd} = \frac{\gamma G_s \sqrt{P}}{\sqrt{\sigma}} + t_c \]

\( p = \text{whichever is relevant, as given in Table 6.2.1} \)

\( \sigma = 160/k \text{ N/mm}^2. \)

2.4.1.2. The thickness is not to be less than:
- for the lowest tier:
  \[ t_{\min ssd} = 5 + 0.01 L \text{ (mm), maximum 8 mm} \]
- for higher tiers:
  \[ t = 4 + 0.01 L \text{ (mm), maximum 7 mm, minimum 5 mm}. \]

2.4.1.3. The section modulus requirement for stiffeners is given by:
\[ Z_{ssf} = \frac{100 l_{st sp}}{\sigma} \text{ cm}^3 \]

\( p = \text{as given in 2.3} \)

\( \sigma = 160/k \text{ for longitudinal, vertical and transverse stiffeners in general} \)

\( = 90 \text{ k} \sigma \text{ for longitudinals at strength deck in long deckhouse within 0.4 L amidships. The} \)

\( \text{-value may be increased linearly to the general value at the} \)

\( \text{first deck above the strength deck and at 0.1 L from the perpendiculars.} \)

2.4.1.4. Front stiffeners are to be connected to deck at both ends with a connection area not less than:
\[ a = 0.07 \ast k \ast l_{st sp} \text{ (cm}^2 \text{)} \]

\( \text{Sniped ends may be allowed, however, for stiffeners above the 3rd tier provided the} \)

\( \text{formula in Chapter 3 Section 3 is fulfilled. Side and after end stiffeners in the lowest} \)

\( \text{tier of erections are to have end connections.} \)

2.4.1.5. Deck beams under front and aft ends of deckhouses are not to be scalloped for a distance of 0.5 m from each side of the deckhouse corners.

2.4.2. Protected casings

2.4.2.1. The thickness of plating is not to be less than:
\[ t = 8.5 \text{ s minimum 6.0 mm in way of cargo holds} \]

\[ = 6.5 \text{ s minimum 5.0 mm in way of accommodation.} \]

2.4.2.2. The section modulus of stiffeners is not to be less than:
\[ Z = 3 \ast l_{st} \ast s \ast k \]

\[ l_{st} = \text{length of stiffeners in m, minimum 2.5 m.} \]

2.4.2.3. Casings supporting one or more decks above are to be adequately strengthened.

2.4.3. Bulwarks

2.4.3.1. The thickness of bulwark plates is not to be less than required for side plating in a superstructure in the same position, if the height of the bulwarks is 1.8 m. If the height of the bulwark is 1 metre or less the thickness need not be greater than 6.0 mm.
For intermediate heights, the thickness of the bulwark may be found by interpolation.

2.4.3.2. A strong bulb section or similar is to be continuously welded to the upper edge of the bulwark. Bulwark stays are to be spaced not more than 2 m apart, and are to be in line with transverse beams or local transverse stiffening, alternatively the toe of stay may be supported by a longitudinal member. The stays are to have sufficient width at deck level. The deck beam is to be continuously welded to the deck in way of the stay.

Bulwarks on forecastle decks are to have stays fitted at every frame where the flare is considerable.

Stays of increased strength are to be fitted at ends of bulwark openings. Openings in bulwarks should not be situated near the end of superstructures.

2.4.4. Aluminium deckhouses

2.4.4.1. The strength of aluminium deckhouses is to be related to that required for steel deckhouses, see below. The scantlings are to be based on the mechanical properties of the applied alloy.

2.4.4.2. The minimum thicknesses given in 2.4.1.2 and 2.4.2.1 are to be increased by 1 mm. For the section modulus requirements given in 2.4.1.1 and 2.4.2.1, \( f_1 \) need not be taken less than 0.6.

2.5. Superstructures on elastic supports

2.5.1. General

2.5.1.1. The scantlings of the bulkhead and the deck of the after peak are to be in accordance with the applicable chapter.

In the upper part of the after peak, a non-tight longitudinal bulkhead is generally to be fitted in the centreline.

When the bottom in the after zone is of the flat type and raised towards the extreme stern, a centre bottom girder and side bottom girders are to be fitted, as well as transverses with scantlings as per [2.2].
CHAPTER 7 OUTFITTING & EQUIPMENT

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1.1. **Forward zone**

1.1.1. The region between extreme bow and 0.2 L aft of the forward limit of L.

Inclined bow: A bow with an upward inclined longitudinal bottom from the keel towards the weather deck level, which is flat in the transverse direction.

Aft zone: The zone abaft the after peak bulkhead.

1.2. **Bow structure**

1.2.1. Rounded bow ships

1.2.1.1. If the ship has a rounded bow, which extends scaling to ship’s breadth B from the fore perpendicular, the frame spacing is to be altered to 300 mm, or intermediate frames are to be fitted having a section modulus (Z) equal to 50% of the value which was computed by the formulae in Chapter 5 Section 2.

In the case of unconnected ends of intermediate frames, a longitudinal stiffener with a web having a depth of minimum 1.5 times the frame depth is to be fitted.

In case of a transversely framed structure, it is to be fitted with

- floors with increased depth
- a side longitudinal, when D > 4 m, at a height of about 0.5 D. Such longitudinal should extend inside the forepeak.

In case of a longitudinally framed structure, the floors with increased depth to be fitted, is to be spaced not more than 1.5 m apart.

1.2.2. Inclined bow ships

1.2.2.1. In ships with longitudinally framed bottom and deck, the bow is to be strengthened by transverses with a spacing of not more than 2 m apart.

Such structures are to extend from the fore end to the collision bulkhead, or to the point where the bow begins to rise, whichever is aft.

The section modulus (Z), in cm³, of the transverses to be placed in the bow, is to be not less than the values calculated by the following formulae:

a. bottom and side transverses:

\[ Z = 9b \cdot S^2 \cdot h_{g-wdk} \cdot K \]

b. deck transverses:

\[ Z = 7b \cdot S^2 \cdot D \]

Where:

s: spacing, in m, of transverses

S: conventional span, in m, as defined in Chapter 5 Sec 2

\( h_{g-wdk} \): distance, in m, from the mid-length of the girder considered to the weather deck.

1.3. **Propeller shaft brackets**

1.3.1. Double arm propeller shaft brackets
1.3.1.1. Double arm propeller shaft brackets consist of two arms arranged at approximately right angles and converging in the propeller shaft bossing.

The scantlings of cast or forged propeller shaft brackets having arms of elliptical section are to have a minor axis $d_1$ and a major axis $d_2$, in mm, not less than those given by the following formulae:

\[
\begin{align*}
    d_1 &= 0.4 \, d_p \\
    d_2 &= 0.004 \, l_B \left( \frac{d_p}{d_1} \right)^3
\end{align*}
\]

Where:

- $l_B$: length of the longer arm, measured from the section at the root of the palm to that at the root of the boss, in mm
- $d_p$: propeller shaft diameter, measured inside the liner, if any, in mm.

In the case of arms of other shapes, the moment of inertia of the section about its major axis is to be not less than the value $J$, in cm$^4$, given by the following formula:

\[
J = 0.4 \, l_B \cdot (d_p)^3 \cdot 10^{-7}
\]

The thickness of the propeller shaft bossing is to be not less than 0.33 $d_p$.

1.3.2. Ends of bossed propeller shaft brackets

Bossed propeller shaft brackets consist of a U-shaped cast steel arm connected to the hull plating by means of a substantial palm and ending in a boss for propeller shaft support. The scantlings of the arm and the boss are subject to approval by IRS.

As guidance, the above scantlings are normally to be in accordance with the requirements of a., b. and c. below.

a. The section modulus at the root of the arm, calculated about the horizontal neutral axis of the root section, is to be not less than the value $Z$, in cm$^3$, calculated by the following formula:

\[
Z = 60 \, l_B \cdot (d_p)^2 \cdot 10^{-7}
\]

b. The length of the boss, in mm, is to be between 2.3 $d_p$ and 3 $d_p$.

c. The thickness of the boss, in mm, is to be not less than 0.33 $d_p$, in mm.

The symbols $l_B$ and $d_p$ used above have the same meaning as in [1.3.1].

1.4. Scuppers and discharges

All exposed decks are to be fitted with scuppers in such number and with such dimensions as to ensure water discharge overboard. All enclosed spaces and sanitary discharges are to discharge into special drainage tanks provided with suction systems.

If scuppers and discharge pipes discharging over-board pass through cargo holds, their thickness is to be equal to the outer shell thickness in way of ship ends, but need not be greater than 8 mm.
SECTION 2 EQUIPMENT

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2.1. General

All ships should be provided with anchors, chain cables, ropes and any other required Mooring Equipment based on their Equipment Number EN, as suggested in Tab 1, 2 and 3.

Considering factors like use of the ship and the operating conditions in the service area, the equipment mentioned in the previous tables may be reduced at the sole discretion of IRS.

In this case, the area of use of the ship should be indicated on the Certificate of Classification. In case of the vessel has to engage in "strong current" during its intended service, the anchor mass may be increased at the sole discretion of IRS.

It should be borne in mind that some waterways or sections thereof may be subject to special requirements of the corresponding Administration.

2.2. Equipment number and equipment

The equipment number EN for all cargo ships engaged in inland waterway service is to be obtained by the formula:

\[ EN = \Delta_{dd} \]

Where:
\( \Delta \) = displacement, in t, of the ship at deepest draught.

For passenger ships and for ships with a large surface exposed to wind, the equipment number EN is to be obtained by the formula:

\[ EN = \Delta_{dd} + A_{awl} \]

Where:
\( A \) = area, in m², in profile view, of the parts of the hull, superstructures and deckhouses above the deepest draught waterline, which have a breadth greater than B/4.

2.3. Particulars of anchors, chain cables and ropes

2.3.1. Anchors

Anchors may be stockless and with articulated flukes. When anchors of mass less than or equal to 90 kg are required, four-fluke grapnel anchors may be used.

When stocked anchors are used, their mass, excluding the stock, should be equal to 80% of the mass indicated in Tab 7.2.1.

When use of "high holding power" anchors is applicable, the anchor mass may be reduced by 25%.

Ships are to be fitted, in general, with two bower anchors.

At the discretion of IRS, depending on the area of use of ships, cases of ‘one bower anchor only’ may also be accepted.

In case of two bower anchors being fitted, it is recommended that both have the same mass.

In case of a mass difference, the mass of the lighter anchor should not be less than 45% of the total mass as indicated in Tab 7.2.1.

2.3.2. Chain cables and wire ropes for anchors
2.3.2.1. Chain cables

Bower anchors are to be used in association with stud link or studless chain cables. The breaking load of chain cables should not be less than 35 times the mass of the anchor to which they are connected.

In case of the use of “high holding power” anchors, the breaking load of chain cables should not be less than 47 times the mass of the actual anchor.

In the above case, grade U2 steel chain cables should be used.

The diameter of stud link or studless chain-cables may be obtained from Table 7.2.2 depending on the breaking load.

In case of different bower anchors being fitted, it is recommended that both have the same mass.

In case of a mass difference, the mass of the lighter anchor should not be less than 45% of the total mass as indicated in Tab 7.2.1.

In any case a length greater than 60 m is not required.

The length of the chain cable for the stern anchor is to be not less than 40 m.

Ships which are to be capable of stopping along the stream are to be equipped with a stern anchor chain cable length not less than 60 m.

At the discretion of IRS, the anchor chain cable may be replaced by a steel wire rope having the same breaking load as required for the chain cable. The steel wire rope length is to be increased by 20 m in respect of the length required in the previous provisions.

2.3.2.2. Chain lockers

Chain lockers should have sufficient capacity so as to easily contain the whole chain cable.

Each anchoring line (either chain cable or wire rope) should be adequately connected to a reinforced structure of the chain locker, or of the hull, and should be fitted with a release device if possible.

2.3.2.3. Ropes

Towlines, as well as warping and mooring lines, may be of steel wire, natural or synthetic fibre or a mixture of steel wire and fibre.

The breaking loads given in Tab 7.2.3 refer to steel wires or natural fibre ropes.

Ropes are to be of the flexible type, preferably having not less than:

- 144 threads in 6 strands with 7 fibre cores, for towlines and mooring lines;
- 222 threads in 6 strands with one fibre core for warping lines.

When synthetic fibre ropes are adopted, their size will be determined taking into account the type of material used and the manufacturing characteristics of the rope, as well as the different properties of such ropes in comparison with natural fibre ropes.

The equivalence between synthetic fibre ropes and natural fibre ropes may be assessed by the following formula:

\[ CR_S = 7.4 \delta \cdot CR_M^{8/9} \]
Where:

\[ \delta = \text{elongation to breaking of the synthetic fibre rope, to be assumed not less than 0.3 (i.e. 30 per cent elongation)}; \]
\[ CR_s = \text{breaking load of the synthetic fibre rope, in kN}; \]
\[ CR_M = \text{breaking load of the natural fibre rope, in kN, given by Tab 7.2.3}. \]

Where fibre ropes are adopted, rope diameters under 20 mm are not allowed, even in cases of low required breaking load, where a smaller diameter could be adopted.

2.4. Equipment

2.4.1. General

2.4.1.1. Maneuvering appliances are to be adequately connected to the hull.

It should be easy and safe for the personnel to maneuver such appliances. Fittings and their connections to the hull should have sufficient strength to withstand a tensile force at least equal to the breaking load of the chain cables or ropes for which they are intended.

2.4.2. Maneuvering of bower anchors

If the bower anchors are of the type intended to be housed in hawse pipes, the ship should be fitted with well faired hawse pipes of adequate strength.

The stern anchor is preferably to be housed in a hawse pipe or arranged on a special slipway so as to be always ready for use.

Grapnel anchors and stocked anchors are to have adequate arrangements on deck so as to enable them to be easily dropped and recovered.

Chain cables should be placed in appropriate lockers located inside the hull. For anchors with mass exceeding 50 kg, a windlass should be provided, which should be proportionate to the size of chains, power operated or manually operated depending on the mass of anchors.

2.4.3. Maneuvering of stern anchors

The helmsman is to be capable of dropping the stern anchor or anchors from his position. This does not apply to pushed or coupled convoys not less than 86 m in length.
<table>
<thead>
<tr>
<th>Equipment number EN</th>
<th>Bower anchor Total mass kg</th>
<th>Self-propelled ship Stern anchor</th>
<th>Non-self-propelled ships Stern anchor</th>
<th>Passenger ships Stern anchor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number</td>
<td>Mass of each anchor kg</td>
<td>Number</td>
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<td>-</td>
</tr>
<tr>
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</tr>
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<td>-</td>
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### Table 7.2.1: Anchors (Continued)

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<tr>
<th>Equipment number</th>
<th>Bower anchor Total mass kg</th>
<th>Self-propelled ship</th>
<th>Non-self-propelled ships</th>
<th>Passenger ships</th>
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<td>Number</td>
<td>Mass of each anchor kg</td>
<td>Number</td>
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<td>710</td>
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</tr>
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<td>12000</td>
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</table>

(1) For self-propelled ships having LFT > 86 m, two stern anchors are required.

For self-propelled ships equipped for pushing other ships, two stern anchors are required.

Instead of the two stern anchors, one anchor only may be fitted, provided its mass is equal to the sum of the masses of the two anchors.
### Table 7.2.2: Chain cables for anchors

<table>
<thead>
<tr>
<th>Chain cable diameter mm</th>
<th>Stud link chain cables</th>
<th>Studless chain cables</th>
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<td></td>
<td>Steel grade *** Nominal breaking strength kN</td>
<td>Steel grade *** Nominal breaking strength kN</td>
</tr>
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<td>12.5</td>
<td>66</td>
<td>92</td>
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### Table 7.2.3: Ropes

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<th>Length m</th>
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### Contents

- **3.1 Symbols and definitions** ................................................................. 145
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3.1 Symbols and definitions

\( V_{AV} \) : maximum ahead speed in still water, when the ship on the full load waterline, in knots. For the above-mentioned speed, the value \( V_{MIN} \), calculated by the following formula should be considered in the calculation:

\[
V_{MIN} = 0.6\left(\frac{P}{\Delta^{2/3}}\right)^{1/3}
\]

Wherein:
\( P \) : nominal power, in kW, of the propulsion engine(s).
\( V_{AD} \) : maximum astern speed of the ship, in knots; in no case is the said speed to be taken less than the value:

\[
V_{AD} = 0.5 \times V_{AV}
\]

\( A \) : total area of rudder blade, in m², bounded by the blade external contour, including the main-piece and the part forward of the centreline of the rudder pintles, if any

\( A_D \) : total area of rudder blade, in m², bounded by the blade external contour, including the main-piece and the part forward of the centreline of the rudder pintles, if any

\( x_G \) : distance, in m, from the centroid of the area \( A \) to the centreline of pintles.

\( k_1 \) : shape factor, whose value, depending on the ratio \( \Lambda \) defined below, is given by the following formula:

\[
k_1 = (\Delta + 2)^{1/3}
\]

\( \Delta \) : \( h^2/ A_T \), where \( h \) is the mean height of the rudder blade area, in m. In no case is the value of \( \Delta \) to be taken greater than 2.

The mean height \( h \) and mean breadth \( b \) of the rudder blade are to be calculated according to Fig 7.3.1.

\( A_T \) : area, in m², obtained by adding, to the rudder blade area, the area of rudder post or rudder horn, if any, up to the height \( h \).

\( k_3 \) : 0.8, for rudders outside the propeller jet (centre rudders on twin screw ships, or similar cases)

\[
= 1.15 \text{ for rudders behind a fixed propeller nozzle}
\]

\[
= 1.0 \text{ in other cases.}
\]

\( D_T \) : Rule diameter, in mm, of rudder stock subject to combined torque and bending.

\( C_R \) : rudder force, in N, i.e. force acting on the rudder blade, as defined in [3.2].

\( Q_R \) : rudder torque, in Nm, i.e. torque acting on the rudder stock, as defined in [3.2]

3.2 Materials

Rudder stocks, pintles and bolts are to be made of rolled, forged or cast C-Mn steel, in accordance with the relevant requirements of Part 2 of the Rules.
Figure 7.3.1

\[ b = \frac{(x_2 + x_3 - x_1)}{2}, \text{ mean breadth of rudder, in } \text{m} \]

\[ h = \frac{(z_3 + z_4 - z_2)}{2}, \text{ mean height of rudder, in } \text{m} \]

The material used for rudder stocks, pintles, keys and bolt is to have a minimum yield stress \((R_{eh})\) 200N/mm².

The requirements relevant to the determination of scantlings contained in this Section is applicable to steels having a minimum yield stress \(R_{eh} = 235\) N/mm².

In case of use of steels having a yield stress \(R_{eh}\) other than 235 N/mm², the values of diameters and thicknesses calculated with the formulae contained in the following Articles are to be modified, as indicated, depending on the factor \(K_1\) obtained from the following formula:

\[ K_1 = \left(\frac{235}{R_{eh}}\right)^\gamma \]

\(R_{eh}\): minimum yield stress of steel employed, in N/mm²; it is not to be taken higher than 0.7 \(R_m\), and in no case is \(R_{eh}\) to be taken greater than 450 N/mm².

\(R_m\): minimum ultimate tensile strength of steel employed, in N/mm²

\(\gamma\) : 0.75, for \(R_{eh} > 235\) N/mm²

\[ = 1.0, \text{ for } R_{eh} \leq 235\) N/mm².

In general, significant reductions in rudder stock Rule diameter for the application of steels having yield stress \(R_{eh}> 235\) N/mm² may be accepted by IRS, subject to the results of a check calculation of rudder stock deformation.
Table 7.3.1

<table>
<thead>
<tr>
<th>Rudder profile type</th>
<th>$k_2$ for ahead condition</th>
<th>$k_2$ for astern condition</th>
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<tbody>
<tr>
<td>NACA-00 - Goettingen profiles</td>
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<td>1,4</td>
</tr>
<tr>
<td>Hollow profiles</td>
<td>1,10 to 1,35</td>
<td>1,4</td>
</tr>
<tr>
<td>Flat side profiles</td>
<td>1,10</td>
<td>1,4</td>
</tr>
<tr>
<td>High lift rudders</td>
<td>1,7</td>
<td>Special consideration</td>
</tr>
</tbody>
</table>

This, in order to avoid significant rudder stock deformations, so as not to create excessive edge pressures in way of bearings. Welded parts of rudders are to be made of rolled hull steels of a type approved by IRS.

3.3 Conventional rudders

3.3.1 General

The requirements of this sub-section apply to ordinary profile rudders, without any special arrangements like fins or flaps, steering propellers, etc. for increasing the rudder force. Rudders of unusual form or type will be subject to special consideration by IRS.

Effective means should be provided to support the weight of the rudder without excessive bearing pressure (e.g. by means of a rudder carrier attached to the upper part of the rudder stock). The hull structure in way of the rudder carrier is to be suitably strengthened. Suitable arrangements are to be provided to prevent the rudder from lifting; in addition, structural rudder stops of suitable strength are to be provided, except where the steering gear is provided with its own rudder stopping devices. In rudder trunks which are open to the external water, a seal or stuffing box is to be fitted above the deepest load water-line, 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 full load waterline, two separate seals or stuffing boxes are to be provided.
3.3.2 Determination of the force acting on the rudder blade and the torque acting on the rudder stock

i) Rudder blades without cut-outs

In the case of rudder blades having a rectangular or trapezoidal external contour without cut-outs (see Fig 7.3.6 (b) and (c)), the rudder force $C_R$, in N, is to be calculated by the following formula:

$$C_R = 132 A.V^2.k_1.k_2.k_3$$

The rudder torque $Q_R$, in N-m, is to be calculated for both ahead and astern conditions according to the formula:

$$Q_R = C_R. r$$

$V$: $V_{AV}$, or $V_{AD}$, depending on the condition under consideration.

$r$ : $b(\alpha - k_A)$, in m; for the ahead condition, $r$ is to be taken not less than 0.1 $b$.

$b$ : mean breadth of rudder area, in m, measured in accordance with Figure 7.3.1.

$\alpha = 0.33$, for ahead condition; 0.66, for astern condition

$k_A : A_f/A$, where $A_f$ is the area, in m$^2$, of the rudder blade portion afore the centreline of rudder pintles (see Fig 7.3.1).

ii) Rudder blades with cut-outs (semi-spade rudders)

In the case of rudder blades having a rectangular or trapezoidal external contour with cut-outs (see Fig 7.3.6 (a), (d) and (e)), the force $C_R$, in N, acting on the blade is to be calculated in accordance with [3.3.2 i)].

The pressure distribution over the rudder blade area, upon which the determination of rudder torque $Q_R$ is to be based, is to be derived as follows.

The rudder blade area may be divided into two rectangular or trapezoidal parts having areas $A_1$ and $A_2$ (see Fig 7.3.6 (d) and (e)), so that:

$$A = A_1 + A_2$$

The levers $r_1$ and $r_2$, in m, of the force $C_R$ are given by the following formulae:

$$r_1 = b_1(\alpha - k_{A1}); r_1 = b_1(\alpha - k_{A2})$$

$b_1$, $b_2$ : mean breadth of the blade parts having areas $A_1$ and $A_2$, determined as appropriate in accordance with Fig 7.3.1 :

$$k_{A1} = A_{1f}/A_1$$

$$k_{A2} = A_{2f}/A_2$$

$A_{1f}$, $A_{2f}$ : area, in m$^2$, of the blade parts indicated in Fig 7.3.2

$\alpha = 0.33$, for ahead condition; 0.66, for astern condition.

For rudder parts located behind a fixed structure such as a rudder post, the following values apply:

$\alpha = 0.25$, for ahead condition; 0.55, for astern condition

The values $C_{R1}$ and $C_{R2}$ of the resulting force, in N, acting on each part of the rudder blade may be calculated by the following formulae:

$$C_{R1} = C_R (A_1/A)$$

$$C_{R2} = C_R (A_2/A)$$
The values \( Q_{R1} \) and \( Q_{R2} \), in Nm, of the resulting torque relevant to each part of the rudder blade may be derived from the following formulae:

\[
Q_{R1} = C_{R1} \cdot r_1 \\
Q_{R2} = C_{R2} \cdot r_2
\]

The total torque acting on the rudder stock, \( Q_R \), is to be calculated for both ahead and astern conditions according to the formula:

\[
Q_R = Q_{R1} + Q_{R2}
\]

For the ahead condition, \( Q_R \) is to be taken not less than the minimum value \( Q_{R,\text{MIN}} \), in Nm, calculated by the following formula:

\[
Q_{R,\text{MIN}} = 0.1 \cdot C_R \cdot [(A_1 \cdot b_1) + (A_2 \cdot b_2) / A]
\]

**Figure 7.3.2:**

3.3.3 Rudder stock

i) Column buckling without rotation of the transverse section

Rudder stocks subject to torque only (see Fig 7.3.6 (e)) are to have scantlings such that the torsional stress, in N/mm², does not exceed the following value:

\[
\tau_{TAMM} = 68 / K_1
\]

The rudder stock diameter, in mm, is therefore to be not less than the value \( d_T \), in mm, calculated by the following formula:

\[
d_T = 4.2 \cdot (Q_R \cdot K_1)^{1/3}
\]

ii) Rudder stocks subject to combined torque and bending (see Fig 7.3.6 (b), (c) and (d)) are to have scantlings such that their equivalent stress \( \sigma_E \), in N/mm², does not exceed the value determined by the formula:

\[
\sigma_{E,\text{AMM}} = 118 / K_1
\]

where \( \sigma_E \) is given by the formula:

\[
\sigma_E = \sqrt{(2B^2 + 3\tau^2_T)}
\]

Where:
\( \sigma_B \): bending stress component, in N/mm\(^2\), given by the following formula:
\[
\sigma_B = \frac{10.2 M_{RS}}{d_T^3} \times 1000
\]

\( \tau_T \): torsional stress component, in N/mm\(^2\), given by the following formula:

The rudder stock diameter, in mm, is to be therefore not less than the value \( d_{TF} \), in mm, calculated according to the following formula:
\[
d_{TF} = d_T \left[ 1 + \frac{4}{3} \left( \frac{M_{RS}}{Q_R} \right)^2 \right]^{1/6}
\]

Where:

\( M_{RS} \): bending moment on rudder stock, in N m, which is given by the following formula:
\[
M_{RS} = 0.866 \left( \frac{C_R}{A} \right) \cdot H
\]

Where:

\( H = A_2 \cdot (H_C + H_2/2) \) for spade rudders (see Fig 7.3.6 (b))
\( H = A_1 \cdot a_1 \cdot u \cdot H_1 \) for rudders with 2 bearings (with sole piece) (see Fig 7.3.6 (c))
\( H = 0.83 B \) for semi-spade rudders with 2 bearings (with rudder horn) (see Fig 7.3.6 (d))

\( A_1, A_2, H_C, H_1 \) and \( H_2 \) are areas, in m\(^2\), and dimensions, in m, as shown in Fig 7.3.6 (b), (c) and (d).

\( B \) is the greater of the values (absolute values) obtained from the following formulae:
\[
B = A_1 \cdot u \cdot H_1 + A_2 \cdot (v \cdot H_1 + w \cdot H_2)
\]
\[
B = A_1 \cdot a_2 \cdot H_1 - A_2 \cdot (a_3 \cdot H_1 + 0.5 H_2)
\]

The values of the coefficients \( a_1, a_2, a_3, u, v \) and \( w \) are given in Tab 7.3.2 as a function of the ratio \( c \), where:
\[
c = H_1 / (H_C + H_1)
\]

IRS may accept bending moments, shear forces and support reaction forces determined by a direct calculation to be performed with reference to the static schemes and loading conditions set out in Section 4 of this Section.

In the case of rudders having unusual profiles, bending moments, shear forces and support reaction forces are, in any case, to be determined by direct calculation.

In general, the diameter of a rudder stock subject to torque and bending may be gradually tapered above the upper stock bearing so as to reach the value of \( d_T \) in way of the quadrant or tiller.
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<th>v</th>
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<td>0.834</td>
<td>1.000</td>
<td>0.621</td>
<td>0.924</td>
<td>0.617</td>
</tr>
</tbody>
</table>
3.3.4 Rudder Plating

3.3.4.1 Double rudder plating

Double plating rudders consist of a welded plating box, stiffened by horizontal and vertical webs which may or may not incorporate the main piece. The generic horizontal cross-section of the rudder plating is to be such that stress components, in N/mm², do not exceed the following values:

i) rudder of the type shown in Fig 7.3.6 (b) and (c)
   normal bending stress \( \sigma_{FL} \): 110 \( / K_1 \)
   shears stress \( \tau \): 50 \( / K_1 \)
   equivalent stress \( \sigma_E = (\sigma_{FL}^2 + 3\tau^2)0.5 \): 100 \( / K_1 \)

ii) rudder of the type shown in Fig 7.3.6 (d) and (e):
   normal bending stress \( \sigma_{FL} \): 75 \( / K_1 \)
   shears stress \( \tau \): 50 \( / K_1 \)
   equivalent stress \( \sigma_E = (\sigma_{FL}^2 + 3\tau^2)0.5 \): 100 \( / K_1 \)

The thickness of each rudder plate panel is to be not less than the value \( t_F \), in mm, calculated by the following formula:

\[
t_F = \left[ 5.5 \cdot s \cdot \beta (T_{fl} + \frac{C_R \cdot 10^{-4}}{A})^2 + 2.5 \right] K_1^{0.5}
\]

Where:

\( T_{fl} \): draught with the ship on the full load waterline, in m
\( \beta \): \( [1.1 - 0.5 (s/b_L)^2]^{0.5} \), which need not be taken greater than 1.

where:

\( s \): minor side of the plating panel, in m,
\( b_L \): major side of the plating panel, in m.

Vertical webs with spacing greater than twice that of horizontal webs are not acceptable.

Web thickness is to be at least 70% of that required for rudder plating and in no case is it to be less than 8 mm, except for the upper and lower webs. The thickness of any of these webs is to be uniform and not less than that of the web panel having the greatest thickness \( t_F \) as calculated with the above formula. In any case it is not required that the thickness is increased by more than 20% in respect of normal webs.

In case of the design of the rudder not incorporating a main-piece, it should be replaced by two vertical webs closely spaced, having a thickness generally not less than 1.5 times that of normal webs. In rudders having an area \( A \) smaller than 5 m², one vertical web alone may be accepted provided its thickness is at least twice that of normal webs, in general. As a rule, the increased thickness of such webs should not exceed 30 mm, unless otherwise required in special cases to be individually considered by IRS.
The thickness of the side plating between the two vertical webs replacing the main piece, or in way of the only rein-forced web, is to be increased by at least 20%.

The welded connections of blade plating to vertical and horizontal webs are to comply with the requirements of Chapter 2, Section 7.

Where internal access to the rudder is not practicable, connections are to be by means of slots on a supporting flat welded to the webs, to be cut on one side of the rudder only, in accordance with Chapter 1, Section 7.

Rudder nose plates are to have a thickness not less than 1.25 $t_f$. In general this thickness need not exceed 22 mm, unless otherwise required in special cases to be individually considered by IRS.

On completion of manufacture, the rudder plating is to be subjected to a leak test using air as required in Chapter 2 Section 8.

### 3.3.5 Rudder Pintles

#### 3.3.5.1 Rudder pintles are to have a diameter not less than the value $d_A$, in mm, calculated by the following formula:

$$d_A = \left[ \frac{0.38 V_{AV}}{V_{AV}+3} \cdot (F_A \cdot K_1)^{0.5} + f_C \right]$$

Where:

- $F_A$: force, in N, acting on the pintle, calculated as specified in the following item 3.3.5.6
- $f_C$: coefficient depending on corrosion, whose value may generally be obtained as follows: $f_C = 30 K_1^{0.5}$.

IRS may accept lower $f_C$ values based on considerations of ship dimensions and satisfactory service experience, supported by documents, of corrosion control systems adopted.

#### 3.3.5.2 Provision should be made for a suitable locking device to prevent the accidental loosening of pintles. The pintle housings should generally be tapered with a taper ranging of:

- from 1:12 to 1:8 for pintles with non-hydraulic assembly and disassembly arrangements
- from 1:20 to 1:12 for pintles with hydraulic assembly and disassembly arrangements.

#### 3.3.5.3 The housing height is to be not less than:

$$0.35 (F_A \cdot K_1)^{0.5}$$

#### 3.3.5.4 The maximum value of the pressure acting on the gudgeons, in N/mm$^2$, and in general on the rudder supports, calculated by the following formula:

$$p_F = \frac{F_A}{(d_A \cdot h_A)}$$

is not to exceed the values given in Tab 7.3.3, where $h_A$ is the contact length between pintle and housing, to be taken not greater than 1.2 $d_A$. Values in excess of those given in Tab 7.3.3 may be accepted by IRS on the basis of specific tests.
The thickness of the pintle housing in the gudgeon is to be not less than 0.25\(d_A\).
The manufacturing tolerances on the diameter of metallic supports should not be lesser than:
\[d_A/1000 + 1.0, \text{ in mm.}\]

In the case of non-metallic supports, the tolerances are to be carefully evaluated on the basis of the thermal and distortion properties of the materials employed; the tolerance on support diameter is in no case to be less than 1.5 mm.

3.3.5.5 Where a direct calculation is used to obtain the rudderstock stress components, the value \(F_A\) is also to be derived from the same calculation (see Section 5 of this Chapter).

3.3.5.6 Otherwise, the value \(F_A\) is to be calculated from the following formula:
\[F_A = \left(\frac{C_R}{A}\right) \cdot A_G\]

Where:
- \(C_R\): force, in N, acting on the rudder blade, determined as specified in [3.3.2];
- \(A_G\): part of the rudder blade area A, in \(m^2\), supported by the pintle, calculated as specified in items (1) and (2) below.

1. For rudders (excluding semi-spade rudders) with two bearings, i.e. with sole-piece (see Fig 7.3.6 (c)), \(A_G\) is to be not lower than the value obtained from the following formula:
\[A_G = A \cdot \left[\frac{(H_C + 0.5 H_1)}{(H_C + H_1)}\right]\]

2. For semi-spade rudders with two or more bearings (with rudder horn) (see Fig 7.3.6 (d) and (e)), the area \(A_{G1}\), for the lower pintle, is to be not less than the value \(A_{G1}\) calculated by the following formula:
\[A_{G1} = C_3 \cdot A_1 + \left[C_1 \cdot \left(\frac{H_2}{(H_C + H_1)}\right) + C_2\right] \cdot A_2\]
In no case is the value of \(A_{G1}\) to be greater than \(A\).

For the upper pintle (see Fig 7.3.6 (e)), the area \(A_G\) is to be not less than the greater of the values \(A_{G2}\) obtained from the following formulae:
\[A_{G2} = A - A_{G1}\]
\[A_{G2} = 0.35 A\]

The values of coefficients \(C_1\), \(C_2\) and \(C_3\) are given in Tab 7.3.2 as a function of the ratio \(c\), \(c\) being as defined in [3.3.3].
Table 7.3.3:

<table>
<thead>
<tr>
<th>Bearing</th>
<th>( p_F ), in N/mm(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lignum vitae</td>
<td>2.5</td>
</tr>
<tr>
<td>White metal, oil lubricated</td>
<td>4.5</td>
</tr>
<tr>
<td>Synthetic material with hardness between 60 and 70 (1) Shore D</td>
<td>5.5</td>
</tr>
<tr>
<td>Steel (2), bronze and hot-pressed bronze-graphite materials</td>
<td>7.0</td>
</tr>
</tbody>
</table>

(1) Indentation hardness test at 23 °C and with 50% moisture to be performed according to a recognized standard. The type of synthetic bearing materials is to be approved by IRS.

(2) Stainless and wear-resistant steel in combination with stock liner approved by IRS.

3.3.6 Rudder couplings

3.3.6.1 Horizontal flange couplings

Horizontal flange couplings are to be connected by fitted bolts in number \( n_B \) not less than 6, having a diameter not less than \( d_B \), in mm, given by the following formula:

\[
d_B = \frac{0.62d_1^{3/2}}{n_B^{0.5}} \cdot \left( \frac{K_{1P}}{K_{1B}} \right)^{0.5} \cdot \frac{1}{e_M^{0.5}}
\]

The thickness of the coupling flange should not be less than the value \( t_P \), in mm, calculated by the following formula:

\[
t_P = d_B \cdot \left( \frac{K_{1P}}{K_{1B}} \right)^{0.5}
\]

In any case \( t_P \) is to be \( >0.9 \) \( d_B \), with \( d_B \), calculated for a number of bolts not exceeding 8.

The symbols used have the following meanings:

- \( d_1 \): rule diameter \( d_T \) or \( d_{TF} \) in mm, of the rudderstock, in compliance with the requirements in [3.3.3];
- \( K_{1B}, K_{1A}, K_{1P} \): coefficients depending on the high strength steel used for bolts, rudder stock and coupling flange, respectively, whose values are to be taken as defined in [3.2]
- \( e_M \): mean distance, in mm, of the bolt axes from the longitudinal axis through the coupling centre.

The distance from the bolt axes to the external edge of the coupling flange is generally to be not less than 1.2 \( d_B \).

A suitable locking device is to be provided to prevent the accidental loosening of nut.

Non-fitted bolts may be used provided that, in way of the mating plane of the coupling flanges, a key is fitted having a section of 0.25 \( d_T \times 0.10 \) \( d_T \), and keyways in both the coupling flanges, and provided that at least two of the coupling bolts are fitted bolts.
3.3.6.2 Vertical flange couplings

Vertical flange couplings are to be connected by fitted bolts, in number \( n_B \), not less than 8, having a diameter \( d_B \), in mm, not less than the value calculated by the following formula:

\[
d_B = \frac{0.81d_1}{b_B^{0.5}} \left( \frac{K_{1B}}{K_{1A}} \right)^{0.5}
\]

\( d_1, K_{1B} \) and \( K_{1A} \) are defined in [3.3.6.1]

The first moment of area of the sectional area of bolts about the vertical axis through the centre of the coupling is to be not less than the value \( MS \), in \( \text{cm}^3 \), calculated by the following formula:

\[
MS = 0.43d_1^3 \cdot 10^{-6}
\]

The thickness of the coupling flange is generally to be not less than \( d_B \).

The distance of the bolt axes from the external edge of the coupling flange is generally to be not less than 1.2 \( d_B \).

A suitable locking device is to be provided to prevent the accidental loosening of nuts.

3.3.6.3 Cone couplings

Cone couplings of the shape shown in Fig 7.3.3 (with reference to the symbols indicated in the same Figure) are to have the dimensions indicated in (a) and (b) below:

i) Cone couplings with hydraulic arrangements for assembling and disassembling the coupling:

Taper: \( \frac{1}{20} \leq \frac{(d_4 - d_0)}{t_s} \leq \frac{1}{12} \)

\[
t_s \leq 1.5 \, d_4
\]

\[
d_G > 0.65 \, d_1
\]

\[
t_N > 0.60 \, d_G
\]

\( d_N > 1.2 \, d_0 \) and, in any case, \( d_N > 1.5 \, d_G \)

Between the nut and the rudder gudgeon a washer is to be fitted having thickness not less than 0.13 \( d_G \) and an outer diameter not less than 1.3 \( d_0 \) or 1.6 \( d_G \), whichever is the greater.

ii) Cone couplings without hydraulic arrangements for assembling and disassembling the coupling:

Taper: \( \frac{1}{12} \leq \frac{(d_4 - d_0)}{t_s} \leq \frac{1}{8} \)

\[
t_s \leq 1.5 \, d_4
\]

\[
d_G > 0.65 \, d_1
\]

\[
t_N > 0.60 \, d_G
\]

\( d_N > 1.2 \, d_0 \) and, in any case, \( d_N > 1.5 \, d_G \).
The dimensions of the locking nut, in both (a) and (b) above, are given purely for guidance, the determination of adequate scantlings being left to the responsibility of the Designer.

In cone couplings of type (b) above, a key is to be fitted having a cross-section $0.25 \, d_T \times 0.10 \, d_T$ and keyways in both the tapered part and the rudder gudgeon.

In cone couplings of type (a) above, the key may be omitted. In this case the Designer is to submit to IRS shrinkage calculations supplying all data necessary for the relevant check.

All necessary instructions for hydraulic assembly and disassembly of the nut, including indication of the values of all relevant parameters, are to be available on board.

3.3.7 Supporting arrangements and rudder stops

3.3.7.1 General

The weight of the rudder is normally supported by a carrier bearing inside the rudder trunk. In the case of unbalanced rudders having more than one pintle, the weight of the rudder may be supported by a suitable disc fitted in the sole piece gudgeon.

Robust and effective structural rudder stops are to be fitted, except where adequate positive stopping arrangements are provided in the steering gear.
3.3.7.2 Solepiece

At no cross-section of the sole piece is the section modulus $Z_z$, in cm$^3$, about the vertical axis $Z$ (see Fig 7.3.4) to be less than:

$$Z_z = \frac{M_B \cdot K_1}{80}$$

The section modulus $Z_y$, in cm$^3$, about the horizontal axis $Y$ is to be not less than:

$$Z_y = 0.5 \cdot Z_z$$

The cross-sectional area $A_S$, in mm$^2$, is to be not less than:

$$A_S = \frac{(B_1 \cdot K_1)}{48}$$

In addition to the dimensional limits above, at no section within the length $l_{50}$ is the equivalent stress $\sigma_E$, in N/mm$^2$, to exceed the value 115/K1, where:

$$\sigma_E = (\sigma_B + 3 \tau)^{0.5}$$

$\sigma_B = \frac{M_B}{Z_z}$, in N/mm$^2$

$\tau = \frac{B_1}{A_S}$, in N/mm$^2$

$M_B = B_1 \cdot x$, (0 $\leq$ x $\leq$ l$_{50}$), bending moment, in N m, at the section considered

$B_1$ : supporting force, in N, of the sole piece (in general $B_1 = \frac{C_R}{2}$).

3.3.7.3 Rudder horn

The stress components (see Fig 7.3.5) acting on the generic rudder horn cross-section at a distance $z$ from the horizontal axis are the following:

$M_B = B_1 \cdot z$, bending moment, in N-m

$Q = B_1$, shear force, in N
Where $B_1$, in N, is generally given by the formula:

$$B_1 = C_R \cdot \left[ b / (l_{20} + l_{30}) \right]$$

(For $b$, $l_{20}$, and $l_{30}$, see Fig 7.4.2).

The modulus $Z_x$, in cm³, of the section about the horizontal axis is to be not less than:

$$Z_x = (M_B \cdot K_1) / 67$$

The shearing stress $\tau$, in N/mm², due to the shear force is not to exceed the value:

$$\tau = 48 / K_1$$

At no horizontal section of the rudder horn, for $0 \leq z \leq d$ is the equivalent stress $\sigma_E$, in N/mm², to exceed $120 / K_1$, where:

$$\sigma_E = \left( \sigma_B^2 + 3(\tau^2 + \tau_T^2) \right)^{0.5}$$

$\sigma_B = M_B / Z_x$, in N/mm²

$\tau = B_1 / A_H$, in N/mm²

$\tau_T = (MT \cdot 10^3) / (2AT \cdot t_h)$, in N/mm²

$A_H$ : effective shear area of the rudder horn in y-direction, in mm²

$A_P$ : area in the horizontal section enclosed by the rudder horn plating, in mm²

### 3.4 Single plate rudders

Single plate rudders consist of a main piece of circular shape, connected to two or more arms fitted alternate on either side of the rudder blade plate.

The rudder stock diameter is to be calculated according to [3.3].

The main piece diameter is to be not less than the rudder stock diameter. For spade rudders, the lower third may taper down to 0.75 times the rudder stock diameter.

The blade thickness $t_B$, in mm, is to be not less than:

$$t_B = (1.5s \cdot V_{AV} + 2.5) \cdot K_1^{0.5}$$

Where:

$s$ : spacing of stiffening arms, in m, in no case to be more than 1 m.

The thickness of the arms is to be not less than the blade thickness; the section modulus, in cm³, of the generic cross-section is to be not less than:
Where:

\( C_1 \) : horizontal distance, in m, from the aft edge of the rudder to the cross-section.

### 3.5 Steering nozzles

#### 3.5.1 General

In this Article the requirements for scantlings for steering nozzles are given, applicable to nozzles for which:

\[(P_{\text{prop}} \cdot d_M)^{0.5} \leq 130\]

- \( P_{\text{prop}} \) : power transmitted to the propeller, in kW
- \( d_M \) : inside diameter of the nozzle, in m.

Nozzles for which \((P_{\text{prop}} \cdot d_M)^{0.5}\) exceeds the above value will be specially considered in each case by IRS.

Nozzles normally consist of a double skin cylindrical structure stiffened by ring webs and other longitudinal webs placed perpendicularly to the nozzle.

At least two ring webs are to be fitted, one of which, of greater thickness, is to be placed in way of the axis of rotation of the nozzle.

The number of ring webs is to be increased, as deemed necessary by IRS, on nozzles with an inner diameter \(d_M\) exceeding 3 m.

Care is to be taken in the manufacture of the nozzle to ensure the welded connection between plating and webs. The internal part of the nozzle is to be adequately protected against corrosion.

Upon completion of manufacture, the nozzle is to be subjected to a leak test using air as required in Chapter 2 Section 8.

#### 3.5.2 Nozzle plating and internal diaphragms

The inner plating of the nozzle is to have a thickness \( t_r \), in mm, not less than that given by the formulae in (a) or (b) below, as appropriate.

- **a)** For \((P_{\text{prop}} \cdot d_M)^{0.5} \leq 78\):
  \[
  t_r = [0.085 (P_{\text{prop}} \cdot d_M)^{0.5} + 9.65] \cdot K_1^{0.5}
  \]
- **b)** For \((P_{\text{prop}} \cdot d_M)^{0.5} > 78\):
  \[
  t_r = [0.085 (P_{\text{prop}} \cdot d_M)^{0.5} + 11.65] \cdot K_1^{0.5}
  \]

The symbols \(P_{\text{prop}}\) and \(d_M\) used in (a) and (b) above have the same meanings specified in [3.5.1].

The thickness \( t_r \) is to be extended to a length across the transverse section containing the propeller blade tips equal to 1/3 of the total nozzle length. Outside the above length, the thickness may be not less than \( t_r - 7 \) mm. In no case are both of the above thicknesses to be less than 7 mm. Ring webs and longitudinal webs are to have a thickness not less than \( t_r - 7 \) mm, or 7 mm, whichever is the greater. However, the ring web, in way of the axis of rotation and connected above to the head box and below to the pintles support structure, is to have a thickness not less than \( t_r \). Where stainless steel accepted by IRS is used, thicknesses may be reduced, at the discretion of IRS, in relation to the type of stainless steel concerned.
The requirements for scantlings given in [3.5] may also be applied to fixed nozzles (nozzle propellers).

3.5.3 Nozzle stock

The diameter of the nozzle stock is to be not less than the value \( d_{NS} \) given in Table 7.3.4. The diameter \( d_{NS} \) of the nozzle stock may be gradually tapered above the upper stock bearing so as to reach the value \( d_T \), given in Table 7.3.4, in way of the tiller or quadrant.

3.5.4 Pintles

Pintles are to have a diameter \( d_A \), in mm, not less than that calculated by the following formula:

\[
d_A = \left( \frac{11A_{AV}}{V_{AV} + 3 \cdot S_{AV}^0.5 + 30} \right) \cdot K_{1.5}^0.5
\]

\( S_{AV} \) being as indicated in Table 7.3.4.

The net pintle length \( h_A \), in mm, is to be not less than 1.2 \( d_A \). Smaller values of \( h_A \), but in no case smaller than \( d_A \), may be accepted provided that the pressure on the gudgeon bearing \( p_F \), in N/mm², given by the following formula does not exceed the values given in Table 7.3.4.

Where:

- \( d_A' \): actual pintle diameter, in mm
- \( h_A' \): actual bearing length of pintle, in mm
- \( S' \): the greater of the values \( S_{AV} \) and \( S_{AD} \), in kN, given in Table 7.3.4

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Formula for its determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>( d_{NS} ), in mm</td>
<td>64.23 ( (M_T \cdot K_1)^{1/2} )</td>
</tr>
<tr>
<td>( d_{NS} ), in mm</td>
<td>0.73 ( d_T )</td>
</tr>
<tr>
<td>( M_{AV} ), in kN\cdot m</td>
<td>0.3 ( S_{AV} \cdot a )</td>
</tr>
<tr>
<td>( M_{AD} ), in kN\cdot m</td>
<td>( S_{AD} \cdot b )</td>
</tr>
<tr>
<td>( S_{AV} ), in kN</td>
<td>0.147 ( A \cdot V_{AV}^2 )</td>
</tr>
<tr>
<td>( S_{AD} ), in kN</td>
<td>0.196 ( A \cdot V_{AD}^2 )</td>
</tr>
<tr>
<td>( A_1 ), in m²</td>
<td>1.35 ( A_1 + A_2 )</td>
</tr>
<tr>
<td>( A_2 ), in m²</td>
<td>( L \cdot d_M )</td>
</tr>
<tr>
<td>( A_2 ), in m²</td>
<td>( L_1 \cdot H_1 )</td>
</tr>
</tbody>
</table>

**Note 1:** \( M_T = M_{AV} \) or \( M_{AD} \), whichever is the greater;

- \( a, b, L, d_M, L_1, H_1 = \) nozzle dimensions, in metres, as shown in Fig 7.3.6 (f);
- \( V_{AV} \) and \( V_{AD} \) = ahead and astern speed, in knots, as defined in [3.1.1].

3.5.5 Nozzle coupling

In addition to the requirements in [3.3.6.1] for horizontal flange couplings, coupling bolts are to have a diameter not less than the value \( d_B \), in mm, calculated by the following formula:

\[
d_A = 0.23d_{NS} \cdot (K_{1B}/K_{1A})^{0.5}
\]

The thickness of the coupling flange is to be not less than the value \( t_F \), in mm, given in the following formula:

\[
t_F = 0.23d_{NS}(K_{1F}/K)
\]

\( d_T \), \( d_B \), and \( t_F \) being as shown in Fig 4 and \( K_{1B}, K_{1A}, \) and \( K_{1F} \) being as defined in [3.3.6.1].
3.6 Special rudder types

Special rudder types will be considered by IRS on a case-by-case basis. Assuming the external pressure $C_R/A$, $C_R$ being the force given in [3.3.2.i], the equivalent stresses for combined torque and bending in the rudder stock are not to exceed $118/K_1 \text{ N/mm}^2$. Where the rudder stock is subject to torque only, the torsional stresses are not to exceed $68/K_1 \text{ N/mm}^2$.

Fig 7.3.6: Rudder Types
SECTION 4 DIRECT CALCULATION OF SUPPORT FORCES AND STRESS COMPONENTS FOR RUDDER STOCKS

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4.1 General

With reference to Fig 7.4.1, Fig 7.4.2 and Fig 7.4.3, the following symbols and definitions apply:

$I_{10}$ to $I_{50} =$ length of the individual elements of the rudder system, in m

$J_{10}$ to $J_{50} =$ moments of inertia of these elements, in cm$^4$.

For rudders supported by a sole piece only, $J_{20}$ indicates the moment of inertia of the pintle in the sole piece. For the rudder in Fig 7.4.1, the load per unit length $P_r$, in kN/m, is given by:

$$P_r = C_r / (10^3 \cdot I_{10})$$

For the rudder in Fig 7.4.2, the load per unit length of its various elements, in kN/m, is given by the following formulae:

$$P_{R10} = C_{R2} / (10^3 \cdot I_{10})$$
$$P_{R20} = C_{R1} / (10^3 \cdot I_{20})$$

Where $C_{R1}$ and $C_{R2}$ are defined in [3.3.2.2].

The spring constant $Z_C$, in kN/m, for the sole piece is given by the following formula (see Fig 7.4.1)

$$Z_C = (6.18 \cdot J_{50}) / I_{50}$$

Where:

$J_{50} =$ moment of inertia of the solepiece about the z-axis, in cm$^4$ (see also in, Sec3, Fig 7.3.44)

$I_{50} =$ effective length of the solepiece, in m.

The stiffness $Z_P$, in kN/m, for the rudder horn is given by the following formula (see Fig 7.4.2):

$$Z_P = 1/(f_B + f_T)$$

Where:

$f_B =$ unit displacement of rudder horn due to a unit force of 1 kN acting in the centroid of the rudder horn, in m/kN, which may be expressed, as guidance, by

$$f_B = 1.3 \cdot (d_3 / 6.18 J_N)$$

$J_N =$ moment of inertia of rudder horn about the x-axis, in cm$^4$ (see also in, Sec 3, Fig 7.3.5)

$f_T =$ unit displacement due to torsion, in m/kN, which may be expressed as guidance by

$$f_T = \frac{d \cdot e^2 \cdot \sum u_i / t_i}{3.14 \cdot 10^8 \cdot F_T^2}$$

Where:

$F_T =$ mean sectional area of rudder horn, in m$^2$

$u_i =$ breadth, in mm, of the individual plates forming the mean rudder horn sectional area.

$t_i =$ thickness of the individual plates above, in mm.

$e,$ $d =$ see Fig 2.
For the rudder in Fig 3, the maximum bending moment $M_B$, in N m, and support forces $B_3$ and $B_2$, in N, may be determined by the following formulae:

$$M_B = c_R \left[ l_{20} + \left( \frac{l_{10} \cdot 2[C_1 + C_2]}{3\cdot (C_1 + C_2)} \right) \right]$$

$$B_3 = \frac{M_B}{l_{30}}$$

$$B_2 = c_R + B_3$$

Fig 7.4.1:
Figure 7.4.2:

Figure 7.4.3:
CHAPTER 8 STABILITY

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## SECTION 1 GENERAL

### Contents

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1.1. General

1.1.1. Application

1.1.1.1. After it has been established that the intact stability of all ships equal to or greater than 24 m in length is adequate for the service proposed, they may be assigned class. Adequate intact stability implies fulfillment of standards lay down by the relevant Administration or the requisites specified in this Chapter taking into consideration the size and type of ship. However, whatever be the case, the level of intact stability is not to be less than that granted by the Rules.

1.1.1.2. Ships less than 24 m in length

To ships less than 24m in length, the Rules are also applicable. In this case, the requisites concerned may be omitted partly subject to the agreement of the Society.

1.1.1.3. Approval of the Administration

For classification purposes, In lieu of the rules given in this Chapter, the Society may accept the specific rules covering stability given by the Administration of the State whose flag the ship is entitled to fly. For the purpose of classification, evidence of approval of the stability by the Administration concerned may be accepted. In cases of application of the above requisites, a suitable entry is made in the classification files of the ship.

1.2. Examination procedure

1.2.1. Documents to be submitted

1.2.1.1. List of documents

The underlying plans and documents are to be submitted to the Society for information and the purpose of the examination of the Stability:

- Lines plan
- Lightweight distribution
- Hydrostatic curves
- General arrangement

As indicated above, the stability documentation to be submitted for approval is as given under:

a) Inclining test report for the ship, as required in [1.2.2] or:

- where the basis of stability data is a sister ship, the inclining test report of that sister ship along with the light-ship measurement report for the ship in question; or
- where methods other than inclining of the ship or its sister determine lightship particulars, the
- as indicated in [2.2.4], lightship measurement report of the ship and a summary of the method used to determine them

b) trim and stability booklet, as required in Sec 2, [1.1.1]
The right to accept or demand the submission of provisional stability documentation for examination is reserved by the Society. Loading conditions are included in provisional stability conditions on the basis of estimated lightship values.

1.2.1.3. Final documentation

Based on the results of the inclining test or the lightweight check, final stability documentation is to be submitted for examination. When provisional stability documentation has already been submitted and the difference between the estimated values of the lightship and those obtained after completion of the test is less than:

- 2% for the displacement, and,
- 1% of the length between perpendiculars for the longitudinal position of the centre of gravity, and the determined vertical position of the centre of gravity is not greater than the estimated vertical position of the centre of gravity, the provisional stability documentation may be accepted as the final stability documentation.

1.2.2. Inclining test/lightweight check

1.2.2.1. Definitions

a) Lightship

The lightship refers to a ship that is complete in all respects but lacks stores, consumables, cargo, crew and effects and also lacks any liquids on board except for machinery and piping fluids, such as hydraulics and lubricants, which are at operating levels.

b) Inclining test

A procedure which involves moving a series of known weights, normally in the transverse direction, and then measuring the resulting change in the equilibrium heel angle of the ship is referred to as inclining test. With the help of this information and applying basic naval architecture principles, the ship's vertical centre of gravity (VCG or KG) is determined.

c) Lightweight check

So that the observed condition of the ship can be adjusted to the lightship condition, a procedure referred to as lightweight check is adopted which involves auditing all items which are to be added, deducted or relocated on the ship at the time of the inclining test. It is required to accurately determine and record the weight and longitudinal, transverse and vertical location of each item. With help of this information, the lightship displacement and longitudinal centre of gravity (LCG) can be obtained, as well as the static waterline of the ship at the time of the inclining test as determined by measuring the freeboard or verified draught marks of the ship, the ship's hydrostatic data and the sea water density.
1.2.2.2. General

When stability investigation is requested for any ship, in order to fulfill the class requirements, it is to be initially subjected to an inclining test allowing the evaluation of the position of the lightship centre of gravity, or a lightweight check of the lightship displacement, so that the stability data can be determined.

In [1.2.2.4] and [1.2.2.5], cases for which the inclining test is required and those for which the lightweight check is accepted in its place are listed. A Surveyor of the Society has to attend the inclining test or lightweight check. The Society may accept inclining tests or lightweight checks attended by a member of the flag Administration. The inclining test is compliant to ships less than 24 m in length, provided that safety measures are taken, on a case-by-case basis, to ascertain the accuracy of the test procedure. For cargo ships with length less than 20 metres, irrespective of their navigation, at the discretion of the Society, in lieu of the inclining test, one or more practical stability test(s) relevant to the most severe conditions anticipated in real service may be conducted.

For passenger ships with length less than 20 m, at the discretion of the Society, in lieu of the inclining test, a practical stability test relevant to the most severe conditions anticipated in real service and a practical passenger crowding test may be conducted.

In such cases, a report is to be made, relevant to the tested loading conditions containing restrictions in the loading conditions and/or in ballasting, if any, which, duly approved by the Society, is to substitute the prescribed stability booklet.

1.2.2.3. Inclining test

In the following cases, the inclining test is required:

- for any new ship, after its completion, excluding the cases specified in [1.2.2.4]
- for any ship, if deemed necessary by the Society, where any changes are made so as to materially affect the stability.

1.2.2.4. Lightweight check

IRS may permit a lightweight check to be conducted in lieu of an inclining test in the case of:

a) an individual ship, if the basic stability data is available from the inclining test of a sister ship and a lightweight check is executed in order to prove that the sister ship corresponds to the prototype ship. The lightweight check is to be done upon completion of the ship. The final stability data to be considered for the sister ship in terms of position and displacement of the centre of gravity are those of the prototype. Whenever, in comparison with the data derived from the prototype, a divergence from the lightship displacement going beyond 1% for ships of 160 m or more in length, or 2% for ships of 50 m or less in length, or as determined by linear interpolation for intermediate lengths, or a divergence from the lightship longitudinal centre of gravity going beyond 0.5% of Ls is found, the ship is to be inclined.

b) special types of ships, for instance, pontoons, provided that the vertical centre of gravity is considered at the level of the deck.

c) special types of ships like the catamarans, provided that:
   - a detailed list of weights and the positions of their centres of gravity is submitted
• a lightweight check is done that depicts accordance between the estimated values and those which are determined
• adequate stability is demonstrated in all the loading conditions reported in the trim and stability booklet.

1.2.2.5. Detailed procedure

In Section 3, a detailed procedure for conducting an inclining test is included.

1.3. Definitions

1.3.1. The definitions given under shall be considered in this Chapter:

• plane of maximum draught: the water plane related to the maximum draught at which the craft is approved to navigate;
• safety clearance: the distance between the plane of maximum draught and the parallel plane passing through the lowest point above which the craft is not deemed to be watertight;
• residual safety clearance: the vertical clearance available, in the event of the vessel heeling over, between the water level and the lowest point of the immersed side, ahead of which the vessel is no longer considered as watertight;
• freeboard (f): the distance between the plane of maximum draught and a parallel plane passing through the lowest point of the gunwale or, not in the presence of a gunwale, the lowest point of the upper edge of the ship's side;
• residual freeboard: the vertical clearance available, in the event of the vessel heeling over, between the water level and the upper surface of the deck at the lowest point of the immersed side or, if there is no deck, the lowest point of the upper surface of the fixed ship's side;
• margin line: an imaginary line drawn on the side plating not less than 10 cm below the bulkhead deck and not less than 10 cm below the lowest non-watertight point of the side plating. If there is no bulkhead deck, a line drawn not less than 10 cm below the lowest line up to which the outer plating is watertight shall be used;
• water displacement( ): the immersed volume of the vessel, in m$^3$;
• displacement: the total weight of the vessel, inclusive of cargo, in t;
• block coefficient (CB): the ratio between the water displacement and the product of length LWL, breadth BWL and draught T;
• lateral plane above water (AV): lateral plane of the vessel above the waterline in m$^2$;
## SECTION 2 INTACT STABILITY

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2.1. General

2.1.1. Information for the Master

2.1.1.1. Stability booklet

Each ship is to be rendered with a stability booklet, approved by the Society, which contains adequate information to enable the Master to operate the ship in observance with the applicable requisites contained in this Section. Where any modifications are made to a ship so as to materially affect the stability information supplied to the Master, altered stability information is to be rendered. If required, the ship is to be re-inclined. Stability data and associated plans are to be drawn up in the official language or languages of the issuing country. If the used languages are neither French nor English, the text that translates it into one of these languages is to be included. In Section 4, the format of the trim and stability booklet and the information included are specified.

2.1.1.2. Loading instrument

As a supplement to the approved stability booklet, a loading instrument, approved by the Society, may be used to make the stability calculations mentioned in Section 4 easy. A simple and straightforward instruction manual is to be provided. To certify the proper functioning of the computer hardware and software, pre-defined loading conditions are to be run in the loading instrument periodically, at least at every periodical class survey. Also, for the future reference, the print-out is to be maintained on board as check conditions in addition to the approved test conditions booklet.

2.1.1.3. Operating booklets for certain ships

Ships with innovative design are to be rendered with additional information in the stability booklet so that the maximum speed, design limitations, worst intended weather conditions or other information regarding the handling of the craft that the Master needs to operate the ship is available.

2.1.2. Permanent ballast

2.1.2.1. If used, permanent ballast is to be located as per the terms of the plan approved by the Society and in a manner that prevents shifting of position. Permanent ballast is not to be removed or relocated from the or within the ship without the approval of the Society. Permanent ballast details are to be noted in the ship's stability booklet. Where any changes are made to a ship so as to materially affect the stability information supplied to the Master, amended stability information is to be provided. If required, the ship is to be re-inclined.

2.1.2.2. Under the supervision of the Society, permanent solid ballast is to be installed.

2.2. Design criteria

2.2.1. General intact stability criteria

2.2.1.1. General

Generally, the intact stability criteria are to be conformed to for the loading conditions given in Section 4, [4.1.2]. But since the lightship condition is not an operational loading case, the Society may accept that part of the above mentioned criteria are not observed. These criteria
set minimum values, but no maximum values are recommended. It is advisable to circumvent excessive values of metacentric height, since these might lead to acceleration forces which could be prejudicial to the ship, its equipment and safe carriage of the cargo.

2.2.1.2.

For ships with length not more than 24 m, it may be accepted that it is only verified that the initial metacentric height $GM_0$ is not less than 0.35 m, excluding the lightship condition for which a positive value can be accepted. For ships greater than 24 m in length, the intact stability is to be verified as per the criteria given from [2.2.1.3] to [2.2.1.5]. Additionally, for each service notation, the requisites given in [2.3] are also to be fulfilled.

2.2.1.3. GZ curve area

The area under the righting lever curve (GZ curve) is to be not less than 0.055 m.rad up to a 30° angle of heel and not less than 0.09 m.rad up to $f = 40^\circ$ or the angle of downflooding $\Phi_f$ if this angle is less than 40°. Additionally, the area under the righting lever curve (GZ curve) between the angles of heel of 30° and 40° or between 30° and $J$, if this angle is less than 40°, is to be not less than 0.03 m.rad.

Note 1: $\Phi_f$ is an angle of heel at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight submerge. In applying this criterion, small openings through which progressive flooding cannot take place need not be considered as open.

2.2.1.4. Minimum righting lever

The righting lever GZ is to be at least 0.20 m at an angle of heel equal to or greater than 30°. When the righting lever curve has a shape with two maximums, the first is to be located at a heel angle not less than 25°.

In cases of ships with a particular design, the Society may accept an angle of heel $J_{\max}$ less than 25° but in no case less than 15°, provided that the area “A” below the righting lever curve is not less than the value obtained, in m.rad, from the following formula:

$$A = 0.055 + 0.001 (30^\circ - \theta_{\max})$$

where $\theta_{\max}$ is the angle of heel in degrees at which the righting lever curve reaches its maximum.

2.2.1.5. Initial metacentric height

The initial metacentric height $GM_0$ is not to be less than 0.15 m.

2.2.1.6. Passenger ships of not more than 24 m in length and carrying not more than 150 passengers

The intact stability check of passenger ships with a length not more than 24 m and carrying up to 150 passengers is to be done in conformity with [2.2.1.2]. For such vessels, the requisites listed from item a) to g) are also to be satisfied.

a) Standard requirements

The requisites in [2.2.1.2] to [2.2.1.5] are to be conformed to, for the loading conditions defined in Section 4.
b) Crowding of passengers

The angle of heel as defined on account of crowding of passengers to one side may not go beyond 10° and in any event the freeboard deck is not to be immersed. For ships with length less than 20 m, the angle of heel is not to be greater than the angle corresponding to a freeboard of 0.1 m before the deck's immersion, or 12° if this is less.

c) Maximum turning angle

The angle of heel on account of turning may not go beyond 10° when calculated using the formula given below:

\[ M_R = 0.02 \frac{V_0^2}{L} \Delta \left( KG - \frac{T_1}{2} \right) \]

Where:

\( M_R \) : Heeling moment, in t
\( V_0 \) : Service speed, in m/s
\( T_1 \) : Mean draught, in m
\( KG \) : Height of centre of gravity above keel, in m.

d) The Society is to be satisfied that the above criteria can be maintained when the devices are in operation, where anti-rolling devices are installed in a ship.

e) Stability criteria

1) Loading conditions

Along with the loading conditions considered in Section 4, the loading condition at arrival, devoid of cargo, with essential water ballast, with all passengers, on all decks assigned to them, crowded on the same side of the ship, is also to be considered. If, in any real loading condition, the stability of the ship is less favorable than in the requested conditions, the stability requisites are also to be checked in such real condition.

In elaborating the stability booklet, following assumptions are to be made:

- weight of each person equal to 75 kg;
- centre of gravity of each person, both standing and sitting, equal to 0.90 m above the upper surface of the relevant deck;
- maximum allowable number of persons equal to the number of sitting places plus two passengers/m²
- m² in the areas available for passengers, clear from the persons seated.

If the competent authority agrees, it may be assumed that number of standing persons is higher.

In calculating the area in which the passengers are crowded among the benches, the distance between two of them may be reduced by 0.3 m x l (length of the bench) to exclude the area obstructed by sitting passengers.
2) Stability requirements in all required loading conditions. The following stability requirements are to be conformed to:

- (r-a) to be not less than 0.35 m.

To this end passengers are to be considered accommodated taking all the sitting places and areas assigned to them with 4 passengers/m², beginning from the highest deck and reaching up to lower decks until the maximum permissible number of passengers is exceeded;

- Distance between the upper surface of the main deck, at side, from the waterline in the final equilibrium status of heeled ship (residual minimum freeboard) not to be below 0.20 m. For this purpose, until the maximum permissible number of passengers is exceeded, passengers are to be considered accommodated on one side of the ship only, from the ship's centreline, taking all the sitting places and regions assigned to them with 4 passengers/m², starting from the highest deck and proceeding to lower decks. If number of all the passengers on one side of the ship does not reach the maximum permissible number, the additional passengers are to be overlooked while calculating the transverse heeling of the ship.

- The maximum permissible number of passengers is to be the lower of 1 and 2 above. These numbers may further be reduced taking into account the following:

  - if the value calculated according to 1 leads to a value of (r-a) less than 0.30 m and this cannot be avoided by the use of ballast of the ship, or by other suitable operations, such number is to be decreased in the calculation by unloading a suitable number of passengers, starting from the lower deck, until (r-a) not less than 0.30 m is reached. Therefore, the resulting reduced number of passengers is to replace the one resulting from 1.

  - if the residual freeboard, calculated through the passenger distribution according to 2, is less than 0.20 m and it cannot be increased by ballasting the ship, or by other suitable operations, the number of passengers calculated according to 2 is to be decreased in the calculation by unloading a suitable number of passengers, starting from those standing closest to the midship plane on the lower deck. Obviously, in such operation an upper deck is not affected by unloading of passengers as far as first all those standing, and then those sitting, in the lower deck are unloaded. The resulting reduced number of passengers is to replace the one resulting from 2.

  - For longitudinal obstructions, such as seats, railings or nets, that are fitted to check passengers from crowding on one side of the ship, the Society may, at its discretion, relax the above-mentioned requisites, decreasing the level of crowding of standing persons. Such longitudinal obstructions may be partly movable for the purpose of ascertaining an appropriate distribution of embarking passengers; nevertheless, the crew undertakes to put the longitudinal obstructions temporarily removed back in place, before the voyage begins.

  - To assist in the calculations, it is allowed not to take into consideration both the shear and the camber of the ship, but to assess the vertical positions of all the centres of gravity referring to the section at ½ L.
Any opening side scuttles situated below the upper deck which, due to the transverse heeling of the ship, may have their lowest point less than 0.20 m above the final waterline, are to be fitted with efficient devices such that they can be effectively closed and protected, under the Master's responsibility, while the passengers are on board. Such condition is to be noted in the ship's logbook. It is permissible in the calculations that such side scuttles are partly or fully submerged at the end of the heeling. In the case of decked ships with length less than 20 m, item b) applies except that the required residual freeboard on the side of passenger crowding, to be not less than 0.20 m, is to correspond to a heeling angle not more than 15°. In the case of ships without decks, the residual freeboard after heeling due to the crowding of passengers on one side of the ship is not to be below 0.30 m with an angle of heel not greater than 15°.

f) Elements affecting stability

A number of influences, such as beam wind on ships with a large windage area, water trapped on deck, icing of topsides, rolling characteristics, following seas etc., which unfavorably affect stability are to be taken into consideration.

g) Elements reducing stability

At all stages of the voyage, provisions are to be made for a safe margin of stability and consideration is being given to additions of weight, such as those due to absorption of water and icing (details regarding ice accumulation are given in [2.6] and to losses of weight such as those due to consumption of fuel and stores.

2.3. Stability criteria according to the type of ship

2.3.1. Passenger ships

2.3.1.1. Standard loading conditions

The requisites of this paragraph are applicable to passenger ships other than those indicated in [2.2.1.2]. The intact stability is to be proven for the standard load conditions given below:

a) at the beginning of the voyage:
   100% passengers, 98% fuel and fresh water, 10% waste water;

b) during the voyage:
   100% passengers, 50% fuel and fresh water, 50% waste water;

c) at the end of the voyage:
   100% passengers, 10% fuel and fresh water, 98% waste water;

d) unladen vessel:
   No passengers, 10% fuel and fresh water, no waste water.

For all standard load conditions, in accordance with normal operational conditions, the ballast tanks are to be considered as either empty or full. As a pre-condition for changing the ballast whilst underway, the requisites of [2.3.1.3] to [2.3.1.5] are to be proved for the following load condition:

100% passengers, 50% fuel and fresh water, 50% waste water, all other liquid (including ballast) tanks are considered filled to 50%.
2.3.1.2. GZ curve area

The area under the righting lever curve (GZ curve) is to be not less than 0.055 m-rad up to J = 30° angle of heel and not less than 0.09 m-rad up to J = 40° or the angle of down flooding \( \phi_f \) if this angle is less than 40°. Additionally, the area under the righting lever curve (GZ curve) between the angles of heel of 30° and 40°, or between 30° and \( \phi_f \), if this angle is less than 40°, is to be not less than 0.03 m-rad.

Note 1: \( \phi_f \) is an angle of heel at which openings in the superstructures, hull or deckhouses which cannot be closed weathertight plunge. When this criterion is applied, small openings through which progressive flooding cannot take place need not be considered as open.

2.3.1.3. Minimum righting lever

The righting lever GZ is to be at least 0.20 m at an angle of heel equal to or greater than 30°.

2.3.1.4. Angle of maximum righting lever

The maximum righting arm is to occur at an angle of heel preferably exceeding 30° but not less than 25°. When the righting lever curve has a shape with two maximums, the first is to be located at a heel angle not less than 25°. In cases of ships with a particular design, the Society may accept an angle of heel \( \phi_f \) max less than 25° but in no case less than 15°, if the area “\( A_{lp} \)” below the righting lever curve is not less than the value obtained, in m-rad, from the formula given under:

\[
A_{lp} = 0.055 + 0.001 (30° - q_{max})
\]

Where \( q_{max} \) is the angle of heel in degrees at which the righting lever curve attains its maximum.

2.3.1.5. Initial metacentric height

The initial metacentric height GM₀ is not to be less than 0.15 m.

2.3.1.6. Elements affecting stability

A number of influences, such as beam wind on ships with a large windage area, water trapped on deck, icing of topsides, rolling characteristics, following seas etc., which unfavorably affect stability, are to be taken into consideration.

2.3.1.7. Elements reducing stability

At all stages of the voyage, provisions are to be made for a safe margin of stability, consideration being given to additions of weight, such as those due to absorption of water and icing (details regarding ice accretion are given in [2.5]) and to losses of weight, such as those due to consumption of fuel and stores.

2.3.1.8. Moment due to crowding of passengers

The heeling moment due to one-sided accumulation of persons is to be calculated as per the formula given under:

\[
M_p = g \times m_p \times y = g \cdot \Sigma P_i \cdot y_i \text{ (kNm)}
\]

Where:
m_p : total mass of persons on board in (t), calculated by adding up the maximum permitted number of passengers and the maximum number of shipboard personnel and crew under normal operating conditions, assuming an average mass per person of 0.075 t;

y : lateral distance of centre of gravity of total mass of persons P from centreline in (m);

g : acceleration of gravity (g = 9.81 m/s^2);

m_{pa} : mass of persons accumulated on area Ai in (t)

P_i = n_i \times 0.075 \times A_i (t)

Where:

A_i : area occupied by persons in (m^2)

n_i : number of persons per square meter

n_i : 4 for free deck areas and deck areas with movable furniture; for deck areas with fixed seating furniture such as benches, n_i is to be calculated by assuming an area of 0.45 m in width and 0.75 m in seat depth per person

y_i : lateral distance of geometric centre of area A_i from centreline in (m).

The calculation is to be done for an accumulation of persons both to starboard and to port. The distribution of persons is to correspond to the most hostile one from the point of view of stability. For the calculation of the persons’ moment, cabins are to be assumed unoccupied.

For the calculation of the loading cases, the centre of gravity of a person is to be taken as 1 m above the lowest point of the deck at 0.5 LWL, disregarding any deck curvature and assuming a mass of 0.075 t per person.

A detailed calculation of deck areas which are occupied by persons may be dispensed with, if the following values are used:

\[ P = 1.1 \cdot F_{\text{max}} \cdot 0.075 \text{ for day trip vessels} \]
\[ 1.5 \cdot F_{\text{max}} \cdot 0.075 \text{ for cabin vessels} \]

Where:

F_{\text{max}} = \text{maximum permitted number of passengers on board}

y = B/2 in (m).

day trip vessel = a passenger vessel without overnight passenger cabins;
cabin vessel = a passenger vessel with overnight passenger cabins.

2.3.1.9. Moment due to lateral wind pressure

The moment due to wind pressure (Mw) is to be calculated as follows:

\[ M_w = p_w \cdot A_w \cdot (l_w + T/2) \text{ (kNm)} \]

Where:

p_w = the specific wind pressure, in kN/m^2, defined in Tab1;
Table 8.2.1: Specific wind pressure

<table>
<thead>
<tr>
<th>Range of navigation</th>
<th>Pw, in kN/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>R200</td>
<td>0.25</td>
</tr>
<tr>
<td>R0</td>
<td>0.15</td>
</tr>
</tbody>
</table>

\[ Aw = \text{lateral plane of the vessel above the plane of draught according to the considered loading condition in m}^2; \]
\[ lw = \text{distance of the centre of gravity of the lateral plane AW from the plane of draught according to the considered loading condition in m}. \]

2.3.1.10. Turning circle moment

The moment due to centrifugal force (Mdr), caused by the turning of the vessel, is to be calculated as follows:

\[ Mdr = cdr \cdot CB \cdot V_s^2 \cdot \Delta /LWL \cdot (KG - T/2) \text{(kNm)} \]

Where:

- \( cdr = \text{a coefficient of 0.45}; \)
- \( CB = \text{block coefficient (if not known, taken as 1.0)}; \)
- \( V_s = \text{maximum speed of the vessel in m/s}; \)
- \( KG = \text{distance between the centre of gravity and the keel line in m}; \)
- \( \Delta = \text{displacement of the vessel (t)} \)

For passenger vessels with propulsion systems (rudder propeller, water jet, cycloidal propeller and bow thruster) Mdr is to be derived from full scale or model tests or else from corresponding calculations.

2.3.1.11. Maximum list angle and minimum freeboard height

a) Under the action of the above heeling moment acting not at the same time, the heeling angle shall be not more than of 12°.

b) For a heeling moment resulting from moments due to passengers, wind and turning as per [2.3.1.8], [2.3.1.9] and [2.3.1.10] the residual freeboard shall be not below 200 mm.

c) For vessels with windows or other openings in the hull and situated below the bulkhead decks and not closed watertight, the residual safety clearance is to be at least 100 mm on the application of the three heeling moments resulting from subparagraph (b).
2.3.1.12. Safety clearance and freeboard

a) The safety clearance is to be at least equal to the sum of:

1) the additional lateral immersion, which, measured on the outside plating, is produced by the permissible heeling angle according to [2.3.1.11] a), and
2) the residual safety clearance as per [2.3.1.11] c).

For vessels without a bulkhead deck, the safety clearance is to be at least 500 mm.

b) The freeboard is to be at least equal to the sum of:

1) the additional lateral immersion, which, measured on the outside plating, is produced by the heeling angle according to [2.3.1.11] a), and
2) the residual freeboard according to [2.3.1.11] b). However, the freeboard is to be at least 300 mm.

c) The plane of maximum draught is to be set so as to ascertain conformation to the safety clearance as per [2.3.1.12]a) and the freeboard as per [2.3.1.12]b).

2.3.2. Intact stability criteria applicable to floating equipment

2.3.2.1. Definition and documentation to be submitted

Floating equipment is to be intended as a floating installation transmitting working gear such as cranes, dredging equipment, pile drivers or elevators. Stability confirmation is to comprise of the data and documents given below:

a) scale drawings of floats and working gear and the detailed data relating to these that are needed to confirm stability, such as content of the tanks, openings providing access to the inside of the vessel etc.;

b) hydrostatic data or curves;

c) curves for the static stability lever curve;

d) description of the operating conditions together with the corresponding data concerning weight and centre of gravity, including the equipment's unladen state and the situation as regards transport;

e) calculation of the heeling, trimming and righting moments, with specification of the trim and heeling angles and the corresponding residual freeboard and residual safety clearances;

f) compilation of the results of the calculation with specification of the limits for operation and the maximum loads.

2.3.2.2. Load assumptions

Confirmation of stability is to be based on at least the following load assumptions:

a) specific mass of the dredging products for dredgers:

- sands and gravels: 1.5 t/m³,
- very wet sands: 2.0 t/m³,
- soil, on average: 1.8 t/m³,
- mixture of sand and water in the ducts: 1.3 t/m³;

b) for clamshell dredgers, the values given under point (a) are to be increased by 15%.
c) for hydraulic dredgers the maximum lifting power is to be considered.

2.3.2.3. Stability confirmation

Confirmation of stability is to take account of the moments resulting from:

a) load;
b) asymmetrical structure;
c) wind pressure;
d) turning whilst underway of self-propelled floating equipment;
e) cross-current, if necessary;
f) ballast and provisions;
g) deck loads and, where appropriate, cargo;
h) free surfaces of liquids;
i) inertia forces;
j) other mechanical equipment.

The moments which may act simultaneously are to be added up.

2.3.2.4. Stability Requirements

It is to be validated that, taking into account the loads applied during the use and operation of the working gear, and the residual safety clearance and the residual freeboard are not less than:

a) residual safety clearance:
   - 0.30 m for watertight and weathertight aperture;
   - 0.40 m for non-weathertight openings;

b) residual freeboard
   - The residual freeboard value is to be not less than 0.30 m.
   - The sum of the list and trim angles is not to go beyond 10° and the base of the hull is not to surface.

2.3.2.5. Stability assessment

The stability assessment is to be executed considering the heeling moments defined in [2.3.2.6] to [2.3.12]. The moments which may act at the same time are to be added up.

2.3.2.6. Load-induced moment

The above moment will be given by the Designer.

2.3.2.7. Asymmetrical structure induced moment

The above moment will be given by the Designer.

2.3.2.8. Moment due to wind pressure

The moment that results by the wind pressure is to be calculated using the formula given under:

\[ M_w = c \cdot p_w \cdot A_{ip} \left( l_w + \frac{V}{2} \right) [kNm] \]

Where:
\[ c = \text{shape-dependent coefficient of resistance} \]
- for frameworks \( c = 1.2 \)
- for solid-section beams \( c = 1.6 \)
- both values take account of gusts of wind.

The whole area encompassed by the contour line of the framework is to be taken to be the surface area exposed to the wind.

\( pw \) = specific wind pressure; this is to be taken to be in conformity with Table 8.2.2;

<table>
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<td>R0</td>
<td>0.15</td>
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</tbody>
</table>

\( A_p \) = lateral plane above the plane of maximum draught in \( m^2 \),
\( lw \) = distance from the centre of area of the lateral plane \( A \) from the plane of maximum draught, in \( m \).

2.3.2.9. Turning circle induced moment

For self-propelled vessels the moments due to turning whilst underway may be derived from the following formula.

\[
M_{dr} = c_{dr} \cdot C_B \cdot V_s^2 \cdot \Delta / L_{WL} \cdot (K_G - T/2) \text{ (kNm)}
\]

Where:
\( c_{dr} \) = a coefficient of 0.45;
\( C_B \) = block coefficient (if not known, taken as 1.0);
\( V_s \) = maximum speed of the vessel in m/s;
\( K_G \) = distance between the centre of gravity and the keel line in m.
\( \Delta \) = displacement of the vessel (t)

2.3.2.10. Cross-current moment

For floating equipment which is anchored or moored across the current while operating, the moment resulting from cross-current is to be taken into consideration only.

2.3.2.11. Ballast and supplies induced moment

From the point of view of stability, the least favorable extent of tank filling is to be determined and the corresponding moment is to be introduced into the calculation when determining the moments resulting from liquid ballast and liquid provisions.
2.3.2.12. Moment due to inertia forces

The moment resulting from inertia forces as per the paragraph 2.3.2.3 (i) is to be given due consideration if the movements of the load and the working gear are likely to affect stability.

2.3.2.13. Moment due to clear surfaces occupied by liquid

The moment due to clear surfaces occupied by liquid is to be calculated as per [2.4].

2.3.2.14. Moment due to other mechanical equipment

The above moment will be given by the Designer.

2.3.2.15. The righting moments for floats with vertical side walls may be calculated using the following formula:

$$Ma = 10 \cdot \Delta \cdot GM \sin \phi \text{ (kNm)}$$

Where:

- $GM =$ metacentric height, in m;
- $\Phi =$ heeling angle in degrees;
- $\Delta =$ displacement of the vessel (t).

Up to heeling angles of 10° or up to a heeling angle corresponding to immersion of the edge of the deck or emergence of the edge of the bottom; this formula is to apply and the smallest angle is to be decisive. To slanting side walls up to heeling angles of 5°, this formula may also apply. If the particular shape of the float(s) does not allow such simplification, the righting lever curves as per paragraph 2.4.7 are necessary.

2.3.2.16. Intact stability in the case of reduced residual freeboard

a) after correction for the free surfaces of liquids, the metacentric height is not less than 0.15 m;

b) for heeling angles between 0 and 30°, there is a righting lever of at least

$$h = 0.30 - 0.28 \cdot \phi_n \text{ (m)}$$

$\phi_n$ being the heeling angle from which the righting lever curve displays negative values (range of stability); it is to be not less than 20° or 0.35 rad and is not to be introduced into the formula for more than 30° or 0.52 rad, taking the radian (rad) ($1^\circ = 0.01745$ rad) for the unit of $\phi^\circ$;

c) the sum of the trim and heeling angles does not exceed 10°;

d) the residual safety clearance is at least:

- 0.30 m for watertight and weathertight openings
- 0.40 m for non-watertight openings

e) there is a residual freeboard of at least 0.05 m;

f) for heeling angles between 0° and 30°, a residual righting lever of at least

$$h = 0.20 - 0.23 \cdot \phi_n \text{ (m)}$$

remains, where $\phi_n$ is the heeling angle from which the righting lever curve displays negative values; it is not to be introduced into the formula for more than 30° or 0.52 rad.

Residual righting lever means the maximum difference existing between 0° and 30° of heel between the righting lever curve and the heeling lever curve. If an
opening towards the inside of the vessel is reached by the water at a heeling angle less than that corresponding to the maximum difference between the lever curves, the lever corresponding to that heeling angle is to be taken into account.

2.3.2.17. Floating installation without confirmation of stability

The following floating equipment may be dispensed from the application of requirements from [2.3.2.4] to [2.3.2.16]:

a) equipment whose working gear can in no way alter its heel or trim, and
b) where any displacement of the centre of gravity can be reasonably excluded.

However:

a) at maximum load the safety clearance is to be at least 0.30 m and the freeboard at least 0.15 m;
b) for apertures which cannot be closed spray-proof and weathertight the safety clearance is to be at least 0.50 m.

2.3.2.18. Intact stability criteria applicable to worksite craft

a) Worksite craft means a vessel, appropriately built and equipped for use at worksites, such as a reclamation barge, hopper or pontoon barge, pontoon or stone dumping vessel;
b) Worksite craft designated as such may navigate outside worksites only when unladen. That restriction shall be entered on the relevant certificate.
c) If a worksite craft is put to use as a reclamation barge or a hopper barge the safety clearance outside the hold area shall be at least 300 mm and at the freeboard at least 150 mm. IRS may allow a smaller freeboard, if by calculation, proof is given that stability is adequate for a cargo with a specific mass of 1.5t/m³ and that no side of the deck get in touch with the water. The effect of liquefied cargo shall be taken into consideration.

2.3.3. Vessel carrying containers

2.3.3.1. The provisions of paragraphs 2.3.3 and 2.3.4 are applicable to vessels transmitting containers. Stability documents are to provide the Master with comprehensible information on vessel stability for each loading condition. Stability documents are to comprise of at least the following:

a) information on the permissible stability coefficients, the permissible KG values or the permissible heights for the centre of gravity of the cargo;
b) data concerning spaces that can be filled with ballast water;
c) forms for checking stability;
d) Instructions or an example of a calculation for use by the Master.

For vessels where it is optional whether containers are carried non-secured or secured, separate calculation methods are to be provided for confirmation of stability for transport of both non-secured and secured cargoes of containers.

A cargo of containers is only to be considered secured if each individual container is firmly attached to the hull of the vessel by means of container guides or securing equipment and its position cannot alter during the voyage.
2.3.3.2. Intact stability of ships carrying non-secured containers

All methods of calculating vessel stability in the case of non-secured containers are to meet the following limit conditions:

a) Metacentric height \( GM \) is to be not less than 1.00 m;
b) Under the joint action of the centrifugal force resulting from the vessel's turning, wind pressure and the free surfaces of liquids, the heeling angle is not to exceed 5° and the edge of the deck is not to be immersed;
c) The heeling lever resulting from the centrifugal force caused by the vessel's turning is to be determined in accordance with the following formula:

\[
h_{kz} = c_{kz} \cdot \frac{v^2}{LW} \cdot \left( KG - \frac{T'}{2} \right) [m]
\]

Where:
- \( c_{kz} \): parameter (\( c_{kz} = 0.04 \)) (\( s^2/m \));
- \( v \): the maximum speed of the vessel in relation to the water (\( m/s \));
- \( KG \): height of centre of gravity of the laden vessel above its base (m);
- \( T' \): draught of the laden vessel (m).
d) The heeling lever resulting from the wind pressure is to be determined in accordance with the following formula:

\[
h_{KW} = c_{KW} \cdot \frac{A_{lp'} \cdot \Delta'}{\Delta} \cdot \left( l_w + \frac{T'}{2} \right) [m]
\]

Where:
- \( c_{KW} \): parameter in (\( t/m^2 \)) to be assumed in conformity with Table 8.2.3;

<table>
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</tr>
</tbody>
</table>

\( A_{lp'} \): lateral plane above the respective plane of draught with the vessel laden (m²);
\( \Delta' \): displacement of the laden vessel (t);
\( l_w \): height of the centre of gravity of the lateral plane \( A' \) above the respective plane of draught (m);
\( T' \): draught of the laden vessel (m).
e) The heeling lever resulting from the free surfaces of rainwater and residual water within the hold or the double bottom is to be determined in accordance with the following formula:

\[
h_{Kfo} = c_{Kfo} \cdot \frac{ \Delta }{b_{ho} \cdot l_{ho}} \cdot \sum b_{ho} \cdot l_{ho} \cdot \left( b_{ho} - (0.55 \sqrt{b_{ho}}) \right) [m]
\]

Where:
- \( c_{Kfo} \): parameter (\( c_{Kfo} = 0.015 \)) (\( t/m^2 \))
- \( b_{ho} \): width of hold or section of the hold in question (m); (see Note 1)
LEN: length of hold or section of the hold in question (m); (see Note 1)

Δ': displacement of the laden vessel (t);

f) Half of the fuel and fresh water supply is to be taken into account for each load condition.

Note 1: The hold sections providing free surfaces that are exposed to water arise from the longitudinal and/or transverse watertight compartmentalization that forms independent sections.

2.3.3.3. The stability of a vessel carrying non-secured containers is to be considered sufficient if the effective KG does not exceed the KG_{zul} resulting from the following formulae. The KG_{zul} is to be calculated for various displacements covering the entire range of draughts.

\[ KG_{zul} = \frac{KM + \frac{BWL}{2F} \left( \frac{Z}{2} Tm - h_{KW} - h_{Kfo} \right)}{BWL\frac{Z+1}{2F}} [m] \]

No value less than 11, 5 (11.5 = 1/tan5°) is to be taken for B/WL/2F

b) KG_{zul} = KM - 1.00 (m)

The lowest value of KG_{zul} in accordance with formula (a) or (b) is to be decisive.

Within the formulae:

KG_{zul} : maximum permissible height of the laden vessel's centre of gravity above its base (m);

KM : height of the metacenter above the base (m) in accordance with the approximation formula in paragraph 3;

F : respective effective freeboard at 1/2 L (m);

Z : parameter for the centrifugal force resulting from turning

v : respective effective freeboard at 1/2 L (m);

t_m : respective average draught (m);

h_{KW} : heeling lever resulting from lateral wind pressure according to [2.3.3.2] d) 1(d) (m);

h_{Kfo} : sum of the heeling levers resulting from the free surfaces of liquids according to [2.3.3.2] e) (m).

2.3.3.4. Approximation formula for KM

Where no sheet of hydrostatic curves is available, the value KM may be determined by the following approximation formulae:
The value KM may be determined by the underlying approximation formulae, where no sheet of hydrostatic curves is available:

a) for vessels in the shape of a pontoon:

\[ KM = \frac{B^2WL}{(12.5 - \frac{Tm}{2}) Tm} + \frac{Tm}{2} \]

b) for other vessels
2.3.4. Intact stability of ships carrying secured containers

2.3.4.1. All methods of calculating vessel stability in the case of secured containers are to meet the following limit conditions:

a) metacentric height $GM$ is to be not less than 0.50 m;
b) no hull opening is to be immersed by the joint action of the centrifugal force resulting from the turning of the vessel, the wind pressure and the free surfaces of liquids;
c) the heeling levers resulting from the centrifugal force due to the vessel's turning, the wind pressure and the free surfaces of liquids are to be determined in accordance with the formulae referred to in (2.3.3.1) (c) to (e);
d) half of the fuel and fresh water supply is to be taken into account for each load condition.

2.3.4.2. The stability of a vessel carrying secured containers is to be considered sufficient if the effective $KG$ does not exceed the $KG_{zul}$ resulting from the following formulae that has been calculated for various displacements covering the entire range of draughts.

$$KG_{zul} = \frac{KM + \frac{B^2_{WL}}{(1.7-1.2 \frac{TR}{L})TR + \frac{TR}{2} (m)}}{0.75 \frac{B_{WL}}{F} Z + 1}$$

No value less than 6.6 is to be taken for $BWL/F'$ and no value less than 0 for $l_{T_{wl}} - i (1 - 1.5 \frac{F}{F'})$.

b) $KG_{zul} = KM - 0.50 \text{ (m)}$

The lowest value for $KG_{zul}$ in accordance with formula (a) or (b) is to be decisive.

Within these formulae, apart from the terms defined previously:

$I_{T_{wl}}$ : transverse moment of inertia of the waterline area at $T_m$ (m$^4$) (for the approximation formula see paragraph 2.3.4.3);

$i$ : transverse moment of inertia of the waterline area parallel to the base, at height $Z$;

$\forall$ : water displacement of the vessel at $T_m$ (m$^3$);

$F'$ : ideal freeboard $F' = H' - T_m$ (m) or

$$F' = a. \frac{B_{WL}}{2.2} \text{ [m]}$$

a : the vertical distance between the lower edge of the opening that is first immersed in the event of heeling and the waterline in the vessel's upright position (m);
b : distance from that same opening from the centre of the vessel (m);
H' : ideal side height

q : sum of the volumes of the deckhouses, hatches, trunk decks and other superstructures up to a maximum height of 1.0 m above H or up to the lowest aperture in the volume under consideration, the lowest value being decisive. Parts of volumes located within a range of 0.05 m from the extremities of the vessel are not to be taken into account (m3).

2.3.4.3. Approximation formula for I

Where there is no sheet of hydrostatic curves available the value for the transverse moment of inertia I of the waterline area may be calculated by the following approximation formulae:

a) metacentric height GM is to be not less than 0.50 m:

b) for other vessels:

2.3.5. Ships carrying bulk dry cargo

2.3.5.1. The requisites of this paragraph are to be applied to ships transmitting dry bulk cargo.

2.3.5.2. Heeling moments

a) Moment due to wind pressure

The moment caused by the wind pressure is to be calculated in accordance with the following formula:

Where:

c = shape-dependent coefficient of resistance
- for frameworks c = 1.2
- for solid-section beams c = 1.6
- both values take account of gusts of wind.

\[ p_w = \text{specific wind pressure; this is to be taken to be in conformity with Table 8.2.4;} \]

\[
\begin{array}{|c|c|}
\hline
\text{Range of navigation} & \text{Pw, in kN/m}^2 \\
\hline
\text{R200} & 0.25 \\
\text{R}) & 0.15 \\
\hline
\end{array}
\]

\[ A_{lp} = \text{lateral plane above the plane of maximum draught in m}^2; \]

\[ lw = \text{distance from the centre of area of the lateral plane } A_{lp} \text{ from the plane of maximum draught, in m.} \]

b) Turning circle induced moment

For self-propelled vessels the moments due to turning whilst underway may be derived from the following formula.

\[ M_d = \text{cdr} \cdot C_B \cdot V_s^2 \cdot \Delta/WL \cdot (KG - T/2) \text{ (kNm)} \]

Where:

cdr = a coefficient of 0.45;

\[ C_B = \text{block coefficient (if not known, taken as 1.0);} \]
\( V_s \) = maximum speed of the vessel in m/s;

\( KG \) = distance between the centre of gravity and the keel line in m.

\( \Delta \) = displacement of the vessel (t)

c) Cargo shift induced moment

For cargo ships carrying goods such as grain or cement, where the vessel lists to an inclination greater than its angle of repose, the cargo shifting induced moment is to be taken into account.

Such moment may be calculated according to ***** of the IRS Rules for the Classification of Ships. In any case such moment is to be calculated assuming an angle of the resulting cargo surface after shifting of 12°.

2.3.5.3. Intact stability requirements

At any time during the voyage the following requirements are to be met:

a) the angle of heel \( \phi_1 \) is to be not greater than 12°;

b) from the lever arm curve it is to be verified that the residual area between the heeling arm curve and the righting arm curve up to an angle of heel \( \phi_2 \) is not less than 0.0065 m.rad in all conditions of loading,

Where:

\( \phi_1 \) : is the heeling angle due to the cargo shift heeling moment

\( \phi_2 \) : is the angle of heel of maximum difference between the ordinates of the heeling arm curve and the righting arm curve, or 27°, or the angle of flooding, whichever is the least.

When ships may list to an angle greater than their angle of repose, such as is the case with vessels carrying grain or cement, the following requirements are to be satisfied:

a) all necessary and reasonable trimming is to be performed to level all free cargo surfaces and minimize the effect of cargo shifting,

b) the surface of the bulk cargo in any partially filled compartment is to be secured so as prevent a cargo shift by over stowing,

c) the longitudinal subdivision in the holds or compartments is to minimize the possibility of shift of cargo.

2.3.6. Tankers

2.3.6.1. Intact stability requirements

According to the requisites stated from [2.2.1.3] to [2.2.1.5], stability is to be assessed.

For ships with cargo tanks of more than 0.70 B in width, the following intact stability requirements are to be satisfied:

a) a minimum righting lever GZ value of 0.10 m is to be reached within the range of positive stability, limited by the angle at which unprotected openings become submerged

b) the area below the GZ curve within the range of positive stability, limited by the angle at which unprotected openings become submerged or 27°, whichever is the lesser, is to be not less than 0.024 m-rad

c) the initial metacentric height \( GM_0 \) value is to be at least 0.10 m
Whatever be the case, the effects of free surfaces of liquids in tanks are to be considered as per [2.4.].

2.3.6.2. Intact Stability for Tankers carrying dangerous Good

a) The basic values for the stability calculation - the vessel's lightweight and location of the centre of gravity - shall be determined either with the help of an inclining experiment or by detailed mass and moment calculation. In the latter case, the lightweight of the vessel shall be checked with the help of a lightweight test with a tolerance limit of \( \pm 5\% \) between the mass determined by calculation and the displacement determined by the draught readings.

b) For all stages of loading and final unloading condition, proof of adequate intact stability shall be furnished.

c) Stability (intact)

According to the requisites stated from [2.2.1.3] to [2.2.1.5], stability is to be assessed:

1) The requisites for intact stability resulting from the damage stability calculation shall be fully observed.

2) For vessels with cargo tanks of more than 0.70 B in width, additional proof shall be furnished that, at an angle of 5° or, when this angle is less, at a heeling angle at which an opening becomes immersed, the righting arm is 0.10 m. The stability-reducing free surface effect in the case of cargo tanks filled to less than 95% of their capacity shall be taken into account.

3) The most stringent requirement of items [2.3.6.1]c) 1) and [2.3.6.1]c) 2) is applicable to the vessel.

2.3.7. Intact Stability for cargo ships carrying dry dangerous goods

2.3.7.1.

a. The basic values for the stability calculation - the vessel's lightweight and location of the centre of gravity - shall be determined either by means of an inclining experiment or by detailed mass and moment calculation. In the latter case the lightweight of the vessel shall be checked by means of a lightweight test with a tolerance limit of \( \pm 5\% \) between the mass determined by calculation and the displacement determined by the draught readings.

b. Proof of sufficient intact stability shall be furnished for all stages of loading and unloading and for the final loading condition.

c. Stability (intact)

1) Stability is to be assessed according to the requirements stated from [2.2.1.3] to [2.2.1.5] and [2.2.3.5] as applicable.

2) The requirements for intact stability resulting from the damaged stability calculations shall be fully complied with.

3) For the carriage of containers, proof of sufficient stability shall also be furnished in accordance with the provision of national regulations.

4) In addition for the carriage of containers also the requirements given in [2.2.3.3] and [2.2.3.4] are to be applied.

2.3.8. Tugs and pushers

2.3.8.1. Intact stability requirements

Proof of adequate intact stability is to be verified according to the general criteria given in [2.2.1].
In addition the following checks are to be carried out:

a) Thrust action

Thrust is to be taken into account on the basis of the maximum permissible heeling moment \( M_{adm} \) as indicated in 2.3.7.1.

b) The stability of tugs is considered to be sufficient if the maximum permissible heeling moment \( M_{adm} \) of the ship is not less than the sum of the heeling moments resulting from the dynamic effect of wind \( M_{dv} \) as in [2.3.7.1] c) and from the dynamic effect of the lateral component of the bollard pull force \( M_t \) specified below, i.e. if:

\[
M_{adm} > M_{dv} + M_t
\]

The heeling moment, in kN.m, resulting from the dynamic effect of the lateral component of the bollard pull force is given by the formula:

\[
M_t = 1.1 T \cdot (Z_t - d)
\]

Where:

\( Z_t \) : height of the point of application of the bollard pull force above the base line, in m

\( T \) : maximum bollard pull force measured on checking at moorings, in kN.

Where the force \( T \) is not known, the following values are to be assumed for calculation purposes:

- for \( \Delta \leq 30 \text{ t} \):
  \( T = 0.13 N_e \), for tugs without propeller nozzles;
  \( T = 0.20 N_e \), for tugs with propeller nozzles;

- for \( \Delta > 30 \text{ t} \):
  \( T = 0.16 N_e \), for tugs without propeller nozzles;
  \( T = 0.20 N_e \), for tugs with propeller nozzles; where \( N_e \) is the total power of the main machinery, in kW.

In addition, the stability of each tug is to be such that the angle of heel resulting from the combined effect of the dynamic wind pressure moment \( M_{dv} \) and the moment \( M_{fc} \) of the centrifugal force on turning does not exceed the critical angle, and, in any case, is less than 15°.

c) Moment due to wind pressure

The moment caused by the wind pressure is to be calculated in accordance with the following formula: where:

\[ c = \text{shape-dependent coefficient of resistance} \]

- for frameworks \( c = 1.2 \)
- for solid-section beams \( c = 1.6 \)
- both values take account of gusts of wind.

The whole area encompassed by the contour line of the framework is to be taken to be the surface area exposed to the wind.

\( pw \) = specific wind pressure; this is to be taken to be in conformity with Table 8.2.5:

<table>
<thead>
<tr>
<th>Range of navigation</th>
<th>( P_w ), in kN/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>R200</td>
<td>0.25</td>
</tr>
<tr>
<td>R0</td>
<td>0.15</td>
</tr>
</tbody>
</table>
2.4. Effects of free surfaces of liquids in tanks

2.4.1. General

2.4.1.1. The initial metacentric height and the righting lever curve are to be right for the effect of free surfaces of liquids in tanks for all loading conditions.

2.4.2. Consideration of free surface effects

2.4.2.1. Free surface effects are to be considered whenever the filling level in a tank is less than 98% of full condition.

Free surface effects need not be considered where a tank is nominally full, i.e. filling level is 98% or above. Free surface effects for small tanks may be ignored under the condition in [2.4.9.1].

2.4.2.2. For ships that have cargo tanks with more breadth than 60% of the ship's maximum beam, the free surface effects when the tanks are filled at 98% or above may not be ignored.

2.4.3. Categories of tanks

2.4.3.1. Tanks which are taken into consideration when determining the free surface correction may be in one of two categories:

- Tanks with fixed filling level (e.g. liquid cargo, water ballast). The free surface correction is to be defined for the actual filling level to be used in each tank.
- Tanks with variable filling level (e.g. consumable liquids such as fuel oil, diesel oil and fresh water, and also liquid cargo and water ballast during liquid transfer operations). Except as permitted in [2.4.5.1] and [2.4.6.1], the free surface correction is to be the maximum value attainable among the filling limits envisaged for each tank, consistent with any operating instructions.

2.4.4. Consumable liquids

2.4.4.1. For tanks containing consumable liquids, when the free surface effect are calculated, it is to be assumed that for each type of liquid at least one transverse pair or a single centerline tank has a free surface and the tank or combination of tanks taken into account is to be the one where the effect of free surface is the most.

2.4.5. Water ballast tanks

2.4.5.1. Where during the course of the voyage, water ballast tanks, including anti-rolling tanks and anti-heeling tanks, are to be filled or discharged; the free surface effect is to be calculated to get an account of the most arduous transitory stage relating to such operations.

2.4.6. Liquid transfer operations

2.4.6.1. For ships involved in liquid transfer operations, the free surface corrections at any stage of the liquid transfer operations, may be determined as per the filling level in each tank at the stage of the transfer operation.
2.4.7. GM₀ and GZ curve corrections

2.4.7.1. The corrections to the initial metacentric height and to the righting lever curve are to be addressed separately as indicated in [2.4.7.2] and [2.4.7.3].

2.4.7.2. In determining the correction to the initial metacentric height, the transverse moments of inertia of the tanks are to be calculated at 0 degrees angle of heel according to the categories indicated in [2.4.3.1].

2.4.7.3. The righting lever curve may be corrected by any of the following methods:

- Correction based on the actual moment of fluid transfer for each angle of heel calculated; corrections may be calculated according to the categories indicated in [2.4.3.1]
- Correction based on the moment of inertia, calculated at 0 degrees angle of heel, modified at each angle of heel calculated; corrections may be calculated according to the categories indicated in [2.4.3.1]
- Correction based on the summation of M_fs values for all tanks taken into consideration, as specified in [2.4.8.1].

2.4.7.4. Whichever method is selected for correcting the righting lever curve, only that method is to be presented in the ship's trim and stability booklet. However, where an alternative method is described for use in manually calculated loading conditions, an explanation of the differences which may be found in the results, as well as an example correction for each alternative, are to be included.

2.4.8. Free surface moment

2.4.8.1. The values for the free surface moment at any inclination in m.t for each tank may be derived from the formula:

\[ M_{fs} = v_{tk} b_{tkm} \rho_{tk} k_b \sqrt{C_{Btk}} \]

Where:

- \( v_{tk} \): Tank total capacity, in m³
- \( b_{tkm} \): Tank maximum breadth, in m
- \( \rho_{tk} \): Mass density of liquid in the tank, in t/m³
- \( k_b \): Dimensionless coefficient to be determined from Table 8.2.6 according to the ratio b/h. The intermediate values are determined by interpolation.
- \( C_{Btk} \): Tank block coefficient, equal to: \( v_{tk}/b_{tkm}h_{tkm} \)
- \( l_{tkm} \): Tank maximum length, in m
- \( h_{tkm} \): Tank maximum height, in m.

2.4.9. Small tanks

2.4.9.1. Small tanks which satisfy the following condition using the values of \( k_b \) corresponding to an angle of inclination of 30° need not be included in the correction:

Where:

\( \Delta_{min} \): Minimum ship displacement, in t, calculated at \( T_{min} \)
2.4.10. Remainder of liquid

2.4.10.1. In calculating the corrections, the usual remainder of liquids in the empty tanks needs not to be taken into account, provided the sum of such residual liquids does not comprise of a substantial free surface effect.

Table 8.2.6 Value of coefficient $k_b$ for calculating free surface corrections

<table>
<thead>
<tr>
<th>$\theta$</th>
<th>5°</th>
<th>10°</th>
<th>15°</th>
<th>20°</th>
<th>30°</th>
<th>40°</th>
<th>45°</th>
</tr>
</thead>
<tbody>
<tr>
<td>b/h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
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<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
<td>0.11</td>
<td>0.1</td>
<td>0.09</td>
</tr>
<tr>
<td>10</td>
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<td>0.11</td>
<td>0.11</td>
<td>0.1</td>
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<td>0.03</td>
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<td>0.02</td>
</tr>
<tr>
<td>0.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>

\[
k_b = \frac{\sin \theta}{12} \left(1 + \frac{(\tan \theta)^2}{2}\right) \frac{b}{h}, \text{where } \cot \theta \geq \frac{b}{h}
\]

\[
k_b = \frac{\cos \theta}{8} \left(1 + \frac{\tan \theta}{b/b}\right) \frac{b}{h} - \frac{\cos \theta}{12} \left(1 + \frac{(\cot \theta)^2}{2}\right) \frac{b}{h}, \text{where } \cot \theta < \frac{b}{h}
\]
SECTION 3 INCLINING TEST AND LIGHTWEIGHT CHECK

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3.1. General conditions of the ship

3.1.1. Society's surveyor is to be satisfied of the following before test:

a) the weather conditions are to be favorable;
b) the ship is to be moored in a quiet, sheltered area free from extraneous forces, so as to permit unrestricted heeling. The ship is to be positioned such that the effects of possible wind, stream and tide are minimized;
c) the ship is to be transversely upright and the trim is to be taken not more than 1% of the length between perpendiculars.; If this condition isn't met, hydrostatic data and sounding tables for the actual trim are to be made available;
d) cranes, derrick, lifeboats and liferafts capable of inducing oscillations are to be secured;
e) main and auxiliary boilers, pipes and any other system containing liquids are to be filled;
f) the bilge and the decks are to be thoroughly dried;
g) all tanks are preferably kept empty and clean, or completely full. The numbers of tanks containing liquids are to be kept to a minimum taking into account the above-mentioned trim. The tank should be so shaped, that the free surface effect can be accurately determined and remains almost constant during the test. All cross connections are to be closed;
h) the weights necessary for the inclination are to be already on board, located in the correct place;
i) onboard, all the work is to be suspended and crew or personnel not directly involved in the inclining test are to depart from the ship;
j) At the time of test, the ship is to be as complete as possible. The number of weights to be removed, added or shifted is to be restricted to a minimum. Transient material, tool boxes, staging, sand, debris, etc. on board are to be reduced to an absolute minimum.

3.2. Inclining weights

3.2.1. Preferentially, the total weight used is to be adequate to provide a minimum inclination of one degree and a maximum of four degrees of heel to each side. However, for large ships, IRS may, accept a smaller inclination angle provided that the requirement on pendulum deflection or U-tube difference in height specified in [3.3] is observed. Test weights are to be compact and of such a configuration that the VCG (vertical centre of gravity) of the weights can be exactly determined. Each weight is to be marked with an identification number and its weight. Re-certification of the test weights is to be executed before the incline. A crane of adequate capacity and reach, or some other means, is to be available during the inclining test to shift weights on the deck in an expeditious and safe manner. Generally, water ballast and people are not acceptable as inclining weight.

3.2.2. Where it is impracticable to use solid weights to produce the inclining moment is demonstrated, the movement of ballast water may be allowed as an alternative method. This acceptance would be granted for a specific test only, and approval of the test procedure by IRS is needed. The conditions given under are to be met:

a. inclining tanks are to be wall-sided and free of large stringers or other internal members that create air pockets;
b. tanks are to be directly opposite to maintain the ship's trim;
c. specific gravity of ballast water is to be measured and recorded;
d. pipelines to inclining tanks are to be full. If the ship's piping layout is unsuitable for internal transfer, portable pumps and pipes/hoses may be used;
e. blanks are to be inserted in transverse manifolds to prevent the possibility of liquids being "leaked" during transfer. Continuous valve control is to be maintained during the test;

f. all inclining tanks are to be manually sounded before and after each shift;

g. vertical, longitudinal and transverse centers are to be calculated for each movement;

h. accurate sounding/ullage tables are to be provided. The ship's initial heel angle is to be established prior to the incline in order to produce accurate values for volumes and transverse and vertical centers of gravity for the inclining tanks at every angle of heel. The draught marks amidships (port and starboard) are to be used when establishing the initial heel angle;

3.3. Pendulums

3.3.1. The use of three pendulums is recommended but a minimum of two are to be used to allow identification of bad readings at any one pendulum station. However, for ships of a length equal to or less than 30 m, only one pendulum may be accepted. They are each to be located in an area protected from the wind. The pendulums are to be long enough to give a measured deflection, to each side of upright, of at least 10 cm. To ensure that recordings from individual instruments are kept separate, it is suggested that the pendulums should be physically located as far apart as practical.

The use of an inclinometer or U-tube is to be considered in each separate case. It is recommended that inclinometers or other measuring devices should only be used in conjunction with at least one pendulum.

3.4. Means of communication

3.4.1. Efficient two-way communications are to be provided between central control and the weight handlers and between central control and each pendulum station. One person at a central control station is to have complete control over all personnel involved in the test.

3.5. Documentation

a) hydrostatic curves or hydrostatic data;
b) general arrangement plan of decks, holds, inner bottoms;
c) capacity plan showing capacities and vertical and longitudinal centers of gravity of cargo spaces and tanks. When water ballast is used as inclining weights, the transverse and vertical centers of gravity for the applicable tanks are to be available for each angle of inclination;
d) tank sounding tables;
e) draught mark locations;
f) docking drawing with keel profile and draught mark corrections, if available.

3.6. Calculation of the displacement

3.6.1. For the calculation of the displacement, the following operations are to be executed:

a. draught mark readings are to be taken at aft, midship and forward, at starboard and port sides;
b. the mean draught (average of port and starboard reading) is to be calculated for each of the locations where draught readings are taken and plotted on the ship's lines drawing or outboard profile to ascertain that all readings are consistent and together define the correct waterline. The resulting plot is to give either a straight line or a waterline which is hogged or sagged. If readings obtained are inconsistent, the freeboards/draughts are to be taken once more;
c. it is required to determine the specific gravity of the sea water. Samples are to be taken from an adequate depth of the water to ascertain a true representation of the sea water and not merely surface water, which could contain fresh water from run-off of rain. A hydrometer is to be placed in a water sample and the specific gravity is read
and recorded. For large ships, it is recommended that samples of the sea water are taken forward, midship and aft, and the readings averaged. For small ships, one sample taken from midship is quite adequate. The temperature of the water is to be taken and the measured specific gravity corrected for divergence from the standard, if required;

d. A correction to water specific gravity is not essential if the specific gravity is determined at the inclining experiment site. Though, correction is essential, if specific gravity is measured when the sample temperature varies from the temperature at the time of the inclining test. Where the value of the average calculated specific gravity is different from that reported in the hydrostatic curves, adequate corrections are to be made to the displacement curve;

e. all double bottoms and all tanks and compartments which can contain liquids, are to be checked, paying due attention to air pockets which may be formed due to the ship's trim and the position of air pipes;

f. it is to be checked that the bilge is dry, and an evaluation of the liquids which cannot be pumped, left in the pipes, boilers, condenser, etc., is to be conducted;

g. the whole ship is to be surveyed to recognize all items which need to be added, removed or displaced to bring the yacht to the lightship condition. Each item is to be clearly distinguished by weight and location of the center of gravity;

h. the probable solid permanent ballast is to be clearly recognized and listed in the report.

3.7. Inclining procedure

3.7.1. Generally, the standard test employs eight distinct weight movements as illustrated in Fig 8.3.1.

![Figure 8.3.1: Weight shift procedure](image)

The weights are to be transversely shifted, so as not to alter the ship's trim and vertical position of the centre of gravity. After each weight shifting, the new location of the transverse centre of gravity of the weights is to be precisely determined.

After each weight movement, the distance the weight was moved (centre to centre) is to be measured and the heeling moment calculated by multiplying the distance by the amount of
weight moved. For each pendulum, the tangent is calculated by dividing the deflection by the length of the pendulum. The resultant tangents are plotted on the graph as illustrated in Fig 8.3.2.

When the ship has reached a final position after each weight shifting, the pendulum deflection is to be read. During reading, no movements of personnel are permitted. For ships with a length equal to or less than 30 m, six distinct weight movements may be accepted.

Figure 8.3.2
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4.1. Information to be included

4.1.1. General

4.1.1.1. A trim and stability booklet is a stability manual, to be approved by IRS, which is to cover adequate information to enable the Master to operate the ship in conformation to the applicable requisites contained in these Rules. The format of the stability booklet and the information included in it differs depending on the ship type and operation.

4.1.2. List of Information

4.1.2.1. The trim and stability booklet is to cover the following information:

a) a general description of the ship, including:
   - the ship's name and IRS classification number
   - the ship type and service notation
   - the class notations
   - the yard, the hull number and the year of delivery
   - the flag, the port of registry, the international call sign
   - the moulded dimensions
   - the design draft
   - the displacement corresponding to the above-mentioned draughts;

b) clear instructions on the use of the booklet;

c) general arrangement and capacity plans indicating the assigned use of compartments and spaces (stores, accommodation, etc.);

d) a sketch indicating the position of the draught marks referred to the ship's perpendiculars;

e) hydrostatic curves or tables corresponding to the design trim, and, if significant trim angles are foreseen during the normal operation of the yacht, curves or tables corresponding to such range of trim. A clear reference relevant to the sea density, in t/m³, is to be included as well as the draught measure (from keel or under keel);

f) cross-curves (or tables) of stability calculated on a free trimming basis, for the ranges of displacement and trim anticipated in normal operating conditions, with indication of the volumes which have been considered in the computation of these curves;

g) tank sounding tables or curves showing capacities, centre of gravity, and free surface data for each tank;

h) lightship data from the inclining test, including lightship displacement, centre of gravity co-ordinates, place and date of the inclining test, as well as IRS approval details specified in the inclining test report. It is recommended that a copy of the approved test report been closed with the stability information booklet. Where the above-mentioned information is derived from a sister ship, the reference to this sister ship is to be clearly indicated, and a copy of the approved inclining test report relevant to this sister ship is to be included;

i) standard loading conditions and examples for developing other acceptable loading conditions using the information contained in the booklet;

j) intact stability results (total displacement and its centre of gravity co-ordinates, draughts at perpendiculars, GM, GM corrected for free surface effect, GZ values and curve when applicable, reporting a comparison between the actual and the required values), which are to be available for each of the above-mentioned operating conditions;

k) information on loading restrictions when applicable;
4.2. Loading conditions

4.2.1. The standard loading conditions to be included in the trim and stability booklet are:

a) ship in the fully loaded departure condition, with full stores and fuel and the full number of guests;
b) lightship condition;
c) ship in the fully loaded arrival condition, with only 10% stores and fuel remaining and the full number of guests. Such loading cases are considered as a minimum requirement and additional loading cases may be included as deemed necessary or useful.

4.3. Stability curve calculation

4.3.1. General

4.3.1.1. On a designed trim basis, hydrostatic and stability curves are normally prepared. However, where the operating trim or the form and arrangement of the ship are such that alterations in trim leaves an appreciable effect on righting arms, such change in trim is to be taken into account. The calculations are to give consideration to the volume of the upper surface of the deck sheathing.

4.3.2. Superstructures and deckhouses which may be taken into account

Enclosed superstructures conforming to the international or national recognized regulations and also the second tier of similarly enclosed superstructures may be taken into account. Deckhouses on the freeboard deck may be taken into account, provided that they conform to the conditions for enclosed superstructures mentioned above. Where deckhouses observe the above conditions, except that no additional exit is given to a deck above, such deckhouses are not to be taken into account; however, any deck openings inside such deckhouses are to be considered as closed even where no means of closure are provided. Superstructures and deckhouses not regarded as enclosed may, however, be taken into account in stability calculations up to the angle at which their openings are flooded (at this angle, the static stability curve is to depict one or more steps, and in ensuing computations the flooded space is to be considered non-existent). Trunks may be taken into account. Hatchways may also be taken into account with due regard to the effectiveness of their closures.

4.3.3. Angle of flooding

In cases where the ship would be submerged due to flooding through any openings, the stability curve is to be cut short at the corresponding angle of flooding and the yacht is to be considered to have completely lost its stability. Small openings such as those for passing wires or chains, tackle and anchors, and also holes of scuppers, as well as of discharge and sanitary pipes are not to be considered as open if they submerge at an angle of inclination more than 30°. If they plunge at an angle of 30° or less, it is assumed that these openings are open, if IRS considers this to be a cause of significant progressive flooding; hence, such openings are to be considered on a case-by-case basis.
CHAPTER 9 FIRE SAFETY MEASURES

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PART 9-C
CHAPTER 9
IRS Rules for Building and Classing Steel Vessels

SECTION 1 PASSENGER VESSELS

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1.1. **Application**

1.1.1. The requirements of Fire safety measures onboard vessels are not applicable for the purpose of classification; however International Register of Shipping carries out surveys relevant to fire protection statutory requirements on behalf of national Authorities. In such cases, fire safety measure’s statutory requirements are considered a matter of class and therefore compliance with these rules is also verified by IRS for classification purpose.

1.1.2. These requirements are applicable to steel ships. The use of other materials is acceptable provided that an equivalent standard of safety is provided.

1.2. **Definitions**

1.2.1. **Accommodation Space**

Accommodation spaces refer to those used for corridors, public spaces, lavatories, offices, cabins, hospitals, cinemas, barber shops, games and hobby rooms, pantries not containing any cooking appliances and similar spaces.

1.2.2. **Public space**

Public spaces refer to those parts of the accommodation which are used as halls, lounges, dining rooms and similar permanently enclosed spaces.

1.2.3. **High risk service space**

High Risk Service Spaces refer to those used for galleys, pantries with cooking appliances, paint and lamp rooms, lockers and storerooms with $4 \text{ m}^2$ ($43 \text{ ft}^2$) of areas or more, and workshops apart from those which forms part of the Machinery Spaces.

1.2.4. **Special category space**

Special Category Spaces refer to those enclosed spaces above or below the bulkhead deck meant for the carriage of motor vehicles with fuels in their tanks for their own propulsion, into and from which such vehicles can be driven and to which passengers have access.

1.2.5. **Corridors**

Corridors are passenger and crew corridors and lobbies.

1.2.6. **Control stations**

Control Stations are those spaces which contain emergency sources of power and lighting, wheelhouse and chartroom space containing the ship’s radio equipment, fire-control rooms, fire-extinguishing rooms, fire-recording stations and control rooms for propulsion machinery when located outside the machinery space.

1.2.7. **Machinery spaces of category A**

Machinery Spaces of Category A are those spaces and trunks to such spaces which contain:

i. Internal combustion machinery used for main propulsion; or
ii. Internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 KW; or
iii. Any oil fire boiler or oil fuel unit.
Auxiliary and domestic boilers are to be so arranged that other equipment is not endangered even in the event of overheating and are placed far away from fuel oil, lubricating oil tanks and hold bulkheads. Oiltight trays are to be provided for oil fired boilers.

1.2.8. Machinery spaces

Machinery Spaces refer to all the machinery spaces of category A and all other spaces that contain propulsion machinery, oil fuel units, boilers, steam and internal combustion engines, oil filling stations, steering gear generators and major electrical machinery, stabilizing, refrigerating, ventilation and air-conditioning machinery and similar spaces and trunks to such spaces.

1.2.9. Non-combustible material

A non-combustible material refers to one which neither burns nor gives off flammable vapors in sufficient quantity for self-ignition when heated approximately to 750°C (1382°F), this being determined by an established recognized test procedure which is to be submitted for review.

1.2.10. Standard fire test

A Standard Fire Test is one in which specimens of the relevant bulkheads or decks are exposed in a test furnace to temperatures corresponding approximately to the standard time temperature curve. The exposed surface area of the specimen should be no less than 4.65m² and height of 2.44 m, the intended construction is to be mimicked with maximum resemblance to the original. To define the standard time temperature curve, a smooth curve is drawn through the following temperature gradients measured above the initial furnace temperature.

At the end of the first:

- 5 minutes: 556°C (1033°F)
- 10 minutes: 659°C (1218°F)
- 15 minutes: 718°C (1324°F)
- 30 minutes: 821°C (1510°F)
- 60 minutes: 925°C (1697°F)

1.2.11. “A” Class Division

“A” Class Divisions are those divisions formed by bulkheads and decks which comply with the following criteria:

i. they are constructed of steel or other equivalent material
ii. they are suitably stiffened
iii. they are to be constructed as to be capable of preventing the passage of smoke and flame to the end of one hour standard fire test.
iv. they are insulated with approved non-combustible materials such that the average temperature of the unexposed side will not rise more than 140°C (284°F) above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180°C (356°F) above the original temperature within the time listed below:
• Class “A-60” 60 minutes
• Class “A-30” 30 minutes
• Class “A-0” 0 minutes

v. A test of a prototype bulkhead or deck to a recognized standard to ensure that it meets the above requirements for integrity and temperature rise is to be carried out.

1.2.12. “B” Class Division

“B” Class Divisions are those divisions formed by bulkheads, decks, ceilings, or linings which comply with the following criteria:

i. they are so constructed as to be capable of preventing the passage of flame to the end of the first half hour of the standard fire test.

ii. they have an insulation value such that the average temperature of the unexposed side will not rise to more than 140°C (284°F) above the original temperature, nor will the temperature at any one point, including any joint, go beyond 225°C (437°F) above the original temperature within the time listed below.

• Class “B-15” 15 minutes
• Class “B-0” 0 minutes

iii. they are to be constructed of approved non-combustible materials and all materials used in the construction and erection of “B” Class divisions are to be non-combustible, with the exception that combustible veneers may be permitted provided they meet other requirements in this section.

iv. A test of a prototype division to a recognized standard to ensure that it meets the above requirements for integrity and temperature rise may be required.

1.2.13. Continuous “B” Class Ceilings or Linings

Continuous “B” Class Ceilings or Linings are those “B” Class ceilings or linings which terminate only at “A” or “B” Class Divisions.

1.2.14. Steel equivalent material

Steel Equivalent Material refers to a non-combustible material which either by itself or due to the insulation provided, has structural and integrity properties equal to steel at the end of the applicable exposure to the standard fire test (i.e. aluminum alloy with appropriate insulation).

1.2.15. Low flame spread surface

A Low Flame Spread Surface refers to a surface that adequately restricts the flame from spreading, this being determined to the satisfaction of the Flag State or IRS by a recognized, and established test procedure.

1.3. Main fire zones

The hull, superstructure, and deckhouses are to be subdivided by “A-60” divisions into main fire zones, each with the mean length on any deck generally not in excess of 48 m (157.50 ft) with a square area of deck not to exceed 1600 m² (17222 ft²).
1.4. Protection of accommodation spaces, service spaces and control stations

1.4.1. Corridor bulkheads are to be “A” or “B” Class divisions extending from deck to deck. Where continuous “B” Class ceilings and/or linings are fitted on both sides of the bulkhead, the “B” Class bulkhead may terminate at the continuous ceiling or lining. Doors fitted in “B” Class divisions may have a louver in the lower half not exceeding 0.05 m$^2$ (78 in$^2$). As an equivalent, these doors may be undercut up to 25 mm (1 in.). Such openings or undercuttings are not to be provided in doors forming a stairway enclosure.

1.4.2. All doors and frames in such bulkheads should be of non-combustible materials and are to be constructed and erected in such a manner that it provides substantial fire resistance and maintains the integrity of the division in which the doors are fitted.

1.4.3. The Machinery Spaces of Category A, High Risk Service Spaces, and Control Stations are to be isolated from adjacent Accommodation Spaces and each other by “A-60” Divisions.

1.4.4. The fire integrity of the deck between accommodation spaces is to be steel or equivalent. However, where a deck is penetrated for the passage of electric cables, pipes and vent ducts, such penetrations are to be of “A” Class integrity.

1.4.5. The fire integrity of the divisions between the accommodation spaces and the machinery spaces of other than Category “A” is to be “A-0” Class.

1.5. Stairways & elevators

1.5.1. Stairways penetrating only a single deck should be protected at least at one level by an “A” Class Division and self-closing door for limiting the rapid spread of fire from one deck to another. Elevator trunks are to be protected by “A” Class divisions. Stairways are to be constructed of steel or equivalent material.

1.5.2. Stairways and elevator trunks penetrating more than a single deck should be surrounded by “A” Class divisions and protected by “A” Class self-closing doors at all levels. Self-closing doors are not to be fitted with hold-back hooks. However, hold-back arrangements incorporating remote release fittings of fail-safe type may be used.

1.6. Non-combustible materials

1.6.1. Linings, ceilings, bulkheads and insulation should be of non-combustible material. Vapor barriers and adhesives used in conjunction with the insulation, as well as insulation of pipe fittings for cold service systems need not have to be non-combustible material, but they should be kept to a minimum and their exposed surfaces are to have resistance to propagation of flame.

1.6.2. Partial bulkheads or decks used for subdividing a space for utility or artistic treatment should also be of noncombustible materials.

1.6.3. The framing, including grounds and the joint pieces of bulkheads, linings, ceilings and draft stops are to be of non-combustible materials.

1.6.4. Each accommodation space/public space on board ships with no overnight accommodations is to be designed with a maximum fire load that should not go beyond 14.6 kg/m$^2$ (3 lbs/ft$^2$).

1.6.5. For those ships designed with onboard overnight accommodations, the maximum fire load should not go beyond 48.8 kg/m$^2$ (10 lbs/ft$^2$). This is to provide for 36.6 kg/m$^2$ (7.5 lbs/ft$^2$) for combustible furniture and 12.2 kg/m$^2$ (2.5 lbs/ft$^2$) for personal effects.
1.7. **Exposed surfaces, deck coverings and paints, varnishes and other paints**

1.7.1. The following surfaces are to have low flame-spread characteristics.

- All exposed surfaces in corridors and stairway enclosures, and of bulkheads, wall and ceiling linings in all accommodation and service spaces and control stations.

1.7.2. The bulkheads, linings and ceilings may have combustible veneers provided that the thickness of such veneers does not exceed 2 mm (0.08 in.) within any space other than corridors, stairway enclosures and control stations where the thickness is not to exceed 1.5 mm (0.06 in.). These veneers are to be included in the fire load calculations discussed above.

1.7.3. Paints, varnishes and other finishes used on exposed interior surfaces should not be of such nature that offers an undue fire hazard and should not produce excessive quantities of smoke or toxic fumes.

1.8. **Details of construction**

In accommodation and service spaces, control stations, corridors and stairways:

i. Air spaces enclosed behind ceilings, paneling or linings are to be suitably divided by close fitting draught stops not more than 14 m apart.

ii. In the vertical direction, such enclosed air spaces, including those behind linings of stairways, trunks, etc., are to be closed at each deck.

1.9. **Ventilation**

1.9.1. Ducts provided for ventilation of Machinery Spaces of Category A and Galleys are not to pass through Accommodation and Service Spaces or Control Stations. However, some relaxation from this requirement will be considered provided that:

i. The ducts are constructed of steel and insulated to “A-60” standards throughout the accommodations, with no openings in the duct work within the accommodation, service or control spaces.

OR

ii. The ducts are constructed of steel and fitted with an automatic fire damper close to the boundary penetrated and insulated to “A-60” standard from the Machinery Space of Category A and galleys to a point at least 5 m (16.4 ft) beyond the fire damper, with no openings in the duct work within the accommodation, service or control spaces.

1.9.2. Generally, ventilation ducts should not pass through main fire zone divisions. However, where this can’t be avoided, they should be equipped with a fail-safe automatic closing fire damper which can be closed manually from each side of the division. Additionally, fail-safe automatic closing fire dampers with manual operation from within the stairway enclosure (for stairs serving more than two decks) should be fitted to all ventilation ducts, serving both the accommodation and service spaces passing through stairways, where the ducts pierce such enclosures. Ventilation ducts serving stairway enclosures should not serve to any other spaces. Ventilation ducts should not serve more than one main fire zone.

1.9.3. Where they pass through the Accommodation Spaces or Spaces containing combustible materials, the exhaust ducts from galley ranges are to be constructed of “A” Class divisions. Each exhaust duct is to be fitted with:

i. A grease trap readily removable for cleaning

ii. A fire damper located in the lower end of the duct

iii. Arrangements, operable from within the galley, for shutting off the exhaust fans
iv. Fixed means for extinguishing a fire within the duct
v. And suitable hatches for inspection and cleaning.

1.9.4. The main inlets and outlets of all ventilation systems are to be capable of being closed from outside the space being ventilated.

1.10. Miscellaneous items

1.10.1. Where “A” or “B” divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for girders, beams or other structural members, arrangements are to be made to ensure that the fire resistance is not impaired.

1.10.2. Pipes penetrating “A” or “B” Class divisions are to be of approved materials having regard to the temperature such divisions are required to withstand.

1.10.3. In spaces where the penetration of oil products is possible, the surface of insulation is to be impervious to oil or oil vapors.

1.10.4. All waste receptacles are to be constructed of non-combustible materials with no openings in sides or bottoms.

1.11. Means of escape

1.11.1. Stairways and ladders are to be arranged to provide ready means of escape to an area of safe refuge.

1.11.2. There are to be at least two means of escape from each main fire zone and from each restricted space of 27.5 m² or more in enclosed area.

1.11.3. In general there are to be at least two means of escape from each Machinery Space of Category A. However, in ships of less than 1,000 tons gross tonnage one means of escape may be dispensed with, provided due regard is paid to the width and disposition of the space, and the number of persons normally employed.

1.11.4. The installation of dead end corridors of any length is not permitted.

1.11.5. Elevators are not to be considered as forming one of the required means of escape.

1.11.6. Windows or scuttles assemblies installed adjacent to weather deck egress routes are to have 6mm thick wire inserted glass mounted in suitable metal frames.

1.11.7. Stairways are to be sized in accordance with recognized national or international standards, but are to have a minimum tread width of 112 cm (44 in.).

1.12. Fire control plans

A fire control plan is to be permanently exhibited for the guidance of the ship’s control station or officers as required by Part 11.
CHAPTER 10 BUCKLING CONTROL AND DIAGRAMS

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# SECTION 1 BUCKLING CONTROL

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1.1. General

1.1.1. Introduction

1.1.1.1. In this section requirements to buckling control of plating subjected to compressive stresses are considered.

1.1.2. Definitions

1.1.2.1. Symbols

\( M_{SW} \) = still water bending moments in kNm

\( M_w \) = wave bending moments in kNm as given in Chapter 4 Section 2.

\( s \) = spacing in m of transverse beams

\( l_{st} \) = distance in m between longitudinal stiffeners

\( t_{pl} \) = plating thickness in mm

\( Z_A = Z_D \) or \( Z_B \)

\( Z_R \) = rule section modulus in cm³

\( Z_D, Z_B \) = midship section modulus in cm³ as built at deck or bottom, respectively.

1.2. Plating subject to longitudinal compressive bending stresses

1.2.1. General

1.2.1.1. The longitudinal bending stresses to be used for buckling control of deck and bottom plating is generally given by:

\[
\sigma_l = \frac{M_{sw} + M_w}{Z_A} 10^3 \text{(N/mm}^2)\]

1.2.1.2. The critical buckling strength \( \delta_{cr} \) of a transversely stiffened plate may be found from the following formulae:

\[
\begin{align*}
\sigma_{cr} &= \sigma_e \quad \text{when } \sigma_e < 0.5 \sigma_y \\
&= \sigma_y \left( 1 - \frac{\sigma_y}{4\sigma_e} \right) \quad \text{when } \sigma_e > 0.5 \sigma_y \\
\sigma &= 2.3 \left[ 1 + \left( \frac{s}{l_{st}} \right)^2 \right] \left( \frac{t-t_k}{1000s} \right)^2 10^5 \text{(N/mm}^2) \\
\end{align*}
\]

1.2.1.3. The plating thickness in deck and bottom amidships should comply with the requirement

\[ \sigma_{cr} \geq \sigma_l \]

1.2.2. Deck plating

1.2.2.1. Sagging water bending moments are to be applied in [1.1.1.1] of Chapter 10.

1.2.2.2. When it is confirmed that the Stillwater bending moments for all relevant loading conditions will not be sagging moments, using \( M_{SW} = 0 \) for the buckling control of the deck plating maybe accepted.
Guidance note:

When $M_{SW}$ is as given in [1.2.2.2] and $l \geq s$, the buckling strength of a transversely stiffened strength deck will normally be satisfactory when

$$t \leq 2.2 \sqrt{I \frac{Z_R}{Z_D}} t_c \text{(mm)}$$

1.2.3. Bottom plating

1.2.3.1. Hogging bending moments are to be applied in Part 9-C, Chapter 10, Section 1, [1.2.1.1].

Guidance note:

When $M_{SW}$ is as given in Part 9-C, Chapter 10, Section 1,[1.2.3.1] and $l \geq s$, the buckling strength of transversely stiffened bottom plating will normally be satisfactory when

$$t \leq 2.8 \sqrt{I \frac{Z_R}{Z_B}} t_c \text{(mm)}$$

Fig 10.1.1: Critical stress for transversely stiffened plating made of mild steel

1.3. Deck plating acting as effective flange for deck girders

1.3.1. General

1.3.1.1. Deck plating acting as effective flange for deck girders which support crossing stiffeners should have a satisfactory buckling strength.

1.3.1.2. Compressive stresses arising in the deck plating due to local loading of girders are to be less than 80% of the critical buckling strength, see Part 9-C, Chapter 10, Section 1, [1.3.1.3]. While calculating the compressive stress the section modulus of the girder may be based on a deck plate flange breadth equal to the distance between girders (100% effective flange).

1.3.1.3. The critical buckling strength is given in Part 9-C, Chapter 10, Section 1, [1.2.1.2], where $l = \text{span of stiffener or distance from girder to any buckling stiffener parallel to the girder}$.

1.3.1.4. Elastic buckling of deck plating may be accepted after special consideration.
1.4. Longitudinals subject to longitudinal compressive stresses

1.4.1. General

1.4.1.1. The buckling strength of longitudinals is to comply with the requirements given in Part 9-C, Chapter 10, Section 1, [1.2.1.1] and Part 9-C, Chapter 10, Section 1, [1.2.1.2] when using:

$$\sigma_e = 210 \frac{I_A}{A l^2} \text{(N/mm}^2)$$

$I_A$ = moment of inertia in cm$^4$ of the longitudinal
$A$ = cross-sectional area in cm$^2$ of the longitudinal
$l$ = span in m of longitudinals.

When calculating $I_A$ and $A$, a plate flange corresponding to 0.8 times the longitudinal spacing is included.

1.4.1.2. The buckling strength of longitudinals is to comply with the requirement:

$$\sigma_{cr} \geq 1.2 \sigma_l$$
SECTION 2 APPROXIMATE CALCULATIONS

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2.1. Stillwater bending moment for hull girder

2.1.1. Method of calculation

2.1.1.1. When the stillwater bending moment $M_{SV}$ is not determined by a direct calculation, the following approximation method may be applied:

$$M_{SV} = 5 \left[(\Delta - DW)z + \sum(W_i y) - \Delta x\right](kNm)$$

Where:

- $\Delta$ = displacement of ship in tonnes
- $DW$ = deadweight of ship in tonnes
- $\sum p = DW$
- $W_i$ = individual weights in tonnes
- $y$ = distance in metres from $L/2$ to centre of gravity of the respective individual weights. Weights extending beyond $L/2$ are divided at $L/2$ and each part is considered separately
- $x = 0.18 \left( C_B + 0.35 \right) L$ in metres
- $C_B$ = block coefficient of ship at draught in question
- $z = 0.2 L$ for ships with machinery amidships
  = 0.24 L for ships with machinery at quarter length aft
  = 0.27 L for ships with machinery aft
- $L$ = length of ship in meters.

The expression for $M_{SV}$ may be positive or negative, and the moments are defined as follows:

- $M_{SV}$ positive = hogging moment
- $M_{SV}$ negative = sagging moment.

When calculating $M_{SV}$ the deadweight is to be so located that the ship will have no trim at full draught.

2.2. Built sections

2.2.1. Description

2.2.1.1. Diagram A, which may be applied to build sections of the type shown in Fig.10.2.1, gives as parameters the flange area ($A_F$) and the depth of the section ($h$) for values of moments of inertia ($I$) and section moduli ($Z$) about the neutral axis $x-x$, based on the following simplified equations:

$$I = A p a^2 + \frac{h^3 t}{12} + A_W \left( h - \frac{a}{2} \right)^2 + A_F (h - a)^2$$

$$Z = \frac{I}{h-a} cm^3$$

where

$$a = h \left( \frac{0.5 A_W + A_F}{A_F + A_W + A_p} \right)$$
Fig 10.2.1: Built section for which Diagram A may be used

Notations are otherwise as follows:

- $A_F$ = sectional area of face plate in cm$^2$
- $A_P$ = sectional area of effective plating in cm$^2$
- $A_W$ = sectional area of web in cm$^2$, approximate value = ht
- $h$ = depth of section in cm
- $t$ = web thickness in cm.

The sectional area of effective plating $A_P$ is based on rules for effective flange. It is assumed that $A_F \leq A_P$. The equations for $I$ and $Z$ are further simplified by putting $A_P = 60$ cm$^2$, respectively $100$ cm$^2$ and $t = 1$ cm.

2.3. Built sections Nomogram

2.3.1. Description

2.3.1.1. Based on the equations for $I$ and $Z$ as diagram A, the diagram B has been developed in the form of a nomogram or alignment chart for which the restriction is that $A_F \leq A_P$. The fan-shaped diagram is constructed with the ratios $A_W/A_P$ and $I/h$, and the product $hA_P$ as parameters, with values of $Z$ and the ratio $A_W/A_P$ marked off on the two vertical scales. Powers are given to the $n^{th}$ value in order to increase the range of diagram. The actual power is the same for all scales which contain $n$.

A few examples will illustrate the practical use of the diagram (see Part 9-C, Chapter 10, Section 2, [2.3.2] to [2.3.4]) below in connection with Fig.10.2.2.
2.3.2. Example a)

2.3.2.4. Determine the section modulus and moment of inertia of a girder having the following dimensions:

\[ h = 240 \text{ cm} \]
\[ A_P = 175 \text{ cm}^2 \text{ (effective flange area)} \]
\[ A_F = 114 \text{ cm}^2 \]
\[ t = 1.2 \text{ cm}. \]

This gives:
\[ A_F/A_P = 0.65 \text{ and } A_W/A_P \approx 1.65 \text{ and } A_P = 4.2 \times 10^4 \text{ (i.e. } n = 4, \text{ to be used for all scales containing } n \text{ in the diagram).} \]

Through the point determined by the parameters \( A_W/A_P = 1.65 \) and \( h A_P = 4.2 \times 10^4 \) in the diagram and the point \( A_F/A_P = 0.65 \) on the right vertical scale a straight line \( a \) is drawn, intersecting the \( Z \) scale at \( 4.1 \times 10^4 \).

The sought value of \( Z \) is therefore \( 4.1 \times 104 \text{ cm}^3 \). The intersection between the straight line drawn and the parameter \( A_W/A_P = 1.65 \) gives the value of \( I/h = 2.27 \times 10^4 \), i.e. \( I = 5.45 \times 10^6 \text{ cm}^4 \).
2.3.3. Example b)

2.3.3.1. Determine the scantlings of a girder having a given section modulus \( Z = 5 \times 10^3 \) cm\(^3\) and an effective area of plating \( A_P = 140 \) cm\(^2\).

It is necessary in this case to choose the depth \( h \) and thickness \( t \) of the web (a suitable depth may be obtained by means of diagram A). Taking in this instance \( h = 110 \) cm and \( t = 1.3 \) cm, the flange area \( A_F \) is determined as follows:

Through the point determined by the intersection of the parameters \( A_W/A_P = 1.02 \) and \( h A_P = 15.4 \times 10^3 \) and the point 5 on the Z scale a straight line b is drawn intersecting the vertical scale \( A_F/A_P \) on the right at 0.05 i.e. \( A_F = 0.05 \times 140 = 7 \) cm\(^2\).

2.3.4. Example c)

2.3.4.1. The moment of inertia \( I \) of the girder in example b) may be found from the \( I/h \) value determined by the point of intersection of the parameter \( A_W/A_P = 1.02 \) in the left part of the diagram and the straight line drawn.

Thus \( I/h = 3.66 \times 10^3 \), i.e. \( I = 402 \times 10^3 \) cm\(^4\).

If it is desired to obtain the particulars of a girder having an \( I \) value which does not exceed a certain definite rule value, say \( 300 \times 10^3 \) cm\(^4\), a smaller value of \( h \) is chosen by trial and error. For instance if \( h = 86 \) cm, then \( h A_P = 12.05 \times 10^3 \) and \( A_W/A_P = 0.80 \). A straight line c is then drawn from the point 5 on the Z scale through the point of intersection of the parameters \( h A_P = 12.05 \times 10^3 \) and \( A_W/A_P = 0.80 \). This intersects the \( A_W/A_P \) scale at 0.21 and gives a value of \( A_F = 29.4 \) cm\(^2\) and \( I/h \) value = 3.49 from which \( I = 300 \times 10^3 \) cm\(^4\).

2.4. Flat bars, angles and bulbs

2.4.1. Description

2.4.1.1. Diagram C may be applied to flats and inverted welded angle stiffeners. The diagram is based on the usual information given in handbooks of sections. This diagram has been constructed in the same manner as diagram A with \( h \) and \( t \) plotted as parameters and values of \( Z \) and \( I \) marked off on the horizontal and vertical axis respectively.

2.4.1.2. In Table 10.2.1 of Part 9-C, Chapter 10, values of \( I \) and \( Z \) are given for bulb flats with attached plate.
Table 10.2.1: Moment of inertia $I$ and section modulus $Z$ for bulb profile (HP) with attached plate. Profile (mm)

<table>
<thead>
<tr>
<th>Profile (mm)</th>
<th>$I$ (cm$^4$)</th>
<th>$Z$ (cm$^3$)</th>
<th>Plate included (mm)</th>
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<tr>
<td>80×5</td>
<td>165</td>
<td>21</td>
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2.5. **Corrugated bulkhead**

2.5.1. **Description**

2.5.1.1. Diagram D, which may be applied to corrugated bulkheads, is based on the following equation for the section modulus:

\[ Z = \frac{ht}{2} \left( \frac{h}{3\sin \alpha} + s \right) (\text{cm}^3) \]

Notations are as shown on sketch in the diagram, \( h \), \( t \) and \( s \) being in cm. The value of \( Z \) in the diagram applies to a length \( l \) of corrugation having a width of effective flange on each side equal to 0.5s. The diagram has been constructed as a nomogram or alignment chart with the depth of corrugation \( h \) and the angle \( \alpha \) as parameters and values of \( s \) and \( Z/t \) marked off on the vertical axes. As the moment of inertia \( I = \frac{Zh}{2} \), \( Z/t \) may be written \( 2I/ht \).

2.5.2. **Example**

2.5.2.1. Find \( Z/t \) or \( I/t \) of a corrugated bulkhead having the following particulars:

\[ s = 400 \text{ mm} \]
\[ h = 500 \text{ mm} \]
\[ \alpha = 45^\circ \]

Through the point of intersection (see Fig.3) between the parameters \( h = 500 \) and \( \alpha = 45^\circ \) and the point 400 on the \( s \) scale, a straight line is drawn intersecting the \( Z/t \) scale at 100. The sought value of \( Z/t \) or \( 2I/ht \) is therefore 1 600 cm\(^2\). If the thickness \( t \) of the bulkhead is known, \( Z \) or \( I \) may be found. Conversely, if a certain section modulus and/or moment of inertia is stipulated, the least depth of corrugation may be evaluated from the equation \( h = 2I/Z \). If the angle of corrugation is known, the point of intersection between the parameters \( h \) and \( \alpha \) may be found. Through this point and the point corresponding to the known value of \( Z/t \) on the left vertical scale, a straight line may be drawn intersecting the scale of \( s \). Thus the size of it may be obtained.

2.6. **Swedged plating**

2.6.1. **Description**

2.6.1.1. The diagram E may be used for estimating \( Z/t \) - values for swedged stiffeners applied on light walls and bulkheads in accommodation, deckhouses etc.
Fig 10.2.3: Corrugated bulkhead nomogram
Fig 10.2.4
Fig 10.2.5
Fig 10.2.6
Fig 10.2.7
Fig 10.2.8

MOMENT OF INERTIA & SECTION MODULUS (I & Z)
FOR FLAT BARS WITH 600 x 6.5mm PLATE

DIMENSIONS IN mm

Diagram C
Fig 10.2.9
MOMENT OF INERTIA & SECTION MODULUS (I & Z)
FOR INVERTED ANGLES WITH 600 x 5.5 mm PLATE

\[
\frac{I}{h^3} \quad \text{DIMENSIONS IN mm}
\]

DIAGRAM C

Fig 10.2.11
Fig 10.2.12
Fig 10.2.13

Diagram C

For inverted angles with 600 x 10 mm plate

Dimensions in mm

I cm²

Z cm³
Fig 10.2.14
CORRUGATED BULKHEAD

\[ Z = \frac{h \cdot t}{2} \left( \frac{h}{3 \sin \alpha + s} \right) \text{cm}^3, \text{WITH } h, t \text{ AND } s \text{ IN cm} \]

\[ Z h \text{ cm}^2 = \frac{21}{h} \]

\( h = 800 \text{ mm} \)
\( h = 700 \text{ mm} \)
\( h = 600 \text{ mm} \)
\( h = 500 \text{ mm} \)
\( h = 400 \text{ mm} \)
\( h = 300 \text{ mm} \)
\( h = 200 \text{ mm} \)
\( h = 100 \text{ mm} \)

**DIAGRAM D**

Fig 10.2.15

*EFFECTIVE FLANGE TAKEN AS 0.5 s, Z VALID FOR 1*