ClassIBS

ISTHMUS BUREAU OF SHIPPING

PART 2
HULL CONSTRUCTION

Rev. 06 *January 2022*

PRINCIPLES FOR THE CLASSIFICATION AND CONSTRUCTION OF STEEL SHIPS

PART 2 HULL CONSTRCTION

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PRINCIPLES FOR THE CLASSIFICATION AND CONSTRUCTION OF STEEL SHIPS

PART 2 HULL CONSTRUCTION

Chapter 1 GENERAL

1.1 General

1.1.1 Application

1. The requirements in this part apply to ships not less than 90 *m* in length and of normal form and proportion intended for unrestricted service.

2. Hull construction, equipment and scantlings of ships to be classed for restricted service may be appropriately modified according to the condition of service.

3. In the application of the relevant provisions in this part to ships which do not comply with the requirements of International Load line Conventions (*ILLC*), L_f is to be read as L and B_f as B.

1.1.2 Special Cases in Application

Notwithstanding the provisions in **1.1.1**, the requirements for hull construction, equipment, arrangement and scantlings of ships which are especially long or that do not comply with the requirements in this part for some special reason are to be at the Society s discretion.

1.1.3 Ships of Unusual Form or Proportion, or Intended for Carriage of Special Cargoes

1. In ships of unusual form or proportion, or intended for carriage of special cargoes, the requirements concerning hull construction, equipment, arrangement and scantlings will be decided individually based upon the general principle of the Rules instead of the requirements in this part.

2. For ships intended for the carriage of lumber cargoes in cargo spaces and/or on decks, notwithstanding being marked with the load lines corresponding to timber freeboard assigned in accordance with the provisions of *ILLC*, hull structural members are to be protected to a degree deemed appropriate by the Society. In addition, for ships intended for the carriage of lumber cargoes in decks, special considerations are to be taken related to stowage and securing of cargoes.

3. Deck structures for the loading of vehicles are to comply with the provisions of **9.9** and **16.3.5**.

4. Reinforcement of the ship for loading containers is to be done in accordance with the provisions of **29.2.1**. Cell guide constructions, where provided, are to be in accordance with the provisions of **29.7**.

1.1.4 Equivalency

Alternative hull construction, equipment, arrangement and scantlings will be accepted by the Society, provided that the Society is satisfied that such construction, equipment, arrangement and scantlings are equivalent to those required in this Part.

1.1.5 Stability

The requirements in this part apply to ships having appropriate stability in all conceivable conditions. The society emphasizes that special attention is to be paid to ship stability by the builders during design and construction stages and by the masters while in service.

1.1.6 Materials

1. The requirements in this part are based upon the use of materials which comply with the requirements in **Part 10**, unless otherwise specified.

2. Where high tensile steel specified in **Chapter 3, Part 10** is used, the construction and scantlings of the ship are to comply with the following requirements in **(1)** to **(3)**:

(1) The section modulus of the transverse section of the hull is not to be less than the value obtained by multiplying the following coefficient with the value specified in **Chapter 14**. Moreover, the extent of high tensile steel use is to be at the discretion of the Society.

0.78: where high tensile steels *KA*32, *KD*32, *KE*32 or *KF*32 are used

0.72 where high tensile steels *KA*36, *KD*36, *KE*36 or *KF*36 are used

0.68: where high tensile steels *KA*40, *KD*40, *KE*40 or *KF*40 are used.

(2) With the exception of the requirements in **(1)**, details such as the thickness of decks and shell plating, and the section modulus of stiffeners and other scantlings are to be at the discretion of the Society.

(3) With the exception of the requirements in **(1)**, the construction and scantlings where high tensile steels are used are to be at the discretion of the Society.

3. Where stainless steel or stainless clad steel specified in **Chapter 3, Part 10** is used for the main hull structure, use of the materials and their scantlings are to be subject to the following.

(1) The section modulus of the transverse section of the hull is not to be less than the value obtained by multiplying the following coefficient (K) with the value specified in **Chapter 14**. However, the coefficient (K) is to be rounded to three decimal places and not less than 0.72.

$$K = f\left\{8.81\left(\sigma_y/1000\right)^2 - 7.56\left(\sigma_y/1000\right) + 2.29\right\}$$

σ_Y: The minimum value of yield strength or proof stress of stainless steel or stainless clad steel specified in **Chapter 3, Part 10** of the Rules (N/mm^2)

f: To be given by the following formula:

$0.0025(T - 60) + 1.00$

If T is more than 100 °C, the value is at the discretion of the Society.

T: The maximum temperature in (°C) of cargo in contact with the materials. If the temperature is less than 60° C, *T* is to be taken as 60 °C.

(2) Where the materials used have effective resistance against corrosion from cargoes carried, the scantlings required by the relevant requirements may be reduced as deemed appropriate by the Society.

4. Where materials other than steels complying with **Part 10** of the Rules are used for the main hull structure, the use of such materials and corresponding scantlings are to be at the discretion of the Society.

5. Where materials other than those specified in the Rules are used, the use of such materials and corresponding scantlings are to be specially approved by the Society.

6. Materials used for the hull construction of ships classed for *Smooth Water Service* are to be at the Society's discretion.

1.1.7 Fire-proof Construction

Fire-proof construction is to be in accordance with the requirements in **Part 6** of the Rules.

1.1.8 Means of Escape

Means of escape are to be in accordance with the requirements in **Part 6** of the Rules.

1.1.9 Application of Steels

1. The steels used for hull structures are to be of the grades provided in **Part 10** in accordance with the requirements given in **Table 1.1** and **1.2**. In applying these requirements *KB*, *KD* or *KE* may be substituted for *KA*; *KD* or *KE* for *KB*; *KE* for *KD*; *KD*32, *KE*32 or *KF*32 for *KA*32; *KE*32 or *KF*32 for *KD*32; *KF*32 for *KE*32; *KD*36, *KE*36 or *KF*36 for *KA*36; *KE*36 or *KF*36 for *KD*36; and *KF*36 for *KE*36; *KD*40, *KE*40 or *KF*40 for *KA*40; *KE*40 or *KF*40 for *KD*40; *KF*40 for *KE*40, respectively.

2. Within 0.4*L* amidships, the widths of single strakes of sheer strakes to the strength deck, stringer plates in the strength deck, bilge strakes excluending ships of less than 150 m in length L_1 having trouble bottom structures, deck plates adjoined to longitudinal bulkheads and other members of grade *KE*, *KE*32, *KE*36, *KE*40,*KF*32, *KF*36 and *KF*40 are to be not less than the value given by the following formula (maximum being 1,800 *mm*). The widths of single strakes on rounded gunwales are to be determined by the Society.

$5L_1+800$ (*mm*)

L_1: Length (*m*) of ship specified in **1.2.2, Part 1A** or 0.97 times the length (*m*) of ship on the load line, whichever is smaller

3. Where stainless clad steel specified in **Chapter 3, Part 10** is used for hull construction, the thickness of the base steel is to be used as the thickness of the plate in **Table 1.1** and **Table 1.2**.

4. The steels with thicknesses from 50 *mm* up to 100 *mm* used for the stern frame may be of the grades *KE*, *KE*32 and *KE*36, *KE*40.

5. Application of steels with thicknesses above 50 *mm* used for hull structures (except for the stern frame) is to be at the discretion of the Society.

6. Where steel having properties different from those specified in **Table 1.1** or **Table 1.2** are used, the application of those steels is to be specially considered based on their specification and properties which shall be submitted to the Society for approval.

Table 1.1 (a) Application of Mild Steels for Various Structural Members

<table>
<tr><th rowspan="2">Structural member</th><th colspan="2" rowspan="2">Application</th><th colspan="6">Thickness of plate: t (mm)</th></tr>
<tr><th>$t \le 15$</th><th>$15 < t \le 20$</th><th>$20 < t \le 25$</th><th>$25 < t \le 30$</th><th>$30 < t \le 40$</th><th>$40 < t \le 50$</th></tr>
<tr><td colspan="9">Shell plating</td></tr>
<tr><td rowspan="4">Sheer strake at strength deck</td><td rowspan="2">within 0.4 L amidship</td><td>$L_1 \le 250$</td><td>A^{*1*4}</td><td>B</td><td colspan="2">D</td><td colspan="2">E</td></tr>
<tr><td>$L_1 > 250$</td><td colspan="6">E</td></tr>
<tr><td colspan="2">within 0.6 L amidship excluding the above</td><td colspan="2">A^{*1*4}</td><td>B</td><td colspan="2">D</td><td>E</td></tr>
<tr><td colspan="2">other than those mentioned above</td><td colspan="4">A^{*1*4}</td><td>B</td><td>D</td></tr>
<tr><td rowspan="2">Side plating</td><td rowspan="2">within 0.4 L amidship</td><td>within 0.1 D downward from the lower surface of strength deck</td><td colspan="2">A^{*1*4}</td><td>B</td><td colspan="2">D</td><td>E</td></tr>
<tr><td>other than those mentioned above</td><td colspan="4">A^{*1*4}</td><td>B</td><td>D</td></tr>
<tr><td rowspan="4">Bilge strake</td><td rowspan="2">within 0.4 L amidship</td><td>$L_1 > 250$</td><td colspan="4">D</td><td colspan="2">E</td></tr>
<tr><td>ships of 150 <$L_1 \le 250$, having double bottom structures and ships having single bottoms structures</td><td>A^{*1*4}</td><td>B</td><td colspan="2">D</td><td colspan="2">E</td></tr>
<tr><td colspan="2">within 0.6 L amidship excluding the above</td><td colspan="2">A^{*1*4}</td><td>B</td><td colspan="2">D</td><td>E</td></tr>
<tr><td colspan="2">other than those mentioned above</td><td colspan="4">A^{*1*4}</td><td>B</td><td>D</td></tr>
<tr><td>Bottom plating including keel plate</td><td colspan="2">within 0.4 L amidship</td><td colspan="2">A</td><td>B</td><td colspan="2">D</td><td>E</td></tr>
</table>

Table 1.1 (b) Application of Mild Steels for Various Structural Members (continued)

<table>
<tr><th rowspan="2">Structural member</th><th rowspan="2" colspan="2">Application</th><th colspan="6">Thickness of plate : t (*mm*)</th></tr>
<tr><th>$t\le15$</th><th>$15<t\le20$</th><th>$20<t\le25$</th><th>$25<t\le30$</th><th>$30<t\le40$</th><th>$40<t\le50$</th></tr>
<tr><td colspan="9">Deck Plating</td></tr>
<tr><td rowspan="4">Stringer plate in strength deck</td><td rowspan="2">within 0.4L amidship</td><td>$L_1\le250$</td><td>A^{*2}</td><td>B</td><td colspan="2">D</td><td colspan="2">E</td></tr>
<tr><td>$L_1>250$</td><td colspan="6">E</td></tr>
<tr><td colspan="2">within 0.6L amidship excluding the above</td><td colspan="2">A</td><td>B</td><td colspan="2">D</td><td>E</td></tr>
<tr><td colspan="2">other than those mentioned above</td><td colspan="3">A</td><td>B</td><td>D</td></tr>
<tr><td rowspan="3">Strength deck strake adjoining to longitudinal bulkhead</td><td colspan="2">within 0.4L amidship</td><td>A^{*2}</td><td>B</td><td colspan="2">D</td><td colspan="2">E</td></tr>
<tr><td colspan="2">within 0.6L amidship excluding the above</td><td colspan="2">A</td><td>B</td><td colspan="2">D</td><td>E</td></tr>
<tr><td colspan="2">other than those mentioned above</td><td colspan="3">A</td><td>B</td><td>D</td></tr>
<tr><td>Strength deck other than mentioned above</td><td colspan="2">within 0.4L amidship</td><td colspan="2">A^{*2}</td><td>B</td><td colspan="2">D</td><td>E</td></tr>
<tr><td rowspan="4">Strength deck at cargo hatch corner</td><td colspan="2">container carriers and other shpis with similar hatch openings configuration</td><td>A^{*2}</td><td>B</td><td colspan="2">D</td><td colspan="2">E</td></tr>
<tr><td rowspan="2">bulk carriers, or carriers, combination carriers and other shpis with similar hatch openings configuration</td><td>within 0.6L amidship</td><td>A^{*2}</td><td>B</td><td colspan="2">D</td><td colspan="2">E</td></tr>
<tr><td>cargo region excluding the above</td><td colspan="2">A</td><td>B</td><td colspan="2">D</td><td>E</td></tr>
<tr><td colspan="2">other than those mentioned above within 0.4L amidship</td><td colspan="2">A^{*2}</td><td>B</td><td colspan="2">D</td><td>E</td></tr>
<tr><td>Deck plating exposed to weather, in general</td><td colspan="2">within 0.4L amidship</td><td colspan="3">A</td><td>B</td><td>D</td></tr>
<tr><td colspan="9">Longitudinal bulkhead plate</td></tr>
<tr><td>Upper strake in longitudinal bulkhead adjoining to strength deck</td><td colspan="2">within 0.4L amidship</td><td colspan="2">A</td><td>B</td><td colspan="2">D</td><td>E</td></tr>
<tr><td>Other than those mentioned above</td><td colspan="2">within 0.4L amidship</td><td colspan="3">A</td><td>B</td><td>D</td></tr>
<tr><td colspan="9">Longitudinals</td></tr>
</table>

<table>
<tr><td>Upper strake in slogging plate of topside tank adjoining to strength deck</td><td colspan="2">within 0.4L amidship</td><td colspan="2">A</td><td>B</td><td colspan="2">D</td><td>E</td></tr>
<tr><td rowspan="4">Longitudinal plating members above strength deck including bracket and face plate of longitudinals</td><td rowspan="2">corners of dome openings on trunk deck and inner deck planting above strengh deck in shios with membrane tanks carriying liquefied gases in bulk</td><td>within 0.6L amidship</td><td><u>A*5</u></td><td><u>B</u></td><td colspan="2"><u>D</u></td><td colspan="2"><u>E</u></td></tr>
<tr><td>cargo region excluding the above</td><td colspan="2"><u>A</u></td><td><u>B</u></td><td colspan="2"><u>D</u></td><td><u>E</u></td></tr>
<tr><td>longitudinal girders including end brackets and face plates</td><td>within 0.4L amidship</td><td colspan="2"><u>A*3*5</u></td><td><u>B</u></td><td colspan="2"><u>D</u></td><td><u>E</u></td></tr>
<tr><td>longitudinal plating members other than those montioned above</td><td>within 0.4L amidship</td><td colspan="2">A*3<u>*5</u></td><td>B</td><td colspan="2">D</td><td>E</td></tr>
</table>

Table 1.1(c) Application of Mild Steels for Various Structural Members (continued)

<table>
<tr><td rowspan="2">Structural member</td><td colspan="2" rowspan="2">Application</td><td colspan="6">Thickness of plate : t m (mm)</td></tr>
<tr><td>t≤15</td><td>15<t≤20</td><td>20<t≤25</td><td>25<t≤30</td><td>30<t≤40</td><td>40<t≤50</td></tr>
<tr><td colspan="9">Cargo Hatch</td></tr>
<tr><td rowspan="3">Face plate web of cargo hatch coaming longitudinally extended on the strength deck</td><td rowspan="3">Longitudinal members over 0.15L (including face plate and the its flange, but excluding other stiffener) and end brackets and deck house transition</td><td>within 0.4L amidship</td><td colspan="4">D</td><td colspan="2">E</td></tr>
<tr><td>within 0.6L amidship excluding the above</td><td colspan="5">D</td><td>E</td></tr>
<tr><td>other than those mentioned above</td><td colspan="6">D</td></tr>
<tr><td>Hatch cover</td><td colspan="2"></td><td colspan="4">A</td><td>B</td><td>D</td></tr>
</table>

Stern					
Stern frame, rudderhorn, shaft bracket	___	*A*	*B*	*D*	*E*
Rudder					
Rudder plate	___	*A*	*B*	*D*	*E*
Other					
Other members than mentioned above (including stiffeners)		A^{*1*4}			

Remarks:

1 For ships with length of L_1 exceeding 150*m* and single strength deck, single side strakes for ships without inner continuous longitudinal bulkhead(s) between bottom and the strength deck within cargo region are not to be less than grade *KB* as defined in **Part 10**

2 For ships with length of L_1 exceeding 150*m* and single strength deck, longitudinal strength members of strength deck plating within 0.4*L* amidship are not to be less than grade *KB* as defined in **Part 10**.

3 For ships with length of L_1 exceeding 150*m* and single strength deck, continuous longitudinal strength members above strength deck within 0.4*L* amidship are not to be less than grade *KB* as defined in **Part 10**.

5 for ships with membrane tanks carriying liquefied gases in bulk with length of L_1 excceeeding 150 m havinh deck structure compring trunk deck and inner deck, the following structural members within 0.4L amidship are not to be less than grade KB asdefined in **Part 10.**

(1) Strength deck

(2) Inner deck above strength deck

(3) Longitudinal strength member plating between trunk deck and inner above strength deck

The above structural member for ships having similar deck structure are not to be less than *KB* where deemed necessary by the Society.

Notes:

1 *A*, *B*, *D*, *E* refers to the following grades of steel.
A: *KA*, *B*: *KB*, *D*: *KD*, *E*: *KE*

2 *L*1 is the length (*m*) of ship specified in **1.2.2, Part 1 A** or 0.97 times the length (*m*) of the ship on the load line, whichever is smaller.

3 Where the strength deck strake adjoined to the inner skin bulkhead of double hull ships is not a deck stringer plate, the deck strake may be treated as an ordinary strength deck strake.

4 Applicable areas of bilge strakes are as follows.

(1) If the point where the bottom flat line stops being parallel to the centre line of the ship is within 0.6 *L* amidships, the applicable part is to be taken as 0.6 *L* amidships.

(2) If the point where the bottom flat line stops being parallel to the centre line of the ship is outside 0.6 *L* amidships, the applicable part is to be taken as is.

5 The type of steel used in way of lower pintle for type D and type E rudders specified in **Chapter 3** and in way of upper part of type C rudder specified in **Chapter 3** is to be approved by the Society.

6 <u>Continuos longitudinal plating of strength members above strength deck (including trunk deck, inner and longitudinal strength member plating between trunk deck and inner deck) are to be treated as longitudinal plating members above streght deck.</u>

Table 1.2 (a) Application of High Tensile Steels for Various Structural Members

<table>
<tr><th rowspan="2">Structural member</th><th rowspan="2" colspan="2">Application</th><th colspan="6">Thickness of plate : t (mm)</th></tr>
<tr><th>$t\le 15$</th><th>$15<t\le 20$</th><th>$20<t\le 25$</th><th>$25<t\le 30$</th><th>$30<t\le 40$</th><th>$40<t\le 50$</th></tr>
<tr><td colspan="9">Shell plating</td></tr>
<tr><td rowspan="4">Sheer strake at strength deck</td><td rowspan="2">within 0.4L amidship</td><td>$L_1\le 250$</td><td colspan="2">AH</td><td colspan="2">DH</td><td colspan="2">EH</td></tr>
<tr><td>$L_1>250$</td><td colspan="6">EH</td></tr>
<tr><td colspan="2">within 0.6L amidship excluding the above</td><td colspan="3">AH</td><td colspan="2">DH</td><td>EH</td></tr>
<tr><td colspan="2">other than those mentioned above</td><td colspan="5">AH</td><td>DH</td></tr>
<tr><td rowspan="2">Side plating</td><td rowspan="2">within 0.4L amidship</td><td>within 0.1L downward from the lower surface of strength deck</td><td colspan="3">AH</td><td colspan="2">DH</td><td>EH</td></tr>
<tr><td>other than those mentioned above</td><td colspan="5">AH</td><td>DH</td></tr>
<tr><td rowspan="4">Bilge Strake</td><td rowspan="2">within 0.4L amidship</td><td>$L_1>250$</td><td colspan="4">DH</td><td colspan="2">EH</td></tr>
<tr><td>ships of $150<L_1\le 250$, having double bottom structures and ships having single bottom structures</td><td colspan="2">AH</td><td colspan="2">DH</td><td colspan="2">EH</td></tr>
<tr><td colspan="2">within 0.6L amidship excluding the above</td><td colspan="3">AH</td><td colspan="2">DH</td><td>EH</td></tr>
<tr><td colspan="2">other than those mentioned above</td><td colspan="5">AH</td><td>DH</td></tr>
<tr><td>Bottom plating including keel plate</td><td colspan="2">within 0.4L amidship</td><td colspan="3">AH</td><td colspan="2">DH</td><td>EH</td></tr>
<tr><td colspan="9">Deck plating</td></tr>
<tr><td rowspan="4">Stringer plate in strength deck</td><td rowspan="2">within 0.4L amidship</td><td>$L_1\le 250$</td><td colspan="2">AH</td><td colspan="2">DH</td><td colspan="2">EH</td></tr>
<tr><td>$L_1>250$</td><td colspan="6">EH</td></tr>
<tr><td colspan="2">within 0.6L amidship excluding the above</td><td colspan="3">AH</td><td colspan="2">DH</td><td>EH</td></tr>
<tr><td colspan="2">other than those mentioned above</td><td colspan="5">AH</td><td>DH</td></tr>
<tr><td rowspan="3">Strength deck strake adjoining to longitudinal bulkhead</td><td colspan="2">Within 0.4L amidship</td><td colspan="2">AH</td><td colspan="2">DH</td><td colspan="2">EH</td></tr>
<tr><td colspan="2">within 0.6L amidship excluding the above</td><td colspan="3">AH</td><td colspan="2">DH</td><td>EH</td></tr>
<tr><td colspan="2">other than those mentioned above</td><td colspan="5">AH</td><td>DH</td></tr>
<tr><td>Strength deck other than mentioned above</td><td colspan="2">within 0.4L amidship</td><td colspan="3">AH</td><td colspan="2">DH</td><td>EH</td></tr>
<tr><td rowspan="2">Strength deck at cargo hatch corner</td><td colspan="2">container carriers and others ships with similar hatch opening configuration</td><td colspan="2">AH</td><td colspan="2">DH</td><td colspan="2">EH</td></tr>
<tr><td>bulk carriers, ore carriers,</td><td>within 0.6L amidship</td><td colspan="2">AH</td><td colspan="2">DH</td><td colspan="2">EH</td></tr>
</table>

	combination carriers and others ships with similar hatch opening configuration	cargo region excluding the above	*AH*	*DH*	*EH*
	other than those mentioned above within 0.4*L* amidship		*AH*		*DH*
Deck plating exposed to weather, in general	within 0.4*L* amidsship		*AH*		*DH*

Table 1.2 (b) Application of High Tensile Steels for Various Structural Members (continued)

Structural member	Application		Thickness of plate : t (*mm*)					
			t≤15	15<t≤20	20<t≤25	25<t≤30	30<t≤40	40<t≤50
Longitudinal bulkhead plate								
Upper strake in longitudinal bulkhead adjoining to strength deck	within 0.4L amidship		*AH*			*DH*		*EH*
other than those mentioned above	within 0.4L amidship		*AH*					*DH*
Longitudinals								
Upper strake in sloping plate of tpside tank adjoining to strength deck	within 0.4Lamidship		*AH*			*DH*		*EH*
Longitudinal members above strength deck including bracket and face of longitudinals	within 0.4L amidship		*AH*			*DH*		*EH*
Cargo hatch								
Face plate and web of cargo hatch coaming longitudinally extended on the strenght deck	longitudinal members over 0.15L and end brakets and deck house transition	within 0.4L amidship	*DH*				*EH*	
		within 0.6L amidship excluding the above	*DH*					*EH*
		other than those mentioned above	*DH*					
Hatch cover			*AH*					*DH*
Stern								

Stern frame, rudderhorn, shaft bracket	___	*AH*	*DH*	*EH*
Rudder				
Rudder plate	___	*AH*	*DH*	*EH*
Other				
Other members than those mentioned above		*AH*		

Notes:

1 *AH*, *DH*, *EH* refer to the following grades of steel.

AH: *KA*32, *KA*36 and *KA*40; *DH*: *KD*32, *KD*36 and *KD*40; *EH*: *KE*32, *KE*36 and *KE*40

2 L_1 is the length (m) of ship specified in **1.2.2, Part 1 A** or 0.97 times the length (m) of the ship on the load line, whichever is smaller.

3 Where the strength deck strake adjoined to the inner skin bulkhead of double hull ships is not a deck stringer plate, the deck strake may be treated as an ordinary strength deck strake.

4 An applicable area of bilge strakes is as follows.

(1) If the point where the bottom flat line stops being parallel to the centre line of the ship is within 0.6 *L* amidships, the applicable part is to be taken as 0.6 *L* amidships.

(2) If the point where the bottom flat line stops being parallel to the centre line of the ship is outside 0.6 *L* amidships, the applicable part is to be taken as is.

5. The type of steel used in way of lower pintle for type D and type E rudders specified in **Chapter 3** and in way of upper part of type.

6 C rudder specified in **Chapter 3** is to be approved by the Society.

1.1.10 Special Requirements for Application of Steels

1. For ships that have been designed to a specific design temperature (T_D) in order to operate in areas with low air temperatures (e.g. Arctic or Antarctic waters), the application of steels used for hull structures is to be suitable for the design temperature, regardless of the requirements specified in **Table 1.1** and **Table 1.2**.

2. For ships carrying cargoes with low temperatures, the application of steels used for longitudinals in the cargo hold is to be suitable for the design temperature, regardless of the requirements specified in **Table 1.1** and **Table 1.2**. In this case, the design temperature (T_D) of the cargo hold is to be determined.

3. Ships subject to the requirements in **-1** are registered with the relevant notations.

1.1.11 Scantlings

1. "The midship part" and "end parts" of the ship used when describing the location of structural members and their scantlings are the parts defined in **1.2.9** and **1.2.10, Part 1 A** respectively.

2. Unless specified otherwise, scantlings of structural members of the midship part can be reduced gradually over the length of 0.1*L* afore and abaft.

3. Section moduli specified by the Rules include the steel plates with an effective breadth of $0.1l$ on either side of the members, unless specified otherwise. However, the $0.1l$ steel plates are not to exceed one-half of the distance to the next member. l is the length of the member specified in the relevant Chapters.

4. When calculating the section moduli of longitudinals or longitudinal stiffeners, these values may be properly reduced where these members are effectively supported inside the span defined in the formula.

5. Where flat bars, angles or flanged plates are welded to form beams, frames or stiffeners for which section moduli are specified, they are to be of suitable depth and thickness in proportion to the section modulus specified in the Rules.

6. For members such as girders and floors, to which sectional area of face plate is specified, the breadth of the flange is not to be less than that obtained from the following formula, where the inner edge of the web plate is flanged in lieu of a face plate.

$$\frac{100A}{t} + 1.5t \quad (mm)$$

Where

A: Required sectional area (cm^2) of face plate

t: Thickness (*mm*) of web plate

1.1.12 Connection of Ends of Stiffeners, Girders and Frames

1. Where the ends of girders are connected to locations such as bulkheads and tank tops, the end connections of all girders are to be balanced by effective supporting members on the opposite side of these locations.

2. The length of the frame-side arm of brackets connected to the frames or stiffeners of locations such as bulkheads or deep tanks is not to be less than one-eighth of l specified in the relevant Chapter, unless otherwise specified.

3. Where stiffeners support the longitudinals penetrating floors or transverse girders in tanks, the connection of the stiffeners to the longitudinals is to have enough fatigue strength for the dynamic pressure that occurs in such tanks.

These stiffeners are to be of a thickness not less than the minimum thickness required for floors or transverse girders and the depth of which is not to be less than 0.08 times the depth of girders or transverse floors (d_0 (*mm*)) minus the height of the longitudinals. However, stiffeners of an equivalent or greater strength are deemed acceptable.

1.1.13 Brackets

The size of brackets is to be determined by **Table 1.3** according to the length of the longer arm.

The thickness of brackets is to be suitably increased where the depth of the brackets at the throat is less than two-thirds of the longer arm of the bracket.

Where lightening holes are cut into the brackets, the distance from the circumference of the hole to the free flange of the bracket is not to be less than the diameter of the lightening hole.

Where the length of the longer arm exceeds 800 *mm*, the free edges of the brackets are to be stiffened by flanging or by other means, except where tripping brackets or the like are provided.

Table 1.3 Brackets (Unit: *mm*)

Lenght of longer arm	Thickness		Breddth flange	Length of longer arm	Thickness		Breddth flange
	Plane	Flanged			Plane	Flanged	
150	6.5	—	—	700	14.0	9.5	70
200	7.0	6.5	30	750	14.5	10.0	70
250	8.0	6.5	30	800	—	10.5	80
300	8.5	7.0	40	850	—	11.0	85
350	9.0	7.0	40	900	—	11.0	90
400	10.0	8.0	50	950	—	11.5	90
450	10.5	8.0	50	1000	—	11.5	95
500	11.0	8.5	55	1050	—	12.0	100
550	12.0	8.5	55	1100	—	12.5	105
600	12.5	9.0	65	1150	—	12.5	110
650	13.0	9.0	65				

1.1.14 Modification of Span (*l*) for Thicker Brackets

Where brackets are not thinner than the girder plates, the value of *l* specified in **Chapter 7** and **Chapters 10** to **13** may be modified in accordance with the following:

(1) Where the sectional area of the face plate of the bracket is not less than one-half that of the girder and the face plate of the girder is carried to the bulkhead, deck, tank top, etc., *l* may be measured to a point 0.15 *m* inside the toe of the bracket.

(2) Where the sectional area of the face plate of the bracket is less than one-half that of the girder and the face plate of the girder is carried on to the bulkhead, deck, tank top, etc., *l* may be measured to a point where the sum of sectional areas of the bracket and its face plate outside the line of the girder is equal to the sectional area of the face plate of girder, or to a point 0.15 *m* inside the toe of the bracket, whichever is greater.

(3) Where brackets are provided and the face plates of girders extend along the free edge of brackets to the bulkhead, deck, tank top, etc., even if the free edge of brackets is curved *l* is to be measured to the toe of the bracket.

(4) Brackets are not to be considered effective beyond the point where the arm along the girder is 1.5 times the length of the arm on the bulkhead, deck, tank top, etc.

In no case is the allowance in l at either end to exceed one-quarter of the overall length of the girder including the part of end connection.

1.1.15 Workmanship

1. The workmanship is to be of the best quality. During construction, the builder is to supervise and inspect in detail every job performed in the shed and yard.

2. The connection of structural parts of the hull is to be fair and sound.

3. The edges of steel plates are to be accurate and fair.

4. The flanging inner radius is not to be less than two times but not greater than 3 *times* the thickness of plate.

5. Where frames or beams pass through watertight decks or bulkheads, the deck or bulkhead is to be constructed watertight without using wooden materials or cement.

6. The details of welded joints and their workmanship are to be as specified in **Part 11**.

1.1.16 Docking

Every ship is recommended to be dry docked within six months after launching.

1.1.17 Equipment

Masts and riggings, cargo handling, mooring and anchoring arrangements and other fittings for which there are no particular requirements in this part are to be of appropriate construction and arrangement suitable for their respective purposes, and tests are to be carried out to the satisfaction of the Surveyor, where deemed necessary.

1.1.18 Carriage of Oils or Other Flammable Liquids

1. The requirements for the construction and arrangement of ships for the carriage of fuel oils specified in this part apply to ships carrying fuel oils having a flashpoint not less than 60°C determined by a closed cup test.

2. The construction and arrangement of ships for the carriage of fuel oils having a flashpoint less than 60°C determined by a closed cup test are to be in accordance with the requirements provided in this Part, as well as other requirements deemed necessary by the Society.

3. The construction and arrangement of deep oil tanks of ships intended to carry cargo oils are to be in accordance with the requirements in **Chapter 26**.

4. Oils or other flammable liquids are not to be carried in tanks forward of the collision bulkhead.

1.1.19 Approved Corrosion Control

1. Where an approved measure of corrosion control is applied to tanks, the required scantlings of structural members in the tanks may be reduced at the Society s discretion.

1.1.20 Direct Calculations

1. Where approved by the Society, direct calculations may be used to determine the scantlings of primary members. Where direct calculations are used, the data necessary for the calculations are to be submitted to the Society.

2. Where deemed necessary by the Society based on factors such as the type and size of the ship, the scantlings of primary members are to be determined by the direct strength analysis.

1.1.21 Structural Details

1. Structural discontinuities and the abrupt changes of cross sections are to be avoided as far as practicable.

2. Corners of all openings are to be well rounded.

3. Where rigid structural members with small sectional areas, such as brackets, are welded on to relatively thin plate, at least the toes of such members are to be welded on to other rigid members.

4. When deemed necessary by the Society, a fatigue strength assessment is to be carried out on the structural details of areas where stress is concentrated, such as joints of longitudinals (between the forward end of the engine room and the collision bulkhead) and transverse members (including ordinary transverses, transverse bulkheads or floors); girder members connecting side shell plating or bulkheads; and discontinuous structures.

5. Where a fatigue strength assessment is required by the requirements in **-4**, the documents related to the fatigue strength assessment are to be submitted to the Society.

1.1.22 Ship Identification Number

1. For cargo ships not less than 300 *gross tonnages* engaged on international voyages, the ship's identification number is to be permanently marked as follows.

(1) In a visible place either on the stern of the ship or on either side of the hull, amidships port and starboard, above the deepest assigned load line or either side of the superstructure etc., port and starboard or on the front of the superstructure etc.

(2) In an easily accessible place either on one of the end transverse bulkheads of the machinery spaces, as defined in **1.2.33, Part 1A**, or on one of the hatchways or, in the case of tankers, in the pump-room or, in the case of ships with ro-ro spaces, as defined in regulation **3.2.41, Part 6**, on one of the end transverse bulkheads of the ro-ro spaces.

2. The ship's identification number is to be marked as follows.

(1) The permanent marking is to be plainly visible, clear of any other markings on the hull and is to be painted in a colour contrasting with the surroundings.

(2) The permanent marking referred to in **-1(1)** is to be not less than 200 *mm* in height and the permanent marking referred to in **-1(2)** is to be not less than 100 *mm* in height. The width of the marks is to be proportionate to the height.

(3) The permanent marking may be made by raised lettering or by cutting it in or by centre punching it or by any other equivalent method of marking, and may be ensured that the marking is not easily expunged. In this case, the strength of the ship's construction is not to be affected by the method of marking.

1.2 Welding

1.2.1 Application

The welding used in hull construction and important equipment is to be in accordance with the requirements in **Part 11** as well as those in **1.2** of this part.

1.2.2 Arrangements

1. Special attention is to be paid to the arrangements of hull structural members so that welding may be carried out without much difficulty.

2. Welding joints are to be properly shifted from places where the stresses may be highly concentrated.

1.2.3 Details of Joints

1. The details of butt welded joints are to be within the set limits which are approved in accordance with the requirements in **Chapter 4, Part 12**. The breadth of overlap for lap joints or joggled lap joints which may be subject to bending is to be equivalent to the standards specified below.

(1) The breadth of overlap for lap joints is not to be less than that obtained from the following formula, but need not exceed *50 mm*.

$$2t + 25\ (mm)$$

Where:

t: Thickness (*mm*) of the thinner plate

(2) The breadth of overlap for joggled lap joints is not to be less than that obtained from the following formula, but need not exceed 40 *mm*.

$$t + 25\ (mm)$$

Where:

t: Thickness (*mm*) of the thinner plate

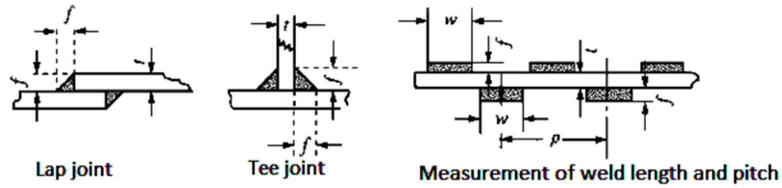
2. Butt welded joints of plates having a difference in thickness over 4 *mm* are generally to be tapered by not more than one-third at the end of the thicker plate.

3. The kind and size of fillet welds are to be in accordance with **Table 1.4** and their application to the hull construction is to be as required by **Table 1.5**. In tankers, they are also to be in accordance with **Table 26.20**.

4. Slot welds are to have adequate shapes to permit a thoroughly fused bead to be applied all around the bottom edge of the opening. The fillet size of slot welds is to be $F1$ as specified in **Table 1.4** and the spacing of the slots is to be as determined by the Society.

Table 1.4 Kinds and Sizes of Fillet Welds Unit: (*mm*)

<table>
<tr><td rowspan="4">Kind of fillet weld

Thickness of members</td><td colspan="6">
</td></tr>
<tr><td colspan="2">Continuous fillet weld</td><td colspan="4">Intermittent fillet weld</td></tr>
<tr><td colspan="2">Size of fillet f</td><td rowspan="2">Size of fillet f</td><td rowspan="2">Length of fillet w</td><td colspan="2">Pitch p</td></tr>
<tr><td>F1</td><td>F2</td><td>F3</td><td>F4</td></tr>
<tr><td>Up to 5</td><td>3</td><td rowspan="2">3</td><td>3</td><td>60</td><td>150</td><td>250</td></tr>
<tr><td>6</td><td>4</td><td>4</td><td rowspan="21">75</td><td rowspan="21">200</td><td rowspan="21">350</td></tr>
<tr><td>7</td><td rowspan="2">5</td><td rowspan="5">4</td><td rowspan="2">5</td></tr>
<tr><td>8</td></tr>
<tr><td>9</td><td rowspan="3">6</td><td rowspan="3">6</td></tr>
<tr><td>10</td></tr>
<tr><td>11</td></tr>
<tr><td>12</td><td rowspan="3">7</td><td rowspan="3">5</td><td rowspan="3">7</td></tr>
<tr><td>13</td></tr>
<tr><td>14</td></tr>
<tr><td>15</td><td rowspan="3">8</td><td rowspan="3">6</td><td rowspan="3">8</td></tr>
<tr><td>16</td></tr>
<tr><td>17</td></tr>
<tr><td>18</td><td rowspan="4">9</td><td rowspan="8">7</td><td rowspan="4">9</td></tr>
<tr><td>19</td></tr>
<tr><td>20</td></tr>
<tr><td>21</td></tr>
<tr><td>22</td><td rowspan="4">10</td><td rowspan="4">10</td></tr>
<tr><td>23</td></tr>
<tr><td>24</td></tr>
<tr><td>25</td></tr>
<tr><td>From 26 to 40</td><td>11</td><td>8</td><td>11</td></tr>
</table>

Notes

1 Generally, the size of the fillet "f" for Tee joints is to be determined according to the thickness of webs in case of connections of beams, frames, stiffeners and girders to deck plating, inner bottom plates, bulkhead plates, shell plating or face plates, and the thickness of the thinner plate in case of connections of other members.

2 Lap joints are to have the fillet size of $F1$ determined according to the thickness of the thinner plate.

3 The throat thickness of the fillet is to be $0.7f$.

4 Generally, $F2$ is to be the minimum fillet size.

5 Intermittent fillet welds are to be staggered and performed on both sides for w from both ends.

6 The minus tolerance for fillet size is to be 10% of the nominal size.

Table 1.5 (a) Application of Fillet Welds

Line No.	Item			Aplication		Kind of weld
1	Rudders	Rudder Frames		Rudder plates		*F*3
2				Vertical frames forming main pieces		*F*1
3				Rudder frames (except above)		*F*2
4	Single bottoms	Floor plates		Shell plates	In strengthened bottom forward, after peaks and deep tanks	*F*3
5					Elsewhere	*F*4
6				Face plates of floor plates	In strengthened bottom forward and main engine room	*F*3
7					Elsewhere	*F*4
8				Ttrough plates and rider plates of centre keelsons		*F*1
9		Centre Keel-sons	Girders	Flat plate keels	In strengthened bottom forward	*F*2
10					Elsewhere	*F*3
11				Rider plates		*F*3
12				Floor plates		*F*2
13		Side Keel-sons	Girders	Shell plates	In strengthened bottom forward	*F*3
14					Elsewhere	*F*4
15				Rider plates	In main engine rooms	*F*3
16					Elsewhere	*F*4
17				Floor plates		*F*3
18	Double bottoms with transverse framing	Solid floors		Shell plates	In strengthened bottom forward	*F*3
19					Elsewhere	*F*4
20				Inner bottom plates	Bed plates of main engine and thrust bearings	*F*2
21					In strengthened bottom forward and main engine room (except above)	*F*3
22					Elsewhere	*F*4
23				Girders under inner bottom below main engine seatings		*F*1
24				Centre girders	In strengthened bottom forward and main engine room (except above)	*F*2
25					Elsewhere	*F*3
26				Margin plates		*F*2
27		Oiltight or watertight floors		Boundaries		*F*1
28		Stiffeners on floor plates		Oiltight and watertight floors		*F*3
29				Elsewhere		*F*4

Table 1.5 (b) Application of Fillet Welds (continued)

Line No.	Item			Aplication		Kind of weld
30	Double bottoms with transverse framing	Open floors	Frames	Shell plates		*F*4
31			Reverse frame	Inner bottom plates		*F*4
32			Brackets	Centre girders		*F*3
33				Margin plates		*F*2
34			Vertical struts	Side girders		*F*4
35		Centre girders		Flat plate keels	Where oiltight or watertight	*F*1
36					Elsewhere	*F*3
37				Inner bottom plates	Where oiltight or watertight	*F*1
38					Lower portion of girders for main engine seatings or thrust bearings	*F*2
39					Elsewhere	*F*3
40		Side girders (intercostal plates)		Shell plates	In strengthened bottom forward	*F*3
41					Elsewhere	*F*4
42				Inner bottom plates	In engine rooms	*F*3
43					Elsewhere	*F*4
44				Solid floors	In strengthened bottom forward and main engine rooms	*F*3
45					Elsewhere	*F*4
46		Main engine girders		Inner bottom plates		*F*2
47				Shell plates		*F*4
48		Margin plates		Shell or gusset plates		*F*1
49		Tank side brackets		Margin plates		*F*1
50				Gusset plates		*F*2
51		Shell stiffeners		Connections to shell plates are as required for longitudinal frames		
52		Half-height girders		Connections to shell plates solid floors are as required for siede girders		
53	Double bottoms with longitudinal framing	Longitudinal frames		Shell plates in strengthened bottom forward		*F*3
54				Shell plates (except above) or inner bottom plates		*F*4
55		Solid floors		Shell plates and bottom plates	For two frame spaces at the end of floors	*F*2
56					Elsewhere	*F*3
57				Centre girders		*F*2
58		Brackets on centr girders		Centre girders, Shell plates and inner bottom plates		*F*3
59		Brackets on margin plates in double bottoms		Margin plates		*F*2
60				Shell plates and inner bottom plates		*F*3

Table 1.5 (c) Application of Fillet Welds (continued)

Line No.	Item		Application		Kind of weld
61		Stiffeners on side girders	Side girders		*F*4
62	Frames	Shell plates	In after peak tanks, for 0.125*L* from fore end, and in deep tanks		*F*3
63			Elsewhere		*F*4
64	Built-up frames	Webs	Shell plates or face plates	0.125*L* from fore end, and in deep tanks	*F*2
65				Elsewhere	*F*3
66	Decks	Stringer plates	Shell plates	In strength decks	*F*1
67				Elsewhere	*F*2
68		Beams	Decks	In tanks	*F*3
69				Elsewhere	*F*4
70	Built-up beames	Webs	Decks or face plates	In tanks	*F*2
71				Elsewhere	*F*3
72	Pillars	Pillars	Heels and heads		*F*1
73			Connections of built-up pillar members		*F*3
74	Hatchways	Coamings	Decks (except below)		*F*2
75			Hatchway corners on strength decks		*F*1
76		Portable beams	Connections of members		*F*3
77	Bulkheads	Stiffeners	Bulkheads plates	Above the lower ends of brackets connecting stiffeners to deck girder	*F*1
78				In deep tank bulkhead	*F*3
79				Elsewhere	*F*4
80		Bulkhead plates	Boundaries	In oiltight and watertight bulkheads	*F*1
81				Elsewhere	*F*3
82	Seatings	Girders or brackets	Bed plates	In seatings for main engine, thrust bearings, boiler bearers and main dynamo engines	*F*1
83			Inner bottom plates or shell	In seatings for main engine or thrust bearings	*F*2
84			Girder plates	In seatings for main engine or thrust bearings	*F*1
85	Web beams, web frames, side stringers, deck girders and girders on bulkheads	Web plates or girder plates	Shell, decks or bulkheads	In tanks, web frames for 0.125*L* from fore end and side stringers	*F*2
86				Elsewhere	*F*3
87			End conections of both ends of webs or girder plates to shell, deck, inner bottom plates or bulkheads		*F*1
88			Webs or face plates of webs	In tanks, web frames for 0.125*L* from fore end and side stringers	*F*2

Table 1.5 (d) Application of Fillet Welds (concluded)

<table>
<tr><th>Line No.</th><th colspan="2">Item</th><th colspan="3">Application</th><th>Kind of weld</th></tr>
<tr><td>89</td><td rowspan="4">Web beams, web frames, side stringers, deck girders and girders on bulkheads</td><td rowspan="2">Web plates or girders plates</td><td rowspan="2">Webs or face plates of webs</td><td rowspan="2">Elsewhere</td><td>Where face area exceeds 65cm^2</td><td>$F2$</td></tr>
<tr><td>90</td><td>Where face area does not exceed 65cm^2</td><td>$F3$</td></tr>
<tr><td>91</td><td>Tripping brackets on webs or girder plates</td><td colspan="3">Boundaries</td><td>$F3$</td></tr>
<tr><td>92</td><td>Slotted parts of webs or girder plates</td><td colspan="3">Webs of frames, beams or stiffeners</td><td>$F2$</td></tr>
<tr><td>93</td><td colspan="2">Brackets at ends of members</td><td colspan="3">Connections of members to brackets (except otherwise specified)</td><td>$F1$</td></tr>
</table>

Notes:

1 Where longitudinal strength members are mutually connected by fillet welds, the fillet sizes are to be in accordance with **Table 1.4** and this Table, except that the total throat areas of fillet joints are not to be less than the minimum sectional area of the members.

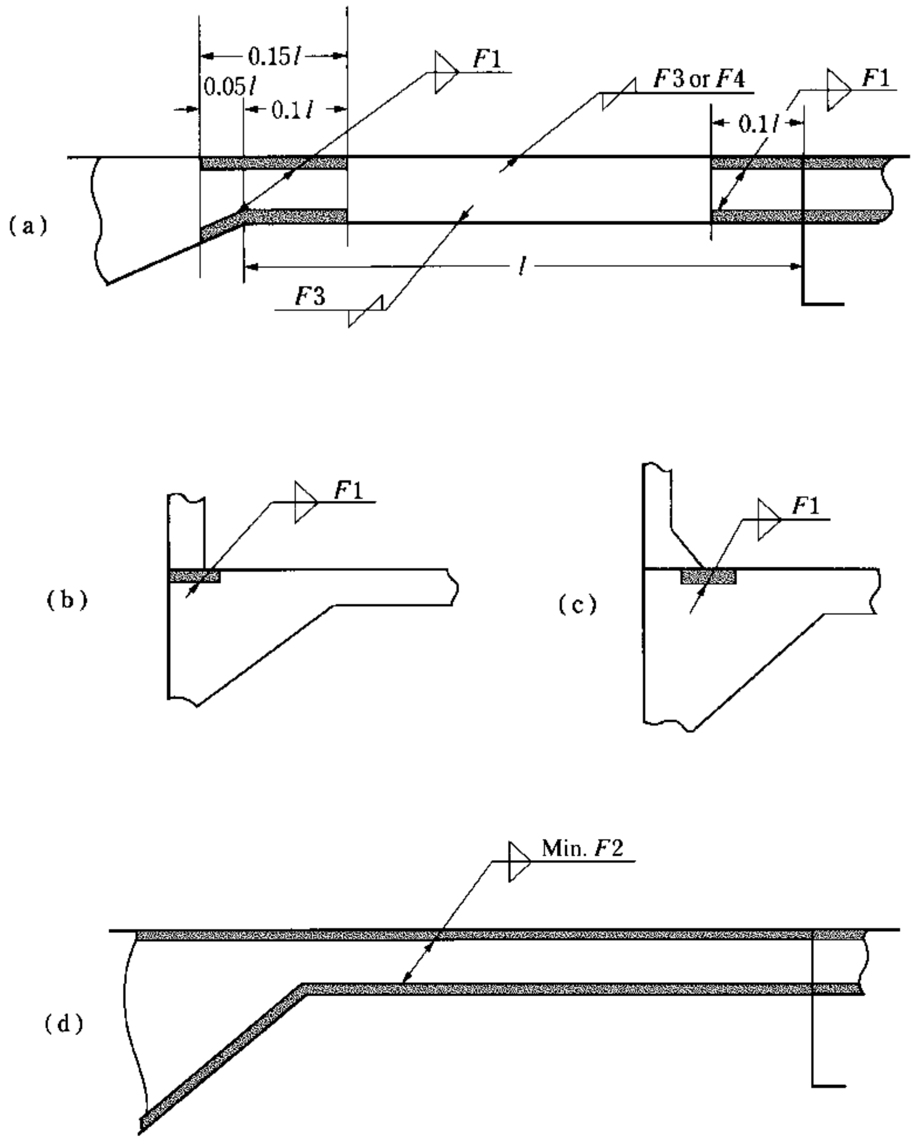
2 Where the ends of frames, beam and stiffeners are directly fillet welded to deck, shell, inner bottom or bulkhead plates, the fillet sizes are not to be less than 0.7 *times* the web thickness of the members.

3 Where beams, frames, stiffeners and girders are intermittently welded to deck, shell, inner bottom plates and bulkhead plates, the fillet welds are to be partly continuous as shown in **Fig. 1.1** (a). Where the members are backed by other members at the opposite side as shown in **Fig. 1.1** (b) or (c), the fillet welds are to be continuous for a proper length at the ends of the members or at the toes of the brackets of the members. The fillet weld may be as shown in **Fig. 1.1** (d), where the whole lengths of the joints are welded with the effective fillet size not less than $F2$.

4 Where the rider plates or inner bottom plates consist of bed plates of the main engine seating or seatings of other important machinery, the kind of fillet is to be in accordance with the requirements for the type of seating.

5 For connections other than those specified in double bottoms with longitudinal framing, the requirements for transverse framing are to be applied.

Fig. 1.1 Parts of Continuous Fillet Weld



Chapter 2 STEMS AND STERN FRAMES

2.1 Stems

2.1.1 Plate Stems

1. The thickness of steel plate stems at the designed maximum load line is not to be less than that obtained from the following formula. Above and below the designed maximum load line, the thickness may be gradually tapered toward the stem head and the keel. At the upper end of stem it may be equal to the thickness of the side shell plating (at the fore end part) of the ship, and at the lower end of stem, it is to be equal to the thickness of the plate keel.

$$1.5\sqrt{L-50}+30\ (mm)$$

2. Ribs are to be provided on the stem plates at an interval preferably not exceeding one metre, and where the radius of curvature at the fore end of the stem is large, proper reinforcement is to be made by providing it with a centre line stiffener or by increasing the thickness of the stem plates specified in **-1**, or by any other appropriate means.

2.2 Stern Frames

2.2.1 Application

The requirements in 2.2 apply only to stern frames without rudder post.

2.2.2 Propeller Posts

1. Propeller posts of cast steel stern frames and those of plate stern frames are to be of a shape suitable for the stream line at the after part of the hull, and the standard scantlings are given by the formulae and figures in Fig. 2.1. Below the propeller boss, the breadth and thickness of the propeller post are to be gradually increased in order to provide sufficient strength and stiffness in proportion to the shoe pieces.

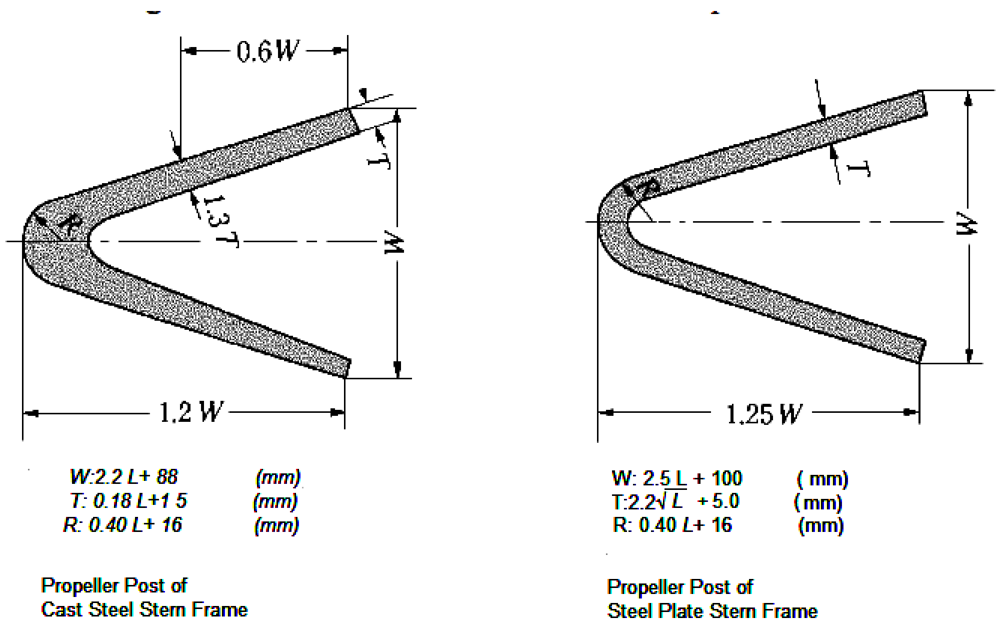
2. The thickness of the boss of the propeller post is not to be less than that obtained from the following formula:

$$0.9L+10\ (mm)$$

3. The propeller posts of cast steel stern frames and those of plate stern frames are to be provided with ribs at a suitable interval. Where the radius of curvature is large, a centre line stiffener is to be provided.

4. For ships with relatively high speed for their length and ships exclusively engaged in towing purposes, the scantlings of various parts of propeller posts are to be suitably increased.

Fig. 2.1 Standard Dimensions of Propeller Posts



2.2.3 Shoe pieces

1. The scantling of each cross-section of the shoe piece (*See* **Fig. 2.2**) is to be determined by the following formulas **(1)** to **(4)**, considering the bending moment and shear force acting on the shoe piece when the rudder force specified in **3.2** is applied to the rudder.

(1) The section modulus Z_z with respect to the vertical Z-axis is not to be less than:

$$Z_Z = \frac{MK_{sp}}{80}\ (cm^3)$$

Where:

M : Bending moment at the section considered, which is obtained from the following formula.

$M = Bx\ (M_{max} = Bl)(Nm)$

B : Supporting force in the pintle bearing (N) as given in **3.4.1**

x : Distance (m) from the mid-point of the pintle bearing to the section considered, as specified in **Fig. 2.2**

l : Distance (m) from the mid-point of the pintle bearing to the fixed point of the shoe piece, as specified in **Fig. 2.2**

K_{SP} : Material factor for the shoe piece as given in **3.1.2**

(2) The section modulus Z_Y with respect to the transverse Y-axis is not to be less than:

$Z_Y = 0.5Z_Z\ (cm^3)$

Where:

Z_Z : As specified in **(1)**

(3) The total section area $\boldsymbol{A_S}$ of the members in the Y- direction is not to be less than:

$$A_S = \frac{BK_{SP}}{48} \ (mm^2)$$

Where:

B and K_{SP}: As specified in **(1)**

(4) At no section within length $\boldsymbol{l}$ is the equivalent stress to exceed $115/K_{SP}$ (N/mm^2). The equivalent stress $\boldsymbol{\sigma_e}$ is to be obtained from the following formula:

$$\sigma_e = \sqrt{\sigma_b^2 + 3t^2} \ (N/mm^2)$$

The bending stress and the shear stress acting on the shoe piece are to be obtained from the following formulae respectively:

Bending stress: $\sigma_b = \frac{M}{Z_Z(X)} \ (N/mm^2)$

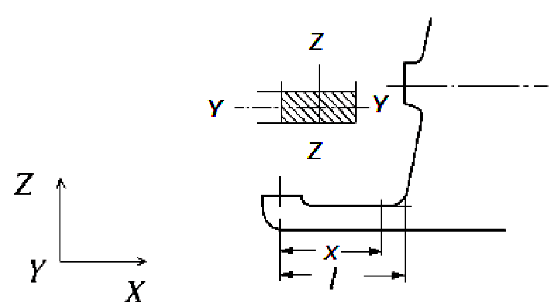
Shear stress: $t = \frac{B}{A_S} \ (N/mm^2)$

Where:

Z_Z, A_S, M and B : As specified in **(1)** to **(3)**

2. The thickness of the steel plates forming the main part of the shoe piece of the steel plate stern frame is not to be less than that of the steel plates forming the main part of the propeller post. Ribs are to be arranged in the shoe piece below the propeller post, under brackets and at other suitable positions.

Fig. 2.2 Shoe Piece



2.2.4 Heel Pieces

The heel piece of the stern frame is to be of length at least three *times* the frame space at that part and is to be strongly connected to the keel.

2.2.5 Rudder Horns

1. The scantling of each cross-section of the rudder horn (*See* **Fig. 2.3**) is to be determined by the following formulae **(1)** to **(3)**, considering the bending moment, shear force, and torque acting on the rudder horn when the rudder force specified in **3.2** is applied to the rudder.

(1) The section modulus Z_x with respect to the horizontal X-axis is not to be less than:

$$Z_x = \frac{MK_{rh}}{67}\ (cm^3)$$

Where:

M: Bending moment at the section considered which is obtained from the following formula (*See* **Fig. 2.3**).

$$M = Bz\ (M_{max} = Bd)(Nm)$$

B: Supporting force in the pintle bearing (N) as given in **3.4.1**

z: Distance (m) from the mid-point of the length of the pintle bearing to the section under consideration, as specified in **Fig. 2.3**

K_{rh}: Material factor of the rudder horn obtained from the requirements in **3.1.2**

(2) The total sectional area A_h of the members in the Y-direction is not to be less than:

$$A_h = \frac{BK_{rh}}{48}\ (mm^2)$$

Where:

K_{rh}: As specified in **(1)**

(3) At no section within the height d, the equivalent stress is to exceed 120 / K_{rh} (N/mm^2).

The equivalent stress σ_e s is to be obtained from the following formula:

$$\sigma_e \sqrt{\sigma_b^2 + 3(t^2 + t_1^2)}\ (N/mm^2)$$

The bending stress, shear stress and torsional stress acting on the rudder horn are to be obtained from the following formulae respectively:

Bending stress: $\sigma_b = \frac{M}{Z_x}\ (N/(mm^2)$

Shear stress:$t = \frac{B}{A_h}\ \ (N/mm^2)$

Torsional stress:$\tau_t = \frac{1000T_h}{2A_t\tau_h}\ \ (\frac{N}{mm^2})$

Where:

T_h : The torsional moment at the section considered which is obtained from the following formula (*See* **Fig. 2.3**).

$$T_h = Bc\ (Z) = (N/mm^2)$$

A_t : Area in the horizontal section enclosed by the rudder horn (mm^2)

t_h : Plate thickness of the rudder horn (mm)

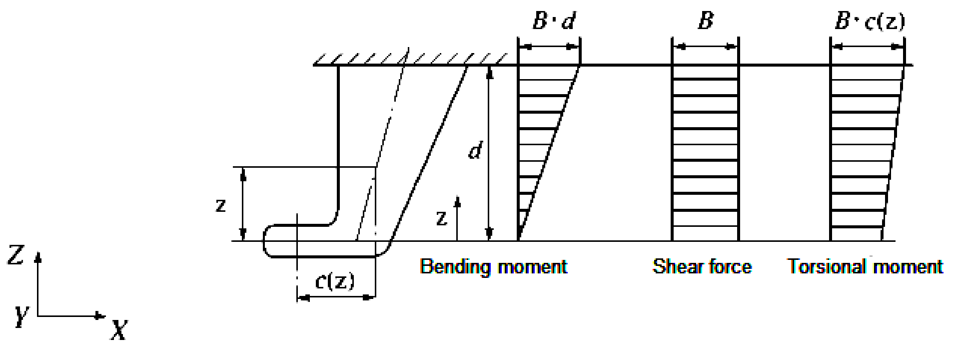
M, Z_x, B and K_{rh} : As specified in **(1)**

A_h : As specified in **(2)**

2. At the connection between the rudder horn and the hull structure, particular attention is to be paid to structural continuity.

3. When the connection between the rudder horn and the hull structure is designed as a curved transition into the hull plating, particular attention is to be paid to the effectiveness of the rudder horn plate in bending and to the stresses in the transverse web plates.

Fig. 2.3 Rudder Horn



2.2.6 Attachment of Stern Frame to Floor Plates

The stern frame is to be extended upward at the part of the propeller post and connected securely to the transom floor of thickness not less than the value obtained from the following formula.

$0.035L + 8.5$ (*mm*)

2.2.7 Gudgeons

1. The depth of gudgeons is not to be less than the length of pintle bearing.

2. The thickness of the gudgeon is not to be less than $0.25d_{po}$. For ships specified in **3.1.3**, the thickness of the gudgeon is to be appropriately increased.

Where:

d_{po}**:** Actual diameter of the pintle measured at the outer surface of the sleeve (*mm*)

Chapter 3 RUDDERS

3.1 General

3.1.1 Application

1. The requirements in this Chapter apply to double plate rudders of stream line section and ordinary shape, being divided into the following types.

(1) Type *A*: Rudders with upper and bottom pintles (*See* **Fig. 3.1** (*A*))

(2) Type *B*: Rudders with neck bearing and bottom pintle (*See* **Fig. 3.1** (*B*))

(3) Type *C*: Rudders having no bearing below the neck bearing (*See* **Fig. 3.1** (*C*))

(4) Type *D*: Mariner type rudders with neck bearing and pintle, of which lower end is fixed (*See* **Fig. 3.1** (*D*))

(5) Type *E*: Mariner type rudders with two pintles, of which lower ends are fixed (*See* **Fig. 3.1** (*E*))

2. The construction of rudders having three or more pintles and of those having special shape or sectional form will be specially considered by the Society.

3. The construction of rudders designed to move more than 35 *degrees* on each side will be specially considered by the Society.

3.1.2 Materials

1. Rudder stocks, pintles, coupling bolts, keys, edge bars and cast parts of rudders are to be made of rolled steel, steel forging or carbon steel casting conforming to the requirements in **Part 10**. For rudder stocks, pintles, coupling bolts, keys, and edge bars, the minimum yield stress is not to be less than 200 N/mm^2. The requirements in this Chapter are for materials with a yield stress of 235 N/mm^2. If materials having a yield stress differing from 235 N/mm^2 are used, the material factor K is to be determined by the following formula.

$$K = \left(\frac{235}{\sigma_Y}\right)^e$$

Where:

$e = 0.75$ for $\sigma_Y > 235\ N/mm^2$

$e = 1.00$ for $\sigma_Y \leq 235\ N/mm^2$

Where:

σ_Y: Yield stress (N/mm^2) of material used, and is not to be taken as greater than $0.7\sigma_B$ or 450 N/mm^2, whichever is smaller.

σ_B: Tensile strength (N/mm^2) of material used

2. When the rudder stock diameter is reduced because of using steels with a yield stress exceeding 235 N/mm^2, special consideration is to be given to deformation of the rudder stock to avoid excessive edge pressures at the edge of bearings.

3. Welded members of rudders such as rudder plates, rudder frames and rudder main pieces are to be made of rolled steel conforming to the requirements in **Part 10**. The required scantlings may be reduced when high tensile steels are used. When reducing the scantling, the material factor K is to be the values specified in **1.1.6-2(1)**.

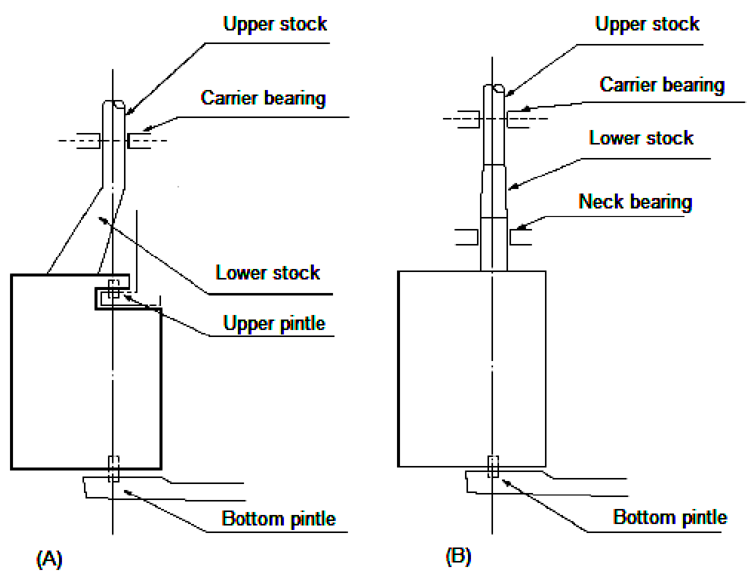
3.1.3 Increase in Diameter of Rudder Stocks for Special Cases

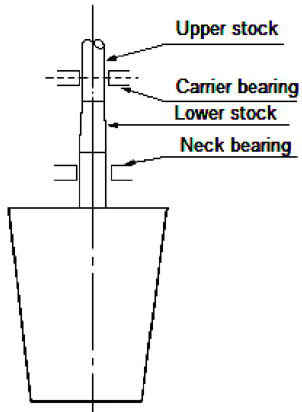
1. The diameter of rudder stocks of ships exclusively engaged in towing services is not to be less than 1.1 times those required in this Chapter.

2. In ships which may be frequently steered at a large helm angle when sailing at their maximum speed, such as fishing vessels, the diameters of rudder stocks and pintles, as well as the section modulus of main pieces, are not to be less than 1.1 times those required in this Chapter.

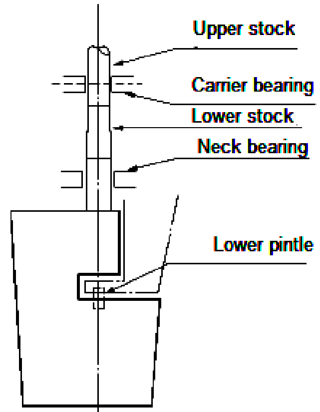
3. In ships which might require quick steering, the diameter of rudder stocks is to be properly increased beyond the requirements in this Chapter.

Fig. 3.1

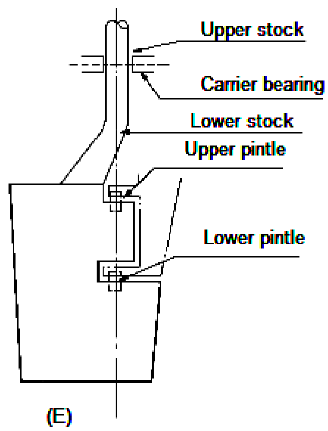




(C)



(D)



(E)

3.1.4 Sleeves and Bushes

Bearings located up to well above the designed maximum load line are to be provided with sleeves and bushes.

3.2 Rudder Force

The rudder force F_R is used to determine the rudder scantlings and is obtained from the following formula, for ahead and astern conditions. However, when the rudder is arranged behind the propeller that produces an especially great thrust, the rudder force is to be appropriately increased.

$F_R = 132 K_1 K_2 K_3 A V^2$ (N)

Where:

A: Area of rudder plate (m^2)

V: Speed of ship (Kt)

When the speed is less than 10 *knots*, V is to be replaced by V_{min} obtained from the following formula:

$$V_{min} = \frac{V + 20}{3} (kt)$$

For the astern condition, the astern speed V_a is to be obtained from the following formula. However, when the maximum astern speed is designed to exceed V_a , the design maximum astern speed is to be used.

$$V_a = 0.5V = (kt)$$

Where:

K_1: Factor depending on the aspect ratio Λ of the rudder area obtained by the following formula.

$$K_1 = \frac{\Lambda + 2}{3}$$

Where:

Λ: As obtained from the following formula, however, Λ is not required to be greater than 2

$$\Lambda = \frac{h^2}{A_t}$$

Where:

h : Mean height of rudder (m), which is determined according to the coordinate system in **Fig. 3.2**

A_t : Sum of rudder plate area A (m^2) and area of rudder post or rudder horn, if any, within the mean height of rudder h

K_2 : Factor depending on the rudder profile (*See* **Table 3.1**)

K_3 : Factor depending on the location of rudder, as specified below:

For rudders outside the propeller jet: 0.8

For rudders behind a fixed propeller nozzle: 1.15

Otherwise: 1.0

Fig. 3.2 Coordinate System of Rudder

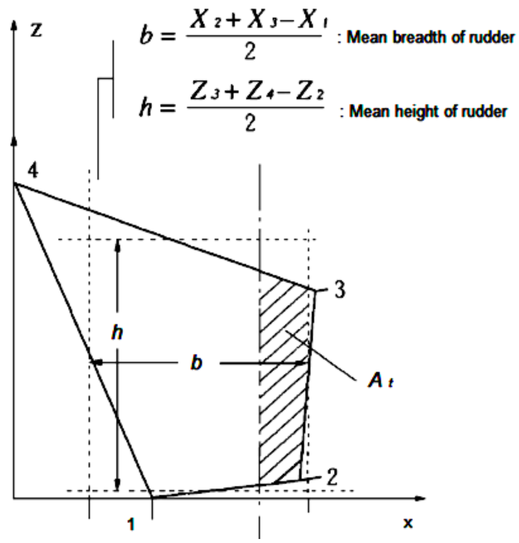
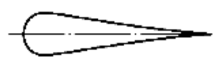


Table 3.1 Factor K_2

Profile type	K_2	
	Ahead Condition	Astern Condition
NACA-00 Göttingen-profiles 	1.1	0.80
Hollow profiles 	1.35	0.90
Flat side profiles 	1.1	0.90

3.3 Rudder Torque

3.3.1 Rudder Torque of Type B and C Rudders

The rudder torque T_R of Type *B* and *C* rudders is to be obtained for ahead and astern conditions, respectively, according to the following formula.

$$T_R = F_R r \ (Nm)$$

Where:

F_R : As specified in **3.2**

r: Distance from the centre of the rudder force on the rudder to the centreline of the rudder stock, determined by the following formula

$$r = b(\alpha - e)(m)$$

For the ahead condition, r is not to be less than r_{min} obtained from the following formula.

$$r_{min} = 0.1b \ (m)$$

Where:

b : Mean breadth (m) of rudder determined by the coordinate system in **Fig. 3.2**

α: To be as follows:

For ahead condition: 0.33

For astern condition: 0.66

e : Balance factor of the rudder obtained from the following formula.

$$e = \frac{A_f}{A}$$

Where:

A_f : Portion (m^2) of the rudder plate area situated ahead of the centreline of the rudder stock

A : As specified in **3.2**

3.3.2 Rudder Torque of Type A, D and E Rudders

The rudder torque T_R of Type A, D and E rudders is to be obtained for the ahead and astern conditions, respectively, according to the following formula:

$$T_R = T_{R1} + T_{R2} (Nm)$$

For the ahead condition, T_R is not to be less than T_{Rmin} obtained from the following formula:

$$T_{Rmin} = 0.1 F_R \frac{A_1 b_1 + A_2 b_2}{A} \ (Nm)$$

Where:

T_{R1} and T_{R2} : Rudder torque (N-m) of portion of A_1 and A_2, respectively

A_1 and A_2 : Areas of respective rectangles (m^2) determined by dividing the rudder area into two parts so that $A = A_1 + A_2$ (A_1 and A_2 include A_{1f} and A_{2f} respectively), as specified in **Fig. 3.3**.

b_1 and b_2 : Mean breadth (m) of portions A_1 and A_2 determined by applying **Fig. 3.2**.

F_R and A: As specified in **3.2**.

T_{R1} and T_{R2} , the rudder torque of portions A_1 and A_2, are to be obtained from the following formulae.

$$T_{R1} = F_{R1} r_1 (Nm)$$

$$T_{R2} = F_{R2} r_2 (Nm)$$

F_{R1} and F_{R2}, the rudder force of portions A_1 and A_2, are to be obtained from the following formula

$$F_{R1} = F_R \frac{A_1}{A} \ (N)$$

$$F_{R2} = F_R \frac{A_2}{A} \ (N)$$

r_1 and r_2, the distances from each centre of rudder force of portions A_1 and A_2 to the centreline of the rudder stock, are to be determined from the following formulae.

$$r_1 = b_1 (a - e_1)(m)$$

$$r_2 = b_2 (a - e_2)(m)$$

e_1 and e_2, the balance factors of portions A_1 and A_2 respectively are to be obtained from the following formulae

$$e_1 = \frac{A_{1f}}{A_1}, e_2 = \frac{A_{2f}}{A_2}$$

α is to be as follows:

For parts of a rudder not behind a fixed structure such as rudder horn:

For ahead condition: 0.33

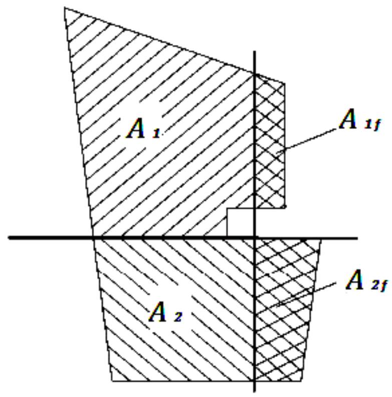
For astern condition: 0.66

For parts of a rudder behind a fixed structure such as the rudder horn:

For ahead condition: 0.25

For astern condition: 0.55

Fig. 3.3 Division of Rudder



3.4 Rudder Strength Calculation

3.4.1 Rudder Strength Calculation

1. The rudder strength is to be sufficient to withstand the rudder force and rudder torque as given in **3.2** and **3.3**. When the scantling of each part of a rudder is determined, the following moments and forces are to be considered.

For rudder body: bending moment and shear force

For rudder stock: bending moment and torque

For pintle bearing and rudder stock bearing: supporting force

2. The bending moments, shear forces, and supporting forces to be considered are to be determined by direct calculation or by a simplified approximation method as deemed appropriate by the Society.

3.5 Rudder Stocks

3.5.1 Upper Stocks

The diameter d_u of the upper stock, which is the stock above the bearing centre of the rudder carrier required for the transmission of the rudder torque, is to be determined such that torsional stress does not exceed $68/KS$ (N/mm^2).

Considering this, the diameter of the upper stock may be determined by the following formula:

$$d_u = 4.2\sqrt[3]{T_R K_S} \ (mm)$$

Where:

T_R : As specified in **3.3**

K_S : Material factor for rudder stock, as given in **3.1.2**

3.5.2 Lower Stocks

The diameter d_l of the lower stock, which is the stock below the bearing centre of the rudder carrier subject to the combined forces of torque and bending moment, is to be determined such that the equivalent stress in the rudder stock does not exceed 118/ K_S (N/mm^2)

The equivalent stress σ_e is to be obtained from the following formula.

$$\sigma_e = \sqrt{\sigma_b^2 + 3\tau_t^2} \quad (N/mm^2)$$

The bending stress and torsional stress acting on the lower stock are to be determined as follows:

Bending stress: $\sigma_b = \frac{10.2M}{d_l^3} x10^3 (N/mm^2)$

Torsional stress: $\tau_t = \frac{5.1T_R}{d_l^3} x10^3 (N/mm^2)$

Where:

M : Bending moment (N-m) at the section of rudder stock considered

T_R : As specified in **3.3**

When the horizontal section of the lower stock forms a circle, the lower stock diameter $\boldsymbol{d_l}$ may be determined by the following formula:

$$d_1 = d_u \sqrt[6]{1 + \frac{4}{3}\left[\frac{M}{T_R}\right]^2} \ (mm)$$

Where:

d_u : Diameter of upper stock (mm) as given in **3.5.1**

3.6 Rudder Plates, Rudder Frames and Rudder Main Pieces

3.6.1 Rudder Plate

The rudder plate thickness t is not to be less than that obtained from the following formula:

$$t = 5.5S\beta\sqrt{\left(d + \frac{F_R x10^{-4}}{A}\right)} K_{Pl} + 2.5 (mm)$$

Where:

A and $\boldsymbol{F_R}$: As specified in **3.2**

K_{pl}: Material factor for the rudder plate as given in **3.1.2**

β: To be obtained from the following formula:

$$\beta = \sqrt{1.1 - 0.5\left(\frac{S}{a}\right)^2},$$

but need not excee 1.0 $\left(\frac{a}{S} \geq 2.5\right)$

Where:

S : Spacing (m) of horizontal or vertical rudder frames, whichever is smaller

a : Spacing (m) of horizontal or vertical rudder frames, whichever is greater

3.6.2 Rudder Frames

1. The rudder body is to be stiffened by horizontal and vertical rudder frames enabling it to withstand bending like a girder.

2. The standard spacing of horizontal rudder frames is to be obtained from the following formula:

$$0.2\left(\frac{L}{100}\right) + 0.4\ (m)$$

3. The standard distance from the vertical rudder frame forming the rudder main piece to the adjacent vertical frame is to be 1.5 *times* the spacing of horizontal rudder frames.

4. The thickness of rudder frames is not to be less than 8 *mm* or 70% of the thickness of the rudder plates as given in **3.61.**, whichever is greater.

3.6.3 Rudder Main Pieces

1. Vertical rudder frames forming the rudder main piece are to be arranged forward and afterward of the center line of the rudder stock at a distance approximately equal to the thickness of the rudder if the main piece consists of two rudder frames, or at the centerline of the rudder stock if the main piece consists of one rudder frame.

2. The section modulus of the main piece is to be calculated in conjunction with the vertical rudder frames specified in **-1** above and the rudder plates attached thereto. The breadth of the rudder plates normally taken into calculation are to be as follows:

(1) Where the main piece consists of two rudder frames, the breadth is 0.2 *times* the length of the main piece.

(2) Where the main piece consists of one rudder frame, the breadth is 0.16 *times* the length of the main piece.

3. The section modulus and the web area of horizontal sections of the main piece are to be such that bending stress, shear stress, and equivalent stress should not exceed the following values.

Bending stress: $\sigma_b = \frac{110}{K_m}\left(\frac{N}{mm^2}\right)$

Shear stress: $\tau = \frac{50}{K_m}(N/mm^2)$

Equivalent stress: $\sigma_e = \sqrt{\sigma_b^2 + 3t^2} = \frac{120}{K_m}\ (N/mm^2)$

In the cases of Type *A*, *D* and *E* rudders, however, the section modulus and the web area of a horizontal section of the main piece in way of cutouts are to be such that bending stress, shear stress, and equivalent stress should not exceed the following values.

Bending stress: $\sigma_b = \frac{75}{K_m}(N/mm^2)$

Shear stress: $\tau = \frac{50}{K_m}\ (N/mm^2)$

Equivalent stress: $\sigma_e = \sqrt{\sigma_b^2 + 3\tau^2} = \frac{100}{K_m}(N/mm^2)$

Where:

K_m : Material factor for the rudder main piece as given in **3.1.2**

4. The upper part of the main piece is to be so constructed as to avoid structural discontinuity.

5. Maintenance openings and cutouts of rudder plates in Type *A*, *D* and *E* rudders are to be rounded off properly.

3.6.4 Connections

Rudder plates are to be effectively connected to rudder frames, free from defects, with due attention paid to the workmanship.

3.6.5 Painting and Draining

The internal surfaces of rudders are to be coated with effective paint, and a means for draining is to be provided at the bottoms of the rudders.

3.7 Couplings between Rudder Stocks and Main Pieces

3.7.1 Horizontal Flange Couplings

1. Coupling bolts are to be reamer bolts, and at least 6 reamer bolts are to be used in each coupling.

2. The diameter of coupling bolts d_b is not to be less than the dimension obtained from the following formula:

$$d_b = 0.62\sqrt{\frac{d^3 K_b}{n e_m K_S}}\ (mm)$$

Where:

d : Stock diameter (mm), the greater of the diameters d_u or d_l according to **3.5.1** and **3.5.2**

n : Total number of bolts

e_m : Mean distance (mm) of the bolt axes from the centre of the bolt system

K_s : Material factor for the rudder stock as given in **3.1.2**

K_b : Material factor for the bolts as given in **3.1.2**

3. The thickness of the coupling flanges t_f is not to be less than that determined by the following formula, provided that the thickness is not less than $0.9d_b$ (mm).

$$t_f = d_b\sqrt{\frac{K_f}{K_b}}\ (mm)$$

Where:

K_f: Material factor for flange as given in **3.1.2**

K_b : As specified in **-2**

d_b : Bolt diameter (*mm*), determined by a number of bolts not exceeding 8

4. The width of the material outside the bolt holes of the coupling flanges is not to be less than $0.67d_b$ (*mm*).

3.7.2 Cone Couplings

1. Cone couplings that are mounted or dismounted without hydraulic arrangements (e.g. oil injection and hydraulic nut) are to be tapered 1:8~1:12 of the diameter. (*See* **Fig. 3.4**)

The taper length *l* of rudder stocks fitted into the rudder plate and secured by the slugging nut is generally not to be less than 1.5 *times* the rudder stock diameter d_0 at the top of the rudder. In this case, for couplings between stock and rudder, a key is to be provided. The scantling of the key is to be to the discretion of the Society.

2. The dimensions of the slugging nut as specified in **-1** are to be as follows (*See* **Fig. 3.4**):

External thread diameter: $d_g \geq 0.65d_0 (mm)$

Length of nut: $h_n \geq 0.6d_g (mm)$

Outer diameter of nut: $d_n \geq 1.2d_e \; or \; 1.5d_g \; (mm)$, whichever is greater

3. Notwithstanding the provinsions in -1 above, where a key is fitted to the coupling between stocks and rudders, and it is considered that rudder torque is transmitted by friction at the couplings, the scantlings of the key as well as the push-up force and push-up length are to be at the discretion of the Society.

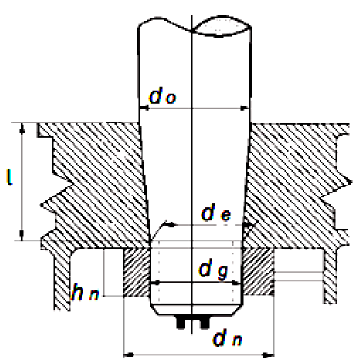
4. Cone couplings that are mounted or dismounted with hydraulic arrangements (e.g. oil injection and hydraulic nut) are to be tapered 1:12~1:20 of the diameter. (*See* **Fig. 3.4**)

The push-up force and the push-up length are to be to the discretion of the Society.

5. The nuts fixing the rudder stocks are to be provided with efficient locking devices.

6. Couplings of rudder stocks are to be properly protected from corrosion.

Fig. 3.4 Cone Coupling



Taper = $\frac{d_o - d_e}{l}$

3.7.3 Vertical Flange Couplings

1. Coupling bolts are to be reamer bolts, and at least 8 reamer bolts are to be used in each coupling.

2. The diameter of the coupling bolts d_b is not to be less than the dimension obtained from the following formula.

$$d_b = \frac{0.81d}{\sqrt{n}}\sqrt{\frac{K_b}{K_s}} \qquad (mm)$$

Where:

d : Stock diameter (mm), the greater of the diameters du or dl according to **3.5.1** and **3.5.2**

n : Number of bolts

K_b : Material factor for bolts as given in **3.1.2**

K_s : Material factor for the rudder stock as given in **3.1.2**

3. The first moment of area M of the bolts about the centreline of the coupling flange is not to be less than the value obtained from the following formula:

$$M = 0.00043d^3 \quad (cm^3)$$

4. The thickness of the coupling flanges is to be at least equal to the bolt diameter.

5. The width of the flange material outside the bolt holes is not to be less than 0.67 d_b (mm).

3.8 Pintles

3.8.1 Diameter of Pintles

The diameter of pintles d_p is not to be less than the dimension obtained from the following formula.

$$d_p = 0.35\sqrt{BK_p}\,(mm)$$

Where:

B : Reaction force in bearing (N)

K_p : Material factor for pintles as given in **3.1.2**

3.8.2 Construction of Pintles

1. Pintles are to be constructed as taper bolts with a taper on the diameter not exceeding the following values, and capable of being fitted to the cast parts of the rudders. The nuts fixing the pintles are to be provided with efficient locking devices.

For pintles to be assembled and locked with slugging nuts: 1:8~1:12

For pintles mounted with hydraulic arrangements (oil injection and hydraulic nut, etc.): 1:12~1:20

2. The minimum dimensions of the threads and the nuts of pintles are to be determined by applying the requirements in **3.7.2-2** correspondingly.

3. The taper length of the pintle is not to be less than the maximum actual diameter of the pintle.

4. Pintles are to be properly protected from corrosion.

3.9 Bearings of Rudder Stocks and Pintles

3.9.1 Minimum Bearing Surface

The bearing surface A_b (defined as the projected area: *length outside diameter of sleeve*) is not to be less than the value obtained from the following formula.

$$A_b = \frac{B}{q_a} \quad (mm^2)$$

Where:

B : As specified in **3.8**

q_a : Allowable surface pressure (N/mm^2)

The allowable surface pressure for the various bearing combinations is to be taken from **Table 3.2.** When verified by tests, however, values different from those in this Table may be taken.

Table 3.2 Allowable surface pressure q_a

Bearing material	q_a (N/mm^2)
Lignum vitae	2.5
White metal (oil-lubricated)	4.5
Synthetic material with hardness between 60 and 70, Shore D (Note 1)	5.5
Steel (Note 2),bronze and hot pressed bronze graphite materials	7.0

Notes:

1 Indentation hardness test at the temperature of 23° C and the humidity of 50%, according to a recognized standard. Synthetic bearings are to be of the type as deemed appropriate by the Society

2 Stainless and wear-resistant steel in an approved combination with a stock liner.

3.9.2 Length of Bearings

The length/diameter ratio of the bearing surface is not to be less than 1.0. However, the ratio is not to be greater than 1.2 unless specially approved by the Society.

3.9.3 Bearing Clearances

With metal bearings, clearances are not to be less than d_{bs} /1000 +1.0 (*mm*) on the diameter.

d_{bs} is the inner diameter of the bush.

If non-metallic bearing material is used, the bearing clearance is to be specially determined considering the material’s swelling and thermal expansion properties. This clearance is in no way to be taken as less than 1.5 *mm* on the bearing diameter.

3.10 Rudder Accessories

3.10.1 Rudder Carrier

Suitable rudder carriers are to be provided according to the form and the weight of the rudder, and care is to be taken to provide efficient lubrication at the support.

3.10.2 Prevention of Jumping

A suitable arrangement is to be provided to prevent the rudder from jumping due to wave shocks

Chapter 4 SINGLE BOTTOMS

4.1 General

4.1.1 Application

1. The requirements in this Chapter apply to the single bottoms of ships whose double bottom is omitted partially or wholly in accordance with the requirements in **6.1.1-2** or **-3**.

2. The bottom constructions in way of fore and after peaks are to be in accordance with the requirements in **8.2** and **8.3**

4.2 Centre Keelsons

4.2.1 Arrangement and Construction

All single bottom ships are to have centre keelsons composed of girder plates and rider plates, and the centre keelsons are to extend as far forward and afterward as practicable.

4.2.2 Girder Plates

1. The thickness of girder plates is not to be less than that obtained from the following formula. Beyond the midship part, the thickness may be gradually reduced and it may be 0.85 times the midship value at the end parts of the ship.

$$5.2 + 0.065L \quad (mm)$$

2. The girder plates are to extend to the top of floors.

4.2.3 Rider Plates

1. The thickness of rider plates specified in **4.2.1** is not to be less than that required for the continuous girder plates amidships and the rider plates are to extend from the collision bulkhead to the after peak bulkhead.

2. The breadth of rider plates provided on the girder plates is not to be less than that obtained from the following formula:

$$16.6L - 200(mm)$$

The breadth may be gradually reduced beyond the midship part and at the end parts of the ship it may be 0.8 times the required value obtained from the above formula.

4.2.4 Centre Keelsons in Boiler Rooms

In the boiler room, the thickness of structural members of centre keelsons is to be increased by 1.5 *mm* above the thickness required in **4.2**.

4.3 Side Keelsons

4.3.1 Arrangement

1. Side keelsons are to be so arranged that their spacing is not more than 2.15 *metres* between the centre keelson and the lower turn of bilge.

2. At least one row of shell stiffeners of proper size is to be provided within $0.4L$ amidships between the side keelsons, the centre keelson and side keelson, and the side keelson and lower turn of the bilge.

3. In the space between the collision bulkhead and the position $0.05L$ abaft the strengthened bottom forward specified in **4.8.2**, the spacing of side keelsons is not to exceed 0.9 *metres*.

4.3.2 Construction

Side keelsons are to be composed of girder plates and rider plates and are to be extended as far forward and afterward as practicable.

4.3.3 Rider Plates

The thickness of rider plates fitted up to the side keelsons is not to be less than that of the girder plates, and the sectional area of each rider plate in the midship part is not to be less than that obtained from the following formula:

$$8.8 + 0.454L \quad (cm^2)$$

Beyond the midship part, the sectional area may be gradually reduced to 0.9 times the midship value at the end parts of the ship.

4.3.4 Girder Plates

1. The thickness of girder plates of side keelsons in the midship part is not to be less than that obtained from the following formula:

$$5.8 + 0.042L \quad (mm)$$

Beyond the midship part, the thickness may be gradually reduced to 0.85 times the midship value at the end parts of the ship.

2. The thickness of continuous centre girder plates in the engine space is not to be less than that required in **4.2.2-1**.

4.3.5 Side Keelsons in Boiler Spaces

The thickness of rider plates and girder plates of side keelsons in the boiler space is to be increased by 1.5 *mm* above the thickness given in **4.3.3** and **4.3.4**.

4.4 Floor Plates

4.4.1 Arrangement and Scantlings

1. Floor plates are to be provided on every frame and the scantlings are not to be less than that obtained from the following formulae, but the thickness need not exceed 12 *mm*.

Depth at the centre line: $0.0625\, l \quad (m)$

Thickness: $10\, d_o + 4 \quad (mm)$

Where:

l: Span between the toes of frame brackets measured amidships plus 0.3 *metres*. Where curved floors are provided, the length *l* may be suitably modified.

d_o: Depth (m) of floor plates at the centre line

2. Beyond 0.5L amidships, the thickness of floor plates may be gradually reduced to 0.90 times the value specified in **-1** at the end parts of the ship. In the flat part of the bottom forward, this reduction is not to be mad

3. Floors under engines and thrust seats are to be of ample depth and to be specially strengthened. Their thickness is not to be less than that of the continuous centre girder plate

4. The thickness of floors under boilers is to be increased by at least 2 *mm* above the thickness of midship floors.

Where boilers are less than 460 *mm* clear of the floors, the thickness is to be further increased.

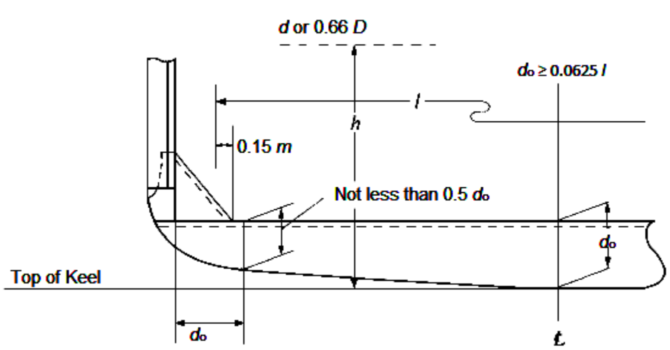
4.4.2 Depth of Floors

1. Upper edges of floor plates at any Part are not to be below the level of the upper edges at the centre line.

2. In the midship part, the depth of floors measured at a distance d_o specified in **4.4.1-1** from the inner edge of the frames along the upper edge of floors is not to be less than 0.5d_0 (*See* **Fig. 4.1**). Where frame brackets are provided, the depth of floors at the inner edge of brackets may be 0.5d_0.

3. In ships having an unusually large rise in the floor, the depth of floor plates at the centre line is to be suitably increased.

Fig, 4.1 Shape of Floors



4.4.3 Floors in Bottom Forward

At the strengthened bottom forward specified in 5.8.2, the depth of floor plates is to be increased, or alternatively, the sectional area of face plates of floors required by 4.5.2 is to be doubled.

Where the ship has an unusually small draught in the ballast condition and has especially high speed for the ships length, special consideration is to be paid to the floors in the bottom forward.

4.4.4 Frame Brackets

The size of frame brackets is to be in accordance with the following requirements, and the free edge of brackets is to be stiffened.

(1) The brackets are to extend above the top of the keel to a height twice the required depth of floors at the centre line.

(2) The arm length of brackets measured from the outer edge of frames to the bracket toe along the upper edge of floors is not to be less than the required depth of floors at the centre line.

(3) The thickness of brackets is not to be less than that of the floors required in 4.4.1.

4.4.5 Limber Holes

Limber holes are to be provided above the frames in all floor plates on each side of the centre line and, in addition, at the lower turn of the bilge in ships having flat bottoms.

4.4.6 Lightening Holes

Lightening holes may be provided in floor plates. Where the holes are provided, appropriate strength compensation is to be made by increasing the floor depth or by some other suitable means.

4.4.7 Floor Plates Forming Part of Bulkheads

Floor plates forming part of bulkheads are to be in accordance with the requirements in Chapters 12 and 13.

4.5 Face Plates fitted up to Upper Edge of Floors

4.5.1 Construction

Face plates fitted up to the upper edge of floors, are to be continuous from the upper part of the bilge at one side to the upper part of the bilge at the opposite side in case of curved floors, or to be continuous floor plate in case of bracketed floors.

4.5.2 Scantlings

1. The thickness of face plates fitted up to the upper edge of floors is not to be less than that of the floor plates on which they are provided.

2. The breadth of face plates specified in **-1** above, is to be sufficient for lateral stability and the sectional area of face plates is not to be less than that obtained from the following formula

$$\frac{42.7}{1000}\frac{Shl^2}{d_0} - \frac{5}{3}d_o t \quad (cm^2)$$

Where:

l : Span (m) defined in **4.4.1-1**

S : Floor spacing (m)

h : d (m) or $0.66D$ (m), whichever is greater

d_0 : Depth (m) of floor plates at the centre line

t : Thickness (mm) of floor plates

3. The thickness of face plates under boilers is to be increased by 2 *mm* above that of the face plate having a sectional area as obtained from the above formula substituting the thickness of floor plates amidships specified in **4.4.1** for *t*.

4. Flanging of the upper edge of floor plates in lieu of face plates is not permitted under the main engine seats and boiler seats.

4.5.3 Floors under Main Engine Seats and Boiler Seats and at Bottom Forward

1. The sectional area of face plates of the floors under main engine seats and boiler seats is to be two times the sectional area required by **4.5.2-2**.

2. The construction and scantlings of floors of strengthened bottom forward specified in **5.8.2** are to be in accordance with the requirements in **4.4.3**.

Chapter 5 DOUBLE BOTTOMS

5.1 General

5.1.1 Application

1. Ships are to be provided with watertight double bottoms extending from the collision bulkhead to the after peak bulkhead. The longitudinal system of framing is, in general, to be adopted. The inner bottom is to be continued out to the ship's sides in such a manner as to protect the bottom to the turn of the bilge, and 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 (m) measured from the keel line specified in **1.2.47, Chapter 1, Part 1 A**.

$h = B'/20$

B': Is the greatest moulded breadth in metres of the ship at or below the deepest subdivision draught.

However, in no case is the value of h to be less than 0.76 m, and need not be taken as more than 2.0 m

2. Part or all of double bottoms may be omitted for ships less than 500 *gross tonnage*; ships not engaged in international voyages that are less than 100 m in length; or ships that are deemed by the Society to not require a double bottom due to factors such as structural configuration, hull form, or purpose.

3. Double bottoms may be omitted in way of watertight tanks, including dry tanks of moderate size subject to the safety of the ship is not impaired in the event of bottom or side damage.

4. The scantlings of double bottoms are to be as deemed appropriate by the Society for areas of special construction such as inclined side shells or double side shells, or where longitudinal bulkheads are provided, or for parts beyond the midship part.

5. The scantlings of members in double bottom tanks intended to be deep tanks are to be in accordance with the requirements in **Chapter 13**. However, the thickness of inner bottom plating need not be increased by 1.0 mm as given for the top plating of deep tanks in **13.2.7**.

6. The requirements in this Chapter are to be applied where the apparent specific gravity of cargoes in the loaded hold γ is not greater than 0.9. The requirements in **Chapter 28** are to be applied where γ is more than 0.9, or to double bottom ships with holds that are empty in fully loaded condition or that have bilge hoppers. The specific gravity of cargoes γ is to be obtained from the following formula:

$$\frac{W}{V}$$

Where:

W : Mass (t) of cargoes for the hold

V : Volume (m^3) of the hold excluding its hatchway

7. Special consideration is to be given to the double bottom structure of the hold when it is intended to carry heavy cargoes, where the ratio of cargo weight per unit area (kN/m^2) of the inner bottom plating to d is less than 5.40 or where cargo loads cannot be treated as evenly distributed loads. Where the value of cargo weight per unit area is given in t/m^2, kN/m^2 is obtained from the product of the value in t/m^2 and 9.81.

5.1.2 Manholes and Lightening Holes

1. Manholes and lightening holes are to be provided in all non-watertight members to ensure accessibility and ventilation, except in way of widely spaced pillars.

2. The number of manholes in tank tops is to be kept to the minimum compatible with securing free ventilation and ready access to all parts of the double bottom. Care is to be taken for locating the manholes to avoid the possibility of interconnection of main subdivision compartments through the double bottom so far as practicable.

3. Covers of manholes in tank tops are to be of steel, and where no ceiling is provided in the cargo holds, the covers and their fittings are to be effectively protected against damage by the cargo.

4. Air and drainage holes are to be provided in all non-watertight members of the double bottom structure.

5. The proposed location and size of manholes and lightening holes are to be indicated in the plans submitted for approval.

5.1.3 Drainage

1. Efficient arrangements are to be provided for draining water from the tank top.

2. With the exception of the after tunnel well, where bilge wells are provided for water drainage, such wells are not to extend for more than one-half the depth of the double bottom as far as practicable. In addition, they are not to come within 460 *mm* of the bottom shell. However, where bilge tanks deemed appropriate by the Society are provided instead of bilge wells, this requirement may be waived.

5.1.4 Striking Plates

Striking plates of adequate thickness or other arrangements are to be provided under sounding pipes to prevent the sounding rod from injuring the ship’s bottom plating.

5.1.5 Cofferdams

Oiltight cofferdams are to be provided in the double bottom between tanks carrying oil and those carrying fresh water, such as for personnel use or boiler feed water, to prevent the fresh water from being contaminated by oil.

5.1.6 Strengthening Under Boilers

Under boilers, the thickness of structural members is to be suitably increased.

5.1.7 Under Pillars or Toes of End Brackets for Bulkhead Stiffeners

In double bottoms, under pillars or toes of end brackets for bulkhead stiffeners, suitable reinforcement is to be provided by means of additional side girders, half-height girders or floors.

5.1.8 Wells

1. Small wells constructed in the double bottom in connection with drainage arrangements of holds are not to extend downward more than necessary. A well extending to the outer bottom is, however, permitted at the after end of the shaft tunnel.

2. Other wells (e.g. for lubricating oil under main engines) may be permitted by the Society if satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with this Chapter.

3. For wells specified in **-1** and **-2** above except a well at the end of the shaft tunnel, the vertical distance from the bottom of such a well to a plane coinciding with the keel line specified in **1.2.47, Part 1A** of the Rules is not to be less than 0.5 *m*.

5.1.9 Continuity of Strength

Where the longitudinal system of framing is transformed into the transverse system, or the depth of the double bottom changes suddenly, special care is to be taken for the continuity of strength by means of additional intercostal girders or floors.

5.1.10 Minimum Thickness

No structural member of the double bottom construction is to be less than 6 *mm* in thickness.

5.2 Centre Girder and Side Girders

5.2.1 Arrangement and Construction of Girders

1. Centre girder is to extend as far forward and afterward as practicable.

2. Centre girder plates are to be continuous for 0.5L amidships.

3. Where double bottoms are used for carriage of fuel oil, fresh water or water ballast, the centre girders are to be watertight.

4. The requirement in **-3** may be suitably modified in narrow tanks at the end parts of the ship or where other watertight longitudinal girders are provided at about 0.25B from the centre line or where deemed appropriate by the Society

5. Side girders in 0.5L amidships and aft are to be so arranged that the distance from the centre girder to the first side girder, between girders, or from the outermost girder to the margin plate does not exceed approximately 4.6 *metres*, and to extend as far afterwards as practicable.

6. In the bottom forward of ships, side girders and half-height girders are to be provided as required by **5.8.3**.

7. Adequate strengthening is to be made under main engines and thrust seatings by means of additional full or half-height girders.

5.2.2 Depth of Centre Girder

The depth of the centre girder is not to be less than $B/16$ unless specially approved by the Society.

5.2.3 Thickness of Centre Girder Plates and Side Girder Plates

The thickness of the centre girder plates and side girder plates is not to be less than that obtained from the following requirements **(1)** and **(2)**, whichever is greater:

(1) The thickness is to be obtained from the following formula depending on the location in the hold:

$$C_1 \frac{SBd}{d_0\text{-}d_1}\left(2.6\frac{x}{l_H}\text{-}0.17\right)\left\{1\text{-}4\left(\frac{y}{B}\right)^2\right\}+2.5 \quad (mm)$$

Where:

S : Distance (m) between the centres of two adjacent spaces from the centre or side girder under consideration to the adjacent longitudinal girders or the line of toes of tank side brackets

d_0 : Depth (m) of the centre or side girder under consideration

d_1 : Depth (m) of the opening at the point under consideration

l_H : Length (m) of the hold

x : Longitudinal distance (m) between the centre of l_H of each hold and the point under consideration

However, where x is under $0.2l_H$, x is to be taken as $0.2l_H$, and where x is $0.45l_H$ and over, x may, be taken as $0.45l_H$.

y : Transverse distance (m) from the centre line of the ship to the longitudinal girder

C_1 : Coefficient given by the following formula

Where $\frac{B}{l_H}$ is 1.4 and over, $\frac{B}{l_H}$ is to be taken as 1.4, and where $\frac{B}{l_H}$ is under 0.4, $\frac{B}{l_H}$ is to be taken as 0.4.

Longitudinal framing: $\dfrac{3\text{-}\frac{B}{l_H}}{103}$

Transverse framing: $\dfrac{3\text{-}\frac{B}{l_H}}{90}$

(2) The thickness is to be obtained from the following formula:

$$C_1' d_0 + 2.5 \quad (mm)$$

Where:

d_0: Depth (m) of the girder at the point under consideration

However, where horizontal stiffeners are provided at half the depth of the girder, d_o is the distance (m) from the horizontal stiffener to the bottom shell plating or inner bottom plating or the distance between the horizontal stiffeners.

C_1': Coefficient obtained from **Table 5.1** corresponding to S_1/d_0,

For intermediate values of S_1/d_0, C_1' is to be obtained by interpolation.

S_1 : Spacing (m) of the brackets or stiffeners provided on the centre girder or the side girders

Table 5.1 Coefficient C_1'

$\frac{S_1}{d_0}$		0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6 and over
C_1'	Centre girder	4.4	5.4	6.3	7.1	7.7	8.2	8.6	8.9	9.3	9.6	9.7
	Side girders	3.6	4.4	5.1	5.8	6.3	6.7	7.0	7.3	7.6	7.9	8.0

5.2.4 Brackets

1. Where the longitudinal framing system is adopted in the double bottom, transverse brackets are to be provided between the solid floors with a spacing of not more than 1.75 *metres* connecting the centre girder plates to the bottom shell plating as well as the adjacent bottom longitudinals. Where the spacing of these brackets exceeds 1.25 *metres*, additional stiffeners are to be provided on the centre girder plates.

2. The thickness of the brackets specified in **-1** is not to be less than that obtained from the following formula. However, the thickness need not be greater than that of the solid floors at the same location.

$$0.6\sqrt{L} + 2.5 \quad (mm)$$

3. The stiffener specified in **-1** is to be a flat bar having the same thickness as that of the girder plates and the depth not less than $0.08d_0$, where d_0 is the depth of the centre girder in *metres*, or equivalent thereto.

5.2.5 Thickness of Half-height Girders

The thickness of half-height girders is not to be less than that obtained from the formula in 5.2.4-2.

5.2.6 Scantlings of Vertical Stiffeners and Struts

1. Vertical Stiffeners are to be provided to side girders at every open floor where the double bottom is framed transversely, or at a suitable distance where the double bottom is framed longitudinally, and vertical struts are to be provided on half-height girders at every open floor.

2. The vertical stiffeners required by **-1** are to be flat bars having the same thickness as that of the girder plates and the depth is not to be less than $0.08d_0$, where d_0 is the depth (m) of the side girder under consideration, or equivalent thereto.

3. The sectional area of vertical struts required by **-1** is not to be less than requirements in 5.4.4.

5.3 Solid Floors

5.3.1 Arrangement of Solid Floors

1. Solid floors are to be provided at a spacing not exceeding 3.5 *metres*.

2. In addition to complying with the requirements in **-1**, solid floors are to be provided at the following locations:

(1) At every frame in the main engine room Solid floors may, however, be provided at alternate frames outside the engine seatings, if the double bottom is framed longitudinally.

(2) Under thrust seatings and boiler bearers

(3) Under transverse bulkheads

(4) At the locations specified in **5.8.3**, between the collision bulkhead and the after end of the strengthened bottom forward specified in **5.8.**

3. Watertight floors are to be so arranged that the subdivision of the double bottom generally corresponds to that of the ship.

5.3.2 Thickness of Solid Floors

The thickness of solid floors is not to be less than that obtained from the following requirements **(1)** and **(2)**, whichever is greater:

(1) The thickness is to be obtained from the following formula depending on the location in the hold:

$$C_2 \frac{SB^{'}d}{d_0 - d_1}\left(\frac{2y}{B^{''}}\right) + 2.5 \quad (mm)$$

Where:

S : Spacing (m) of solid floors

$B^{'}$: Distance (m) between the lines of toes of tank side brackets at the top of inner bottom plating at the midship part

$B^{''}$: Distance (m) between the lines of toes of tank side brackets at the top of inner bottom plating at the position of the solid floor y

y : Transverse distance (m) from the centre line to the point under consideration

However, where y is under $\frac{B^{''}}{4}$, y is to be taken as $\frac{B^{''}}{4}$, and where y is $\frac{B^{''}}{2}$ and over, y may be taken as $\frac{B^{''}}{2}$.

d_0 : Depth (m) of the solid floor at the point under consideration.

d_1 : Depth (m) of the opening at the point under consideration

C_2 : Coefficient obtained from **Table 5.2** depending on B/l_H

l_H : Length defined in **5.2.3**

(2) The thickness is to be obtained from the following formula depending on the location in the hold:

$$8.6\sqrt[3]{\frac{H^2 d_0^2 * (t_1 - 2.5)}{C_2^{'}}} + 2.5 \quad (mm)$$

Where:

t_1: Thickness obtained from the requirement **(1)**

d_0 : Depth defined in **(1)**

C_2': Coefficient given in **Table 5.3** depending on the ratio of the spacing of stiffeners S_1 (m) to d_0

For intermediate values of S_1/d_0, the value of C_2': is to be determined by interpolation.

H : Value obtained from the following formulae:

(a) Where slots are provided on solid floors without reinforcement, H is given by the following formula, which, however, is to be 1.0, if d_1/S_1 is 0.5 and under:

$$\sqrt{4.0\frac{d_1}{S_1} - 1.0}$$

Where:

d_1 : Depth (m) of slot without reinforcement provided at the upper and lower parts of solid floors, whichever is greater

(b) Where openings are provided on solid floors without reinforcement, H is given by the following formula:

$$1 + 0.5\frac{\emptyset}{d_0}$$

Where:

$\emptyset$: Major diameter (m) of the openings

(c) Where slots and openings are provided on solid floors without reinforcement, H is a product of the values given by **(a)** and **(b)**.

(d) Except where **(a)**, **(b)**, and **(c)** applies, H is to be taken as 1.0.

Table 5.2 Coefficient C_2

B/l_H		C_2		
and above	below	Longitudinal framing	Transverse framing: Where solid floors are provide at every frame	Transverse framing: Esewhere
	0.4	0.029		0.020
0.4	0.6	0.027		0.019
0.6	0.8	0.024		0.017
0.8	1.0	0.022		0.015
1.0	1.2	0.019		0.013
1.2		0.017		0.012

Table 5.3 Coefficient C_2'

$\frac{S_1}{d_0}$	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_2'	64	38	25	19	15	12	10	9	8	7

5.3.3 Vertical Stiffeners

1. Vertical stiffeners are to be provided at a suitable spacing on solid floors when the double bottom is framed transversely, and at every longitudinal when the double bottom is framed longitudinally.

2. Where the double bottom is framed transversely, the vertical stiffeners prescribed in **-1** are to be flat bars having the same thickness as that of the floor plate and the depth is not to be less than $0.08d_0$, where d_0 is the depth (m) of the floor at the point under consideration, or equivalent thereto. Where the double bottom is framed longitudinally, the depth and thickness of the vertical stiffeners are to be as required in **1.1.14-3**.

5.4 Longitudinals

5.4.1 Construction

Longitudinals are to be continuous through floors or to be attached to floors by brackets so as to effectively develop the resistance to tension and bending.

5.4.2 Spacing

1. The standard spacing of longitudinals is obtained from the following formula:

$$2L + 550 \quad (mm)$$

2. It is recommended that the spacing of longitudinals should not exceed 1.0 *metre*.

5.4.3 Longitudinals

1. The section modulus of bottom longitudinals is not to be less than that obtained from the following formula:

$$\frac{100C}{24 - 15.5f_B}\left(d + 0.026L'\right)Sl^2 \quad (cm^3)$$

Where:

C : Coefficient given below:

Where no strut specified in **5.4.4** is provided midway between floors: 1.0

Where a strut specified in **5.4.4** is provided midway between floors,

Lower part of deep tanks: 0.625

Elsewhere: 0.5

However, where the width of vertical stiffeners provided on floors and the width of struts are especially large, the coefficient may be properly reduced.

f_B : Ratio of the section modulus of transverse section of hull required in **Chapter 15** to the actual section modulus of transverse section of hull at the bottom

L': Length (m) of ship

However, where L exceeds 230 m, L' is to be taken as 230 m.

l : Spacing (m) of solid floors

S : Spacing (m) of longitudinals

2. The section modulus of inner bottom longitudinals is not to be less than that obtained from the following formula. However, the section modulus of inner bottom longitudinals is not to be less than 0.75 times that of the bottom longitudinals at the same location.

$$\frac{1000C'Shl^2}{24-12f_B} \quad (\text{cm}^3)$$

Where:

C': Coefficient obtained from the following:

Where no strut specified in **5.4.4** is provided midway between floors: 0.9

Where a strut specified in **5.4.4** is provided midway between floors: 0.54

However, where the width of vertical stiffeners provided on floors and the width of struts are especially large, the coefficient may be properly reduced.

f_B , l and S : As specified in **-1**

h : Vertical distance (m) from the top of the inner bottom plating to the lowest deck at centre line However, where the cargo is carried exceeding the lowest deck, h is to be taken from the top of the inner bottom plating to the deck just above the top of the cargo at centre line.

5.4.4 Vertical Struts

1. Vertical struts are to be rolled sections other than flat bars or bulb plates and are to sufficiently overlap the webs of bottom and inner bottom longitudinals.

2. The sectional area of the above mentioned vertical struts is not to be less than that obtained from the following formula:

$$1.8CSbh \quad (cm^2)$$

Where:

S : Spacing (m) of longitudinals

b : Breadth (m) of the area supported by the strut

h : As obtained from the following formula (m):

$$\frac{d + 0.026L' + h_i}{2}$$

h is not to be less than d

L' : As specified in **5.4.3-1**

h_i : 0.9 times the value of h (m) specified in **5.4.3-2**

However, under deep tanks, h (m) is not to be less than the vertical distance from the upper surface of the inner bottom to the midpoint between the top of the overflow pipe and the top of the inner bottom or 0.7 times the vertical distance from the upper surface of the inner bottom to the point 2.0 *metres* above the top of the overflow pipe, whichever is greater.

C : Coefficient obtained from the following formula:

$$\frac{1}{1-0.5\frac{l_s}{k}}$$

The value of the coefficient is not to be less than 1.43

l_s : Length (m) of struts

k : Minimum radius (m) of gyration of struts, obtained from the following formula

$$\sqrt{\frac{I}{A}}$$

I : The least moment (cm^4) of inertia of the struts

A : Sectional area (cm^2) of the struts

5.5 Inner Bottom Plating, Margin Plates and Bottom Shell Plating

5.5.1 Thickness of Inner Bottom Plating

1. The thickness of the inner bottom plating is not to be less than that obtained from the following formulae, whichever is greater:

$$\frac{C}{1000}\frac{B^2 d}{d_0} + 2.5 \quad (mm)$$

$$C' S\sqrt{h} + 2.5 \quad (mm)$$

Where:

d_0: Height (m) of centre girders

S : Spacing (m) of inner bottom longitudinals for longitudinal framing or frame spacing (m) for transverse framing

h : As specified in **5.4.3-2**

C : b_0 or 1 ab given below according to the value of: $\frac{B}{l_H}$

b_0 for $\frac{B}{l_H} < 0.8$

b_0 or αb_1 whichever is greater for $0.8 \leq \frac{B}{l_H} < 1.2$

αb_1 for $1.2 \leq \frac{B}{l_H}$

l_H : As specified in **5.2.3**

b_0 and b_1 : As given in **Table 5.4** according to the value of $\frac{B}{l_H}$

However, for transverse framing, b_1 is to be 1.1 times the value given in this Table.

α: As given by the following formula:

$$\frac{13.8}{24 - 11 f_B}$$

f_B : As specified in **5.4.3-1**

C': Coefficient given by the following formula, according to the value of $\frac{l}{S}$:

$0.43\frac{l}{S} + 2.5$ for $l \leq \frac{l}{S} < 3.5$

4.0 for $3.5 \leq \frac{l}{S}$

l: Distance (*m*) between floors for longitudinal framing or distance (*m*) between girders for transverse framing

2. Where cargoes whose specific gravity is especially low are carried, the thickness of inner bottom plating may be suitably modified.

3. The thickness of inner bottom plating under hatchways, where no ceiling is provided, is to be increased by 2 *mm* above that obtained from the second formula in **-1** or that specified in **5.1.1-5**, whichever is greater, except where the provision in **-4** applies.

4. In ships in which cargoes are regularly handled by grabs or similar mechanical appliances, the thickness of inner bottom plating is to be increased by 2.5 *mm* above that specified in **-1** or in **5.1.1-5**, whichever is greater, except where a ceiling is provided.

5. The thickness of the inner bottom plating in the main engine room is to be increased by 2 *mm* above that specified in **-1** or in **5.1.1-5**, whichever is greater.

Table 5.4 Coefficients b_0 and b_1

B/l_H	And over		0.4	0.6	0.8	1.0	1.2	1.4	1.6
	Less than	0.4	0.6	0.8	1.0	1.2	1.4	1.6	
b_o		0.4	3.9	3.3	2.2	1.6	-	-	-
b_1		-	-	-	2.2	2.1	1.9	1.7	1.4

5.5.2 Thickness of Margin Plates

The thickness of margin plates is to be increased by 1.5 *mm* above that obtained from the second formula in **6.5.1-1**. However, the thickness of margin plates is not to be less than that of the inner bottom plating at the location.

5.5.3 Breadth of Margin Plates

Margin plates are to be of adequate breadth and to extend well inside from the line of toes of tank side brackets.

5.5.4 Brackets

1. Where the double bottom is framed longitudinally, transverse brackets are to be provided at every hold frame extending from the margin plate to the adjacent bottom and inner bottom longitudinals and to be connected with margin plates, shell plating and longitudinals.

2. The thickness of brackets specified in **-1** is not to be less than that obtained from the formula in **5.2.4-2.**

5.5.5 Bottom Shell Plating

The thickness of bottom shell plating of cargo holds in way of double bottom is not to be less than that obtained from the formula in **15.3.4** or from the first formula in **5.5.1-1**, whichever is greater. However, in application of the latter formula, α is to be as given by the following formula:

$$\frac{13.8}{24 - 15.5 f_B}$$

Where:

f_B : As specified in **5.4.3-1**

5.6 Tank Side Brackets

5.6.1 Tank Side Brackets

1. The thickness of brackets connecting hold frames to margin plates is to be increased by 1.5 *mm* above that obtained from the formula in **5.2.4-2.**

2. The free edges of brackets are to be properly stiffened.

3. Where the shape of ship requires exceptionally long brackets, additional stiffness is to be provided by fitting angles longitudinally across the top of flanges, or by other suitable means.

5.6.2 Gusset Plates

1. Tank side brackets and margin plates are to be connected by gusset plates of the same thickness as that of the margin plates.

2. The gusset plates may be omitted where deemed dispensable in relation to structural arrangement.

5.7 Open Floors

5.7.1 Arrangement

Where the double bottom is framed transversely, open floors are to be provided at every hold frame between solid floors in accordance with the requirements in **5.7**.

5.7.2 Scantlings of Frames and Reverse Frames

1. The section modulus of frames is not to be less than that obtained from the following formula:

$$CShl^2 \quad (cm^3)$$

Where:

l : Distance (m) between the brackets attached to the centre girder and the margin plate
Where side girders are provided, l is the greatest distance among the distances between the vertical stiffeners on side girders and brackets (*See* **Fig. 6.1**).

S : Spacing (m) of frames

h : $d + 0.026L'$

L' : As specified in **5.4.3-1**

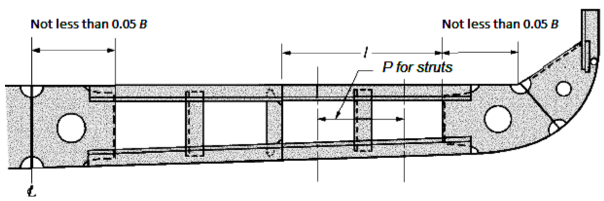
C : Coefficient given below:

Where no vertical strut specified in **5.7.3** is provided: 6.67

Where vertical struts specified in **5.7.3** are provided, for holds which are used as deep tanks and holds which become empty in the full load condition: 4.17

Elsewhere: 3.33

Fig. 5.1 Open Floors



2. The section modulus of reverse frames is not to be less than that obtained from the following formula:

$C'Shl^2 \quad (cm^3)$

l and S : As specified in **-1**

h : As specified in **5.4.3-2**

C': Coefficient given below:

Where no vertical strut specified in **5.7.3** is provided: 6.0

Where vertical struts specified in **5.7.3** are provided: 3.6

5.7.3 Vertical Struts

1. Vertical struts are to be rolled sections other than flat bars or bulb plates and are to sufficiently overlap the webs of frames and reverse frames.

2. The sectional area of the vertical struts specified in **-1** is to be in accordance with the requirements in **5.4.4**.

5.7.4 Brackets

1. Frames and reverse frames are to be connected to the centre girder and margin plates by brackets whose thickness is not to be less than that obtained from the formula in **5.2.4-2**.

2. The breadth of the brackets specified in **-1** is not to be less than 0.05B and the brackets are to sufficiently overlap the frames and reverse frames. The free edges of the brackets are to be properly stiffened.

5.8 Construction and Strengthening of the Bottom Forward

5.8.1 Application

In ships having a bow draught under 0.037 L' in the ballast condition, the construction of the strengthened bottom forward is to be in accordance with the requirements in **6.8**, where L' is as defined in **5.4.3-1**.

In ships having an unusually small draught in the ballast condition and that have especially high speed for the ship's length, special attention is to be paid to the construction of the strengthened bottom forward.

In ships having a bow draught of not less than 0.037 L' in the ballast condition, the construction of the strengthened bottom forward may be as specified in **5.2**, **5.3** and **5.4**.

5.8.2 Strengthened Bottom Forward

1. The part of flat bottom forward from the position specified in **Table 5.5** is defined as the strengthened bottom forward.

2. Notwithstanding the requirement in **-1**, ships that have an especially small draught in ballast condition or where C_b is especially small are to have the strengthened bottom forward extended to the satisfaction of the Society.

Table 5.5 After End of Range of Strengthened Bottom Forward

$V/\sqrt{L}$	And over		1.1	1.25	1.4	1.5	1.6	1.7
	Less than	1.1	1.25	1.4	1.5	1.6	1.7	
Position (from stern)		0.15L	0.175L	0.2L	0.225L	0.25L	0.275L	0.3L

5.8.3 Construction

1. Between the collision bulkhead and 0.05L abaft the after end of the strengthened bottom forward, side girders are to be spaced not more than approximately 2.3 *metres* apart. Where transverse framing is adopted, half-height girders or longitudinal shell stiffeners are to be provided between the side girders, between the collision bulkhead and 0.025 L abaft the after end of strengthened bottom forward.

2. Between the collision bulkhead and the after end of the strengthened bottom forward, solid floors are to be provided at every frame in the transverse framing system, or at least at alternate frames in the longitudinal framing system.

3. The solid floors are to be strengthened by providing vertical stiffeners in way of half-height girders or longitudinal shell stiffeners, except where the longitudinal shell stiffeners are spaced especially close and the solid floors are adequately reinforced, the vertical stiffeners for the solid floors may be provided on alternate shell stiffeners.

4. In ships having a bow draught of more than 0.025 L' but less than 0.037 L' in the ballast condition, where the construction and arrangement of the strengthened bottom forward are impracticable to comply with the above-mentioned requirements, suitable compensation is to be provided for the floors and side girders.

5.8.4 Scantlings of Longitudinal Shell Stiffeners or Bottom Longitudinals

1. In ships having a bow draught of not more than 0.025 L' in the ballast condition, the section modulus of longitudinal shell stiffeners or bottom longitudinals in way of the strengthened bottom forward is not to be less than that obtained from the following formula:

$$0.53P\,\lambda l^2 \quad (cm^3)$$

Where:

l : Spacing (*m*) of solid floors

λ: 0.774 *l*

However, where the spacing (*m*) of longitudinal shell stiffeners or bottom longitudinals is not more than 0.774 *l*, λ is to be taken as the spacing.

P: Slamming impact pressure obtained from the following formula:

$$2.48\frac{LC_1C_2}{\beta} \quad (kPa)$$

C_1 : Coefficient given in **Table 5.6**

For intermediate values of $V\sqrt{L}$, C_1 is to be obtained by linear interpolation.

C_2 : Coefficient obtained from the following formula:

Where $\frac{V}{\sqrt{L}}$ is 1.0 and under: 0.4

Where $\frac{V}{\sqrt{L}}$ is over 1.0, but less than 1.3: $0.667\frac{V}{\sqrt{L}} - 0.267$

Where $\frac{V}{\sqrt{L}}$ is 1.3, and over: $1.5\frac{V}{\sqrt{L}} - 1.35$

β : Slope of the ship's bottom obtained from the following formula, but C_2/β need not be taken as greater than 11.43 (*See* **Fig. 5.2**)

$$\frac{0.0025L}{b}$$

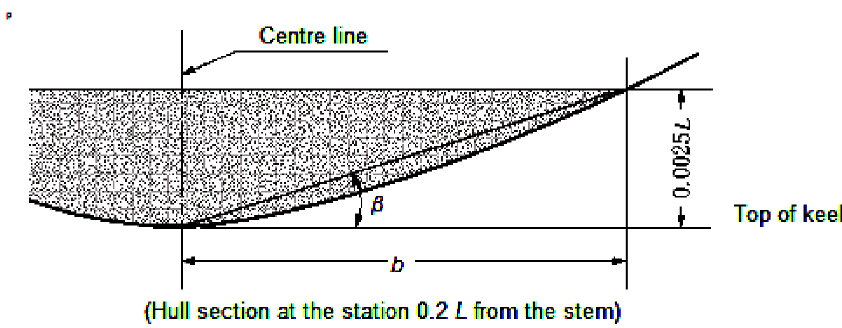
b : Horizontal distance (*m*) measured in the station 0.2*L* from the stem, from the centre line of ship to the intersection of the horizontal line 0.0025*L* above the top of keel with the shell plating (*See* **Fig. 5.2**)

2. In ships having a bow draught of more than 0.025 L' but less than 0.037 L' in ballast condition, the section modulus of longitudinal shell stiffeners or bottom longitudinals in way of the strengthened bottom forward is to be obtained by linear interpolation from the values given by the requirements in **-1** and **5.4**.

Table 5.6 Value of C_1

$V/\sqrt{L}$	1.0 and under	1.1	1.2	1.3	1.4	1.5 and over
C_1	0.12	0.18	0.23	0.26	0.28	0.29

Fig. 5.2 Measurement of *b*



Chapter 6 FRAMES

6.1 General

6.1.1 Application

The requirements in this Chapter apply to ships having transverse strength and transverse stiffness provided by bulkheads that are not less effective than those specified in **Chapter 12**. Where the transverse strength and stiffness provided by the bulkheads are less effective, additional stiffening is to be made by means of increasing scantlings of frames, additional provision of web frames, etc.

6.1.2 Frames in Way of Deep Tanks

The scantlings of frames in way of deep tanks are to comply with the provisions in **Chapter 13** as well as those in this Chapter.

6.1.3 Consideration for the Tightness of Tank Tops

Frames are not to extend through the tops of water or oil tanks, unless the effective watertight or oiltight arrangements are specially submitted and approved.

6.1.4 Increase of Scantlings due to Holes

Where large holes are cut in the web of frames, the scantlings of the frames are to be appropriately increased.

6.1.5 Lower End Construction of Frames

Thorough consideration is to be given to the concentration of stress and other forces acting on the lower end construction of frames.

6.1.6 Frames in Boiler Spaces and in Way of Bossing

1. In boiler spaces, the scantlings of members such as frames, web frames, and side stringers are to be appropriately increased.

2. The construction and scantlings of frames in way of bossing are to be at the discretion of the Society.

6.1.7 Frames and Stringers Fitted to Shell at Extremely Small Angles

Where the angle between the web of frames or stringers and shell plating is extremely small, the scantlings of frames or stringers are to be suitably increased above the normal requirements and where necessary, appropriate supports are to be provided to prevent tripping.

6.1.8 Consideration of Bow Impact Pressuare

The transverse frames, side longitudinals and web frames supporting side longitudinals that are fitted where the bow flare is considered to endure large wave impact pressure are to be properly strengthened and particular attention is to be paid to the effectiveness of their end connections.

6.2 Frame Spacing

6.2.1 Transverse Frame Spacing

1. The standard spacing of transverse frames is obtained from the following formula:

$$450 + 2L \quad (mm)$$

2. Transverse frame spacing in peaks or cruiser sterns is not to exceed 610 *mm*.

3. Transverse frame spacing between $0.2L$ from the fore end and the collision bulkhead is not to exceed 700 *mm* or the standard spacing specified in **-1**, whichever is smaller.

4. The requirements in **-2** and **-3** may be modified, where structural arrangements or scantlings are suitably considered.

6.2.2 Longitudinal Frame Spacing

The standard spacing of longitudinal frames is obtained from the following formula:

$$550 + 2L \quad (mm)$$

6.2.3 Consideration for Frame Spacing Exceeding the Standard

Where the spacing of frames exceeds the standard spacing stipulated in **6.2.1** and **6.2.2** by at least 250 *mm*, the scantlings and structural arrangement of double bottoms and other relevant structures are to be specially considered.

6.2.4 Maximum Frame Spacing

Frame spacing is recommended not to exceed one *metre*.

6.3 Transverse Hold Frames

6.3.1 Application

1. The transverse hold frame is the frame below the lowest deck from the collision bulkhead to the after peak bulkhead including the machinery space.

2. The provisions in **6.3.2** to **6.3.4** apply to the transverse hold frames of ships of ordinary construction.

3. The application of these provisions to transverse hold frames of ships which have bilge hopper tanks, or which have a special construction such as a double side shell, are to be at the discretion of the Society.

4. Special considerations are to be given to the scantlings of transverse hold frames, where the specific gravity of cargoes γ defined in **5.1.1-6** in the loaded hold exceeds 0.9.

6.3.2 Scantlings of Transverse Hold Frames

1. The section modulus of transverse hold frames between $0.15L$ from the fore end and the after peak bulkhead is not to be less than that obtained from the following formula:

$$C_0 CShl^2 \quad (cm^3)$$

Where:

S : Frame spacing (*m*)

l : Vertical distance (*m*) from the top of the inner bottom plating at side to the top of the deck beams above the frames For frames abaft $0.25L$ from the fore end, *l* is to be measured at amidships. For frames between $0.25L$ and $0.15L$ from the fore end, *l* is to be measured at $0.25L$ from the fore end. For frames that are attached to the shell that has a remarkable flare, *l* is to be the length of the frame between supports. Where the length of frames is markedly different from that measured above on account of discontinuity in the lowest deck or change in the height of the double bottom, lines extended from the lowest deck or the top of the double bottom parallel to the upper deck or keel respectively are to be taken as the lowest deck or double bottom top and *l* is to be measured at the corresponding places of measurement. (*See* **Fig. 6.1** and **Fig. 6.2** (a) and (b))

h : Vertical distance (*m*) from the lower end of *l* at the place of measurement to a point d+0.038 L' above the top of the keel (*See* **Fig. 6.2** (a) and (b))

L' Length of ship (*m*)

However, where L exceeds 230 *m*, L' is to be taken as 230 *m*.

C : Coefficient obtained from the following formula, but not to be less than 0.85

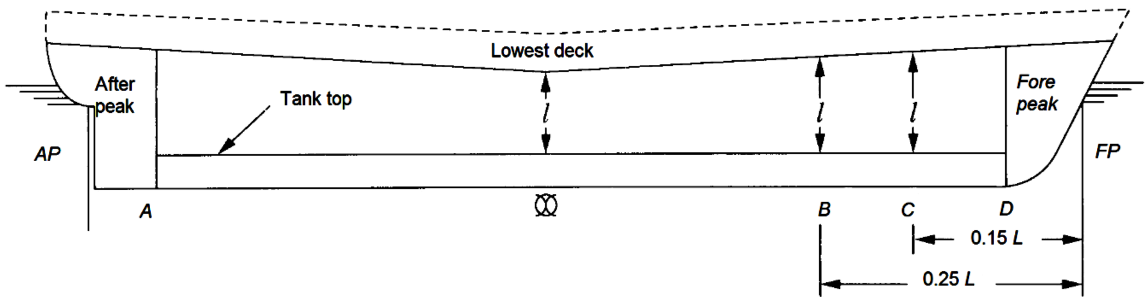
$$1.25 - 2\frac{e}{l}$$

e : Height (*m*) of the tank side bracket measured from the lower end of *l*

C : Coefficient obtained from the following formula:

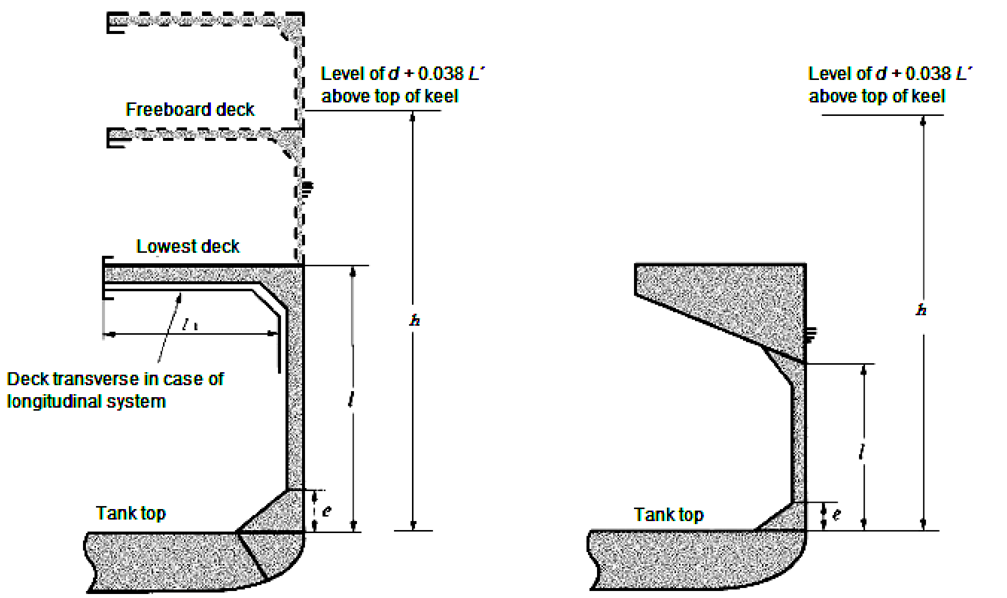
$$C_1 + C_2$$

Fig. 6.1 Measuring Points of *l* for Hold Frames



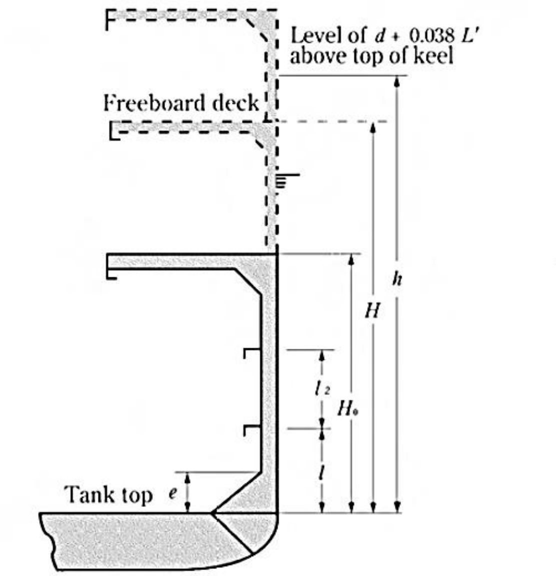
For frame between *A* and *B*, *l* is to be measured at ⊗
For frame between *B* and *C*, *l* is to be measured at *B*
For frame between *C* and *D*, *l* is to be measured at *C*

Fig. 6.2 Measurement of *l*, *h*, *H*, etc. for Transverse Hold Frames



(a) Ordinary Framing System without Top Side Tanks

(b) Framing System with Top Side Tanks



(c) Web and Stringer system

Remarks :

e is not to be more than 0.25 l.
Where l is less than 2 *metres*, l is to be one *metre* greater than a half of the actual span.

(1) For ordinary framing systems without top side tanks

$$C_1 = 2.1 - 1.2\frac{l}{h}$$

$$C_2 = 2.2ka\frac{d}{h}$$

α : Coefficient given in **Table 6.1**

For intermediate values of B/l_H, α is to be obtained by linear interpolation.

l_H : Length of hold (m)

k : Coefficient given below according to the number of layers of deck:

13 (For single deck systems)

21 (For double deck systems)

50 (For triple deck systems)

Where B/l exceeds the following value according to the deck systems, the value of k is to be suitably increased:

2.8 (For single deck systems)

4.2 (For double deck systems)

5.0 (For triple deck systems)

(2) For framing systems with top side tanks

$$C_1 = 3.4 - 2.4\frac{l}{h}$$

$$C_2 = 27a\frac{d}{h}$$

α : As specified in **(1)**

Where $B/\boldsymbol{l}$ exceeds 4.0, the value of C_2 is to be suitably increased.

Table 6.1 Coefficient α

B/l_H	0.5 and under	0.6	0.8	1.0	1.2	1.4 and over
α	0.023	0.018	0.010	0.006	0.0034	0.002

2. The section modulus of transverse hold frames between 0.15L from the fore end and the collision bulkhead is not to be less than that obtained from the following formula:

$$C_0 CShl^2 \ (cm^3)$$

Where:

l : As given by **-1**, except that it is to be measured at 0.15 L from the fore end

S, h and C_0 : As stipulated in **-1**

C : Coefficient, 1.3 times the value specified in **-1**

3. For the frames under transverse web beams supporting deck longitudinals, the section modulus is to be obtained as in **-1** and **-2**, but not to be taken as less than that obtained from the following formula:

$$2.4n\left\{0.17+\frac{1}{9.81}\frac{h_1}{h}\left(\frac{l_1}{l}\right)^2-0.1\frac{l}{h}\right\}Shl^2 \quad (cm^3)$$

Where:

n : Ratio of transverse web beam spacing to frame spacing

h_1 : Deck load (kN/m^2) stipulated in **10.2** for the deck beam at the top of frame

l_1 : Total length (m) of the transverse web beam (*See* **Fig. 6.2** (a))

S, l and h : Values stipulated in **-1** and **-2**

4.

(1) Where the ratio of the depth of the frame to the length measured from the deck at the top of the frame to the toe of the lower bracket is less than 1/24 for the frame prescribed in **-1** and 1/22 for **-2**, the scantlings of such frames are to be suitably increased.

(2) Where the depth of the double bottom centre girder is less than B/16, the scantlings of frames are to be suitably increased.

5. Where long hatchways or multi-row hatchways are provided on the deck at the top of frames, special consideration is to be given to the scantlings of transverse hold frames and their upper end construction.

6.3.3 Transverse Hold Frames Supported by Web Frames and Side Stringers

1. Where transverse hold frames are supported by web frames and side stringers specified in **Chapter 7**, the section modulus of frames is not to be less than that obtained from the following formula:

(1) For frames between 0.15L from the fore end and the after peak bulkhead.

$2.1CShl^2$ (cm^3)

(2) For frames between 0.15L from the fore end and the collision bulkhead.

$3.2CShl^2$ (cm^3)

h : As specified in 6.3.2-1

l : As specified in 6.3.2-1 or -2, as applicable

Where this distance is less than 2 *metres*, l is to be one *metre* greater than one half of the distance. (*See* Fig. 6.1 and Fig 6.2 (c))

C : As obtained from the following formula, but to be taken as 1.0, where C is less than 1.0:

$$C = \left\{\alpha_1\left(3 - \frac{l_2}{l}\right) - \alpha_2\frac{e}{l}\right\}C_4$$

Where:

l_2 : Vertical distance (m) at side from the lowest side stringer to the one immediately above or to the deck (*See* Fig. 6.2 (c))

e : Height (m) of the lower bracket measured from the lower end of l

However, where this height (m) exceeds 0.25 l, e is to be taken as 0.25 l. (*See* Fig. 6.2 (c))

α_1 and α_2**:** As given in Table 6.2

C_4 : As obtained from the following formula, but to be taken as 1.0 where C_4 is less than 1.0, and as 2.2 where C_4 exceeds 2.2

$$2\frac{H}{H_0} - 1.5$$

H_0: Vertical distance (m) from the top of the inner bottom plate at side to the lowest deck (*See* Fig. 6.2 (c))

H : Vertical distance (m) from the lower end of H_0 to the freeboard deck at side (*See* Fig. 6.2 (c))

2. The scantlings of frames specified in **-1** are to be as deemed appropriate by the Society if the difference between any two adjacent unsupported spans of the frames (the vertical distance between adjacent stringers or from a stringer to the end of the frame) is not less than 25% or the difference between the largest and smallest unsupported spans is not less than 50%.

3. Where the height of lower brackets of frames is less than 0.05 times l specified in **-1**, special considerations are to be given to the scantlings of transverse hold frames and their lower end constructions.

Table 6.2 Values of α_1 and α_2

Nos. of side stringers provided below the lowest deck	α_1	α_2
1	0.75	2.0
2	0.90	1.8
3 and more	1.25	1.3

6.3.4 Connection of Transverse Hold Frames

1. Transverse hold frames are to be overlapped with tank side brackets by at least 1.5 times the depth of frame sections and are to be effectively connected thereto.

2. The upper ends of transverse hold frames are to be effectively connected by brackets with the deck and deck beams, and where the deck at the top of frames is longitudinally framed, the upper end brackets are to be extended and connected to the deck longitudinals adjacent to the frames.

6.4 Side Longitudinals and Other Structural Members

6.4.1 Side Longitudinals

1. The section modulus of side longitudinals in the midship part below the freeboard deck is not to be less than that obtained from the following formula, whichever is greater:

$$100CShl^2 \quad (cm^3)$$

$$2.9\sqrt{L'}\,S\,l^2 \quad (cm^3)$$

Where:

S : Spacing (m) of longitudinals

l : Distance (m) between the web frames or between the transverse bulkhead and the web frame including the length of connection

h : Vertical distance (m) from the side longitudinal concerned to a point $d + 0.038L'$ above the top of keel

L': Length (m) of ship However, where L exceeds 230 m, L' is to be taken as 230 m.

C : Coefficient given by the following formula:

$$\frac{l}{24-k}$$

k: $15.5f_B\left(1-2.5\frac{y}{D_s}\right)$ or 6, whichever is greater

y : Vertical distance (m) from the top of keel to the longitudinal under consideration

f_B : Ratio of the section modulus of the transverse section of hull required in **Chapter 14** to the actual section modulus of the transverse section of hull at bottom.

However, where f_B is less than 0.85, it is is to be taken as 0.85.

2. Beyond the midship part, the section modulus of side longitudinals may be gradually reduced towards the ends of the ship, and may be 0.85 times that obtained from the formula in **-1** at the ends. However, the section modulus of side longitudinals between 0.15L from the fore end and the collision bulkhead is not to be less than that obtained from the formula in **-1**.

3. The depth of flat bars used for longitudinals is not to exceed 15 times the thickness of flat bars.

4. Side longitudinals on sheer strakes in the midship Part are to be of a slenderness ratio not greater than 60, as far as is possible.

5. The section modulus of bilge longitudinals need not exceed that of bottom longitudinals.

6. Side longitudinals are to be continuous through transverse bulkheads or to be connected thereto by brackets, so as to provide adequate fixity and continuity of longitudinal strength.

6.4.2 Web Frames

The web frames supporting side longitudinals are to comply with the requirements in **(1)** to **(3)**.

(1) Web frames are to be arranged at sections where solid floors are provided.

(2) The scantlings of web frames are not to be less than that obtained from the following formulae:

Depth: 0.1*l* (*m*) or 2.5 times the depth of the slot for longitudinals, whichever is greater

Section modulus: $C_1 Shl^2$ (cm^3)

Thickness of web: t_1 or t_2, whichever is greater

$$t_1 = \frac{C_2}{1000}\frac{Shl}{d_0} + 2.5 \quad (mm)$$

$$t_2 = 8.6\sqrt[3]{\frac{d_0^2(t_1 - 2.5)}{k}} + 2.5 \quad (mm)$$

Where:

S : Web frame spacing (*m*)

l : Unsupported length (*m*) of web frame

d_0: Depth (*m*) of web frame

However, in the calculation of t_1, the depth of slots for side longitudinals, if any, is to be deducted from the web depth. Where the depth of webs is divided by vertical stiffeners, the divided depth may be taken as d_0 in the calculation of t_2.

h : Vertical distance (*m*) from the lower end of *l* to a point d+0.038 L' above the top of keel

However, where the distance is less than 1.43*l* (*m*), h is to be taken as 1.43*l* (*m*).

L' : As specified in **6.4.1-1**

C_1 and C_2 : Coefficients given in **Table 6.3**

k : Coefficient given in **Table 6.4** according to the ratio of S_1 (*m*) to d_0, where S_1 is the spacing (*m*) of stiffeners or tripping brackets provided on web plates

For the intermediate values of S_1/d_0, *k* is to be obtained by linear interpolation.

(3) Web frames are to be provided with tripping brackets at an interval of about three *metres*. Where the breadth of the face plates of web frames exceeds 180 *mm* on either side of the web, the tripping brackets are to support the face plates as well. Moreover, a stiffener is to be provided on the web at every longitudinal except for the middle part of the span of web frames where stiffeners may be provided at alternate longitudinals. Webs of longitudinals and web frames are to be connected to each other.

Table 6.3 Coefficients C_1 and C_2

	For web frames abaft 0.15L from the fore end	For web frames between 0.15L from the fore and the collision bulkhead
C_1	$6.6\left(1-0.4\frac{l}{h}\right)$	$8.6\left(1-0.4\frac{l}{h}\right)$
C_2	$35\left(1.43-0.43\frac{l}{h}\right)$	$45.5\left(1.43-0.43\frac{l}{h}\right)$

Table 6.4 Coefficient *k*

S_1/d_0	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0 and over
k	60.0	40.0	26.8	20.0	16.4	14.4	13.0	12.3	11.1	10.2

6.5 Cantilever Beam Systems

6.5.1 Cantilever Beams

Cantilever beams are to comply with the requirements in **(1)** to **(7)**:

(1) The depth of cantilever beams measured at the toe of end brackets is not to be less than one-fifth of the horizontal distance from the inboard end of the cantilever beam to the toe of the end bracket.

(2) The depth of cantilever beams may be gradually tapered from the toe of end brackets towards the inboard end where it may be reduced to about a half of the depth at the toe of the end bracket.

(3) The section modulus of cantilever beams at the toe of end brackets is not to be less than that obtained from the following formula: (*see* Fig. 6.3)

$$7.1Sl_0\left(\frac{1}{2}b_1h_1+b_2h_2\right) \quad (cm^3)$$

Where:

S : Cantilever beam spacing (m).

L_0 : Horizontal distance (m) from the inboard end of cantilever beams to the toe of end brackets

b_1 : Horizontal distance (m) from the inboard end of cantilever beams to the toe of end brackets of beam or transverse deck girder at side

However, where the deck is framed longitudinally and no deck transverse is provided between the cantilever beams, b_1 is to be taken as l_0.

b_2 : A half of the breadth (m) of the hatch opening in the deck supported by the cantilever beams

h_1 : Deck load (kN/m^2) stipulated in 9.2 for the deck transverses supported by the cantilever beams

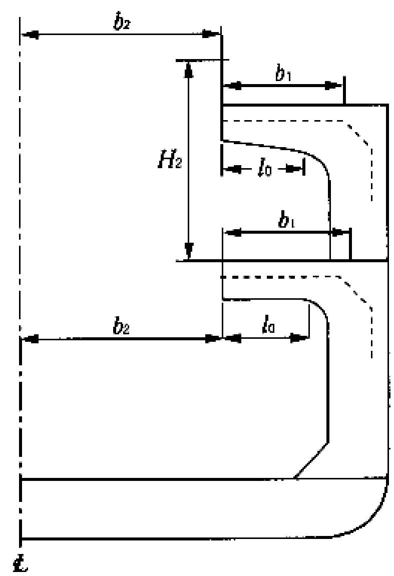
h_2 : Load (kN/m^2) on hatch covers of the deck supported by the cantilever beams which is not to be less than obtained from the following **(a)** to **(c)**, depending on the type of deck

(a) For weather decks, h_2 is the deck load stipulated in **9.2.1-2** for the deck transverses or the maximum design cargo weight on hatches per unit area (kN/m^2), whichever is greater. The value of y in **9.2.1-2(1)** may be taken as the vertical distance from the designed maximum load line to the upper edge of the hatch coaming. In either case, h_2 is not to be less than 17.5 (kN/m^2) for hatches at Position I and 12.8 (kN/m^2) for those at Position II specified in **Chapter 19**, respectively.

(b) For decks other than the weather deck where ordinary cargoes or stores are intended to be carried, h_2 is the deck load stipulated in **9.2.1-1**.

(c) For decks other than those specified in **(a)** or **(b)** above, h_2 is the value equal to h_1.

Fig. 6.3 Measurement of l_0, b_1, b_2 and H_2



The loading height of cargo, H_2 shown in the figure, is to be taken into consideration when h_2 of the lower deck is assumed.

(4) The sectional area of face plates of cantilever beams may be gradually tapered from the inner edge of end brackets towards the inboard end of cantilever beams, where it may be reduced to 0.60 times that at the inner edge of the end brackets

(5) The web thickness of cantilever beams at any point is not to be less than the greater of the values obtained from the following formula:

$$t_1 = 0.0095\frac{S\left(\frac{1}{2}b_1h_1 + b_2h_2\right)}{d_c} + 2.5 \quad (mm)$$

$$t_2 = 5.8\sqrt[3]{d_c^2(t_1 - 2.5)} + 2.5 \quad (mm)$$

Where:

S, b_1 ,b_2 , h_1 and h_2 : As stipulated in **(3)**

However, where the deck is framed longitudinally and no deck transverse is provided between the cantilever beams, $b_1/2$ is to be substituted by the horizontal distance in *metres* from the inboard end of cantilever beams to the section under consideration in the formula for t_1.

d_c : Depth (m) of the cantilever beam at the section under consideration

However, in the calculation of t_1, the depth of slots for deck longitudinals, if any, is to be deducted from the depth of cantilever beams. Where the webs are provided with horizontal stiffeners, the divided web depth may be used for d_c in the formula for t_2.

(6) Cantilever beams are to be provided with tripping brackets at an interval of about three *metres*. Where the breadth of the face plates of cantilever beams exceeds 180 *mm* on either side of the web, the tripping brackets are to support the face plates as well. Moreover, a stiffener is to be provided on the web at every longitudinal except for the middle part of the span of cantilever beams where stiffeners may be provided at alternate longitudinals.

(7) Web plates adjacent to the inner edge of end brackets are to be specially reinforced.

6.5.2 Web Frames

The web frames supporting cantilever beams are to comply with the requirements in **(1)** to **(7)**.

(1) The depth of web frames is not to be less than one-eighth of the length including the length of connections at both ends.

(2) The section modulus of web frames is not to be less than that obtained from the following formula. However, where a tween deck web frame in association with a cantilever beam supporting the deck above is provided at the top of the web frame, the value of the formula may be reduced to 60%.

$$7.1Sl_1\left(\frac{1}{2}b_1h_1 + b_2h_2\right) \quad (cm^3)$$

Where:

S : Web frame spacing (m)

l_1 : Horizontal distance (m) from the end of supported cantilever beams to the inside of web frames

b_1 , b_2 , h_1 and h_2 : As stipulated in **6.5.1(3)** for the supported cantilever beams

However, where the deck is framed longitudinally and no deck transverse is provided between the cantilever beams, l_1 is to be substituted for b_1.

(3) The section modulus of tween deck web frames is to be in accordance with the requirements in **(2)**, and is not to be less than that obtained from the following formula:

$$7.1C_1Sl_1\left(\frac{1}{2}b_1h_1 + b_2h_2\right) \quad (cm^3)$$

Where:

S, l_1 , b_1 ,b_2 , h_1 and h_2 : As stipulated in **(2)**

C_1 : Coefficient obtained from the following formula:

$$C_1 = 0.15 + 0.5\frac{\frac{1}{2}b_1'h_1' + b_2'h_2'}{\frac{1}{2}b_1h_1 + b_2h_2}$$

b_1', b_2', h_1' and h_2' : b_1, b_2, h_1 and h_2 respectively stipulated in **(2)** in respect to the cantilever beams provided below the web frames concerned.

(4) The web thickness is not to be less than that obtained from the following formula, whichever is greater:

$$t_1 = 0.0095\frac{C_2S\left(\frac{1}{2}b_1h_1 + b_2h_2\right)}{d_w}\frac{l_1}{l} + 2.5 \qquad (mm)$$

$$t_2 = 5.8\sqrt[3]{d_w^2(t_1 - 2.5)} + 2.5 \qquad (mm)$$

Where:

S, b_1 ,b_2 , h_1 , h_2 and l_2 : As stipulated in **(2)**

d_w : The smallest depth (m) of web frame

However, in the calculation of t_1, the depth of slots for side longitudinals, if any, is to be deducted from the web depth. Where the depth of webs is divided by vertical stiffeners, the divided depth may be used for d_w in the calculation of t_2.

l : Length (m) of web frame including the length of connections at both ends

C_2 : Coefficient given below

For hold web frames:

Where a web frame in association with a cantilever beam supporting the deck above is provided directly above: 0.9

Elsewhere: 1.5

For tween deck web frames: C_1+0.6

C_1 : Coefficient given by (3)

(5) Where web frames supporting cantilever beams also support side longitudinals or side stringers, the scantlings are to comply with the following requirements in addition to those in 6.4.2 or Chapter 7.

(a) The section modulus is not to be less than that obtained from the formula in **(2)**, multiplied by the following coefficient:

Where tween deck web frame together with cantilever beam is provided above:

$$0.6 + 9.81\frac{0.05hl^2 + 0.09h_ul_u^2}{1.4\left(\frac{1}{2}b_1h_1 + b_2h_2\right)l_1}$$

Elsewhere: 1.0

Where:

l : Length (m) of hold web frame including the length of connections at both ends

l_u: Length (m) of tween deck web frame provided directly above, including the length of connections at both ends

h : Vertical distance (m) from the middle of l to a point d + 0.038L' above the top of keel

L': Length of ship (m)

However, where L exceeds 230 m, L' is to be taken as 230 m.

h_u : Vertical distance (m) from the middle of l_u to a point to which h is measured

However, where the point is below the middle of l_u , h_u is to be taken as zero.

b_1, b_2 , h_1 , h_2 and l_1 : As given by **(2)**.

(b) The web thickness is not to be less than that given by **(4)**, in which the value of t_1 is to be increased by the amount obtained from the following formula:

$$0.0255\frac{Shl}{d_w} \quad (mm)$$

S : Web frame spacing (m)

h and l : As stipulated in **(a)** above

d_w : As stipulated in **(4)**

(6) Web frames are to be provided with tripping brackets at an interval of about three *metres*. Where the breadth of the face plates of web frames exceeds *180 mm* on either side of the web, the tripping brackets are to support the face plates as well. Moreover, a stiffener is to be provided on the webs at every side longitudinal except for the middle part of the span of web frames where stiffeners may be provided at alternate longitudinals. Webs of longitudinals and web frames are to be connected to each other.

(7) Web frames are to be effectively connected with other web frames located beneath or solid floors so as to maintain strength continuity.

6.5.3 Connection of Cantilever Beams to Web Frames

Cantilever beams and web frames supporting them are to be effectively connected by brackets required in **(1)** to **(4)**.

(1) The radius of curvature of the free edges of brackets is not to be less than the depth of cantilever beams at the toes of brackets.

(2) The thickness of brackets is not to be less than that of the webs of cantilever beams or web frames, whichever is greater.

(3) The brackets are to be properly strengthened by stiffeners.

(4) The free edges of brackets are to have face plates of a sectional area not less than that of cantilever beams or web frames, whichever is greater, and the face plates are to be connected with those of cantilever beams and web frames.

6.6 Tween Deck Frames

6.6.1 General

1. The scantlings of tween deck frames are to be determined in relation to the strength of hold frames, the arrangement and transverse stiffness of bulkheads, etc.

2. Tween deck frames are, in association with the hold frames, to be determined in consideration of maintaining the continuity of strength of framing from the bottom to the uppermost deck.

3. The scantlings of tween deck beams specified in **6.6** are based on the standard structural arrangement so as to maintain transverse stiffness of ships by means of efficient tween deck bulkheads provided above the hold bulkheads or by web frames extended to the top of superstructures at proper intervals.

6.6.2 Scantlings of Tween Deck Frames

1. The section modulus of tween deck frames below the freeboard deck is not to be less than that obtained from the following formula:

$$6Shl^2 \quad (cm^3)$$

Where:

S : Frame spacing (*m*)

l : Tween deck height (*m*)

h : Vertical distance (*m*) from the middle of *l* to the point $d + 0.038L'$ above the top of keel

However, where *h* is less than $0.03L$ (*m*), *h* is to be taken as $0.03L$ (*m*).

L': Length of ship (*m*)

However, where *L* exceeds 230 *m*, L' is to be taken as 230 *m*.

2. The section modulus of tween deck frames except those specified in **-1** is not to be less than that obtained from the following formula:

$$CSlL \quad (cm^3)$$

Where:

S and *l* : As specified in **-1**

C : Coefficient given in **Table 6.5**

3. The scantlings of tween deck frames below the freeboard deck within $0.15L$ from the fore end and within $0.125L$ from the after end are to be appropriately increased above those given by **-1** and **-2**.

4. Where decks are supported by longitudinal beams and web beams, the section modulus of tween deck frames supporting web beams is not to be less than that obtained from the following formula, in addition to those in **-1** and **-3**.

$$2.4\left(1 + 0.0714n\frac{h_1}{h}\right)Shl^2 \quad (cm^3)$$

Where:

S, *h* and *l* : As stipulated in **-1**.

n : Ratio of spacing of web beams to tween deck frame spacing.

h_1 : Deck load stipulated in **9.2** for the deck beam at the top of frame (kN/m^2)

Table 6.5 Coefficient *C*

Description of tween deck frames	*C*
Superstructure frames (excluding the following two lines)	0.44
Superstructure frames for 0.125L from aft end	0.57
Superstructure frames for 0.125L from fore end and cant frames at stern	0.74

6.6.3 Special Precautions Regarding Tween Deck Frames

1. Care is to be taken so that the strength and stiffness of framing at the ends of the ship may be increased in proportion to the actual unsupported length of frame as well as the vertical height of tween decks.

2. In ships having an especially large freeboard, the scantlings of tween deck frames may be properly reduced.

6.6.4 Superstructure Frames

1. Superstructure frames are to be provided at every frame located below.

2. Notwithstanding the requirements in **6.6.2-2**, superstructure frames for four frame spaces at the ends of bridges and of detached superstructures within 0.5L amidships are to be of the section modulus obtained from the formula in **6.6.2** using 0.74 as the coefficient *C*.

3. Web frames or partial bulkheads are to be provided above the bulkheads required by **Chapter 12** or at other positions such as may be considered necessary to give effective transverse rigidity to the superstructures.

6.6.5 Frames of Cruiser Sterns

The section modulus of frames of cruiser sterns is not to be less than 0.86 times that required by **6.8.1**.

6.7 Frames below Freeboard Deck forward of Collision Bulkhead

6.7.1 Transverse Frames below Freeboard Deck

The section modulus of transverse frames below the freeboard deck is not to be less than that obtained from the following formula:

$$8Shl^2 \quad (cm^3)$$

Where:

S : Frame spacing (m).

l : Unsupported length of frame (m), but not to be less than 2.15 *metres*.

h : Vertical distance from the middle of l to a point $0.12L$ above the top of keel (m). However, where h is less than $0.06L$ (m), h is to be taken as $0.06l$ (m).

6.7.2 Longitudinals below Freeboard Deck

Longitudinals below the freeboard deck are to comply with the requirements in **(1)** and **(2)**.

(1) The section modulus of longitudinals is not to be less than that obtained from the following formula. However, the modulus obtained from the formula is to be increased by 25% (between $0.05D$ and $0.15D$ from the top of the keel), and 50% (below $0.05D$ from the top of the keel).

$8Shl^2 \quad (cm^3)$

where:

S : Longitudinal frame spacing (m).

l : Distance between the side transverse or between the side transverse and the transverse bulkhead (m).

However, where l is less than 2.15 *metres*, l is to be taken as 2.15 *metres*.

h : Vertical distance from the longitudinals to a point $0.12L$ above the top of keel (m). However, where h is less than $0.06L$ (m), h is to be taken as $0.06l$ (m).

(2) Longitudinals are to be connected at each end to breast hooks and transverse bulkheads by efficient brackets.

6.8 Frames below Freeboard Deck abaft of After Peak Bulkhead

6.8.1 Transverse Frames below Freeboard Deck

1. The section modulus of transverse frames below the freeboard deck is not to be less than that obtained from the following formula:

$8Shl^2 \quad (cm^3)$

where:

S : Frame spacing (m).

l : Unsupported length of frame (m). However, where the length is less than 2.15 *metres*, l is to be taken as 2.15 *metres*.

h : Vertical distance from the middle of l to a point $d + 0.038L'$ above the top of keel (m). However, where the distance is less than that 0.04 L (m), h is to be taken as $0.04L$ (m).

L': Length of ship (m). However, where L exceeds 230 m, L' is to be taken as 230 m.

2. Where the ship speed exceeds 14 *kts*, the section modulus of side frames is to be increased over the value required by **-1** by 2% per *knot* excess to a maximum of 12%.

Chapter 7 WEB FRAMES AND SIDE STRINGERS

7.1 General

7.1.1 Application

The requirements in this Chapter apply to side stringers supporting the transverse hold frames specified in 6.3.3 and the web frames supporting these side stringers.

7.1.2 Arrangement of Web Frames and Side Stringers

Web frames and side stringers are to be arranged to provide effective stiffeners to the ship side structures.

7.1.3 Web Frames and Side Stringers in Way of Deep Tanks

The strength of web frames and side stringers in way of deep tanks is not to be less than that required for vertical or horizontal girders on deep tank bulkheads.

7.1.4 Consideration of Bow Impact Pressure

The side stringers supporting transverse hold frames that are fitted where the bow flare is considered to endure large wave impact pressure, and the web frames supporting these side stringers are to be properly strengthened and particular attention is to be paid to the effectiveness of their end connections.

7.2 Web Frames

7.2.1 Scantlings of Web Frames

1. The scantlings of web frames supporting side stringers are not to be less than that obtained from the following formula:

Depth: $0.125l$ (m)

Section modulus: $C_1 Shl^2$ (cm^3)

Thickness of web: t_1 or t_2 whichever is greater:

$$t_1 = \frac{C_2}{1000}\frac{Shl}{d_0} + 2.5 \quad (mm)$$

$$t_2 = 8.6\sqrt[3]{\frac{d_0^2(t_1 - 2.5)}{k}} + 2.5 \quad (mm)$$

Where:

S : Web frame spacing (m)

l : Unsupported length (m) of web frame

h : Vertical distance (m) from the lower end of l to a point $d + 0.038L'$ above the top of keel

L' : Length of ship (m)

Where, however, L exceeds $230m$, L' is to be taken as $230m$.

d_0 : Depth of web frame (m)

Where the webs are provided with vertical stiffeners, the divided web depth may be used for d_0 in the formula for t_2.

C_1 and C_2 : Coefficients given in **Table 7.1**

k : Coefficient given in **Table 7.2** according to the ratio of S_1 to d_0, where S_1 is the spacing (m) of stiffeners or tripping brackets provided on web plates of web frames

For the intermediate values of S_1 / d_0, k is to be obtained by linear interpolation.

2. Where the web frames are in close proximity to boilers, the thickness of webs and face plates is to be suitably increased.

Table 7.1 Coefficients C_1 and C_2

	For web frames abaft 0.15L from the fore end	For web frames between 0.15L from the fore end and the collision bulkhed
C_1	3.0	3.8
C_2	23	28

Table 7.2 Coefficient k

S_1/d_0	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0 and over
k	60.0	40.0	26.8	20.0	16.4	14.4	13.0	12.3	11.1	10.2

7.2.2 Stiffening of Webs

1. Stiffeners or tripping brackets are to be provided on webs of web frames as may be required.

2. Tripping brackets are to be arranged at intervals of about 3 *metres*.

3. Where the breadth of face plates on either side of the web exceeds 180 *mm*, tripping brackets are to be arranged to support the face plates.

7.2.3 Continuity of Transverse Strength

Below the bulkhead deck, tween deck web frames are to be provided over the hold web frames as may be required, to provide continuity of transverse strength of the web frames in holds and machinery spaces.

7.2.4 Beams at the Top of Web Frames

Beams at the top of web frames are to be suitably increased in both strength and stiffness.

7.3 Hold Side Stringers

7.3.1 Scantlings of Hold Side Stringers

1. The scantlings of side stringers are not to be less than that obtained from the following formula:

Depth: 0.125*l* (*m*) plus one quarter of the depth (*m*) of slot for ordinary frames.

Section modulus:

$$C_1 Shl^2 \ (cm^3)$$

Thickness of web: t_1 or t_2 whichever is greater

$$t_1 = \frac{c_2}{1000}\frac{Shl}{d_0} + 2.5 \quad (mm)$$

$$t_2 = 8.6\sqrt[3]{\frac{d_0^2(t_1 - 2.5)}{k}} + 2.5 \quad (mm)$$

Where:

S : Distance (*m*) between the mid-points of the spaces from the side stringer concerned to the adjacent side stringers or to the top of the inner bottom plating at side or to the top of deck beams at side

l : Web frame spacing (*m*)
However, where effective brackets are provided, the span *l* may be modified as specified in **1.1.**

h : Vertical distance (*m*) from the middle of *S* to a point *d*+0.038 *L*' above the top of keel
However, where *h* is less than that 0.05*L* (*m*), *h* is to be taken as 0.05*L* (*m*).
L': As specified in **7.2.1-1**

d_0 : Depth of side stringer (*m*)
However, where the depth of the web is divided by providing a stiffener in parallel to the face plate, the divided depth may be taken as d_0 in the calculation of t_1.

C_1 and C_2 : Coefficients given in **Table 7.3**

k : Coefficient given in **Table 7.2** according to the ratio of S_1 to d_0, where S_1 is the spacing (*m*) of stiffeners or tripping brackets provided on web plates of side stringers
For the intermediate values of S_1 / d_0, *k* is to be obtained by linear interpolation.

2. In boiler spaces, the thickness of various parts of the stringer plate such as web plates and face plates are to be suitably increased

Table 7.3 Coefficients C_1 and C_2

	For side stringers abaft 0.15*L* from the fore end	For side stringers between 0.15*L* from the fore end and the collision bulkhead
C_1	5.1	6.4
C_2	42	52

7.3.2 Stiffeners on Webs

Stiffeners that cover the entire width of the web are to be provided on the webs of side stringers at alternate frames.

7.3.3 Tripping Brackets

1. Tripping brackets are to be provided on side stringers at intervals of about 3 *metres*.

2. Where the breadth of face plates on either side of the side stringer exceeds 180 *mm*, tripping brackets are to be arranged to support the face plates.

7.3.4 Connection of Side Stringers to Web Frames

1. Connection of side stringers to web frames is to extend for the full depth of the web frame.

2. Where stringers are of the same depth as web frames, efficient gussets are to be used to connect the face plates of the side stringers with the face plates of the web frames.

7.3.5 Connection of Side Stringers to Transverse Bulkhead

Brackets of a proper size are to be used to effectively connect side stringers to the transverse bulkheads.

Chapter 8 ARRANGEMENTS TO RESIST PANTING

8.1 General

8.1.1 Application

1. Suitable arrangements to resist panting are to be provided in way of spaces from the fore end of the ship to an appropriate point beyond the collision bulkhead and from the aft end of the ship to an appropriate point beyond the aft peak bulkhead.

2. Transverse frames and side longitudinals provided in way of the spaces specified in **-1**, are to be in compliance with the requirements in **6.7** and **6.8**.

8.1.2 Swash Plate

In fore and after peak tanks to be used as deep tanks, effective swash plates are to be provided at the centre line of the ship or the scantlings of structural members are to be suitably increased.

8.1.3 Stringers Fitted to Shell at Extremely Small Angles

Where the angle between the web of stringers and the shell plating is extremely small, the scantlings of stringers are to be suitably increased above the normal requirements and where necessary, appropriate supports are to be provided to prevent tripping.

8.2 Arrangements to Resist Panting Forward of Collision Bulkhead

8.2.1 Arrangement and Construction

1. Deep centre girder or centreline longitudinal bulkhead is to be provided in the forward direction of the collision bulkhead.

2. In fore peaks constructed of transverse framing, floors having sufficient height are to be arranged at the frame spacing stipulated in **6.2.1-2**, and side girders are to be arranged at intervals not exceeding about 2.5 *metres*.

Transverse frames are to be supported by the structures specified in **8.2.2-2** at intervals not exceeding 2.5 *metres*.

3. In fore peaks of longitudinal framing, bottom transverses supporting bottom longitudinals and side transverses supporting side longitudinals are to be arranged at intervals not exceeding about 2.5 *metres*. Bottom transverses andside transverses are to be effectively connected to each other and deck transverses are to be arranged on the deck in the same section to create a ringed structure.

8.2.2 Transverse Framing Systems

1. Floors, Centre Girder and Side Girders

(1) The thicknesses of floors and centre girders in fore peaks are not to be less than that obtained from the following formula:

$4 + 0.6\sqrt{L}$ (mm)

(2) Floors are to extend to a height necessary to give adequate stiffness to the structure and are to be properly stiffened with stiffeners as may be required.

(3) The upper edges of the floors and centre girders are to be properly stiffened.

(4) The thickness of side girders is to be approximately equal to that of centre girders, and side girders are to extend to appropriate heights proportionate to those of the floors.

2. Side Construction to Resist Panting

(1) Where panting beams are provided at alternate frames together with stringer plates connected to the shell plating:

(a) Panting beams are to be angle or channel sections of sectional area not less than $0.3L$ $(cm2)$, being connected effectively with frames by means of brackets having a thickness of not less than that of the frames. Moreover, the panting beams are to be sufficiently connected vertically and longitudinally at the centre line of the ship by means of angles as may be required in consideration of the span.

(b) The scantlings of stringer plates are not to be less than that obtained from the following formula, and their inner edges are to be suitably stiffened by flanging or by angle sections.

Breadth: $2.5L + 500$ (mm)

Thickness: $0.02L + 6.5$ (mm)

(c) The frames to which no panting beam is provided are to be connected to the stringer plates by brackets. The length of each arm of the bracket is to be at least equal to one half of the breadth of the stringer plates required in **(b)** and the thickness of the brackets are to be at least equal to that of the stringer plates. The stringer plates are to be stiffened by providing flat bars extending from the toes of brackets to the inner edge of stringer plates.

(d) Stringer plates are to be connected by effective brackets to the breast hooks and the horizontal girders of the transverse bulkhead.

(2) Where panting beams are provided at every frame and the beams are covered with perforated steel plates from one side of the ship to the other side:

(a) The sectional area of panting beams is not to be less than that obtained from the following formula:

$5 + 0.1L$ (cm^2)

(b) The thickness of perforated steel plates covering the panting beams is not to be less than that obtained from the following formula:

$0.02L + 5.5$ (mm)

(3) Where transverse frames are supported by side stringers:

(a) The scantlings of side stringers are not to be less than that obtained from the following formula:

Web depth: $0.2l$ (m), $0.5 + 0.0025L$ (m) or 2.5 times the depth of slot for the transverse frames, whichever is the greatest.

Section modulus: $8Shl^2$ (cm^3)

Web thickness: t_1 or t_2, whichever is greater.

$$t_1 = 0.042\frac{Shl}{d_0} + 2.5 \quad (mm)$$

$$t_2 = 11\sqrt[3]{\frac{d_0^2\,(t_1 - 2.5)}{k}} + 2.5 \quad (mm)$$

Where:

l : Horizontal distance (*m*) between the supporting points of side stringers

S : Spacing (*m*) of side stringers

h : Vertical distance (*m*) from the middle of *S* to a point 0.12*L* above the top of keel

However, where *h* is less than that 0.06*l* (*m*), *h* is to be taken as 0.06*L* (*m*).

d_0 : Depth of side stringers (*m*)

However, in the calculation of t_1, the depth of slots for longitudinals, if any, is to be deducted from the depth of side stringers. Where the depth of side stringers is divided by horizontal stiffeners, the divided depth may be taken as d_0 in the calculation of t_2.

k : Coefficient given in **Table 8.1** according to the ratio of S_1 to d_0, where S_1 (*m*) is the spacing of stiffeners or tripping brackets provided on web plates of side stringers

For the intermediate values of S_1/d_0, *k* is to be obtained by linear interpolation.

Table 8.1 Coefficient *k*

S_1/d_0	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0 And over
k	60.0	40.0	26.8	20.0	16.4	14.4	13.0	12.3	11.1	10.2

(b) Side stringers are to be provided with tripping brackets at intervals of about three *metres*. Where the breadth of face plates of side stringers exceeds 180 *mm* on either side of the web, the tripping brackets are to support the face plates as well. Moreover, stiffeners are to be provided on the webs at every longitudinal except for the middle part of the span of side stringers where they may be provided at alternate transverse frames.

(c) Where the side stringers are supported by cross ties, the scantlings of cross ties are not to be less than that obtained from the following formula:

Sectional area:

Where $\frac{l}{k_0}$ is 0.6 and over: $\frac{0.77\,Sbh}{1-0.5\frac{l}{k_0}} \quad (cm^2)$

Where $\frac{l}{k_0}$ is less than 0.6: $1.1Sbh\ (cm^2)$

Web thickness: $16d_w\sqrt{\frac{Sbh}{A}} \quad (mm)$

Where:

S : Spacing (*m*) of side stringers

b : Breadth (m) of area supported by the cross tie

h : Vertical distance (m) from the middle of b to a point 0.12 L above the top of keel

However, where h is less than that $0.06L$ (m), h is to be taken as $0.06L$ (m)

l : Length (m) of cross tie.

K_0 : Minimum radius (cm) of gyration of cross tie, obtained from the following formula:

$$\sqrt{\frac{I}{A}}$$

I : The least moment (cm^4) of inertia of cross tie

A : Sectional area (cm^2) of cross tie

d_w : Web depth (m) of cross tie

However, where stiffeners are fitted up horizontally, the largest divided web depth may be taken as $d_{w.}$

(d) Cross ties are to be effectively connected with the side stringers by brackets or by other suitable arrangements and the side stringers are to be provided with tripping brackets in way of the cross ties.

(e) Where the breadth of the face plates of cross ties on either side of the web exceeds 150 mm, stiffeners are to be provided on the webs at suitable intervals. They are to be connected with the face plates and support the face plates.

8.2.3 Longitudinal Framing

1. The side transverses supporting longitudinals are to comply with the following requirements in **(1)** to **(4)**. However, where it is found impracticable to apply these requirements, they are to be at the discretion of the Society.

(1) Side transverses on both sides are to be connected providing cross ties at a vertical interval not greater than that obtained from the following formula:

$2.5 + 0.0125L$ (m)

(2) The scantlings of transverses are not to be less than that obtained from the following formula:

Web depth: $0.2l$ (m), $0.5 + 0.0025L$ (m) or 2.5 times the depth of slots for longitudinals, whichever is the greatest.

Section modulus: $8Shl^2$ (cm^3)

Web thickness: t_1 or t_2, whichever is greater.

$$t_1 = 0.042\frac{Shl}{d_0} + 2.5 \quad (mm)$$

$$t_2 = 11\sqrt[3]{\frac{d_0^2(t_1 - 2.5)}{k}} + 2.5 \quad (mm)$$

Where:

l : Vertical distance (m) between supporting points of side transverses

S : Spacing (m) of side transverses

h : Vertical distance (m) from the middle of l to a point $0.12l$ above the top of keel

However, where h is less than that $0.06L$ (m), h is to be taken as $0.06L$ (m)

d_0 : Depth (m) of side transverse

However, in the calculation of t_1, the depth of slots for longitudinals, if any, is to be deducted from the depth of transverses. Where the depth of side transverses is divided by vertical stiffeners, the divided depth may be taken as d_0 in the calculation of t_2.

k : Coefficient given in **Table 8.1** according to the ratio of S_1 to d_0, where S_1 (m) is the spacing of tripping brackets or stiffeners provided on web plates of side transverses

For the intermediate values of S_1/d_0, k is to be obtained by linear interpolation.

(3) Side transverses are to be connected effectively with bottom transverses. Where side transverses are connected with bottom transverses, the scantlings of webs and face plates in the lowest span are to be so decided as to provide strength continuity in the transient from side to bottom transverses; the sum of the effective sectional area of webs and areas of face plates in the lower half of the lowest span is not to be less than that the required sectional area of webs of the bottom transverse.

(4) Side transverses are to be provided with tripping brackets at intervals of about three *metres*. Where the breadth of the face plates of side transverses exceeds 180 *mm* on either side of the web, the tripping brackets are to support the face plates as well. Moreover, stiffeners are to be provided on the webs at every longitudinal, except that these stiffeners may be provided at alternate longitudinals in the middle part of spans other than that the lowest span.

2. Cross ties specified in **-1(1)** are to comply with the requirements in **(1)** to **(3)**. However, where it is found impracticable to apply these requirements, the construction is to be at the discretion of the Society.

(1) The scantlings of cross ties are not to be less than that obtained from the following formula:

Sectional area:

Where $\frac{l}{k_0}$ is 0.6 and over: $\frac{0.77Sbh}{1-0.5\frac{l}{k_0}}$ (cm^2)

Where $\frac{l}{k_0}$ is less than 0.6: $1.1\ Sbh$ (cm^2)

Web thickness: $16d_w\sqrt{\frac{Sbh}{A}}$ (mm)

Where:

S : Spacing (m) of side transverses

b : Breadth (m) of area supported by cross tie

h : Vertical distance (m) from the centre of b to a point $0.12L$ (m) above the top of keel

However, where h is less than that $0.06L$ (m), h is to be taken as $0.06L$ (m).

l : Length (m) of cross tie

k_0 : Minimum radius (cm) of gyration of cross tie, obtained from the following formula:

$$\sqrt{\frac{I}{A}}$$

I : The least moment (cm^4) of inertia of cross tie

A : Sectional area (cm^2) of cross tie

d_w : Web depth (m) of cross tie

However, where stiffeners are provided horizontally, the largest divided web depth may be taken as d_w.

(2) Cross ties are to be effectively connected with transverses by brackets or by other suitable arrangements and the side transverses are to be provided with tripping brackets in way of the cross ties.

(3) Where the breadth of the face plate of cross ties on either side of the web exceeds 150 mm, stiffeners are to be provided on the webs at suitable intervals. They are to be connected with the face plates and support the face plates.

3. Bottom transverses supporting bottom longitudinals are to be of the construction specified in **(1)** to **(6)** or that is deemed equivalent thereto by the Society. However, for ships capable of maintaining adequate fore draught in rough seas, the section modulus of transverses and the sectional area of webs specified in **(1)** to **(3)** may be reduced by 10% respectively.

(1) The scantlings of bottom transverses are not to be less than that obtained from the following formula, and the bottom transverses are to be supported by struts at the centre line. The adjacent bottom transverses are to be connected to each other by a centre girder of about the same scantlings as those of the bottom transverses or to be supported by an especially deep centre girder or a longitudinal bulkhead.

Web depth: $0.45 + 0.0055L \quad (m)$

Section modulus: $1.2Ll^2 \quad (cm^3)$

Web thickness: $4 + 0.6\sqrt{L} \quad (mm)$

Where:

S : Spacing (m) of bottom transverses

l : Distance (m) between the supporting points of bottom transverses

(2) Where bottom transverses and centre girders are of scantlings exceeding those obtained from the following formula, notwithstanding the requirements in **(1)**, the centre line struts may be arranged at alternate bottom transverses.

Centre girders:

Web depth: $0.68 + 0.008L \quad (m)$

Web thickness: $4.5 + 0.65\sqrt{L} \quad (mm)$

Section modulus: Value obtained from the formula in **(1)**. However, in the formula, the average load bearing width (m) of the centre girder is to be taken as S and the distance between the supporting points of the centre girder (m) as l.

Bottom transverses:

Web depth: $0.45 + 0.005L \quad (m)$

Web thickness: $4.5 + 0.65\sqrt{L} \quad (mm)$

Section modulus: Value obtained from the formula in **(1)**.

(3) Where the scantlings of bottom transverses are greater than that obtained from the following formula, notwithstanding the requirements in **(1)**, the centre line struts or longitudinal bulkheads may be dispensed with.

The scantlings of web plates of centre girders are not to be less than that required in **(1)** for bottom transverses and free edges of web plates are to be suitably stiffened.

Web depth: $0.68 + 0.008L \quad (m)$

Web thickness: $5 + 0.7\sqrt{L} \quad (mm)$

Section modulus: Value obtained from the formula in **(1)**

(4) Where the web depths of bottom transverses and centre girders are greater than required in **(3)**, their thicknesses may be reduced from the thicknesses prescribed in **(3)** notwithstanding the requirements in **(3)**. However, the thickness is not to be less than that obtained from the following formula under any circumstances:

$3.5 + 0.55\sqrt{L} \quad (mm)$

(5) Where the length of bottom transverses measured between their supporting points at each side exceeds $0.045L$ (m) or the spacing of bottom transverses exceeds 2.5 *metres*, the scantlings of bottom transverses and centre girders prescribed in **(1)** to **(4)** are to be suitably increased.

(6) Bottom transverses are to be provided with tripping brackets at intervals of about 3 *metres*. Where the breadth of the face plates of bottom transverses exceeds 180 *mm* on either side of the web, the tripping brackets are to support the face plates as well. Moreover, stiffeners are to be provided on the webs at every longitudinal.

4. The struts stipulated in **-3(1)** and **-3(2)** are not to be less effective than that required by the following **(1)** to **(3)** or equivalent thereto.

(1) The scantlings of struts are not to be less than that obtained from the following formula:

Sectional area:

Where $\frac{l}{k_0}$ is 0.6 and over: $\frac{0.115SbL}{1-0.5\frac{l}{k_0}} \quad (cm^2)$

Where $\frac{l}{k_0}$ is less than 0.6: $0.164\,SbL \quad (cm^2)$

Web thickness:

$6.2d_w\sqrt{\frac{Sbl}{A}} \quad (mm)$

Where:

S : Length (m) in longitudinal direction of the area supported by strut

b : Breadth (m) of the area supported by strut

l : Length (m) of strut

k_0: Minimum radius (cm) of gyration of struts, obtained from the following formula

$\sqrt{\frac{I}{A}}$

I : The least moment (cm^4) of inertia of strut

A : Sectional area (cm^2) of strut

d_w : Breadth (m) of web

However, where the web is provided with stiffeners along the length of the strut, the maximum spacing of such stiffeners is to be taken as d_w.

(2) As a rule, the struts are to extend to the lowest deck, and are to be effectively connected with the cross ties by brackets.

(3) Where the breadth of face plates on either side of the webs exceeds 150 *mm*, stiffeners are to be provided on the webs and so arranged as to support the face plates at suitable intervals.

5. Side girders of appropriate scantling are to be provided in line with those abaft of the collision bulkhead in order to give additional stiffness to the flat bottom structure.

8.2.4 Ships Having Unusual Bow Sections

Structural arrangement at the fore end of ships having a bulbous bow or other unusual form of bow section is to be at the discretion of the Society.

8.3 Arrangements to Resist Panting Abaft of After Peak Bulkhead

8.3.1 Floors

The requirements in **8.2.2-1** apply to the scantlings and arrangement of floors in the after peak. The floors are to extend well above the stern tubes.

8.3.2 Panting Beams and Stringers

1. The structure below the lowest deck is to be effectively stiffened by means of panting beams and stringer plates as required for the fore peak in **8.2.2-2**.

2. Where the distance between the supports at any part of the girth of frame exceeds 2.5 *metres*, the scantlings of frames are to be increased, or side stringers or struts are to be additionally provided to give adequate stiffness to the side structure.

8.3.3 Cruiser Sterns

Cruiser sterns are to be strengthened by structural members such as web frames and side stringers as found necessary.

8.4 Arrangements to Resist Panting Between Both Peaks

8.4.1 Arrangements to Resist Panting Abaft of Collision Bulkhead

The side shell structure abaft the collision bulkhead is to be properly reinforced so as to maintain continuity of strength with that in the fore peak tank.

8.4.2 Arrangements to Resist Panting Forward of After Peak Bulkhead

Where unsupported spans between frames are especially long (in comparison to the amidships) forward of the after-peak bulkhead, side stringers are to be provided or the scantlings of frames are to be increased in accordance with the structure abaft the collision bulkhead.

Chapter 9 BEAMS

9.1 General

9.1.1 Camber of Weather Deck

The standard camber of weather deck is $\frac{B}{50}$ *at* midship.

9.1.2 Connections of Ends of Beams

1. Longitudinal beams are to be continuous or to be connected with brackets at their ends in such a manner as to effectively uphold the sectional area and to have sufficient strength to withstand bending and tension.

2. Transverse beams are to be connected to frames by brackets.

3. Transverse beams provided at positions where frames are omitted in tween decks or superstructures are to be connected to the side plating by brackets.

4. Transverse beams on decks (boat decks, promenade decks, etc.) may be connected at their ends by clips.

9.1.3 Transition from Longitudinal Beam to Transverse Beam System

Special care is to be taken to keep the continuity of strength in parts where the longitudinal beam system changes to a transverse beam system.

9.2 Deck Load

9.2.1 Value of *h*

1. Deck load h (kN/m^2) for decks intended to carry ordinary cargoes or stores is to be in accordance with the following **(1)** through **(3)**.

(1) The standard value (kN/m^2) for h is given by taking the tween deck height (m) at side of the space or the height (m) from the deck concerned to the upper edge of the hatch coaming of the deck above as the height of the cargo and multiplying it by 7. However, h may be specified as the maximum design cargo weight per unit area of deck (kN/m^2). In this case, the value of h is to be determined by considering the height of the loaded cargo.

(2) Where timber and/or other cargoes are intended to be carried on the weather deck, h is to be the maximum design cargo weight per unit area of deck (kN/m^2), or the value specified in **-2**, whichever is greater.

(3) Where cargoes are suspended from the deck beams or deck machinery is installed, h is to be suitably increased.

2. Deck load h (kN/m^2) for the weather deck is to be as specified in the following **(1)** to **(4)**.

(1) h for the freeboard deck and the superstructure deck and the top of deckhouses on the freeboard deck is not to be less than obtained from the following formula:

$a(bf - y)$ (kN/m^2)

Where:

a and b : As given by **Table 9.1** according to the position of decks

C_{b1} : Block coefficient, however, where C_b is less than 0.6, C_{b1} is to be taken as 0.6, and where C_b is 0.8 or over, C_{b1} is to be taken as 0.8

f : As given by the following formula (*See* **Fig. 9.1**):

Where L is less than 150 m: $\frac{L}{10}e^{-\frac{L}{300}} + (L/150)^2 - 1.0$

Where L is 150 m or over, but less than 300 metres: $\frac{L}{10}e^{-\frac{L}{300}}$

Where L is 300 m or over: 11.03

y : Vertical distance (m) from the designed maximum load line to the weather deck at side y is to be measured at the fore end for the deck forward of 0.15L and abaft the fore end; at 0.15L abaft the fore end for the deck between 0.3L and 0.15L abaft the fore end; at the midship for the deck between 0.3L abaft the fore end and 0.2L afore the aft end; and at the aft end for deck aft of 0.2L afore the aft end (*See* **Fig. 9.2**).

(2) h for the deck in Line II in **Table 9.1** does not need to exceed that in Line I.

(3) h is not to be less than that obtained from the following formulae in **Table 9.2**, irrespective of the provisions in **(1)** and **(2)**.

(4) Value of h may be suitably modified where the ship has an unusually large freeboard.

3. On the first and second tiers above the freeboard deck, h is to be 12.8 for enclosures of superstructure decks and tops of deckhouses in navigation spaces.

Fig. 9.1 Value of *f*

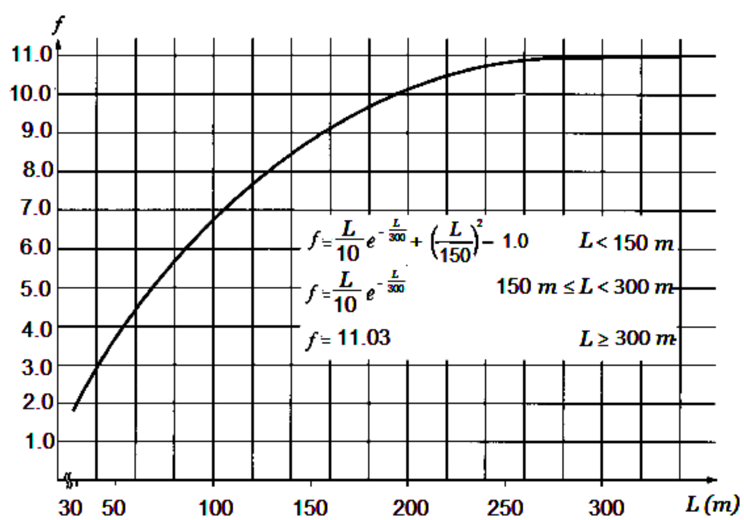


Fig. 9.2 Positions for Measuring *y*

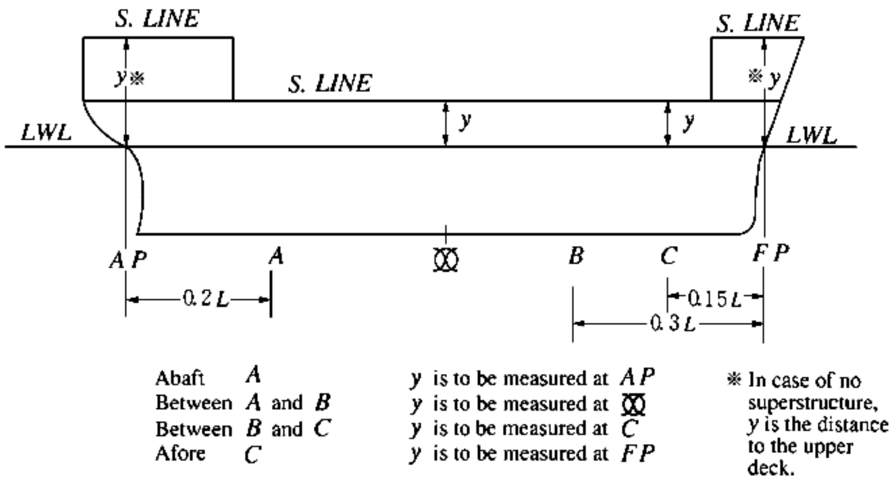


Table 9.1 Values of *a* and *b*

Line	Position of deck	*a*			*b*
		Beams,[1] Deck plating	Pillars	Beams,[1] Deck plating	
I	Forward of 0.15L abaft the fore end	14.7	4.90	7.35	$1+\frac{0.338}{(C_{b1}+0.2)^2}$
II	Between 0.15L and 0.3L abaft the fore end	11.8	3.90	5.90	$1+\frac{0.158}{(C_{b1}+0.2)^2}$
III	Between 0.3L abaft the fore end and 0.2L afore the aft end	6.90	2.25	2.25[2] 3.45[3]	1.0
IV	Afterward of 0.2L afore the aft end	9.80	3.25	4.90	$1+\frac{0.123}{(C_{b1}+0.2)^2}$

Notes:

(1) Where *L* is 150 *m* or less, value *a* may be multiplied by the value of the following formula:

$$0.55\left(\frac{L}{100}\right)+0.175$$

(2) For longitudinal deck girders outside the line of hatchway openings of the strength deck for the midship part

(3) For deck girders other than **2**

Table 9.2 Minimum Values of *h*

Line	Position of Deck	$h^{(1)}$	C	
			Beams, [2] Deck Plating	Pillars, Deck girders
I and II	Forward of 0.3L abarft the fore end	$C\sqrt{L'+50}$	4.20	1.37
III	Between 0.3L abaft the fore end and 0.2L afore the aft end		2.05	1.18
IV	Afterward of 0.2L afore the aft end	$C\sqrt{L'}$	2.95	1.47
Second tier superstructure deck above the freeboard deck			1.95	0.69

Notes:

(1) L': Length of ship (m), but need not be taken as greater than 230 m

(2) Where L is 150 m or less, value C may be multiplied by the value of following formula:

$$0.55\left(\frac{L}{100}\right) + 0.175$$

9.3 Longitudinal Beams

9.3.1 Spacing

1. The standard spacing of longitudinal beams is obtained from the following formula:

$$2L + 550 \quad (mm)$$

2. It is recommended that the spacing of longitudinal beams should not exceed 1 *metre*.

9.3.2 Proportion

1. Longitudinal beams are to be supported by deck transverses of appropriate spacing. The slenderness ratio of deck longitudinals in the strength deck of the midship Part is not to exceed 60. However, this requirement may be suitably modified where longitudinal beams are given sufficient strength to prevent buckling.

2. Flat bars used for longitudinals are not to be of a depth-thickness ratio exceeding 15.

9.3.3 Section Modulus of Longitudinal Beams

1. The section modulus of longitudinal beams outside the line of openings of the strength deck for the midship Part is not to be less than that obtained from the following formula:

$$1.14Shl^2 \quad (cm^3)$$

Where:

S : Spacing (m) of longitudinal beams

h : Deck load (kN/m^2) specified in **9.2**

l : Horizontal distance (m) between bulkhead and deck transverse or between deck transverses

2. The coefficient in the formula in **-1** may be gradually reduced for longitudinal beams outside the line of openings of the strength deck for parts forward and afterward of the midship part. However, the section modulus is not to be less than that obtained from the following formula:

$$0.43Shl^2 \ (cm^3)$$

Where

S, h and l : As specified in **-1**.

3. The section modulus of longitudinal beams for parts other than those stipulated in **-1**, and **-2** is not to be less than that obtained from the formula in **-2**.

9.3.4 Deck Transverses Supporting Longitudinal Beams

In single deck ships, the deck transverses are to be provided in line with the solid floors in the double bottom.In two deck ships, the transverses are also to be provided in line with the solid floors in the double bottom as far as is practicable.

9.4 Transverse Beams

9.4.1 Arrangement of Transverse Beams

Transverse beams are to be provided on every frame.

9.4.2 Proportion

It is preferable that the length/depth ratio of transverse beams be 30 or less at the strength deck, and 40 or less at effective decks (the decks below the strength deck which are considered as strength members in the longitudinal strength of the hull) and superstructure decks as far as practicable.

9.4.3 Section Modulus of Transverse Beams

The section modulus of transverse beams is not to be less than that obtained from the following formula:

$$0.43Shl^2 \quad (cm^3)$$

Where:

S : Spacing (m) of transverse beams

h : Deck load (kN/m^2) specified in **9.2**

l : Horizontal distance (m) from the inner edge of beam brackets to the longitudinal deck girder, or between the longitudinal deck girders

9.5 Beams on Bulkhead Recesses and Others

9.5.1 Section Modulus

The section modulus of beams at deck forming the top of bulkhead recesses, tunnels and tunnel recesses is not to be less than that obtained from the formula in **12.2.8**.

9.6 Beams on Top of Deep Tanks

9.6.1 Section Modulus

The section modulus of beams at deck forming the top of deep tanks is to be in accordance with this Chapter, and not to be less than that obtained from the formula in **13.2.3**, taking the top of deck beams as the lower end of *h* and beams as stiffeners.

9.7 Deck Beams Supporting Especially Heavy Loads

9.7.1 Reinforcement of Deck Beams

The deck beams supporting especially heavy loads or arranged at the ends of superstructures or deckhouses, in way of masts, winches, windlasses and auxiliary machinery, etc. are to be properly reinforced by increasing the scantlings of the beams, or by the addition of deck girders or pillars.

9.8 Unusually Long Machinery Openings

9.8.1 Reinforcement of Decks

For unusually long machinery openings, suitable strengthening is to be made by means of adequate cross ties provided at each level of deck or equivalent arrangement.

9.9 Deck Beams Supporting Vehicles

9.9.1 Section Modulus of Beams

The section modulus of beams of decks loaded with wheeled vehicles is to be determined by considering the concentrated loads from the wheeled vehicles.

9.9.2 Structural Details

The impact of the dynamic load caused by vehicular traffic is to be taken into account when determining the kind of stiffeners used and the fillet welding method for connecting those stiffeners to the car deck.

9.10 Deck Beams Supporting Unusual Cargoes

9.10.1 Section Modulus of Beams

The section modulus of beams of decks carrying cargo loads which cannot be treated as evenly distributed loads is to be determined by taking into account the load distribution of each particular cargo.

Chapter 10 PILLARS

10.1 General

10.1.1 Pillars in Tween Decks

Tween deck pillars are to be arranged directly above those under the deck, or effective means are to be provided for transmitting their loads to the supports below.

10.1.2 Pillars in Holds

Pillars in holds are to be provided in line with the keelsons or double bottom girders or as close thereto as practicable, and the structure above and under where the pillars are connected are to be of ample strength to provide effective distribution of the load.

10.1.3 End Connection of Pillars

The head and heel of pillars are to be secured by thick doubling plates and brackets as necessary. For pillars which may be subject to tensile loads in locations such as under bulkhead recesses, tunnel tops or deep tank tops, the head and heel of the pillars are to be efficiently secured to withstand these loads.

10.1.4 Reinforcement of Structures Connected to Pillars

Where the pillars are connected to the deck plating, the top of shaft tunnels, or the frames, these structures are to be efficiently strengthened.

10.2 Scantlings

10.2.1 Sectional Area of Pillars

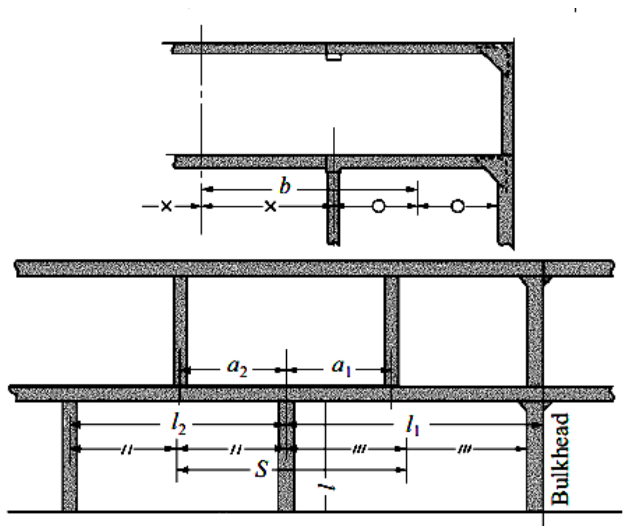
The sectional area of pillars is not to be less than that obtained from the following formula:

$$\frac{0.223w}{2.72-\frac{l}{k_0}} \quad (cm^2)$$

Where:

- l : Distance (m) from the top of inner bottom, deck or other structures on which the pillars are based to the underside of beam or girder supported by the pillars (*See* **Fig. 10.1**)
- k_0 : Minimum radius of gyration (cm) of the section of pillars
- w : Deck load (kN) supported by the pillar, as specified in **10.2.2**

Fig. 10.1 Measurement of *S*, *b*, *l*, etc.



10.2.2 Deck Load Supported by Pillars

1. Deck load *w* supported by a pillar is not to be less than that obtained from the following formula:

$Kw_0 + Sbh(kN)$

Where:

- S : Distance (*m*) between the mid-points of two adjacent spans of girders supported by the pillars or the bulkhead stiffeners or bulkhead girders (*See* **Fig. 10.1**)
- b : Mean distance (*m*) between the mid-points of two adjacent spans of beams supported by the pillars or theframes (*See* **Fig. 10.1**)
- h : Deck load (kN/m^2) specified in **10.2** for the deck supported
- w_0 : Deck load (*kN*) supported by the upper tween deck pillar
- k : As obtained from the following formula:

$$2\left(\frac{a_i}{l_j}\right)^3 - 3\left(\frac{a_i}{l_j}\right)^2 + 1$$

- a_i : Horizontal distance (*m*) from the pillars to the tween deck pillars above
- l_j : Span (*m*) of girder supporting the tween deck pillar or bulkhead (*See* **Fig. 10.1**)

2. Where there are two or more tween deck pillars provided on the deck girder supported by a line of lower pillars, the lower pillars are to be of the scantlings required in **-1**, taking kw_0 for each tween deck pillar provided on two adjacent spans supported by the lower pillars.

3. Where tween deck pillars are located athwart ships from the lower pillars, the scantlings of the lower pillars are to be determined by applying the same principles as in **-1**. and **-2**.

4. The load supported by pillars of decks carrying cargoes which can not be treated as evenly distributed loads is to be determined by taking into account the load distribution of each particular cargo. Where cargo loads can be treated as concentrated loads acting on specific points, the provisions of **-1** and **-2** above may be applied so that such concentrated loads are treated as deck loads supported by the upper tween deck pillars (w_0).

10.2.3 Thickness of Plates

1. The plate thickness of tubular pillars is not to be less than that obtained from the following formula:

$$0.022d_p + 4.6 \quad (mm)$$

Where:

d_p : Outside diameter (mm) of the tubular pillar

However, this requirement may be suitably modified for the pillars provided in accommodation spaces.

2. The thickness of web and flange plates of built-up pillars is to be sufficient for the prevention of local buckling.

10.2.4 Outside Diameter of Round Pillars

The outside diameter of solid round pillars and tubular pillars is not to be less than 50 *mm*.

10.2.5 Pillars Provided in Deep Tanks

1. Pillars provided in deep tank are not to be tubular pillars.

2. The sectional area of pillars is not to be less than that specified in **10.2.1** or obtained from the following formula, whichever is greater:

$$1.09\, Sbh \quad (cm^2)$$

Where:

S and b: As specified in **10.2.2**

h : 0.7 times the vertical distance (m) from the top of the deep tank to the point 2 *metres* above the top of the overflow pipe.

10.3 Bulkheads in Lieu of Pillars

10.3.1 Construction

The transverse bulkheads supporting longitudinal deck girders and the longitudinal bulkheads provided in lieu of pillars are to be stiffened in such a manner as to provide supports not less effective than that required for pillars.

10.4 Casings in Lieu of Pillars

10.4.1 Construction

The casings provided in lieu of pillars are to be of sufficient scantlings to withstand the deck load and side pressure.

Chapter 11 DECK GIRDERS

11.1 General

11.1.1 Application

Transverse deck girders supporting longitudinal deck beams and longitudinal deck girders supporting transverse deck beams are to be in accordance with the requirements in this Chapter.

11.1.2 Arrangement

In way of the bulkhead recesses and the top of tanks, deck girders are to be arranged at intervals not exceeding 4.6 *metres* as far as practicable.

11.1.3 Construction

1. Deck girders are to be composed of face plates provided along the lower edge.

2. Tripping brackets are to be provided at intervals of about 3 *metres* and where the breadth of face plates exceeds 180 *mm* on either side of the girder, these brackets are to be so arranged as to support the face plates as well.

3. The thickness of face plates forming girders is not to be less than that of web plates and the width of the face plates is not to be less than that obtained from the following formula:

$$85.4\sqrt{d_0 l} \quad (mm)$$

Where:

d_0 : Depth of webs (m)

l : Distance (m) between supporting points of girders

However, if effective tripping brackets are provided, they may be regarded as supporting points.

4. The depth of girders is to be more than 2.5 times that of the slots for beams, and is to be kept constant between two adjacent bulkheads for longitudinal girders.

5. The girders are to have sufficient rigidity to prevent excessive deflection of decks and excessive additional stresses in deck beams.

11.1.4 End Connection

1. End connections of deck girders are to be in accordance with the requirements in **1.1.12**.

2. Bulkhead stiffeners or girders at the ends of deck girders are to be suitably strengthened to support deck girders.

3. Longitudinal deck girders are to be continuous or to be effectively connected so as to maintain the continuity at ends.

11.2 Longitudinal Deck Girders

11.2.1 Section Modulus of Girders

1. The section modulus of longitudinal deck girders outside the lines of hatchway openings of the strength deck for the midship part is not to be less than that obtained from the following formula:

$$1.29l(lbh + kw) \quad (cm^3)$$

Where:

l: Distance (*m*) between the centres of pillars or from the centre of the pillar to the bulkhead

Where deck girders are fixed to the bulkhead by effective brackets, *l* may be modified as specified in **1.1.14** (*See* **Fig. 11.1**).

b : Distance (*m*) between the centres of two adjacent spans of beams supported by girders or frames (*See* **Fig. 11.1**)

h : Deck load (kN/m^2) specified in **10.2** for the deck supported

w : Deck load (*kN*) supported by the tween deck pillar as specified in **10.2.2**

k : As specified in the following **(1)** and **(2)**:

(1) Coefficient obtained from the following formula according to the ratio of the horizontal distance (*m*) from the pillar or bulkhead supporting the deck girder to the tween deck pillar *a* and *l* (*See* **Fig. 11.1**).

$$12\frac{a}{l}\left(1-\frac{a}{l}\right)^2$$

(2) Where there is only one tween deck pillar, *k* is to be obtained by measuring *a* from the closest pillar or bulkhead. Where there are two or more tween deck pillars, *a* is to be measured from the same end of *l* for each tween deck pillar, and the sum of *kw* is to be used for the calculation of the formula. In this case, the greater value of *kw* is to be used.

2. The coefficient in the formula in **-1** may be gradually reduced for longitudinal deck girders outside the line of openings of the strength deck for the parts forward and afterward of the midship part. However, the section modulus is not to be less than that obtained from the following formula under any circumstances:

$$0.484l\,(lbh + kw) \quad (cm^3)$$

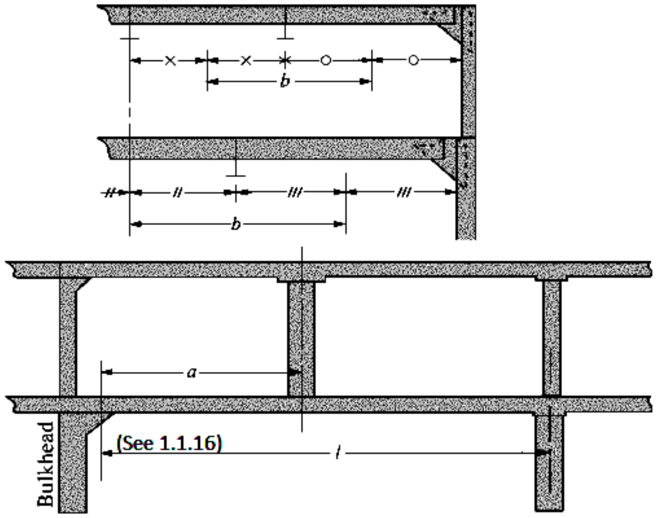
Where:

l, *b*, *h*, *w* and *k* : As specified in **-1**

3. The section modulus of longitudinal deck girders for parts other than that stipulated in **-1** and **-2** is not to be less than that obtained from the formula in **-2**.

4. The section modulus of longitudinal deck girders of decks carrying cargoes which can not be treated as evenly distributed loads is to be determined by taking into account the load distribution of each particular cargo. Where cargo loads can be treated as concentrated loads acting on specific points, the provisions of **-1** to **-3** above may be applied so that such concentrated loads are treated as deck loads supported by the upper tween deck pillars (*w*).

Fig. 11.1 Measurement of *l*, *b*, and *a*



11.2.2 Moment of Inertia of Girders

It is advised that the moment of inertia of girders is not to be less than that obtained from the following formula:

$$CZl \quad (cm^4)$$

Where:

C : Coefficient obtained from the following formulae:

For deck girders arranged outside the line of deck openings of strength deck of midship part: 1.6

For other deck girders: 4.2

Z : Required section modulus (cm^3) of girders specified in **11.2.1**

l : As specified in **11.2.1-1**

11.2.3 Thickness of Web Plates

1. The thickness of web plates is not to be less than that obtained from the following formula:

$$10S_1 + 2.5 \quad (mm)$$

Where:

S_1 : Spacing (m) of web stiffeners or depth of girders, whichever is smaller

2. The thickness of web plates at both end parts for 0.2 l is not to be less than that specified in **-1** and obtained from the following formula, whichever is greater:

$$\frac{4.43}{1000}\frac{bhl}{d_0} + 2.5 \quad (mm)$$

Where:

d_0 : Depth of webs (m)

b, h and l : As specified in **11.2.1-1**

3. The thickness of web plates provided in the deep tanks is to be 1 *mm* thicker than that those obtained from the Formulae in **-1** and **-2**.

11.3 Transverse Deck Girders

11.3.1 Section Modulus of Girders

1. The section modulus of transverse deck girders is not to be less than that obtained from the following formula:

$$0.484l(lbh + kw)\ \ (cm^3)$$

Where:

l : Distance (*m*) between the centres of pillars or from the centre of the pillar to the inner edge of the beam bracket

b : Distance (*m*) between the centres of two adjacent girders or from the centre of the girder to the bulkhead

h : As specified in **11.2.1**

w and k : In accordance with **11.2.1**

2. The section modulus of transverse deck girders of decks carrying cargoes which can not be treated as evenly distributed loads is to be determined by taking into account the load distribution of each particular cargo. Where cargo loads can be treated as concentrated loads acting on specific points, the provisions of **-1** above may be applied so that such concentrated loads are treated as deck loads supported by the upper tween deck pillars (w).

11.3.2 Moment of Inertia of Girders

It is advised that the moment of inertia of girders is not to be less than that obtained from the following formula:

$$4.2Zl \quad (cm^4)$$

Where:

Z : Required section modulus (cm^3) of girders specified in **11.3.1**

l : As specified in **11.3.1**

11.3.3 Thickness of Web Plates

The thickness of web plates is to be in accordance with the requirements in **11.2.3**.

11.4 Deck Girders in Tanks

11.4.1 Section Modulus of Girders

The section modulus of deck girders in tanks is to be in accordance with the requirements in **12.2.1** or **12.3.1**, and the requirements in **13.2.5-1**.

11.4.2 Moment of Inertia of Girders

The moment of inertia of girders is to be in accordance with the requirements in **13.2.5-2**.

11.4.3 Thickness of Web Plates

The thickness of web plates is to be in accordance with the requirements in 11.2.3 or 11.3.3, and the requirements in 13.2.5-3.

11.5 Hatch Side Girders

11.5.1 Girders having Deep Coamings on Decks

Where deep coamings are provided on decks as in the case of hatchways on weather decks, the horizontal coaming stiffener and the coaming up to its stiffener may be included in the calculation of the section modulus, subject to the approval by the Society.

11.5.2 Strength Continuity at Hatchway Corners

At hatchway corners, the face plates of hatch coamings and longitudinal deck girders or their extensions and the face plates on both sides of hatch end girders are to be effectively connected so as to maintain strength continuity.

11.6 Hatch End Beams

11.6.1 Scantlings of Hatch End Beams

The scantlings of hatch end beams are to be in accordance with the requirements in 11.3, 11.4 and 11.5.

11.7 Movable Car Deck Girders

11.7.1 General

Deck girders of movable car decks and girders of similar thin plate construction are to be in accordance with the requirements in this section in addition to 11.1.3.

11.7.2 Strength Requirement

1. The scantlings of movable car deck girders are to be determined in accordance with the following requirements in **-2** through **-4**.

2. The effective width of compressive plate flange for each girder is to be determined by the following **(1)** and **(2)** corresponding to the stiffening direction of the panel.

(1) Effective width for girders parallel to the stiffening direction:

The value specified in 1.1.11-3

(2) Effective width (b_{eft}) for girders crossing at right angles with the stiffening direction:

$$b_{eft} = \sum_{n} \left(\frac{C_{et} \cdot a}{2} \right) \qquad (mm)$$

Where buckling stiffeners for deck plates are fitted properly, these may be taken into account for the determination of effective width. However, it is not to exceed the value specified in **1.1.11-3**.

C_{et} : Coefficient as given by the following formula

However, where C_{et} exceeds 1.0, C_{et} is to be taken as 1.0.

$$C_{et} = \left(\frac{3}{\beta} - \frac{1.75}{\beta^2} \right) \frac{b}{a} + \left(\frac{0.075}{\beta} + \frac{0.75}{\beta^2} \right) \left(1 - \frac{b}{a} \right)$$

n : 1 for girders located on the periphery of the car deck, and 2 for the others

a : Spacing (*mm*) of girders crossing at right angles with the stiffening direction

b : Spacing (*mm*) of stiffeners

β : Coefficient as given by the following formula:

$$\beta = \frac{b}{t} \sqrt{\frac{\sigma_F}{E}}$$

t : Thickness (*mm*) of car deck plating

σ_F: Minimum upper yield stress or proof stress (N/mm^2) of the car deck material

E : Modulus of elasticity (N/mm^2) of the material to be assumed equal to 2.06×10^5 for steel

3. Design load and allowable stresses are to be in accordance with the requirements of the following **(1)** and **(2)**.

(1) Design load *P* (kN/m^2)

(a) For loaded condition with vehicles on car decks

$$P = 1.5(p + w_{deck})$$

p : Design load (kN/m^2) on car deck

w_{deck}: Tare of car deck per unit area (kN/m^2)

(b) For vehicles used for cargo handling only (fork-lifts or similar vehicles used for handling cargo in ports only).

$$P = 1.5(p + w_{deck})$$

p and w_{deck} : As specified in **(a)** above

(2) Allowable stresses (N/mm^2)

As specified in **Table 11.1**.

4. Where the scantlings of girders are determined based upon direct calculations, the method of assessments are to be a grillage model analysis or that as deemed appropriate by the Society.

Table 11.1 Allowable Value

Normal Stresses	$0.80\sigma_F$
Shear Stresses	$0.46\sigma_F$

Note

σ_F : Minimum upper yield stress or proof stress (N/mm^2) of the material

11.7.3 Structural Details

1. The connection of girder webs to the car deck is to use the fillet welding method in accordance with **Table 11.2**.

2. The thickness of web plates is not to be less than that obtained by the following formula, except where an analysis of the buckling strength of the web plate has been conducted.

$$\frac{d}{c} + 1.0 \quad (mm)$$

d : Depth of girders (mm)

C : Coefficient as given by the following:

65 for symmetrically flanged girders

55 for asymmetrically flanged girders

Table 11.2 Fillet Weld of Girder to Movable Car Deck (*4)

<table>
<tr><th></th><th>Panels on which vehicular traffic is frequent(*1)</th><th>Panels other than those specified in the left column</th></tr>
<tr><td>(1) Girders on the deck panel periphery</td><td rowspan="5">$F2$ (Both sides)</td><td rowspan="4">$F2$ (Both sides)</td></tr>
<tr><td>(2) Within 0.3l midspan of girders other than mentioned in (1)(*2)</td></tr>
<tr><td>(3) Within 0.1l end parts of girders other than mentioned in (1)(*2)</td></tr>
<tr><td>(4) Within 0.2l' of intersections of girders other than mentioned in (1)(*3)</td></tr>
<tr><td>(5) Other areas than those mentioned above</td><td>$F2$ (One side), at least</td></tr>
</table>

Notes:

(*1) Deck panels which are subject to the dynamic load in the vicinity of the ramp way and is on the route taken by vehicles when moving between decks

(*2) l is the total length of each girder

(*3) l' is the span of each girder, and 0.1l' on either side of the intersection of girders is to be welded

(*4) "$F2$" in this table is as specified in **Table 1.4**

Chapter 12 WATERTIGHT BULKHEADS

12.1 Arrangement of Watertight Bulkheads

12.1.1 Collision Bulkheads

1. All ships are to have a collision bulkhead, at a position not less than $0.05L_f$ or 10 *m*, whichever is less, from the forward terminal of the length for freeboard, but not more than $0.08L_f$ or $0.05L_f + 3.0$ (*m*), whichever is greater, unless for special structural reasons which are approved by the Society. However, where any part of the ship below the waterline at 85% of the least moulded depth extends forward beyond the forward terminal of the length for freeboard, the above mentioned distance is to be measured from the point that gives the smallest measurement from the following.

(a) The mid-length of such an extension

(b) A distance $0.015L_f$ forward from the above-mentioned forward terminal

(c) A distance 3 *m* forward from the forward terminal

2. The bulkhead may have steps or recesses within the limits specified in **-1** above.

3. Any access openings, doors, manholes or ducts for ventilation, etc. are not to be cut in to the collision bulkhead below the bulkhead deck. Where a collision bulkhead extends up to a deck above the freeboard deck in accordance with the requirements of **12.1.5(2)**, the number of openings in the extension of the collision bulkhead is to be kept to a necessary minimum and all such openings are to be provided with weathertight means of closing.

4. The arrangement of the collision bulkhead in a ship provided with bow doors is to be at the discretion of the Society. However, where a sloping ramp forms a part of the collision bulkhead above the bulkhead, the part of the ramp which is more than 2.3 *m* above the bulkhead deck may extend forward of the limit specified in **-1** above. In this case, the ramp is to be weathertight over its complete length. However, ramps not meeting the above requirement are to be disregarded as an extension of the collision bulkhead.

12.1.2 After Peak Bulkheads

1. All ships are to have an after peak bulkhead situated at a suitable position.

2. The stern tube is to be enclosed in a watertight compartment by the after peak bulkhead or other suitable arrangements.

12.1.3 Machinery Space Bulkheads

A watertight bulkhead is to be provided at each end of the machinery space.

12.1.4 Hold Bulkheads

1. Cargo ships of an ordinary type are to have hold bulkheads in addition to the bulkheads specified in **12.1.1** to **12.1.3** at reasonable intervals so that the total number of watertight bulkheads may not be less than that given by **Table 12.1**.

2. Where it is impracticable to adhere to the number of hold bulkheads required above due to the requirements for the ship's trade, an alternative arrangement may be accepted subject to the approval by the Society.

Table 12.1 Number of Watertight Bulkheads

$L(m)$		Total number of bulkheads
And above	under	
90	102	5
102	123	6
123	143	7
143	165	8
165	186	9
186		As determined by the Society in each case

12.1.5 Height of Watertight Bulkheads

The watertight bulkheads required in 12.1.1 to 12.1.4 are to extend to the freeboard deck with the followingexceptions.

(1) A watertight bulkhead in way of the raised quarter or the sunken forecastle deck is to extend up to the said deck.

(2) Where a forward superstructure having openings without closing appliances leads to a space below the freeboard deck, or a long forward superstructure is provided, the collision bulkhead is to extend up to the superstructure deck and to be made weathertight. However, where the extension is located within the limits specified in 12.1.1 and the part of the deck which forms the step is made effectively weathertight, it need not be fitted directly above the collision bulkhead.

(3) The aft peak bulkhead may terminate at a deck above the designed maximum load line provided that this deck is made watertight to the stern of the ship.

12.1.6 Transverse Strength of Hull

1. Where the watertight bulkheads required in 12.1.1 to 12.1.5 are not extended up to the strength deck, deep webs or partial bulkheads situated immediately or nearly above the main watertight bulkheads are to be provided so as to maintain the transverse strength and stiffness of the hull.

2. Where the length of a hold exceeds 30 *metres*, suitable means are to be provided so as to maintain the transverse strength and stiffness of the hull

12.2 Construction of Watertight Bulkheads

12.2.1 Thickness of Bulkhead Plates

The thickness of bulkhead plates is not to be less than that obtained from the following formula:

$3.2\,S\sqrt{h}+2.5 \quad (mm)$

Where:

S : Spacing (m) of stiffeners

h : Vertical distance (m) measured from the lower edge of the bulkhead plate to the bulkhead deck at the centre line of ship It is not to be less than 3.4 *metres*.

12.2.2 Increase in Thickness of Plates of Special Parts

1. The thickness of the lowest strake of bulkhead plating is to be at least 1 *mm* thicker than that obtained from the formula in **12.2.1**

2. The lowest strake of bulkhead plating is to extend at least 610 *mm* above the top of the inner bottom plating in way of double bottom or 915 *mm* above the top of keel in way of single bottom. Where the double bottom is provided only on one side of the bulkhead, the extension of the lowest strake is to be up to the higher of the two heights given in the preceding sentence.

3. The bulkhead plating in the limber is to be at least 2.5 *mm* thicker than that given in **12.2.1**.

4. The bulkhead plating is to be doubled or increased in thickness in way of the stern tube opening or propelling shaft opening, notwithstanding the requirements in **12.2.1**.

12.2.3 Stiffeners

The section modulus of bulkhead stiffeners is not to be less than that obtained from the following formula:

$2.8CShl^2 \quad (cm^3)$

Where:

l : Span (m) measured between the adjacent supports of stiffeners including the length of connection Where girders are provided, l is the distance from the heel of the end connection to the first girder or the distance between the girders.

S : Breadth (m) of the area supported by the stiffener

h : Vertical distance (m) measured from the mid-point of l for vertical stiffeners, and from the mid-point of S for horizontal stiffeners, to the top of the bulkhead deck at the centre line of the ship
Where the vertical distance is less than 6.0 *metres*, h is to be taken as 1.2 *metres* greater than 0.8 times the vertical distance.

C : Coefficient given in **Table 12.2**, according to the type of end connections.

Table 12.2 Value of *C*

<table>
<tr><td colspan="5">Vertical Stiffener</td></tr>
<tr><td rowspan="3">Lower end</td><td colspan="4">Upper end</td></tr>
<tr><td rowspan="2">Lug-connection or supported by horizontal girders</td><td colspan="2">Connection</td><td rowspan="2">End of stiffener unattached</td></tr>
<tr><td>Type A</td><td>Type B</td></tr>
<tr><td>Lug-connection or supported by horizontal girders</td><td>1.0</td><td>1.00</td><td>1.15</td><td>1.35</td></tr>
<tr><td>Connected by brackets</td><td>0.80</td><td>0.80</td><td>0.90</td><td>1.0</td></tr>
<tr><td>Only the web os stiffener attached at end</td><td>1.15</td><td>1.15</td><td>1.35</td><td>1.60</td></tr>
<tr><td>End of stiffener unattached</td><td>1.35</td><td>1.35</td><td>1.60</td><td>2.00</td></tr>
<tr><td colspan="5">Horizontal Stiffener</td></tr>
<tr><td rowspan="2">The other end</td><td colspan="4">One end</td></tr>
<tr><td colspan="2">Lug-connection, connected by brackets or supported by vertical girders</td><td colspan="2">End of stiffener unattached</td></tr>
<tr><td>Lug-connection, connected by brackets or supported by vertical girders</td><td colspan="2">1.00</td><td colspan="2">1.35</td></tr>
<tr><td>End of stiffener unattached</td><td colspan="2">1.35</td><td colspan="2">2.00</td></tr>
</table>

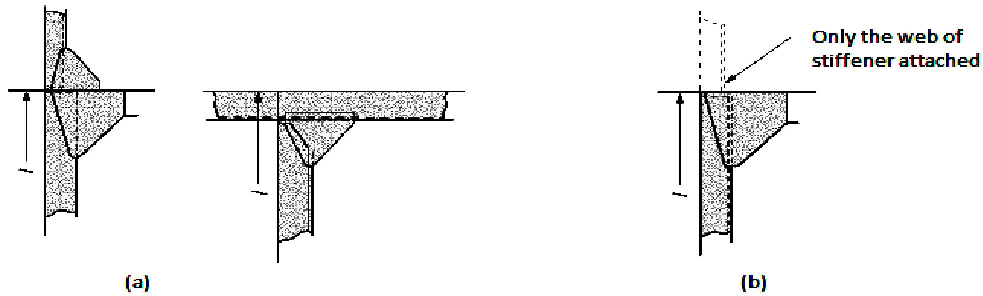
Notes:

1 “Lug-connection” is a connection where both webs and face plates of stiffeners are effectively attached to the bulkhead plating, decks or inner bottoms and which are strengthened by effective supporting members on the opposite side of the plating.

2 Connection Type “A” of vertical stiffeners is a connection by bracket to the longitudinal members or to the adjacent members, in line with the stiffeners, of the same or larger sections. (*See* **Fig. 12.1** (a))

3 Connection Type “B” of vertical stiffeners is a connection by bracket to the transverse members such as beams, or other connections equivalent to the connection mentioned above. (*See* **Fig. 12.1** (b)

Fig. 12.1 Types of End Connections



12.2.4 Corrugated Bulkheads

1. The plate thickness of corrugated bulkheads is not to be less than that obtained from the following formula:

$$3.4CS_1\sqrt{h}+2.5 \quad (mm)$$

Where:

h : As specified in **12.2.1**

S_1 : Breadth (m) of face part or web part indicated as a or b, respectively, in **Fig. 12.2**

C : Coefficient given below:

Face part:

$$\frac{1.5}{\sqrt{1+\left(\frac{t_w}{t_f}\right)^2}}$$

Web part: 1.0

t_f and t_w : Thickness (mm) of plates of face Part and web part, respectively

2. The section modulus per half pitch of corrugated bulkheads is not to be less than that obtained from the following formula:

$$3.6\,CShl^2 \quad (cm^3)$$

Where:

S : Half pitch length (m) of the corrugation (*See* **Fig. 12.2**)

h : As specified in **12.2.3**

l : Length (m) between the supports, as indicated in **Fig. 12.3**

C : Coefficient given in **Table 12.3**, according to the type of end connection

Fig. 12.2 Measurement of *S*

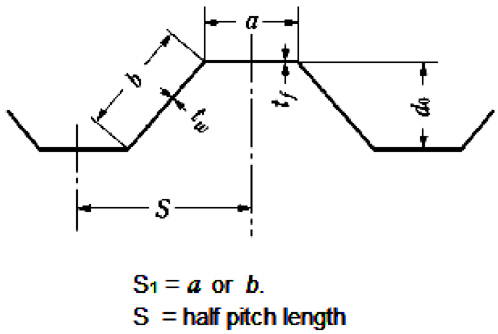


Fig. 12.3 Measurement of *l*

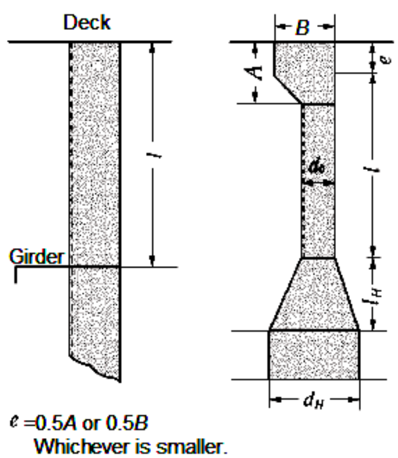


Table 12.3 Values of *C* (for corrugated bulkheads)

The other end of Bulkhead	One end of Bulkhead		
	Supported by horizontal or vertical girders	Upper end welded directly to deck	Upper end welded to stool efficiently supported by ship structure
Supported by horizontal or vertical girders or lower end of bulkhead welded directly to decks or inner bottoms	$\dfrac{4}{2+\dfrac{Z_1}{Z_0}+\dfrac{Z_2}{Z_0}}$	$\dfrac{4}{2.2+\dfrac{Z_2}{Z_0}}$	$\dfrac{4}{2.6+\dfrac{Z_2}{Z_0}}$
Lower end of bulkhead welded to stool efficiently supported by ship structure	$\dfrac{4.8\left(1+\dfrac{l_H}{l}\right)^2}{2+\dfrac{Z_1}{Z_0}+\dfrac{d_H}{d_0}}$	$\dfrac{4.8\left(1+\dfrac{l_H}{l}\right)^2}{2.2+\dfrac{d_H}{d_0}}$	$\dfrac{4.8\left(1+\dfrac{l_H}{l}\right)^2}{2.6+\dfrac{d_H}{d_0}}$
	The value of C is not to be less than that obtained from (1)		

Notes:

Z_0 : Minimum section modulus (cm^3) per half pitch of mid part for 0.6l of the corrugated bulkhead

Z_1 and Z_2 : Section modulus (cm^3) per half pitch of end part

For vertical corrugation, Z_1 is the section modulus of the upper end Part and Z_2 is that of the lower end part. Where the plate thickness is increased in accordance with 12.2.4-5 the section modulus is to be that for the plate thickness reduced by the increment.

l_H : Height (m) of stool measured from inner bottom plating

d_H : Breadth (m) of stool measured on inner bottom plating

d_0 : Depth (m) of corrugation

3. Where the end connection of corrugated bulkheads is remarkably effective, the value of C specified in **-2** may be adequately reduced.

4. The thickness of plates at end parts for 0.2l in line with l is not to be less than that obtained from the following formulae respectively:

Web part:

$$0.0417\frac{CShl}{d_0}+2.5 \quad (mm)$$

The web thickness is not to be less than that obtained from the following formula:

$$1.74\sqrt[3]{\frac{CShlb^2}{d_0}}+2.5 \quad (mm)$$

Face part, except the upper end part of vertically corrugated bulkheads:

$$12a+2.5\ (mm)$$

Where:

S, h, l and d_0 : As specified in **-2**.

a and b : Breadth (m) of face Part and web part, respectively

C : Coefficient given in **Table 12.4**

Where the vertically corrugated bulkheads are constructed with a single span, the value of C may be taken as the value for the uppermost span in the Table.

Table 12.4 Value of *C*

Position		Upper end	Lower end
Vertically corrugated bulkhead	Uppermost span	0.4	1.6
	Other spans	0.9	1.1
Both ends of horizontally corrugated bulkhead		1.0	

5. The thickness of the plates specified in **-1** and **-4** is to be in accordance with **12.2.2**.

6. The actual section modulus per half pitch of corrugated bulkheads is to be calculated by the following formula:

$$\frac{at_f d_0}{0.002}+\frac{bt_w d_0}{0.006}(cm^3)$$

Where:

a and b : Breadth (m) of face part and web part respectively

t_f and t_w : Thickness (mm) of plates of face part and web part respectively

d_0 : Depth (m) of corrugation

12.2.5 Collision Bulkheads

For collision bulkheads, the plate thickness and section modulus of stiffeners are not to be less than that those specified in **12.2.1** and **12.2.3** or **12.2.4** taking h as 1.25 *times* the specified height.

12.2.6 Girders Supporting Bulkhead Stiffeners

1. The section modulus of girders is not to be less than that obtained from the following formula:

$$4.75Shl^2 \text{ (cm}^3\text{)}$$

Where:

S : Breadth (m) of the area supported by the girder

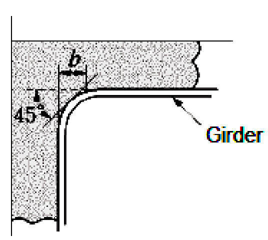
h : Vertical distance (m) measured from the mid-point of l for vertical girders, and from the mid-point of S for horizontal girders, to the top of the bulkhead deck at the centre line of the ship

Where the vertical distance is less than 6.0 *metres*, h is to be taken as 1.2 *metres* greater than 0.8 *times* the vertical distance.

l : Span (m) measured between the adjacent supports of girders

l may be modified in accordance with **1.1.14**. Where brackets with curved free edges are attached, the effective arm length of the brackets is to be taken as b indicated in **Fig. 12.4**.

Fig. 12.4 Measurement of *b*



2. The moment of inertia of girders is not to be less than that obtained from the following formula. The depth of girders is not to be less than 2.5 *times* the depth of slots for stiffeners.

$10hl^4 (cm^4)$

Where:

h and *l* : As specified in **-1**

3. The thickness of web plates is not to be less than that obtained from the following formula:

$10S_1 + 2.5\ (mm)$

Where:

S_1 : Spacing (m) of web stiffeners or depth of girders, whichever is smaller

4. The thickness of web plates at both end parts for $0.2l$ is not to be less than that obtained from the following formulae, whichever is greater:

$$0.0417 \frac{CShl}{d_0} + 2.5 \quad (mm)$$

$$1.74 \sqrt[3]{\frac{CShl_1^2}{d_0}} + 2.5 \quad (mm)$$

Where:

S, *h* and *l* : As specified in **-1**

d: Depth (m) of girders

S_1: As specified in **-3**

C: As specified in **12.2.4-4**

5. Tripping brackets are to be provided at intervals of about 3 *metres* and where the breadth of face plates exceeds 180 *mm* on either side of the girder, these brackets are to be so arranged as to support the face plates.

6. The actual section modulus and moment of inertia of girders are to be calculated in accordance with **1.1.11-3**.

Where stiffeners are provided within the effective breadth, they may be included in the calculation.

12.2.7 Strengthening of Bulkhead Plating, Deck Plating, and Other Plating

Plating of bulkheads, decks, inner bottoms, etc. are to be, if necessary, strengthened at the location of the end brackets of stiffeners and the end of girders.

12.2.8 Bulkhead Recesses

1. In way of bulkhead recesses, beams are to be provided at every frame and under the upper bulkhead in accordance with the requirements in **9.4.3** and **12.2.3** taking the beam spacing as the stiffener spacing. Where the lower end of the upper bulkhead is especially strengthened, the beam under the upper bulkhead may be dispensed with.

2. The thickness of deck plating forming the top of bulkhead recesses is to be at least 1 *mm* greater than that given by **12.2.1**, regarding the deck plating as bulkhead plating and the beams as stiffeners. However, the thickness is not to be less than that required for deck plating in that location.

3. The thickness of pillars supporting bulkhead recesses are to be determined taking into account the water pressure that might be applied on the upper surface of the recesses, and their end connections are to be sufficiently strong enough to withstand the water pressure which might be applied on the under surface.

12.2.9 Construction of Bulkheads in Way of Watertight Doors

Where stiffeners are cut or the spacing of stiffeners is increased in order to provide the watertight door in the bulkhead, the opening is to be suitably framed and strengthened as to maintain the full strength of the bulkhead. The door frames are not to be considered as stiffeners.

12.3 Watertight Doors

12.3.1 General

1. All openings in the watertight bulkheads and the part of the deck which forms the step of the bulkheads are to be closed by watertight closing appliances (referred to as “watertight doors” in this chapter) in accordance with the requirements in **12.3.2** to **12.3.5**.

2. Watertight doors as specified in **-1** above are to be normally closed at sea, except where deemed necessary for the ship’s operation by the Society. Watertight doors or ramps fitted to internally subdivided cargo spaces are to be permanently closed at sea.

12.3.2 Types of Watertight Doors

1. Watertight doors are to be of a sliding type.

2. Notwithstanding the provisions in **-1** above, watertight doors provided at small access openings, which are approved by the Society, may be of a hinged type or rolling type, except where the doors are required to be capable of being operated remotely by the provisions of **12.3.4-2**.

3. Notwithstanding the provisions in **-1** above, watertight doors or ramps fitted to internally subdivided cargo spaces may be of a type other than the sliding type.

4. Doors which are closed by dropping or by the action of a dropping weight are not permitted.

12.3.3 Strength and Watertightness

1. Watertight doors are to be of ample strength and watertightness for water pressure to a head up to the bulkhead deck, and door frames are to be effectively secured to the bulkheads. Where deemed necessary by the Society, watertight doors are to be tested by water pressure before they are fitted.

2. Where watertight doors are provided in cargo spaces, such doors are to be protected by suitable means against damage from items such as cargoes.

12.3.4 Control

1. All watertight doors, except those which are to be permanently closed at sea, are to be capable of being opened and closed by hand locally, from both sides of the doors, with the ship listed 30 *degrees* to either side.

2. In addition to the requirements of **-1** above, watertight doors which are used at sea or normally open at sea are to be capable of being remotely closed by power from the navigation bridge.

3. Watertight doors are not to be able to be opened remotely. In addition, watertight doors complying with the provisions of **12.3.2-3** are not to be remotely controlled.

12.3.5 Indication

1. Watertight doors, except those permanently closed at sea, are to be provided with position indicators showing whether the doors are open or closed on the bridge and at all operating positions.

2. For watertight doors which are to be capable of being remotely closed, an indication is to be placed locally showing that the door is in remote control mode.

12.3.6 Alarms

Watertight doors which are capable of being remotely closed are to be provided with an audible alarm which will sound at the door position whenever such a door is remotely closed.

12.3.7 Source of Power

1. The remote controls, indications and alarms required in **12.3.4** to **12.3.6** are to be operable in the event of main power failure.

2. Electrical installations for devices specified in **-1** except those of a water-proof type approved by the Society are not to be under the freeboard deck.

3. Cables for devices specified in **-1** are to comply with the requirements of **2.9.11, Part 8** of the Rules.

12.3.8 Notices

1. Watertight doors which are to be normally closed at sea but not provided with a means of remote closure are to have notices fixed to both sides of the doors stating “To be kept closed at sea”.

2. Watertight doors which are to be permanently closed at sea are to have notices fixed to both sides stating not to be opened at sea. Such doors which are accessible during the voyage are to be fitted with a device which prevents unauthorized opening.

12.3.9 Sliding Doors

1. Where a sliding watertight door is operated by rods, the lead of the operating rods is to be as direct as possible and the screw is to work in a nut of brass or other approved materials.

2. The frames of vertically sliding watertight doors are not to have a groove at the bottom in which dirt might lodge and prevent the door from closing.

12.3.10 Hinged Doors and Rolling Doors

1. For hinged and rolling watertight doors, the hinge pins and the wheel axle of these doors are to be of brass or other approved materials.
2. Hinged and rolling watertight doors except those that are to be permanently closed at sea are to be of quick acting or single action type which is capable of being closed and secured from both sides of the doors.

12.4 Other Watertight Construction

12.4.1 Maintaining the Watertightness of Trunks

For the application of this chapter, trunks required to maintain watertightness are to be capable of withstanding internal or external pressure under the most severe conditions at the intermediate or final stages of flooding.

Chapter 13 DEEP TANKS

13.1 General

13.1.1 Definition

The deep tank is a tank used for the carriage of water, fuel oil and other liquids, forming a part of the hull in holds or tween decks. Deep tanks used for the carriage of oils that need to be especially specified are designated as “deep oil tanks”.

13.1.2 Application

1. Watertight divisions (other than those specified in **13.1.3-4**), peak tank bulkheads, and boundary bulkheads of deep tanks (excluding the deep tanks for the carriage of oils having a flashpoint below 60°*C*) are to be constructed in accordance with the requirements in this Chapter. Where the bulkhead of a deep tank partly serves as a watertight bulkhead that part of the bulkhead is to be in accordance with the requirements in **Chapter 12**.

2. The bulkheads of deep tanks carrying oils with a flashpoint below 60°*C* are to comply with the requirements in **Chapter 26**, in addition to those in this Chapter.

3. When the relevant provisions in this section are applied to the cargo tanks of the ships carrying liquefied gases or dangerous chemicals in bulk, the cargo tanks are to have strength equivalent to that prescribed in this section taking into account the properties of cargoes and the construction materials.

13.1.3 Divisions in Tanks

1. Deep tanks are to be of a proper size and to be provided with such longitudinal watertight divisions as necessary to meet the requirements for stability in service conditions as well as while the tanks are being filled or discharged.

2. Tanks for fresh water or fuel oil or those which are not intended to be kept entirely filled in service conditions are to have additional divisions or deep wash plates as necessary, to minimize the dynamic forces acting on the structure.

3. Where it is impracticable to comply with the requirements in **-2**, the scantlings required in this Chapter are to be properly increased.

4. Longitudinal watertight divisions which will be subjected to pressure from both sides in tanks which are to be entirely filled or emptied in service conditions may be of the scantlings required for ordinary watertight bulkheads as stipulated in **Chapter 12**. In such cases, the tanks are to be provided with fittings such as deep hatches and inspection plugs in order to ensure that the tanks are kept full in service conditions..

13.1.4 Minimum Thickness

In wing tanks and hold tanks of which the length or breadth exceeds $0.1L + 5.0$ (m) and in topside tanks and hopper tanks, the thickness of girders, struts and their end brackets and bulkhead plates is not to be less than that given by **Table 13.1** in accordance with the length of ship.

Table 13.1 Minimum Thickness

L (m)	and above	90	105	120	135	150	165	180	195	225	275
	Under	105	120	135	150	165	180	195	225	275	
Thickness (mm)		8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5

13.1.5 Additional Strengthening of Bulkhead in Large Tanks

For large tank boundaries, the scantlings of bulkhead plates, stiffeners, girders and cross ties are not to be less than that obtained from the relevant formulae in **13.2.2**, **13.2.3**, **13.2.4**, **13.2.5** and **13.2.6**, where the value of h is the one specified in each requirement or that given by the following formula, whichever is greater.

$$0.85(h+\Delta h)(m)$$

Where

h : As specified in each requirement of **13.2.2**(1) or of **13.2.3**(1)

Δh : Additional water head given by the following formula:

$$\frac{16}{L}(l_t-10)+0.25(b_t-10)(m)$$

l_t: Tank length (m)

Not to be less than 10 m.

b_t : Tank breadth (m)

Not to be less than 10 m, but may be $\frac{2}{3}B$ for ballast holds of bulk carrier with top side tanks.

13.2 Deep Tank Bulkheads

13.2.1 Application

The construction of bulkheads and decks forming boundaries of deep tanks is to be in accordance with the requirements in **Chapter 12**, unless otherwise specified in this Chapter.

13.2.2 Bulkhead Plates

The thickness of deep tank bulkhead plating is not to be less than that obtained from the following formula:

$$3.6S\sqrt{h}+3.5\ (mm)$$

Where:

S : Spacing of stiffeners (m)

h : Greater of the distances given below:

(1) Vertical distance (m) measured from the lower edge of plate to the midpoint of the distance between the top of tanks and the top of overflow pipes

(2) 0.7 times the vertical distance (m) measured from the lower edge of the plate to the point 2.0 m above the top of the overflow pipes

13.2.3 Bulkhead Stiffeners

The section modulus of bulkhead stiffeners is not to be less than that obtained from the following formula:

$7CShl^2$ (cm^3)

Where:

S and l : As specified in 12.2.3

h : Greater of the vertical distances given below, with the lower end being regarded as the mid-point of l for vertical stiffeners and as S for horizontal stiffeners

(1) Vertical distance (m) measured from the lower end to the midpoint of the distance between the top of the tanks and the top of the overflow pipes

(2) 0.7 times the vertical distance (m) measured from the lower end to the point 2.0 m above the top of the overflow pipes.

C : Coefficient given in Table 13.2, according to the type of end connections

Table 13.2 Values of *C*

The other end of stiffeners		One end of stiffeners			
		Lug-connection or supported by girders	Connection		End of stiffener unattached
			Type A	Type B	
Lug-connection or supported by girders		1.00	0.85	1.30	1.50
Connected	Type A	0.85	0.70	1.15	1.30
	Type B	1.30	1.15	0.85	1.15
End of stiffener unattached		1.50	1.30	1.15	1.50

Notes:

1 "Connection Type A" is a connection by bracket of the stiffener to the double bottom or to a stiffener of equivalent strength attached to the face plates of adjacent members, or a connection of equivalent strength. (See Fig. 12.1 (a))

2 "Connection Type B" is a connection by bracket of the stiffener to transverse members such as beams, frames or the equivalent thereto. (See Fig. 12.1 (b))

13.2.4 Corrugated Bulkheads

1. The thickness of plates of corrugated bulkheads is not to be less than that obtained from the following formula:

$$3.6CS_1\sqrt{h}+3.5(mm)$$

Where:

S_1 : As specified in **12.2.4-1**

h : As specified in **13.2.2**

C : Coefficient given below:

For face part:

$$\frac{1.4}{\sqrt{1+\left(\frac{t_w}{t_f}\right)^2}}$$

For web part: 1.0

t_f and t_w : As specified in **12.2.4-1**

2. The section modulus per half pitch of corrugated bulkheads is not to be less than that obtained from the following formula:

$$7CShl^2\ (cm^3)$$

Where:

S : As specified in **13.2.4-2**

l : Length (m) between the supports, as indicated in **Fig 13.1**

C : Coefficient given in **Table 13.3**, according to the type of end connection

h : As specified in **13.2.3**

For bulkheads with lower stools of which the width in the longitudinal direction at the lower end, d_H , is less than 2.5 times the web depth of the bulkhead, d_0 (*See* **Fig. 13.1**), the measurement of l and the values of C are to be at the discretion of the Society.

For vertically corrugated bulkheads, the section modulus per half pitch of the upper part of a corrugated bulkhead which is located above one third of the span measured between the upper deck and the supporting point may not be less than 75% of that obtained by the above formula.

Fig. 13.1 Measurement of *l*

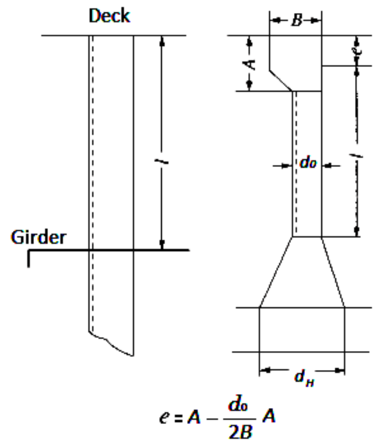


Table 13.3 Values of *C*

Column	Lower end	Upper end		
		Supported by Girders	Welded directly to deck	Welded to stool efficiently supported by ship structure
(1)	Supported by girders or welded directly to decks or inner bottoms	1.00	1.50	1.35
(2)	Welded to stool efficiently supported by ship structure	1.50	1.20	1.00

3. The thickness of plates at end parts for 0.2 l in line with l is not to be less than that obtained from the following formulae:

Thickness of web part:

$$0.0417\frac{CShl}{d_0}+3.5\ (mm)$$

Not to be less than that obtained from the following formula:

$$1.74\sqrt{\frac{CShlb^2}{d_0}}+3.5\ (mm)$$

Thickness of the face part except the upper end part of vertically corrugated bulkheads:

$$12a+3.5\ (mm)$$

Where:

h : As specified in **13.2.3**

C, S, d_0, a and b : As specified in **12.2.4-4**

l : As specified in **-2**

13.2.5 Girders Supporting Bulkhead Stiffeners

1. The section modulus of girders is not to be less than that obtained from the following formula:

$$7.13Shl^2\ (cm^3)$$

Where:

S : Breadth (m) of the area supported by the girders

h : Vertical distance (m) measured from the mid-point of S for horizontal girders, and from the mid-point of l for vertical girders, to the top of h specified in **13.2.3**

l : Span (m) specified in **12.2.6**

2. The moment of inertia of girders is not to be less than that obtained from the following formula. The depth of girders is not to be less than 2.5 times the depth of slots for stiffeners.

$$30hl^4 (cm^4)$$

Where:

h and l : As specified in **-1**

3. The thickness of web plates is not to be less than that obtained from the following formulae, whichever is the greatest:

$$0.0417\frac{CShl}{d_1}+3.5\ (mm)$$

$$1.74\sqrt[3]{\frac{CShlS_1^2}{d_1}}+3.5\ (mm)$$

$$10S_1+3.5\ (mm)$$

Where:

S, h and l : As specified in **-1**

S_1 : Spacing (m) of web stiffeners or the depth (m) of girders, whichever is smaller

d_1 : Depth (m) of the girder at the location considered, reduced by the depth (m) of slots for stiffeners

C : Coefficient obtained from the following formulae

Not to be less than 0.5.

For horizontal girders:

$$C=\left|1-2\frac{x}{l}\right|$$

For vertical girders:

$$C=\left|1+\frac{1}{5}\frac{l}{h}-\left(2+\frac{1}{h}\right)\frac{x}{l}+\frac{l}{h}\left(\frac{x}{l}\right)^2\right|$$

x : Distance (m) measured from the end of l for horizontal girders, and from the lower end of l for vertical girders, to the location considered

4. The actual section modulus and moment of inertia of girders are to be calculated in accordance with the provisions in **12.2.6-6**.

13.2.6 Cross Ties

1. Where efficient cross ties are provided across deep tanks connecting girders on each side of the tanks, the span (l) of girders specified in **13.2.5** may be measured between the end of the girder and the centre line of the cross tie or between the centre lines of adjacent cross ties.

2. The sectional area of cross ties is not to be less than that obtained from the following formula:

$1.3Sb_Sh\ (cm^2)$

Where:

S and h: As specified in **13.2.5**

b_s : Breadth (m) of the area supported by the cross ties

3. The ends of cross ties are to be bracketed to girders.

13.2.7 Top and Bottom Construction

The scantlings of the members forming the top or the bottom of deep tanks are to be in accordance with the requirements in this Chapter, where the members are treated as if they were members forming a deep tank bulkhead at that location. The scantlings of the members are not to be less than that required by the other requirements for the construction of the tank top as well as the bottom. For top plating of deep tanks, the thickness of plates is to be at least 1 *mm* greater than that of the thickness specified in **13.2.2**.

13.2.8 Scantlings of Members not in Contact with Sea Water

The thickness of plates of bulkheads and girders which are not in contact with sea water in service conditions may be reduced from the requirements in **12.2.2**, **13.2.4** and **13.2.5** by the values given below:

For plates with only one side in contact with sea water: 0.5 *mm*

For plates with neither side in contact with sea water: 1.0 *mm*

However, bulkhead plates in way of locations such as bilge wells are to be regarded as plates in contact with sea water.

13.3 Fittings of Deep Tanks

13.3.1 Limbers and Air Holes

Limbers and air holes are to be cut suitably in the structural members to ensure that air or water does not remain stagnated in any part of the tank.

13.3.2 Drainage from Top of Tanks

Efficient arrangements are to be made for draining bilge water from the top of deep tanks.

13.3.3 Inspection Plugs

The inspection plugs provided on deep tank tops as required in **13.1.3** are to be located in readily accessible positions, and the plugs are to be open as far as is practicable when filling the tank with water.

13.3.4 Cofferdams

1. Oiltight cofferdams are to be provided between the tanks carrying oils and those carrying fresh water, such as for personnel use or boiler feed water, to prevent the fresh water from being contaminated by the oil.

2. Crew spaces and passenger spaces are not to be directly adjacent to tanks carrying fuel oil. Such compartments are to be separated from the fuel oil tanks by cofferdams which are well ventilated and accessible. Where the top of fuel oil tanks have no opening and is coated with incombustible coverings of not less than 38 *mm* in thickness, the cofferdam between such compartments and the top of the fuel oil tanks may be omitted.

13.4 Welding of Corrugated Bulkheads

13.4.1 General

1. The welding of corrugated bulkheads is to be in accordance with **Table 13.4**.

2. For the supporting members of corrugated bulkheads or stools, such as floors, girders or other primary supporting members and stiffeners, fillet weld leg length is to be suitably increased or to be bevelled and welded. In cases where the angle between the side plating of a lower stool and inner bottom plating is relative small, the fillet weld leg lengths for supporting members to inner bottom plating are to be suitably increased taking into account such an angle.

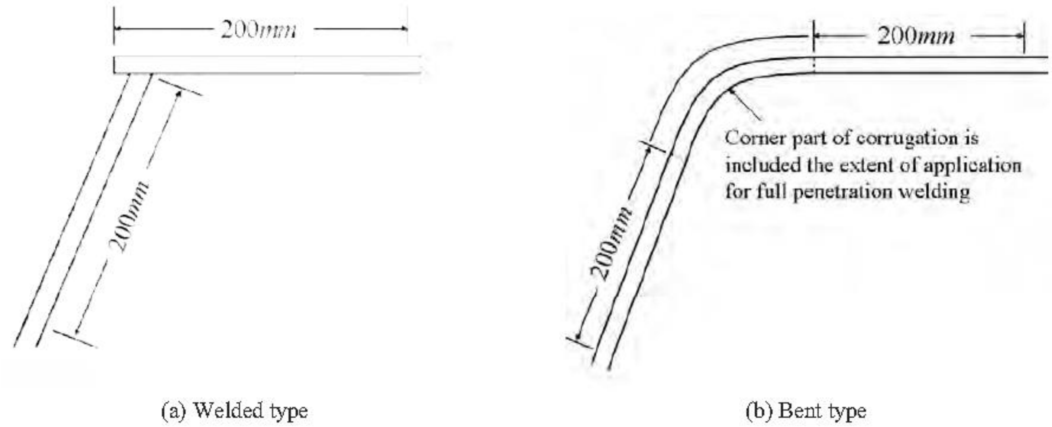
3. In cases where stools are fitted, the fillet weld leg length for the top or bottom plating of stools to the side plating of stools as well as the side plating of stools to inner bottom plating is to be suitably increased or to be bevelled and welded.

4. In cases where gusset plates and shedder plates are fitted at the lower parts of corrugated bulkheads, the welding is to be in accordance with the requirements given in **28A.3.5-5(2) and -6(5).**

Table 13.4 Welding of Corrugated Bulkheads

Type of Corrugated bulkhead		Application	Welding
Vertically corrugated bulkhead	Without stool	Upper deck	Double continuous fillet welding with a fillet weld leg length that is not less than 0.7 times the thickness of the corrugated bulkhead.
		Inner bottom	(1) For ships having a length, L_1, of 150*m* and above · Full penetration double bevel welds (2) For ships having a length, L_1, that is less than 150*m* · Full penetration double bevel welds for webs and flanges of the corrugated bulkhead that are within about 200*mm* from the corner of the corrugation (see **Fig. 13.2**) · For other parts, double continuous fillet welding with a fillet weld leg length that is not less than 0.7 times the thickness of the corrugated bulkhead.
		Corrugated bulkhead	Full penetration double bevel welds
	Lower stool	Top plate	(1) For ships having a length, L_1, of 150*m* and above · Full penetration double bevel welds (2) For ships having a length, L_1, that is less than 150*m* · Full penetration double bevel welds for webs and flanges of the corrugated bulkhead that are within about 200*mm* from the corner of the corrugation (see **Fig. 14.2**) · For other parts, double continuous fillet welding with a fillet weld leg length that is not less than 0.7 times the thickness of the corrugated bulkhead.
	Upper stool	Bottom plate	Double continuous fillet welding with fillet weld leg length that is not less than 0.7 times the thickness of the corrugated bulkhead
Horizontally orrugated ulkhead		Upper deck, Inner bottom, Corrugated bulkhead	Double continuous fillet welding with a fillet weld leg length that is not less than 0.7 times the thickness of the corrugated bulkhead

Fig. 13.2 Extent of About 200*mm* from the Corner of the Corrugation



Chapter 14 LONGITUDINAL STRENGTH

14.1 General

14.1.1 Special Cases in Application

Where there are items for which direct application of the requirements in this Chapter is deemed unreasonable for the following ships given in **(1)** through **(5)**, these items are to be in accordance with the discretion of the Society.

(1) Ships of unusual proportion

(2) Ships with especially large hatches

(3) Ships with especially small C_b

(4) Ships with large flares and high speed

(5) Other ships (ships of special form or construction, ships with special loading requirements, etc.)

14.1.2 Continuity of Strength

Longitudinal members are to be so arranged as to maintain the continuity of strength.

14.2 Bending Strength

14.2.1 Bending Strength at the Midship Part

1. The section moduli of the transverse sections of the hull at the midship part under consideration are not to be less than the values of Z_σ obtained from the following two formulae for all conceivable loading and ballasting conditions.

$Z_\sigma=5.72|M_s+M_w(+)|(cm^3)$

$Z_\sigma=5.72|M_s+M_w(-)|(cm^3)$

M_s: Longitudinal bending moment in still water (kN-m) at the transverse section under consideration along the length of the hull, which is calculated by the method deemed appropriate by the Society The positive value of M_s, however, is to be defined as a positive value which is obtained assuming that downward loads are taken as positive values and are integrated in the forward direction from the aft end of the ship. (*See* **Fig. 14.1**)

M_w (+) and M_w (-): Wave induced longitudinal bending moments (kN-m) at the transverse section under consideration along the length of the hull, which are obtained from the following formulae:

$M_w(+)=+0.19C_1C_2L_1^2BC_b'(kN\text{-}m)$

$M_w(-)=-0.11C_1C_2L_1^2B(C_b'+0.7)(kN\text{-}m)$

C_1: As given by the following formulae:

$10.75-\left(\frac{300-L_1}{100}\right)^{1.5}$ for $L_1\leq300m$

10.75 for $300m<L_1\leq350m$

$10.75-\left(\frac{L_1-350}{150}\right)^{1.5}$ for $350m < L_1$

L_1 : Length (m) of ship specified in 1.2.2, Part 1A or 0.97 *times* the length of ship on the designed maximum load line, whichever is smaller

C_b': Volume of displacement corresponding to the designed maximum load line divided by L_1Bd However, the value is to be taken as 0.6, where it is less than 0.6.

C_2 : Coefficient specified along the length at positions where the transverse section of the hull is under consideration, as given in Fig. 14.2

Fig. 14.1 Positive value of longitudinal bending moment

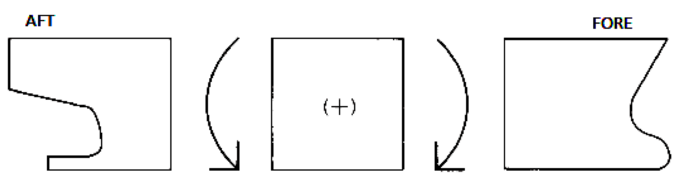
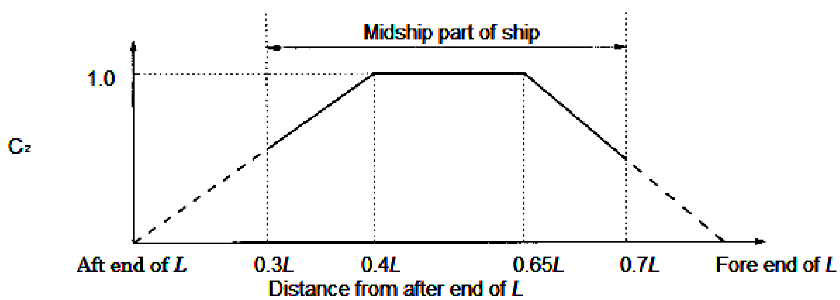


Fig. 14.2 Value of Coefficient C_2



2. Notwithstanding the requirements of **-1** above, the section modulus of the transverse section of the hull at the middle point of L is not to be less than the value of W_{min} obtained from the following formula:

$$W_{min}=C_1L_1^2B(C_b'+0.7)(cm^3)$$

C_1, L_1 and C_b' are to be as specified in **-1** above

3. Moment of inertia of the transverse section of the hull at the middle point of L is not to be less than the value obtained from the following formula. Note, however, that the calculation method for the moment of inertia of the actual transverse section is to be correspondingly in accordance with the requirements in 14.2.3.

$$3W_{min}L_1(cm^4)$$

W_{min} : Section modulus of the transverse section of hull at the middle point of L as specified in **-2** above

L_1 : As specified in **-1** above

4. The scantlings of longitudinal members in way of the midship Part are not to be less than the scantlings of longitudinal members at the middle point of L which are determined by the requirement in **-2** and **-3** above, excluding changes in the scantlings due to variations in the sectional form of the transverse section of the hull.

14.2.2 Bending Strength at Sections Other Than the Midship Part

1. The bending strength of hull at sections other than midship part is to be as determined according to the requirements of **16.2**.

2. Where the Society considers that the application of requirements of **-1** above is inappropriate, the bending strength at sections other than the midship part is to be determined according to **14.2.1-1** with necessary modifications.

14.2.3 Calculation of Section Modulus of Transverse Section of Hull

The calculation of the section modulus of the transverse section of the hull is to be based on the following requirements, as given in **(1)** through **(6)**.

(1) All longitudinal members which are considered effective to the longitudinal strength are to be included in the calculation.

(2) Deck openings on the strength deck are to be deducted from the sectional area used in the calculation of the section modulus. However, small openings not exceeding 2.5 m in length and 1.2 m in breadth need not be deducted, provided that the sum of their breadths in any single transverse section is not more than $0.06(B - \sum b)$. $\sum b$ is the sum of the openings exceeding 1.2 m in breadth or 2.5 m in length.

(3) Notwithstanding the requirement in **(2)**, small openings on the strength deck need not be deducted, provided that the sum of their breadths in one single transverse section does not reduce the section modulus at the strength deck or the ship bottom by more than 3%

(4) Deck openings specified in **(2)** and **(3)** include shadow areas obtained by drawing two tangential lines with an opening angle of 30 degrees having their apex on the line drawn through the centre of the small openings along the length of the ship.

(5) The section modulus at the strength deck is to be calculated by dividing the moment of inertia of the athwartship section about its horizontal neutral axis by the following distance **(a)** or **(b)**, whichever is greater.

   (a) Vertical distance (m) from the neutral axis to the top of the strength deck beam and the side of the ship

   (b) Distance (m) obtained from the following formula:

   $$Y\left(0.9 + 0.2\frac{X}{B}\right)$$

   X : Horizontal distance (m) from the top of continuous strength member to the centre line of the ship

   Y : Vertical distance (m) from the neutral axis to the top of the continuous strength member

In this case, X and Y are to be measured at the point which gives the largest value for the above formula.

(6) The section modulus at the ship bottom is to be calculated by dividing the moment of inertia of the athwartship section about its horizontal neutral axis by the vertical distance from the neutral axis to the top of the keel.

14.3 Shearing Strength

14.3.1 Thickness of Shell Plating of Ships Without Longitudinal Bulkheads

1. The thickness of the side shell plating is not to be less than the values of ts obtained from the following two formulae at any transverse section under consideration along the length of the hull for all conceivable loading and ballasting conditions.

$$t_s = 0.455|F_S + F_w(+)|\frac{m}{l} \quad (mm)$$

$$t_s = 0.455|F_S + F_w(-)|\frac{m}{l} \quad (mm)$$

I : Moment of inertia (cm^4) of the transverse section under consideration about its horizontal neutral axis, where the requirements in **14.2.3** are to be applied to the calculation method

m : Moment of area about the horizontal neutral axis (cm^3) on the transverse section for longitudinal members above the considered position of side shell plating when the considered position is above the horizontal neutral axis, and below the considered position when the considered position is under the horizontal neutral axis.

The requirements in **14.2.3** are to be applied to the calculation method

F_s : Shearing force in still water (kN) at the transverse section under consideration along the length of the hull,which is calculated by a method deemed appropriate by the Society

The positive value of F_s, however, is to be defined as a positive value which is obtained assuming that downward loads are taken as positive values and are integrated in the forward direction from the aft end of the ship. (*See* **Fig. 14.3**)

F_w (+) and F_w (-): Wave induced shearing forces (kN) at the transverse section under consideration along the length of hull, which are obtained from the following formulae:

$$F_w(+) = +0.3C_1C_3L_1B(C_b' + 0.7) \quad (kN)$$

$$F_w(-) = -0.3C_1C_4L_1B(C_b' + 0.7) \quad (kN)$$

C_1, L_1 and C_b' : As specified in **14.2.1-1**

C_3 and C_4 : Coefficients depending upon the positions of the transverse sections under consideration along the length of the hull, which are determined in accordance with **Fig. 14.4** and **Fig 14.5**

Fig. 14.3 Positive value of shearing force

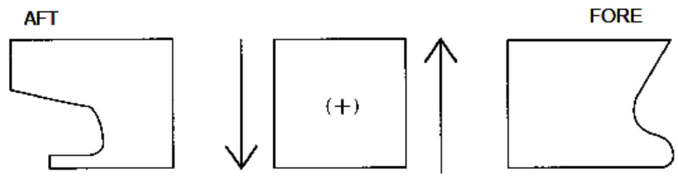


Fig. 14.4 Values of Coefficient C_3

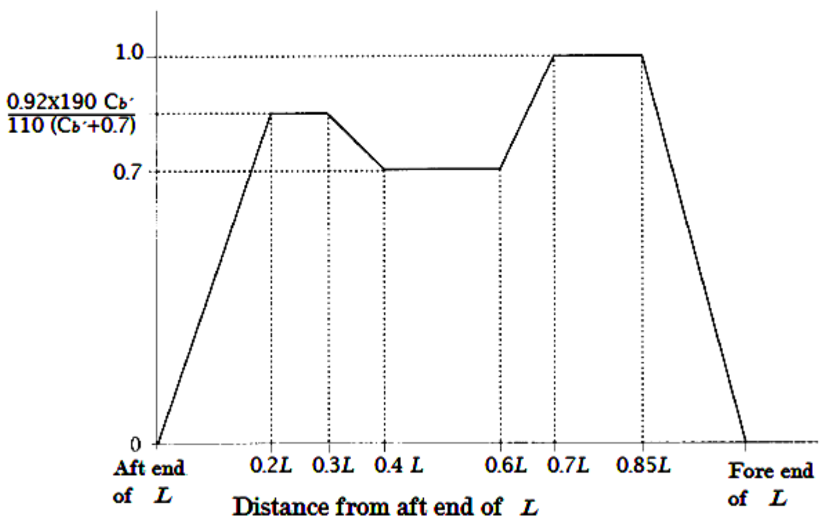
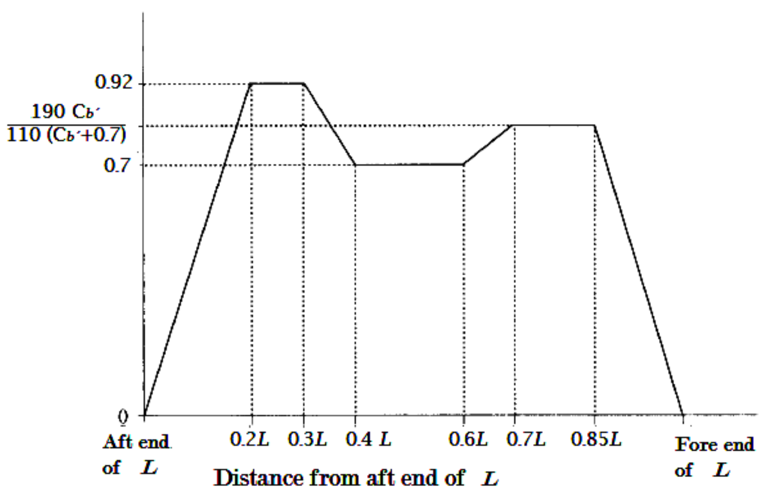


Fig.14.5 Values of Coefficient C_4



2. Where ships have bilge hopper tanks or top side tanks or longitudinal members below the strength deck that are considered to share a part of the shearing force effectively, the thickness of the side shell plating required by **-1** above may be reduced at the discretion of the Society.

14.3.2 Thickness of Side Shell Plating and Longitudinal Bulkhead Plating of Ships Having One to Four Rows of Longitudinal Bulkheads

Thickness t of the side shell plating and longitudinal bulkhead plating of ships of types specified in **Fig. 14.6** is not to be less than the value obtained from the following formula at the transverse section under consideration along the length of hull for all conceivable loading and ballasting conditions. However, ships with double side hull construction provided with bilge hoppers in the double side hull structure are to be as deemed appropriate by the Society.

$$t = 0.91\frac{F_m}{I}(mm)$$

Where:

I and m : As specified in **14.3.1-1**

F : Shearing force acting upon the side shell plating or longitudinal bulkhead plating, the value of which is to be F (+) or F (-), whichever is greater:

$$F(+) = |a(F_s + F_w(+)) + \Delta F| \ \ (kN)$$

$$F(-) = |a(F_s + F_w(-)) + \Delta F| \ \ (kN)$$

Fs, Fw (+) and Fw (-): As specified in **14.3.1-1**

Except when deemed otherwise by the Society, the values of a and ΔF may be based on those specified in **Table 14.1**.

K_1 : Value is to be as specified in (a) to (c) below for longitudinal bulkheads other than those provided in the double side hull

k_2 : Value is to be as specified in (a) to (c) below for longitudinal bulkheads provided in the double side hull.

However, values of k_1 and k_2 may be suitably modified when members are considered to share part of the shearing force.

(a) For parts not provided with longitudinal bulkhead: 0

(b) For parts provided with a longitudinal bulkhead excluding the length of $0.5D_s$ from both ends: 1.0

(c) Value obtained by linear interpolation for the intermediate parts between those specified in (a) and (b)

A_s , A_L and A_{DL} :Sectional area (mm^2) of side shell plating amidships, longitudinal bulkhead plating amidships other than in the double side hull, and longitudinal bulkhead plating amidships in the double side hull

W_a , W_b and W_c : Values obtained from the following formulae:

$$W_a = h_a + h_d - d' \ \ (m)$$

$$W_b = h_b + h_d - d' \ \ (m)$$

$W_c = h_c + h_d - d^{'}\ (m)$

d': Draught (m) at the Part concerned in the loading condition under consideration

h_a , h_b , h_c and h_d : Water head (m) converted from the weight of cargo or ballast in the centre tanks, wing tanks, double side hull tanks (excluding double bottom parts) and double bottom tank in the loading conditions under consideration

Where the double hull forms one single tank, the requirements apply separately to the portion that is the double side hull tank and the portion that is the double bottom tank. Where the double bottom tank is divided within either a, b or c, h_d is to be determined for respective ranges of the tank divided.

a, b and c : Half breadth (m) of the centre tank, breadth (m) of wing tanks, and breadth (m) of double side hull tanks

S : Spacing (m) of floors in double bottom

n_i : Number of floors in double bottom from the mid-point of transverse bulkheads to the section under consideration in the double bottom n_i is negative when counted afterward and positive when counted forward. However, a swash bulkhead with an opening ratio of not less than 20% is not to be considered as a transverse bulkhead. When a floor is provided at mid-point between transverse bulkheads, n_i in this case, is to be obtained counting the floor as 0.5.

β: As specified below:

Where there is no effective centre girder on double bottom: 1.0

Where there is an effective centre girder on double bottom: 0.7

Fig.14.6 Types of Ships with Longitudinal Bulkheads

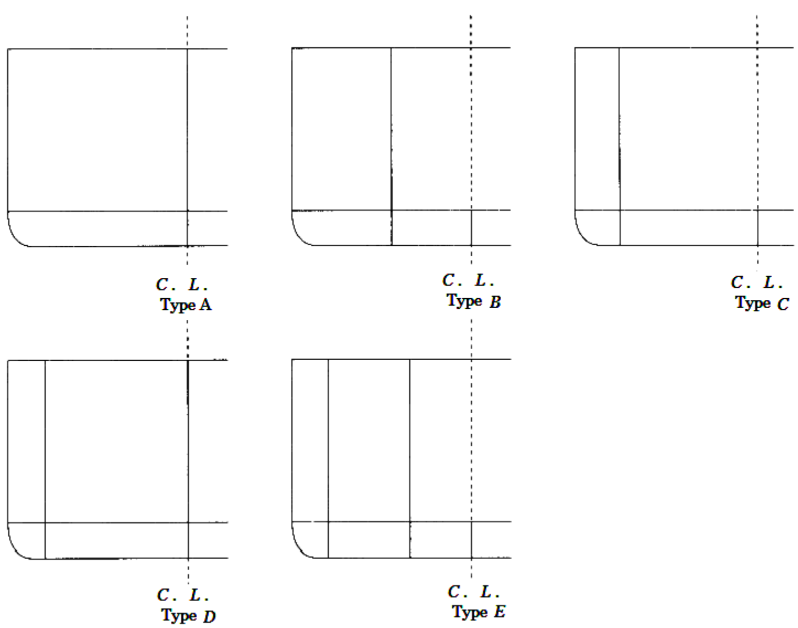


Table 14.1 Values of α and ΔF

Type	Application	$\alpha = (\alpha_1 \cdot \alpha_2)$		$\Delta F = (n_i(R - \alpha f))$	
		α_1	α_2	R	f
A	Side shell	$0.5 - 0.575\frac{k_1 A_L}{2A_s + A_L}$	1	$4.9W_b bS$	$19.6W_b bS$
	Longitudinal bulkhead	$\frac{0.575k_1 A_L}{A_s + A_L}$	2	$9.8W_b bS$	
B	Side shell	$0.5 - \frac{0.55k_1 A_L}{2A_S + A_L}$	1	$4.9W_b bS$	$19.6(W_\alpha a + W_b b)S$
	Longitudinal bulkhead	$\frac{0.55k_1 A_L}{A_s + A_L}$		$9.8(\beta W_\alpha a + 0.5W_b b)S$	
C	Side shell	0.5	$1 - \frac{1.06k_2 A_{DL}}{A_S + A_{DL}}$	$4.9(\beta W_\alpha a + W_c c)S$	$19.6(W_\alpha a + W_c C)S$
	Longitudinal bulkhead		$\frac{1.06k_2 A_{DL}}{A_S + A_{DL}}$		
D	Side shell	$0.5 - \frac{0.675k_1 A_L}{2(A_S + A_{DL}) + A_L}$	$1 - \frac{1.05k_2 A_{DL}}{A_S + A_{DL}}$	$4.9(0.5W_b b + W_c c)S$	$19.6(W_b b + W_c c)S$
	Outer longitudinal bulkhead		$\frac{1.05k_2 A_{DL}}{A_S + A_{DL}}$	$9.8W_b bS$	
	Centre longitudinal bulkhead	$\frac{0.675k_1 A_L}{2((A_S A_{DL}) + A_L}$	2		
E	Side shell	$0.5 - \frac{0.615k_1 A_L}{A_S + A_{DL} + A_L}$	$1 - \frac{1.04k_2 A_{DL}}{A_S + A_{DL}}$	$4.9(0.5W_b b + W_c c)S$	$19.6(W_\alpha a + W_b b + W_c c)S$
	Outer longitudinal bulkhead		$\frac{1.04k_2 A_{DL}}{A_S + A_{DL}}$		
	Centre longitudinal bulkhead	$\frac{0.615k_1 A_L}{A_S + A_{DL} + A_L}$	1	$9.8(\beta W_\alpha a + 0.5W_b b)S$	

14.3.3 Compensation for Opening

Where openings are provided in the shell plating, adequate consideration is to be given to the shearing strength, and suitable compensation is to be made as necessary

14.4 Buckling Strength

14.4.1 General

1. The buckling strength for main members related to longitudinal strength is to be in accordance with the requirements in this section.

2. The buckling strength can be examined by other appropriate analytical measures than that specified in this section subject to the approval by the Society.

3. When calculating the buckling stresses in 14.4.3 and 14.4.4, the standard thickness deductions given in Table 14.2 apply to t_b , t_w , t_f, and t_p according to the location.

Table 14.2 Standard Deductions

Structures	Standard Deduction (*mm*)	Limit Values (*mm*) Min.	Max.
1. Compartments carrying dry bulk cargoes 2. One side exposure to ballast and/or liquid cargo-Horizontal surfaces and surfaces sloped at an angle less than 25˚ to the horizontal line	0.05t	0.5	1.0
1. One side exposure to ballast and/or liguid cargo-Horizontal surface and surfaces sloped at an angle less than than 25˚ to the horizontal line 2. Two side exposure to ballast and/ or liquid cargo-Vertical surfaces and surfaces sloped at an angle less than than 25˚ to the horizontal line	0.10t	2.0	3.0
1. Two side exposure to ballast and/or liquid cargo-Horizontal surfaces and surfaces sloped at an angle less than than 25˚ to the horizontal line	0.15t	2.0	4.0

Notes:
't' is the thickness of structural members under consideration. (*mm*)

14.4.2 Working Stress

1. For examination of buckling strength according to the requirements in this section, the working compressive stress σ_a of the member considered is to be obtained from the following formula, but is not to be less than $30/K$.

$$\sigma_\alpha = \frac{M_S M_W}{I} y x 10^5 \ (N/mm^2)$$

K : Coefficient corresponding to the kinds of steel

e.g. 1.0 for mild steel, the values specified in 1.1.6-2(1) for high tensile steel

M_s : Longitudinal bending moment (kN-m) in still water as specified in 14.2.1

M_w : Wave induced longitudinal bending moment (kN-m) as specified in 14.2.1

For members located above the neutral axis in the transverse section, the maximum values of M_s and M_w are to be taken in sagging condition, and for members located below the neutral axis, the maximum values of M_s and M_w are to be taken in hogging condition.

I : Moment of inertia (cm^4) at the transverse section considered, as specified in **14.3.1-1**

y : Vertical distance (m) from the neutral axis to the location of the member considered in the transverse section

2. For examination of buckling strength according to the requirements in this section, the working shearing stress τ_a of the member considered is to be obtained from the following **(1)** or **(2)**.

(1) Ships without longitudinal bulkhead

$$\tau_a = \frac{0.5mF}{It} x10^2 \ (N/mm^2)$$

F : Shearing force as specified in **14.3.1-1.**, the value of whichever is greater,

$|F_s + F_w(+)|$ or $|F_s + F_w(-)|$ (kN)

m : Moment of area ($cm3$) of the athwartship section considered, as specified in **14.3.1-1**

I : As specified in preceding **-1**

t : Thickness (mm) of the member considered

(2) Ships with longitudinal bulkhead

$$\tau_\alpha = \frac{mF}{It} x10^2 \ (N/mm^2)$$

F : Shearing force (kN) as specified in **14.3.2**

m, I and t : As specified in preceding **(1)**

14.4.3 Elastic Buckling Stresses of Plates

1. Compressive buckling stress σ_E of plates is given by the following formula:

$$\sigma_E = 0.9K_m E \left[\frac{t_b}{1000_S}\right]^2 (N/mm^2)$$

E : Modulus of elasticity for material: 2.06 x10^5 for steel (N/mm^2)

t_b : Thickness (mm) of plating considering standard deductions as specified in **14.4.1-3**

s : Span (m) of shorter side of plate panel

K_m : For plating with longitudinal stiffeners

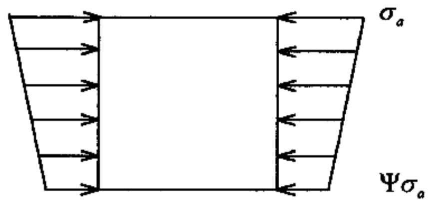
$$K_m = \frac{8.4}{\Psi + 1.1} \ (for\ 0 \le \Psi \le 1)$$

For plating with transverse stiffeners

$$K_m = c\left[1 + \left[\frac{s}{l}\right]^2\right]^2 \cdot \frac{2.1}{\Psi+1.1} \ for\ (0 \le \Psi \le 1)$$

l : Span (m) of longer side of plate panel

ψ: Ratio between min. and max. compressive stress σ_a when linear variation across panel



c : Coefficients obtained according to the kind of stiffeners at compressive side, which are given by the following:

1.30: when plating stiffened by floors or deep girders

1.21: when stiffeners are angles or T-sections

1.10: when stiffeners are bulb flats

1.05: when stiffeners are flat bars

2. Shear buckling stress τ_E of plate is given by the following formula:

$$\tau_E = 0.9 k_1 E \left[\frac{t_b}{1000s}\right]^2 (N/mm^2)$$

K_1 : As given by the following:

$$k_t = 5.34 + 4\left[\frac{s}{l}\right]^2$$

E, t_b and s: As specified in **-1** above

14.4.4 Elastic Buckling of Longitudinals

1. Compressive buckling stress σ_E of longitudinal frame, beam and stiffener is given by the following formula:

$$\sigma_E = 0.001 E \frac{I_a}{Al^2} \ (N/mm^2)$$

E : As specified in **14.4.3-1**

I_a : Moment of inertia (cm^4) of longitudinal including plate flange and calculated with thickness as specified in **14.4.1-3**

A : Cross-sectional area (cm^2) of longitudinal including plate flange and calculated with thickness as specified in **14.4.1-3**

l : Span (m) of longitudinal

2. Torsional buckling stress σ_E of longitudinal frame, beam and stiffener is given by the following formula:

$$\sigma_E = \frac{\pi^2 E I_w}{10^4 I_p l^2}\left[m^2 + \frac{K}{m^2}\right] + 0.385 E \frac{I_t}{I_p} \ (N/mm^2)$$

I_t : St. Venant s moment of inertia (cm^4) obtained without plate flange according to the kind of longitudinals, which is given by the following:

$\frac{h_w {t_w}^3}{3} x10^{-4}$ for flat bars (slabs)

$\frac{1}{3}\left[h_w t_w^3 + b_f t_f^3 \left[1 - 0.63\frac{t_f}{b_f}\right]\right] x10^{-4}$ for flanged section

I_P : Polar moment of inertia (cm^4) about connection of stiffener to plate obtained according to the kind of longitudinals, which is given by the following:

$\frac{h_w^3 t_w}{3} x10^{-4}$ for flat bars (slabs)

$\left[\frac{h_w^3 t_w}{3} + h_w^2 b_f t_f\right] x10^{-4}$ for flanged section

I_w : Sectorial moment of inertia (cm^6) about connection of stiffener to plate obtained according to the kind of longitudinals, which is given by the following:

$\frac{h_w^3 t_w^3}{36} x10^{-6}$ for flat bars (slabs)

$\frac{t_f b_f^3 h_w^2}{12} x10^{-6}$ for T-sections

$\frac{b_f^3 h_w^2}{12(b_f+h_w)^2}\left[t_f\left(b_f^2 + 2b_f h_w + 4h_w^2\right) + 3t_w b_f h_w\right] x10^{-6}$ for angles and bulb sections

h_w : Web height (mm)

t_w : Web thickness (mm) considering standard deductions as specified in **14.4.1-3**

b_f : Flange width (mm)

t_f : Flange thickness (mm) considering standard deductions as specified in **14.4.1-3**

For bulb sections, the mean thickness of the bulb is to be used.

l : Span (m) of longitudinal

K : As given by the following:

$$K = \frac{Cl^4}{\pi^4 E I_w} x\ 10^6$$

C : As given by the following:

$$C = \frac{k_p E t_p^3}{3s\left[1 + \frac{1.33 k_p h_w t_p^3}{1000 s t_w^3}\right]} x10^{-3}$$

s : Spacing (m) of longitudinal

t_P : Thickness (mm) of plate connected to longitudinals considering standard deductions as specified in **14.4.1-3**

k_P : As given by the following, but not less than zero. For longitudinals with flanges, the value need not be taken as less than 0.1:

$$k_P = 1 - \eta_P$$

η_P : As given by follows:

$$\eta_p = \frac{\sigma_\alpha}{\sigma_{EP}}$$

σ_a : Calculated compressive stress for longitudinals as specified in **14.4.2**

σ_{EP} : Elastic buckling stress of supporting plate as calculated in **14.4.3**

E : As specified in **14.4.1-3**

m : As given by **Table 14.3**

3. Compressive buckling stress E s for web plate of longitudinals is given by the following formula:

$$\sigma_E = 3.8E\left[\frac{t_w}{h_w}\right]^2 \left(\frac{N}{mm^2}\right)$$

E,t_w and h_w : As specified in **-2** above

Table 14.3 The value of *m*

	$0 < K < 4$	$4 \le K < 36$	$36 \le K < 144$	$m^2(m-1)^2 \le K < m^2(m+1)^2$
m	1	2	3	M

14.4.5 Critical Buckling Stress

1. The critical buckling stress in compression σ_c s is determined as follows:

$\sigma_c = \sigma_E$ When $\sigma_E \le \frac{\sigma_Y}{2}$

$\sigma_c = \sigma_Y\left[1 - \frac{\sigma_Y}{4\sigma_E}\right]$ When $\sigma_E > \frac{\sigma_Y}{2}$

σ_E: The compressive buckling stress calculated according to **14.4.3** and **14.4.4**

σ_Y: Minimum yield stress (N/mm^2) of material as specified in **Part 10**.

2. The critical buckling stress in shear τ_c is determined as follows:

$\tau_c = \tau_E$ when $\tau_E \le \frac{\tau_Y}{2}$

$\tau_C = \tau_Y\left[1 - \frac{\tau_Y}{4\tau_E}\right]$ when $\tau_E > \frac{\tau_Y}{2}$

Where:

τ_E: The shearing buckling stress calculated according to **14.4.3**

τ_y: As given by the following:

$$\tau_Y = \frac{\sigma_Y}{\sqrt{3}}$$

σ_Y : As specified in **-1** above

14.4.6 Scantling Criteria

The buckling strength for main members related to longitudinal strength is to comply with the following:

(1) $\sigma_c \ge \beta\sigma_a$ for compressive, bending and torsional buckling

β: Coefficient given by the following:

1.0: for plating and for web plating of stiffeners

1.1: for stiffeners

(2) $T_c \ge T_\alpha$ for shearing buckling of plate panels

14.4.7 Other Special Requirements

1. Flanges on angles and T-sections of longitudinals are to comply with the following formula:

$$\frac{b_f}{t_f} \le 15$$

b_f : Flange width (*mm*) for angles, half flange width for T-sections

t_f : As built flange thickness (*mm*)

For flat bars of longitudinals, the ratio between depth and thickness is not to exceed 15.

2. For ships with large flares and high speed, special attention is to be paid to the buckling strength of strength decks, shell plating and longitudinals 0.3*L* from the fore end of the ships.

Chapter 15 PLATE KEELS AND SHELL PLATING

15.1 General

15.1.1 Consideration for Corrosion

The thickness of shell plating at such parts that the corrosion is considered excessive due to the location and/or the service condition of the ship is to be properly increased over that required in this Chapter.

15.1.2 Consideration for Buckling

With regard to the prevention of buckling of the shell, adequate consideration is to be given to the prevention of buckling due to compression in addition to complying with the requirements in **14.4**.

15.1.3 Continuity in Thickness of the Shell Plating

Sufficient consideration is to be made regarding the continuity in the thickness of shell plating and to the avoidance of remarkable differences between the thickness of the shell plating under consideration and that of the adjacent shell plating.

15.1.4 Special Consideration for Contact with Wharf

Where the shell plating is prone to denting due to contact with the wharf, special consideration is to be given to the thickness of the shell plating.

15.1.5 Consideration for Ships Whose Designed Maximum Load Line is Far from the Strength Deck

The requirements in this Chapter for side plating may be appropriately modified when the distance from the designed maximum load line to the strength deck is very large.

15.1.6 Moving Parts Penetrating the Shell Plating

Moving parts penetrating the shell plating below the deepest subdivision draught which corresponds to the summer draught assigned to the ship in accordance with the requirements of International Load Line Convention, are to be fitted with a watertight sealing arrangement acceptable to the Society. The inboard gland is to be located within a watertight space of such volume that, if flooded, the bulkhead deck is not to be submerged. The Society may require that if such a compartment is flooded, essential or emergency power and lighting, internal communication, signals or other emergency devices remain available in other parts of the ship.

15.2 Plate Keels

15.2.1 Breadth and Thickness of Plate Keels

1. The breadth of the plate keel over the whole length of the ship is not to be less than that obtained from the following formula:

$2L + 1000$ (*mm*)

2. The thickness of the plate keel over the whole length of the ship is not to be less than the thickness of the bottom shell for the midship part obtained from the requirements in 15.3.4 plus 2.0 *mm*. However, this thickness is not to be less than that of the adjacent bottom shell plating.

15.3 Shell Plating Below the Strength Deck

15.3.1 Minimum Thickness

The thickness of shell plating below the strength deck is not to be less than that obtained from the following formula:

$\sqrt{L}\ (mm)$

15.3.2 Thickness of Side Shell Plating

The thickness of side shell plating other than the sheer strake of the strength deck of the midship part is to be as required in the following **(1)** and **(2)** in addition to the requirements in 14.3.1 and 14.3.2.

(1) In ships with transverse framing, the thickness of side shell plating is not to be less than that obtained from the following formula:

$C_1 C_2 S\sqrt{d - 0.125D + 0.05L' + h_1} + 2.5\ (mm)$

Where:

S : Spacing (*m*) of transverse frames

L' : Length (*m*) of ship

However, where L exceeds 230 *m*, L' is to be taken as 230 *m*.

C_1 : Coefficient given below:

Where L is 230 *metres* and under: 1.0

Where L is 400 *metres* and over: 1.07

For intermediate values of L, C_1 is to be obtained by linear interpolation.

C_2 : Coefficient given below:

$$\frac{91}{\sqrt{576 - \alpha^2 x^2}}$$

α : As given in (a) or (b), whichever is greater

(a) $15.5 f_B \left(1 - \frac{y}{y_B}\right)$

(b) Where L is 230 *metres* and under: 6.0

Where L is 400 *metres* and over: 10.5

For intermediate values of L, α is to be obtained by linear interpolation.

y_B : Vertical distance (*m*) from the top of keel at midship to the horizontal neutral axis of the athwartship section of hull

y : Vertical distance (m) from the top of keel to the lower edge of the side shell plating under consideration

f_B : Ratio of the section modulus of hull required in **Chapter 14** to the actual section modulus of hull at the bottom

x : As given by the following formula (hereinafter the same applies in **(1)**)

$$\frac{X}{0.3L}$$

X : Distance (m) from the fore end for side shell plating afore the midship, or from the after end for side shell plating after the midship. However, where X is less than that $0.1L$, X is to be taken as $0.1L$ and where X exceeds $0.3L$, X is to be taken as $0.3\,L$.

h_1 : As given in (a) or (b)

(a) For $0.3L$ from the fore end:

$$\frac{9}{4}(17 - 20C_b')(1 - x)^2$$

(b) For elsewhere: 0

C_b': Block coefficient

Where C_b exceeds 0.85, C_b' is to be taken as 0.85.

(2) In ships with longitudinal framing, the thickness of side shell plating is not to be less than that obtained from the following formula:

$$C_1 C_2 S\sqrt{d - 0.125D + 0.05L' + h_1} + 2.5 \ \ (mm)$$

Where:

S : Spacing (m) of longitudinal frames

L' : Length (m) of ship specified in **(1)**

C_1 : Coefficient specified in **(1)**

h_1 : As given in **(1)**

C_2 : Coefficient given by the following formula, but it is not to be less than 3.78

$$\frac{13}{\sqrt{24 - \alpha x}}$$

α: Coefficient specified in **(1)**

x : As given in **(1)**

15.3.3 Sheer Strakes for Midship Part

The thickness of sheer strakes at the strength deck for the midship part is not to be less than 0.75 times that of the stringer plate of the strength deck. However, the thickness is not to be less than that of the adjacent side shell plating.

15.3.4 Thickness of Bottom Shell Plating

The thickness of bottom shell plating is to be as required in **(1)** and **(2)**:

(1) In ships with transverse framing, the thickness is not to be less than that obtained from the following formula:

$$C_1 C_2 S\sqrt{d - 0.035L^1 + h_1} + 2.5 \ (mm)$$

Where:

S : Spacing (m) of transverse frames

L' : Length (m) of ship specified in 15.3.2(1)

C_1 : Coefficient specified in 15.3.2(1)

H_1 : Head specified in 15.3.2(1)

C_2 : Coefficient given below:

$$\frac{91}{\sqrt{576 - (15.5 f_B x)^2}}$$

f_B and x : As specified in 15.3.2(1)

(2) In ships with longitudinal framing, the thickness is not to be less than that obtained from the following formula:

$$C_1 C_2 S\sqrt{d + 0.035L' + h_1} + 2.5 \ (mm)$$

Where:

S : Spacing (m) of longitudinal frames

L', C_1 and h_1 : As specified in 15.3.2(1)

C_2 : Coefficient given below

Where it is less than 3.78, C_2 is to be taken as 3.78.

$$\frac{13}{\sqrt{24 - 15.5 f_B x}}$$

f_B and x : As specified in 15.3.2(1)

15.3.5 Bilge Strakes for Midship Part

1. The thickness of bilge strakes for the midship part is not to be less than that obtained from the following formula.

However, it is not to be less than the thickness of adjacent bottom plating.

$$\left\{5.22(d + 0.035L')\left(R + \frac{a+b}{2}\right)^{\frac{3}{2}} l\right\}^{\frac{2}{5}} + 2.5 \qquad (mm)$$

Where:

R : Bilge radius (m)

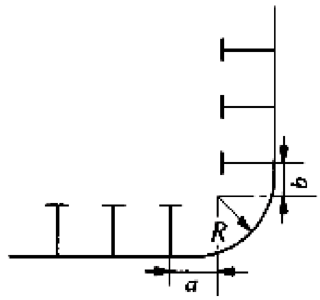
a and b : Distance (m) from the lower and upper turns of the bilge to the longitudinal frames nearest to the turns taking the distance outward from the bilge Part as positive

However, where (a + b) is negative, (a + b) is to be taken as zero. (*See* Fig. 15.1)

L' : As specified in 15.3.2

l : Spacing (m) of solid floors, bottom transverses or bilge brackets

Fig. 15.1 Measurement *a* and *b*



2. Where some of the longitudinal frames at the bilge part in a longitudinal framing system are omitted, longitudinal frames are to be provided as near to the turns of the bilge as practicable and suitably constructed to maintain the continuity of strength.

3. Where longitudinal frames are provided at the bilge part at nearly the same spacing as that of bottom longitudinals, the bilge strakes may be in accordance with the requirements in **15.3.4** irrespective of the requirements in **-1**.

15.4 Special Requirements for Shell Plating

15.4.1 Shell Plating at Large Flare Locations

For shell plating where the flare is especially large, sufficient consideration is to be made regarding reinforcement against forces acting on the bow such as wave impact pressure.

15.4.2 Where the Distance between Frames of Shell Plating Differs Remarkably from the Frame Spacing

Where the distance between frames measured along the shell plating is remarkably different from the frame spacing, the shell plating is to be reinforced by such measures as increasing its thickness in accordance with the spacing of the frames.

15.4.3 Aft Shell Plating of Ships with Especially Powerful Engines

For shell plating at the aft part of ships that have especially powerful engines compared with the ship length, sufficient consideration is to be made regarding reinforcement against vibration.

15.4.4 Shell Plating of Bottom Forward

The thickness of shell plating at the strengthened bottom forward specified in **5.8.2** is to be as required in the following **(1)**, **(2)** and **(3)**. Where the ship has an unusually small draught at the ballast condition and has especially high speed for the ship's length, special consideration is to be given to the thickness of the shell plating.

(1) In ships having a bow draught of not more than 0.025 L' at the ballast condition, the thickness of shell plating at the strengthened bottom forward is not to be less than that obtained from the following formula, where L' is as defined in 15.3.2.

$CS\sqrt{P} + 2.5\ (mm)$

Where:

C : Coefficient given in Table 15.1

For intermediate values of α, C is to be obtained by linear interpolation.

S : Spacing (m) of frames or girders or longitudinal shell stiffeners, whichever is the smallest

α: Value (m) of the spacing of frames or spacing of girders or longitudinal shell stiffeners, whichever is greater divided by S

p : Slamming impact pressure (kPa) specified in 5.8.4

(2) In ships having a bow draught of not less than 0.037 L' at the ballast condition, the thickness of shell plating at the strengthened bottom forward is not to be less than that specified in 15.3.4 or obtained from the following formula, whichever is greater. Where L' is as defined in 15.3.2

$1.34S\sqrt{L} + 2.5\ (mm)$

Where:

S : Spacing (m) of frames, girders or longitudinal shell stiffeners, whichever is the smallest

(3) In ships having an intermediate value of the bow draught specified in **(1)** and **(2)**, the thickness is to be obtained by linear interpolation from the requirements in **(1)** and **(2)**.

Table 15.1 Value of *C*

α	1.0	1.2	1.4	1.6	1.8	2.0 and above
C	1.04	1.17	1.24	1.29	1.32	1.33

15.4.5 Shell Plating Adjacent to Stern Frame or in Way of Spectacle Bossing

The thickness of shell plating adjacent to the stern frame or in way of spectacle bossing is not to be less than that obtained from the following formula. However, where the spacing of transverse frames in the after peak exceeds 610 *mm* or the length of ship exceeds 200 *m*, the thickness of the shell plating concerned is to be in accordance with the satisfaction of the Society.

$4.5 + 0.09L\ (mm)$

15.5 Side Plating in Way of Superstructure

15.5.1 Side Plating in Way of Superstructure where Superstructure Deck is not Designed as a Strength Deck

Where the superstructure deck is not designed as a strength deck, the thickness of the superstructure side plating is not to be less than that obtained from the following formula, but it is not to be less than 5.5 *mm*. Side plating of superstructures exceeding $0.15L$ in length, except for those at the end parts, is to be suitably increased in thickness.

From the fore end to $0.25L$ abaft the fore end:

$$1.15S\sqrt{L} + 2.0\ (mm)$$

Elsewhere: $0.95S\sqrt{L} + 2.0\ (mm)$

Where:

S : Spacing (m) of longitudinal or transverse frames at the position

15.6 Compensation at Ends of Superstructure

15.6.1 Strengthening Method

Breaks of superstructures are to be strengthened according to the following requirements in **(1)** to **(3)**:

(1) Sheer strakes of the strength deck are to extend well into the superstructure and are to be increased in thickness by not less than 20% above the normal thickness for sheerstrakes at that location for an appropriate span on both sides of the superstructure end.

(2) Side plating of the superstructure is to extend to an appropriate length beyond the end of the superstructure and taper off into the upper deck sheerstrakes to avoid an abrupt change of form at the break. The thickness of side plating at the ends of the superstructure is to be 20% greater than the normal thickness of superstructure side plating and this is to be taken as the standard.

(3) For superstructures located at the bow and stern, the requirements in **(1)** and **(2)** may be suitably modified.

15.6.2 Openings in Shell

Gangway ports, large freeing ports and other openings in the shell or bulwarks are to be kept well clear of the end of superstructures. Where holes are unavoidably required in the plating, they are to be made as small as possible and to be circular or oval in form.

15.7 Local Compensation of Shell Plating

15.7.1 Openings in Shell

All openings in the shell plating are to have their corners well rounded and to be compensated as necessary.

15.7.2 Thickness of Sea Chest

Where a sea chest is provided in the shell plating for suction or discharge, the thickness of the sea chest is not to be less than that obtained from the following formula and to be suitably stiffened so as to provide sufficient rigidity as necessary. Also, the thickness is not to be less than the required thickness of the shell plating at that location.

$$\sqrt{L} + 2.0 \ \ (mm)$$

15.7.3 Location of Openings

Openings such as cargo ports and gangway ports are to be kept well clear of discontinuous parts in the hull construction, and the places where they are provided are to be locally compensated for so as to maintain the longitudinal and transverse strengths of the hull.

15.7.4 Shell Plating At and Below Hawse Pipes

The shell plating fitted with hawse pipes and the plating below them is to be increased in thickness or to be doubled, and to be constructed so that their longitudinal seams are not damaged by anchors and anchor cables.

Chapter 16 DECKS

16.1 General

16.1.1 Steel Deck Plating

Decks are to be plated from side to side of the ship except where there are specialized deck openings. However, decks may be of only stringer plates and tie plates, subject to the approval by the Society.

16.1.2 Watertightness of Decks

1. Weather decks, except where hatchway and other openings specified in **Chapter 19** are provided, are to be made watertight.

2. Special consideration is to be given to the water influx to the compartments under the bulkhead deck on ro-ro spaces.

3. Special consideration is to be given to maintaining watertightness where the decks are required to be watertight in compliance with the requirements of **Part 3**.

16.1.3 Continuity of Steps of Decks

Where the strength deck or effective decks (the decks below the strength deck which are considered as strength members in the longitudinal strength of the hull) change in level, special care to preserve the continuity of strength is to be taken. The change in height is to be accomplished by gradual sloping, or by extending each of the structural members which form the decks and tying them effectively together by diaphragms, girders, brackets, etc.

16.1.4 Compensation for Openings

Hatchways or other openings on strength or effective decks are to have well rounded corners, and compensation is to be suitably provided as necessary.

16.1.5 Rounded Gunwales

Rounded gunwales, where adopted, are to have a sufficient radius for the thickness of the plates.

16.2 Effective Sectional Area of Strength Deck

16.2.1 Definition

The effective sectional area of the strength deck is the sectional area, on each side of the ship, of steel plating, longitudinal beams, longitudinal girders, etc. extending for 0.5L amidships.

16.2.2 Effective Sectional Area of Strength Deck

1. The effective sectional area for the midship part for which the modulus of athwartship section of the hull is specified in **Chapter 14.** is to be so determined as to comply with the requirements in **Chapter 14.**

2. Beyond the midship part, the effective sectional area of strength deck may be gradually reduced less than the value at the end of the midship part. However, the values at the position 0.15L from the after and fore end of L, respectively, are not to be less than 0.4 times the value at the middle point of L for ships with machinery amidships, or 0.5 times for ships with machinery aft.

3. Where the section modulus of the athwartship section other than the midship part is greater than the value approved by the Society, the requirements specified in the provisory clause in **-2** may not be necessarily applied.

16.2.3 Strength Deck Beyond 0.15L from Each End

Beyond 0.15L from each end, the effective sectional area and the thickness of the strength deck may be gradually reduced avoiding abrupt changes.

16.2.4 Effective Sectional Area of Strength Deck within Long Poop

Notwithstanding the requirements in **16.2.2**, the effective sectional area of the strength deck within long poop may be properly modified.

16.2.5 Deck Within Superstructure Where Superstructure Deck is Designed as Strength Deck

Where the superstructure deck is designed as the strength deck, the strength deck plating clear of the superstructure is to extend into the superstructure for about 0.05L without reducing the effective sectional area, and may be gradually reduced within.

16.3 Deck Plating

16.3.1 Thickness of Deck Plating

1. The thickness of deck plating is to be as specified in the following **(1)** and **(2)**. However, within enclosed spaces such as superstructures and deckhouses, the thickness may be reduced by 1 *mm*.

(1) The thickness of strength deck plating is to be as specified in the following:

(a) outside the line of openings for the midship part with longitudinal beams

$$1.47CS\sqrt{h} + 2.5\ (mm)$$

Where:

S : Spacing (m) of longitudinal beams

C : Coefficient obtained from the following formula:

$$0.905 + \frac{L'}{2430}$$

L' : Length of ship (m)

However, where L is 230 m and under, L' is to be taken as 230 m, and where L is 400 m and above, L' is to be taken as 400 m.

h : Deck load (kN/m^2) as specified in **9.2**

(b) Outside the line of openings for the midship part with transverse beams

$$1.63CS\sqrt{h} + 2.5 \ (mm)$$

Where:

S: Spacing (m) of transverse beams

C and h: As specified in **(a)**

(c) Elsewhere

$$1.25CS\sqrt{h} + 2.5 \ (mm)$$

Where:

S : Spacing (m) of longitudinal or transverse beams

C and h : As specified in **(a)**

(2) The thickness of deck plating other than the strength deck is to be as specified in the following:

$$1.25CS\sqrt{h} + 2.5 \ (mm)$$

Where:

S, C and h: As specified in **(1)(c)**

2. Where decks inside the line of openings are longitudinally framed, adequate care is to be taken to prevent buckling of the deck plating.

16.3.2 Deck Plating Forming Tops of Tanks

The thickness of deck plating forming the top of tanks is not to be less than that required in **13.2.7** for deep tank bulkhead plating, taking the beam spacing as the stiffener spacing.

16.3.3 Deck Plating Forming Bulkhead Recesses

The thickness of deck plating forming the top of shaft tunnels, thrust recesses or bulkhead recesses is not to be less than that required in **12.2.8-2** for watertight bulkhead plating, taking the beam spacing as the stiffener spacing.

16.3.4 Deck Plating Under Boilers or Refrigerated Cargoes

1. The thickness of effective deck plating under boilers is to be increased by 3 *mm* above the normal thickness.

2. The thickness of deck plating under refrigerated cargoes is to be increased by one *mm* above the normal thickness. Where special means for the protection against the corrosion of the deck is provided, the thickness need not be increased.

16.3.5 Thickness of Deck Plating loaded with Wheeled Vehicles

The thickness of deck plating loaded with wheeled vehicles is to be determined by considering the concentrated loads from the wheeled vehicles.

16.3.6 Thickness of Decks Supporting Unusual Cargoes

The thickness of plates of decks carrying cargo loads which cannot be treated as evenly distributed loads is to be determined by taking into account the load distribution of each particular cargo.

16.4 Deck Compositions

16.4.1 General

The deck composition is to be non-destructive to steel, or to be effectively insulated from the steel by a suitable protecting covering. The composition is to be effectively laid on the deck so that the composition may not cause cracks, exfoliation, etc. *See* **4.4.4**, **6.2.1** and **6.3.1**, **PART 6**.

16.5 Support Structures of Movable Car Decks

1. The requirements in this section apply to structures supporting movable car decks.

2. Support structures of movable car decks are to be arranged appropriately considering factors such as the shape and the design load.

3. The connections of supporting members to hull structural members are to be suitably constructed so as to avoid stress concentration. If necessary, suitable reinforcement is to be provided by means of stiffeners, brackets, etc.

4. Where deck panels are suspended by wire ropes, the ropes are to comply with the requirements of **ILLC** of the Rules or the requirements of the standards as deemed appropriate by the Society, and be subjected to suitable corrosion prevention treatment. The safety factor of the wire ropes is not to be less than the following value, but may not exceed 4.

$$\frac{10^4}{8.85W + 1910}$$

W : Safe working load (*ton*)

5. Scantlings of supporting structural members are to be determined to withstand the design loads defined in **11.7.2-3(1)**, using the following allowable stresses:

shear stress: $T = 0.34\sigma_F\ (N/mm^2)$

bending stress: $\sigma = 0.50\sigma_F\ (N/mm^2)$

equivalent stress: $\sigma_e\sqrt{\sigma^2 3t^2} = 0.64\sigma_F\ (N/mm^2)$

σ_F : Minimum upper yield stress (N/mm^2) or proof stress (N/mm^2) of the material

Chapter 17 SUPERSTRUCTURES

17.1 General

17.1.1 Application

1. Ships are to be provided with forecastles. However, for ships other than those defined in **1.3.1(13), Part 1B**, it may be omitted where the bow freeboard is deemed sufficient by the Society.

2. The construction and scantlings of superstructures are to be in accordance with the relevant Chapters in addition to this Chapter.

3. The requirements in this Chapter are prescribed for the superstructures up to the third tier above the freeboard deck. As for the superstructures above the third tier, the construction and scantlings thereof are to be as deemed appropriate by the Society.

4. As for the superstructures in ships with an especially large freeboard, the construction of end bulkheads may be suitably modified subject to the approval by the Society.

17.2 Superstructure End Bulkheads

17.2.1 Head of Water

1. The head of water for the calculation of the scantlings of superstructure end bulkheads is not to be less than that obtained from the following formula:

$a(bf - y)(m)$

Where:

a : As given by the following formulae:

Exposed front bulkhead of the first tier superstructure:

$$2.0 + \frac{L'}{120}$$

Exposed front bulkhead of the second tier superstructure:

$$1.0 + \frac{L'}{120}$$

Exposed front bulkhead of the third tier superstructure and protected front bulkheads:

$$0.5 + \frac{L'}{150}$$

Aft bulkheads located abaft the midship:

$$0.7 + \frac{L'}{1000} - 0.8\frac{x}{L}$$

Aft bulkheads located afore the midship:

$$0.5 + \frac{L'}{1000} - 0.4\frac{x}{L}$$

L' : Length of ship (m)

However, where L exceeds 300 *metres*, L' is to be taken as 300 *metres*.

b : As given by the following formulae:

Where $\frac{X}{L}$ is less than 0.45:

$$1.0 + \left(\frac{0.45 - \frac{x}{L}}{C_{b1} + 0.2}\right)^2$$

Where $\frac{X}{L}$ is 0.45 and over:

$$1.0 + 1.5\left(\frac{\frac{x}{L} - 0.45}{C_{b1} + 0.2}\right)^2$$

x : Distance (*m*) from the bulkhead to the after perpendicular.

C_{b1} : Block coefficient

However, where C_b is less than that 0.6, C_{b1} is to be taken as 0.6, and where C_b is 0.8 or over, C_{b1} is to be taken as 0.8 When calculating *b* for the aft bulkhead located afore the midship, C_{b1} is to be taken as 0.8.

f: As given in **Fig. 17.1**

y : Vertical distance (*m*) from the designed maximum load line to the mid-point of the span of stiffeners when determining the scantlings of stiffeners; and to the mid-point of plating when determining the thickness of bulkhead plating

2. The head of water is not to be less than that obtained from the formulae in **Table 17.1**, irrespective of the provisions in **-1**:

Fig. 17.1 Value of *f*

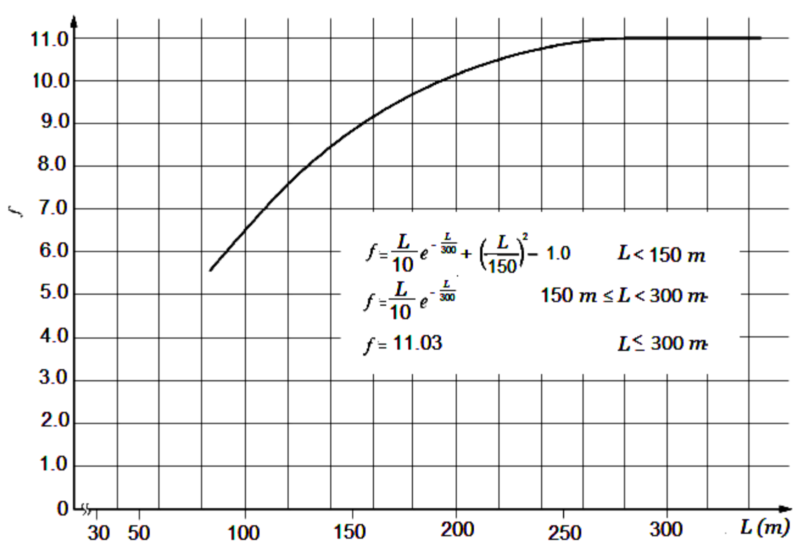


Table 17.1

	Exposed front bulkhead of the first tier superestructure	Others
L is 250 m and under	$2.5 + \frac{L}{100}\ (m)$	$1.25 + \frac{L}{200}\ (m)$
L exceeds 250 m	5.0 (m)	2.5 (m)

17.2.2 Thickness of Bulkhead Plating

1. The thickness of superstructure end bulkhead plating is not to be less than that obtained from the following formula:

$$3S\sqrt{h}\quad (mm)$$

Where:

h : Head of water (m) specified in **17.2.1**

S : Spacing of stiffeners (m)

2. The thickness of bulkhead plating is not to be less than that obtained from the following formula, irrespective of the provisions in **-1**:

Bulkhead plating of the first tier superstructure:

$$5.0 + \frac{L'}{100}(mm)$$

Plating of other bulkheads:

$$4.0 + \frac{L'}{100}(mm)$$

Where:

L': As specified in **17.2.1**

17.2.3 Stiffeners

1. The section modulus of stiffeners on superstructure end bulkheads is not to be less than that obtained from the following formula:

$$3.5Shl^{2}\ (cm^3)$$

Where:

S and h : As specified in **17.2.2**

l : Tween deck height (m)

However, where l is less than 2 *metres*, l is to be taken as 2 *metres*.

2. Both ends of stiffeners on the exposed bulkheads of superstructures are to be connected to the deck by welding except where otherwise approved by the Society.

17.2.4 End Bulkheads of Raised Quarterdecks

1. The fore ends of the raised quarterdecks are to be provided with intact bulkheads.

2. The thickness of plating and the scantlings of stiffeners on the bulkhead specified in **-1** are not to be less than those required by **17.2.2** and **17.2.3** taking this bulkhead as that of the first tier superstructure.

17.3 Closing Means for Access Openings in Superstructure End Bulkheads

17.3.1 Closing Means for Access Openings

1. The doors to be provided on the access openings in the end bulkheads of enclosed superstructures are to be in accordance with the requirements in **(1)** through **(5)**:

(1) The doors are to be made of steel or other equivalent materials and to be permanently and rigidly fitted to the bulkheads.

(2) The doors are to be rigidly constructed, to be of equivalent strength to that of intact bulkhead and to be weathertight when closed.

(3) The means for securing weathertightness are to consist of gaskets and clamping devices or other equivalent devices and to be permanently fitted to the bulkhead or the door itself.

(4) The doors are to be operated from both sides of the bulkheads.

(5) Hinged doors are, as a rule, to open outward.

2.

(1) The height of sills of access openings specified in **-1** is not to be less than 380 *mm* above the upper surface of the deck. For sills protecting access openings to spaces below the freeboard deck, the height is to comply with the provisions of **19.4.2**. However, higher sills may be required when deemed necessary by the Society.

(2) In principle, portable sills are not permitted.

17.4 Additional Requirements for Bulk Carriers, Ore Carriers and Combination Carriers

Bulk Carriers defined in **1.3.1(13), Part 1B** are to be provided with forecastles in accordance with the following requirements. In ships of which for some special reasons, are not applicable, the arrangement of the forecastle deck is to be at the direction of the Society.

(1) The forecastle is to be an enclosed superstructure.

(2) The forecastle is to be located on the freeboard deck with its aft bulkhead fitted in way or aft of the forward bulkhead of the foremost hold. (See **Fig. 17.2**)

(3) The forecastle height H_F above the main deck is to be not less than the value given in the following **(a)** or **(b)** whichever is the greater:

  (a) $H_C + 0.5$ (m), where is the height of the forward transverse hatch coaming of the foremost cargo hold.

  (b) The standard height of superstructure as given in **Table 17.2**. Intermediate values of L_f are to be obtained by linear interpolation.

(4) To reduce the load on the hatch cover of the foremost cargo hold specified in **19.2.3-1.(1)(a)** and/or the pressure applying abaft on the forward transverse hatch coaming specified in **Table 19.8**, the horizontal distance l_F (m) from the hatch coaming to all points of the aft edge of the forecastle deck is to satisfy the following formula:

$l_F \leq 5\sqrt{H_F - H_C}$

H_F and H_C : As specified in **(3)**

(5) A breakwater is not to be fitted on the forecastle deck with the purpose of protecting the hatch coaming or hatch covers. If fitted for other purposes, it is to be located such that its aft edge at the centre line is forward of the aft edge of the forecastle deck a horizontal distance l_w (m) satisfying the following formula:

$l_w \geq H_B / \tan 20^\circ$

H_B : Height of the breakwater above the forecastle.

Fig. 17.2

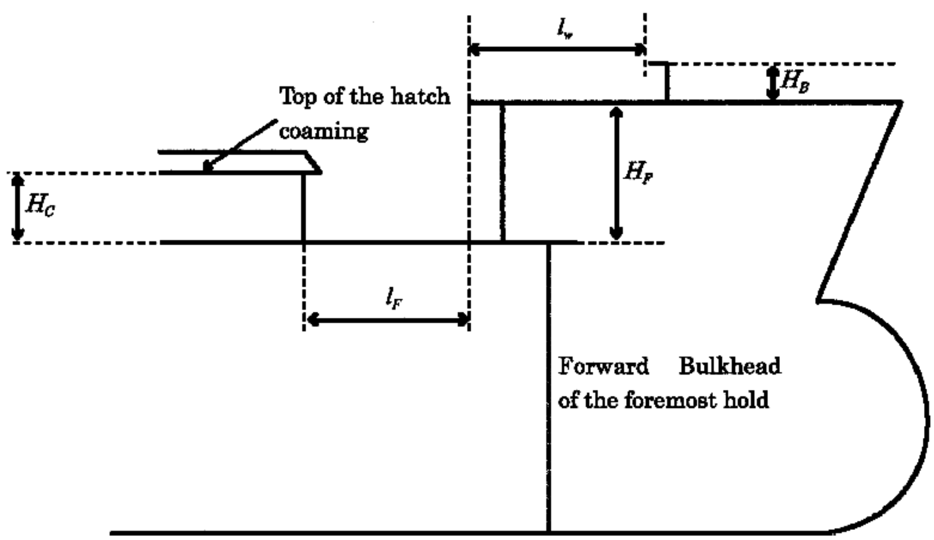


Table 17.2 Standard Height of Superstructure

Length of ship for freeboard (L_f)	Standard Height of Superestructure (m)
75m or less	1.80
125m or more	2.30

Chapter 18 DECKHOUSES

18.1 General

18.1.1 Application

1. The construction and scantlings of deckhouses are to be in accordance with the relevant Chapters in addition to this Chapter.

2. The requirements in this Chapter are prescribed for deckhouses up to the third tier above the freeboard deck. As for the deckhouses above the third tier, the construction and scantlings thereof are to be as deemed appropriate by the Society.

3. As for the deckhouses in ships with an especially large freeboard, the construction of the bulkhead may be suitably modified subject to the approval by the Society.

18.2 Construction

18.2.1 Water Head

1. The water head for the calculation of the scantlings of boundary walls of deckhouses is not to be less than that obtained from the following formula:

$$ac(bf - y) \quad (m)$$

Where:

a : As given by the following formulae:

Exposed front wall of the first tier deck-house:

$$2.0 + \frac{L'}{120}$$

Exposed front wall of the second tier deckhouse:

$$1.0 + \frac{L'}{120}$$

Exposed front wall of the third tier deckhouse, and side walls and protected front walls:

$$0.5 + \frac{L'}{150}$$

Aft walls located abaft the midship:

$$0.7 + \frac{L'}{1000} - 0.8\frac{x}{L}$$

Aft walls located afore the midship:

$$0.5 + \frac{L'}{1000} - 0.4\frac{x}{L}$$

L' : Length of ship (m)

However, where L exceeds 300 m, L' is to be taken as 300 m.

b : As given by the following formulae:

Where $\frac{X}{L}$ is less than 0.45:

$$1.0+\left(\frac{0.45-\frac{x}{L}}{C_{b1}+0.2}\right)^2$$

Where $\frac{X}{L}$ is 0.45 and over:

$$1.0+1.5\left(\frac{\frac{x}{L}-0.45}{C_{b1}+0.2}\right)^2$$

x : Distance (*m*) from the end wall to the after perpendicular, or distance from the mid-point of the side wall to the after perpendicular

However, where the length of the side wall exceeds 0.15*L*, the side wall is to be equally subdivided into spans not exceeding 0.15*L* and the distance from the mid-point of the subdivisions to the after perpendicular is to be taken.

C_{b1} : Block coefficient

However, where C_b is 0.6 or under, C_{b1} is to be taken as 0.6 and where C_b is 0.8 and over, C_{b1} is to be taken as 0.8. In calculating *b* for the aft wall located afore the midship, C_{b1} is to be taken as 0.8.

f : As given in **Fig. 17.1**

c : As given by the following formula

However, where $\frac{b'}{B'}$ is less than 0.25, $\frac{b'}{B'}$ is to be taken as 0.25

$0.3 + 0.7\frac{b'}{B'}$

b' : Breadth (*m*) of deckhouse at the position under consideration

B' : Breadth (*m*) of ship on the exposed deck at the position under consideration

y : Vertical distance from the designed maximum load line to the mid-point of span of stiffeners when determining the scantlings of stiffeners; and to the mid-point of plating when determining the thickness of boundary wall plating

2. The water head is not to be less than that obtained from the formulae in **Table 18.1**, irrespective of the provisions in **-1**:

Table 18.1

	Exposed front wall of the first tier deckhouse	Others
L is 250 *m* and under	$2.5+\frac{L}{100}(m)$	$1.25+\frac{L}{200}(m)$
L exceeds 250 *m*	5.0 (*m*)	2.5 (*m*)

18.2.2 Thickness of Boundary Wall Plating and Scantlings of Stiffeners

1. The thickness of boundary wall plating and the scantlings of stiffeners are not to be less than those required by **17.2.2** and **17.2.3**, taking the water head specified in **18.2.1** as *h*.

2. Both ends of stiffeners on exposed boundary walls of deckhouses are to be connected to the deck by welding except where otherwise approved by the Society.

18.2.3 Closing Means for Access Openings

1. Access openings of deckhouses protecting companion ways giving access to the spaces under the freeboard deck or the spaces in the enclosed superstructures are to be provided with the closing means at least complying with the requirements in **17.3**. However, where stairways are enclosed with boundary walls fitted with closing means complying with the requirements in **17.3**, the external doors need not be weathertight.

2. Openings in the top of a deckhouse on a raised quarterdeck or superstructure of less than standard height, having a height equal to or greater than the standard quarterdeck height, are to be provided with an acceptable means of closing but need not be protected by an efficient deckhouse or companionway, provided that the height of the deckhouse is at least the standard height of a superstructure. Openings in the top of the deckhouse which is less than a standard superstructure height may be treated in a similar manner.

18.2.4 Reinforcement of Construction Under Deckhouses

1. Where deckhouses are arranged just above transverse or longitudinal bulkheads, special consideration is to be given to avoid discontinuities at the connections between the deckhouses and the deck structure.

2. On the side walls and end walls of large deckhouses, partial bulkheads or special stiffeners are to be arranged at intervals not exceeding about 9 *metres* just above the bulkheads, web frames or under deck girders below.

3. At the vicinity of both ends of long deckhouses, special consideration is to be given to the construction connecting the boundary walls of deckhouses to the decks. The side walls are to be suitably constructed so as to maintain strength continuity and to avoid stress concentration.

4. The connections between deckhouses supporting crane posts and deck structure are to be of appropriate construction such that beams or longitudinal members are arranged beneath the wall surrounding the deckhouses to avoid stress concentration.

18.2.5 Spaces Below Especially Heavy Equipment

Deckhouses below especially heavy equipment such as survival craft and deck machinery are to be suitably strengthened.

18.2.6 Deckhouses on the Upper Tiers of Deck

For deckhouses on the upper tiers of the deck, suitable measures are to be taken to prevent vibration in such a manner as to arrange the side walls and pillars of respective tiers of deckhouses in the same plane as far as is practicable.

Chapter 19 HATCHWAYS, MACHINERY SPACE OPENINGS AND OTHER DECK OPENINGS

19.1 General

19.1.1 Relaxation from the Requirements

Relaxation from the requirements in this Chapter will be specially considered where the ship has an unusually large freeboard.

19.1.2 Position of Exposed Deck Openings

For the purpose of this Chapter, two positions of exposed deck openings are defined as follows:

Position I: Upon exposed freeboard and raised quarter decks and exposed superstructure decks situated forward of the point located $0.25L_f$ abaft the fore end of L_f

Position II: Upon exposed superstructure decks situated abaft of the point located 0.25 L_f abaft the fore end of L_f and located at least one standard height of superstructure above the freeboard deck, or

Upon exposed superstructure decks situated forward of the point located 0.25 L_f abaft the fore end of L_f and located at least two standard heights of superstructure above the freeboard deck.

19.1.3 Renewal Thickness of Steel Hatchway Covers and Hatchway Coamings for Ships in Operation

Structural drawings for hatch covers and hatch coamings complying with the requirements of **19.2** are to indicate the renewal thickness ($t_{renewal}$) for each structural element given by the following formula in addition to the as built thickness ($t_{as\text{-}built}$). If the thickness for voluntary addition is included in the as built thicknesses, the value may be at the discretion of the Society.

$$t_{renewal} = t_{as-built} - t_c + 0.5\ (mm)$$

t_c: Corrosion additions specified in **Table 19.1**

Where corrosion addition t_c is 1.0 (mm), renewal thickness may be given by the formula

$$t_{renewal} = t_{as-built} - t_c (mm)$$

19.2 Hatchways

19.2.1 Application

The construction and the means for closing cargo and other hatchways are to comply with the requirements in **19.2.2-10**

19.2.2 Height of Hatchway Coamings

1. The height of coamings above the upper surface of the deck is to be at least 600 *mm* in Position I and 450 *mm* in Position II.

2. For hatchways closed by weathertight steel hatch covers, the height of coamings may be reduced from that prescribed in **-1** or omitted entirely subject to the satisfaction of the Society.

3. The height of hatchway coamings other than those provided in exposed portions of the freeboard or superstructure decks is to be to the satisfaction of the Society having regard to the position of hatchways or the degree of protection provided.

19.2.3 Construction of Hatchway Coamings

1. The scantlings of hatch coamings are not to be less than the scantlings obtained by adding the corrosion addition 1.5 *mm* to the net scantlings obtained from the following requirements. For aft end transverse coamings, only the requirements in **(2)(b)** need be applied.

(1) The design wave load P_{coam} (kN/m^2) is not to be less than that obtained from the following **(a)** or **(b)** according to the type of ship.

(a) Bulk Carriers defined in **1.3.1(13), Part 1B**

I. The forward transverse hatch coaming of the foremost cargo hold

$P_{coam} = 290(kN/m^2)$

Where a forecastle complying with the requirements of **17.4** is fitted, the load may be reduced to 220 (kN/m^2).

II. Hatch coamings other than those specified in **i)** above

$P_{coam} = 220(kN/m^2)$

(b) Ships other than those specified in **(a)** above

The load P_{coam} (kN/m^2) is given by the following **i)** or **ii)**. For ships with an unusually large freeboard, the value of P_{coam} (kN/m^2) may be suitably modified.

I. The forward transverse hatch coaming of the foremost cargo hold

$P_{coam} = 290\ (kN/m^2)$

Where a forecastle complying with the requirements of **17.4** is fitted, the load may be reduced to 220 (kN/m^2).

II. Hatch coamings other than those specified in **i)** above

$P_{coam} = 220\ (kN/m^2)$

Where one forward transverse hatch coaming is protected by the adjacent forward cargo hold hatch or other structures effectively against the green sea forces, the load may be suitably reduced.

(2) The local net plate thickness of the hatch coaming plating $t_{coam\ net}$, is not to be less than that obtained from following requirements.

(a) For forward transverse and side hatch coamings

$t_{coam.net} = 14.9S\sqrt{\frac{1.15P_{coam}}{\sigma_{a.coam}}}\ (mm)$ but not to be less than 9.5 *mm*

S: Secondary stiffener spacing (m)

P_{coam}: As specified in **(1)** above

$\sigma_{a.coam} = 0.95\sigma_F$

σ_F : Minimum upper yield stress (N/mm^2) or proof stress (N/mm^2) of the material

(b) For aft transverse hatch coamings

Where L is 100 m and under: 4.5 + 0.05L (mm)

Where L is greater than 100 m: 9.5 (mm)

(3) The net section modulus of secondary stiffeners of the hatch coaming, based on net member thickness, is not to be less than that obtained from following formula:

$$Z_{net} = \frac{1150 l^2 S P_{coam}}{m c_P \sigma_{a.coam}}$$

m: 16 in general. 12 for the end spans of stiffeners sniped at the coaming corners

l: Span of secondary stiffeners (m)

S, and $\sigma_{a,coam}$: As specified in **(2)** above

c_p : Ratio of the plastic section modulus to the elastic section modulus of the secondary stiffeners with an attached plate breadth equal to 40 t_{net} (mm), where t_{net} is the net plate thickness. The value may be 1.16 in the absence of more precise evaluation.

The net scantlings of coaming stays are to be in accordance with the requirements of the following **(a)** to **(c)**.

(a) The net section modulus and web thickness of coaming stays designed as beams with flanges connected to the deck or sniped and fitted with a bracket (See **Fig. 19.1**) at their connections with the deck, based on member net thickness, are not to be less than that obtained from following formulae:

$$Z_{net} = \frac{1000 H_c^2 S P_{coam}}{2\sigma_{a,coam}} (cm^3)$$

$$t_{w,net} = \frac{1000 H_c S P_{coam}}{h \tau_{a,coam}} (mm)$$

H_C: Stay height (m)

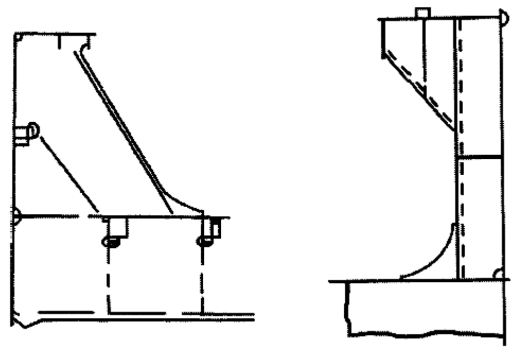
S: Stay spacing (m)

h: Stay depth (mm) at the connection with the deck

P_{coam} and $\sigma_{a,coam}$: As specified in **(2)** above

$\tau_{a,coam} = 0.5\ \sigma_F$

Fig. 19.1 Example of Hatch Coaming Stay



(b) For calculating the net section modulus of coaming stays, the area of their face plates are to be taken into account only when it is welded with full penetration welds to the deck plating and adequate underdeck structure is fitted to support the stresses transmitted by them.

(c) For designs of coaming stays other than those specified in **(a)** above, the stress levels given by following formulae apply and are to be checked at the highest stressed locations.

Normal stresses σ_a : 0.8 σ_F

Shear stresses τ_a: 0.46 σ_F

2. Coamings for hatchways in Position I or coamings of 760 *mm* or more in height for hatchways in Position II are to be stiffened in a suitable position below the upper edge by a horizontal stiffener; the breadth of the horizontal stiffener is not to be less than 180 *mm*.

3. Coamings are to be additionally supported by efficient brackets or stays provided from the horizontal stiffeners specified in **-2** to the deck at intervals of approximately 3 metres.

4. Coamings for all exposed hatchways are to be stiffened on their upper edges by half-round bars or similar section bars and their lower parts are to be constructed efficiently by flanging or other suitable means.

5. For the construction and scantlings of coamings of small hatchways, the requirements in **-1** to **-4** may be suitably modified.

6. The construction and scantlings of coamings over 900 *mm* in height, coamings of hatchways to deep tanks, and coamings of hatchways closed by special types of closing appliances to which the requirements in **19.2.3** are not applicable are to be to the satisfaction of the Society.

7. The design of local details is to comply with the following requirements.

(1) The secondary stiffeners of the hatch coamings are to be continuous over the breadth and length of the hatch coamings.

(2) The local details of the structures are to be designed so as to transfer the pressures on the hatch covers to the hatch coamings and, through them, to the deck structures below. Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.

(3) Underdeck structures are to be checked against the load transmitted by the stays, adopting the same allowable stresses specified in the preceding **-1(4)**.

(4) Double continuous welding is to be adopted for the connections of stay webs with deck plating and the weld throat is to be not less than 0.44 $t_{w,gross}$, where $t_{w,gross}$ is the gross thickness of the stay web.

(5) Toes of stay webs are to be connected to the deck plating with deep penetration double bevel welds extending over a distance not less than 15% of the stay width.

19.2.4 Portable Beams, Hatchway Covers, Steel Pontoon Covers and Steel Weathertight Covers

1. General

(1) The scantlings of structural members of steel hatchway covers, steel pontoon covers and steel weathertight covers (hereinafter referred to as steel hatch covers), and of portable beams are to comply with the requirements in **19.2.4**. When the loading condition or the type of construction differs from that specified in this paragraph, the calculation method is to be as deemed appropriate by the Society.

(2) The thickness of structural members forming the steel hatch covers is not to be less than the thickness obtained by adding the corrosion addition t_c specified in **(3)** to the net thickness t_{net} obtained from the requirements in **19.2.4**.

(3) The corrosion addition t_c is to be taken as specified in **Table 19.1** according to the ship type, the type of structure and structural members of the steel hatch covers.

(4) The allowable normal and shear stresses in the steel hatch covers are as specified in **Table 19.2**.

(5) For grillage or similar constructions, the stresses in steel hatch cover primary supporting members are to be determined by grillage or a FEM analysis. For modelling the structural members, the net scantlings are to be used.

(6) The scantlings of steel hatch covers intended to carry cargoes on them in exposed positions are to be of the values obtained from the requirements for steel hatch covers in exposed positions specified in this section or the values obtained from the requirements for steel hatch covers intended to carry cargoes specified in **19.2.5**, whichever is greater.

(7) The secondary stiffeners and primary supporting members of the steel hatch covers are to be continuous over the breadth and length of the steel hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to ensure sufficient load carrying capacity.

(8) Load bearing connections between the hatch cover panels are to be fitted with the purpose of restricting the relative vertical displacements.

Table 19.1 Corrosion addition

(a) Bulk Carriers [*1]

Type of structure of the steel hatch covers	Corrosion addition $t_c(mm)$	
	For the top, side and bottom plating	For the internal structures
Single plating type hatch cover	2.0	
Double plating type hatch cover	2.0	1.5

(b) Ships other than those specified in **(a)** above

Type of structure of the steel hatch covers	Corrosion addition $t_c(mm)$	
	For the top, side and bottom plating	For the internal structures
Single plating type hatch cover	$2.0^{(*2)}$	
Double plating type hatch cover	$1.5^{(*2)}$	1.0

[*1]: Bulk Carriers defined in **1.3.1(13), Part 1B** of the Rules and ships intended to be registered as bulk carriers.
[*2]: For the steel hatch covers in way of cellular cargo holds intended for containers, corrosion addition *tc* may be taken as 1.0 (*mm*).

Table 19.2 Allowable Stresses

	Nominal Stresses (σ_a)	Shear Stresses (τ_a)
Steel hatchway covers and steel weathertight covers	$0.8\sigma_F$	$0.46\sigma_F$
Portable beams and steel pontoon covers	$0.68\sigma_F$	$0.39\sigma_F$

Note:
σ_F (N/mm^2) means minimum upper yield stress or proof stress of the material.

2. Design wave load

The design wave load P_w (kN/m^2) is not to be less than that obtained from **Table 19.3**. Where two or more panels are connected by hinges, each individual panel is to be considered separately.

Table 19.3 Design Wave Load (*1)(*2) (kN/m²)

		$L_f > 100m$	$L_f \leq 100m$
In Position I	For $0.25L_f$ forward	$34.8 + \{14.8 + (L_f - 100)a\}(1 - \frac{ax}{L_f})^{(*3)(*4)}$	$15.8 + \frac{L_f}{3}\left(1 - \frac{5x}{3L_f}\right) - \frac{3.6x}{L_f}^{(*5)(*6)}$
	Elsewhere	34.3	$0.195L_f + 14.9$
In Position II		25.5	$9.81(1.1L_f + 87.6)/76$

Notes:

(*1) *a*: 0.0726 for type B freeboard ships

0.356 for type B-60 or B-100 freeboard ships

L_f: length of ship for freeboard defined in **1.2.3, Part 1A** (*m*). However, where L_f exceeds 340 *m*, L_f is to be taken as 340 *m*.

x: distance of the mid length of the hatch cover under examination from the forward end of L_f (*m*)

(*2) For exposed hatchways in positions other than Position I or II, value of each design wave load will be specially considered.

(*2) Where a Position I hatchway is located at least one superstructure standard height higher than the freeboard deck, *Pw* may be taken as 34.3 (kN/m^2)

(*4) For portable beams, *Pw* may be taken as 34.3 (kN/m^2).

(*5) Where a Position I hatchway is located at least one superstructure standard height higher than the freeboard deck, *Pw* may be taken as 0.195 L_f + 14.9 (kN/m^2).

(*6) For portable beams, *Pw* may be taken as 0.195 Lf + 14.9 (kN/m^2).

3. Local net plate thickness

The local net thickness t_{net} of the steel hatch cover top plating is not to be less than that obtained from the following formula, and is not to be less than 1% of the spacing of the stiffeners or 6 *mm*, whichever is greater:

$$t_{net} = 15.8F_P S\sqrt{\frac{P_w}{0.95\sigma_F}}\,(mm)$$

F_p : Coefficient given by the following formula:

1.9 σ/σ_a (for $\sigma/\sigma_a \geq 0.8$, for the attached plate flange of primary supporting members)

1.5 (for $\sigma/\sigma_a < 0.8$, for the attached plate flange of primary supporting members)

σ: Normal stress (N/mm^2) of the attached plate flange of primary supporting members

σ_a: Allowable normal stresses defined in **-1(4)** above

S: Stiffener spacing (*m*)

P_w: Design wave load (kN/m^2) specified in **-2** above

σ_F: Minimum upper yield stress (N/mm^2) or proof stress (N/mm^2) of the material

4. Net scantlings of secondary stiffeners

(1) The net section modulus Z_{net} of secondary stiffeners of the hatch cover top plate, based on stiffener net member thickness, is not to be less than that obtained from the following formula. The net section modulus of the secondary stiffeners is to be determined based on an attached plate width assumed equal to the stiffener spacing.

$$Z_{net} = \frac{1000SP_w l_2}{12\sigma_a} (cm^3)$$

l: Secondary stiffener span (m) is to be taken as the spacing of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all secondary stiffener spans, the secondary stiffener span may be reduced by an amount equal to 2/3 of the minimum brackets arm length, but not greater than 10% of the gross span, for each bracket.

S: Stiffener spacing (m)

P_w: Design wave load (kN/m^2) specified in **-2** above

σ_a: Allowable normal stresses defined in **-1(4)** above

(2) The net shear sectional area A_{net} of secondary stiffener webs of the hatch cover top plate is not to be less than that obtained from the following formula.

$$A_{net} = \frac{5SP_w l}{\tau_a} (cm^2)$$

l, S and P_w : As specified in **(1)** above

τ_a: As specified in **-1(4)** above

(3) For flat bar secondary stiffeners and buckling stiffeners, the following formula is to be applied:

$$\frac{h}{t_{W,net}} \leq 15\sqrt{k}$$

h: Height (mm) of the stiffener

$t_{W\,net}$, : Net thickness (mm) of the stiffener

$k = 235/\sigma_F$

σ_F: Minimum upper yield stress (N/mm^2) or proof stress (N/mm^2) of the material

5. Net scantlings of primary supporting members and of portable beams

(1) The net scantlings of portable beams and primary supporting members of steel hatch covers, which are simply supported between hatch coamings with uniformly distributed loads imposed thereupon, are to comply with the following formulae. For steel hatchway covers, S and l are to read as b and S, respectively.

Net section modulus at mid-span of portable beams or primary supporting members:

$$Z_{net} = \frac{1000SP_w l^2 k_1}{8\sigma_a} \quad (cm^3)$$

Net moment of inertia at mid-span of portable beams or primary supporting members:

$$I_{net} = \frac{0.0063SP_w l^3 k_2}{\mu} (cm^4)$$

Net cross-sectional area of web plates at the ends of portable beams or primary supporting members:

$$A_{net} = \frac{5SP_w l}{\tau_a}(cm^2)$$

S: Spacing (m) of portable beams or primary supporting members

l: Unsupported span (m) of portable beams or primary supporting members

b: Width (m) of steel hatch covers

P_w : Design wave load (kN/m^2) specified in **-2** above

k_1 and k_2: Coefficients obtained from the formulae given in **Table 19.4**

σ_a andτ_a: As specified in **-1(4)** above

μ : Coefficient obtained from **Table 19.5**

Table 19.4 Coefficients k_1 and k_2

k_1	$1+\frac{3.2-\gamma-0.8}{7\gamma+0.4}$	k_1 is not to be taken as less than 1.0
k_2	$1+8\alpha^3\frac{1-\beta}{0.2+3\sqrt{\beta}}$	$\alpha = \frac{l_1}{l}$ $\beta = \frac{I_1}{I_0}$ $\gamma = \frac{Z_1}{Z_0}$

$l =$ Overall length of portable beam (m)

l_1= Distance from the end of parallel part to the end of portable beam (m)

I_0 = Moment of interia at mid-span (cm^4)

I_1 = Moment of inertia at ends (cm^4)

Z_0 = Section modulus at mid-span (cm^3)

Z_1 =Section modulus at ends (cm^3)

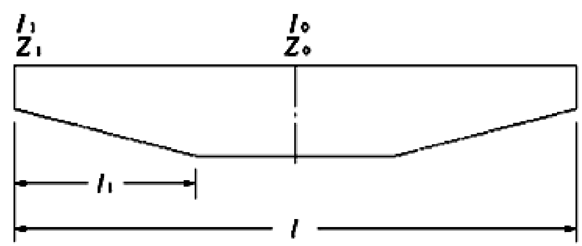


Table 19.5 Coefficient μ

	μ
Steel hatchway covers and steel weathertight covers	0.0056
Portable beams and steel pontoon covers	0.0044

(2) When calculating the normal and shear stresses in the hatch cover structural members by means of direct calculations, these values are not to exceed the allowable stresses specified in **Table 19.2**. For modeling structural members, net scantlings are to be used. When calculated by means of a beam or grillage model, the effective flange area $A_{F,net}$ (cm^2) of the attached plating to be considered for the yielding and buckling checks of primary supporting members is to be obtained by the following formula. In this case, the secondary stiffeners are not to be included in the attached flange area of the primary members.

$$A_{F,net} = \sum_{nf} (10 b_{ef} t) \ (cm^2)$$

nf**:** 2 if attached plate flange extends on both sides of girder web

1 if attached plate flange extends on one side of girder web only

t_{net} **:** Net thickness (*mm*) of considered attached plate

b_{ef} **:** Half the distance (*m*) between the considered primary supporting member and the adjacent one, but not to be taken greater than 0.165*l*

l: Span (*m*) of primary supporting members

(3) The spacing of primary supporting members parallel to the direction of secondary stiffeners is not to exceed 1/3 of the span of primary supporting members.

(4) The breadth of the flange of primary supporting members is to be not less than 40% of their depth for laterally unsupported spans greater than 3.0 *m*. Tripping brackets attached to the flange may be considered as a lateral support for primary supporting members. The flange outstand is not to exceed 15 *times* the gross flange thickness.

6. Critical buckling stress check

The buckling strength for primary supporting members forming the steel hatch cover is to be in accordance with the requirements of the following **(1)** to **(3)**.

(1) The buckling strength for hatch cover top plating is to be in accordance with the requirements of the following **(a)** to **(c)**.

(a) The compressive stress in the hatch cover plate panels induced by the bending of primary supporting members parallel to the direction of secondary stiffeners is not to exceed 0.8 *times* the critical buckling stress σ_{C1}, to be evaluated as defined below:

$$\sigma_{c1} = \sigma_{E1} \text{ When } \sigma_{E1} \leq \frac{\sigma_f}{2}$$

$$\sigma_{C1} = \sigma_F \left\{1 - \frac{\sigma_F}{4\sigma_{E1}}\right\} \text{ when } \sigma_{E1} > \frac{\sigma_F}{2}$$

σ_F: Minimum upper yield stress or proof stress of the material (N/mm^2)

$$\sigma_{E1} = 3.6E \left(\frac{t_{net}}{1000S}\right)^2$$

E: Modulus of elasticity (N/mm^2) of the material to be assumed equal to 2.06 105 for steel

t_{net} : Net thickness (*mm*) of plate panel

S: Spacing (*m*) of secondary stiffeners

(b) The mean compressive stress in each of the hatch cover plate panels induced by the bending of primary supporting members perpendicular to the direction of secondary stiffeners is not to exceed 0.8 *times* the critical buckling stress σ_{C2}, to be evaluated as defined below:

$$\sigma_{c2} = \sigma_{E2} \text{ when } \sigma_{E2} \leq \frac{\sigma_f}{2}$$

$$\sigma_{c2} = \sigma_F \left\{1 - \frac{\sigma_F}{4\sigma_{E2}}\right\} \quad \text{when } \sigma_{E2} > \frac{\sigma_F}{2}$$

σ_F, *E* and t_{net} : As specified in **(a)** above

$$\sigma_{E2} = 0.9mE\left(\frac{t_{net}}{1000s_s}\right)^2$$

$$m = c\left[1 + \left(\frac{s_s}{l_s}\right)^2\right]^2 \frac{2.1}{\psi + 1.1}$$

s_s: Length (*m*) of the shorter side of the plate panel

l_S : Length (*m*) of the longer side of the plate panel

ψ : Ratio between smallest and largest compressive stress

c: Coefficients obtained according to the kind of stiffeners at compressive side, which are given by the following:

1.30: when plating is stiffened by primary supporting members

1.21: when plating is stiffened by secondary stiffeners of angle or T type

1.10: when plating is stiffened by secondary stiffeners of bulb type

1.05: when plating is stiffened by flat bar

(c) The biaxial compressive stress in the hatch cover panels, when calculated by means of a FEM shell element model, is to be at the Society's discretion.

(2) The compressive stress in the top flange of secondary stiffeners, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, is not to exceed 0.8 *times* the critical buckling stress σ_{CS} , to be evaluated as defined below:

$\sigma_{CS} = \sigma_{ES}$ when $\sigma_{ES} \leq \frac{\sigma_F}{2}$

$\sigma_{CS} = \sigma_F\left\{1 - \frac{\sigma_F}{4\sigma_{ES}}\right\}$ when $\sigma_{ES} > \frac{\sigma_F}{2}$

σ_F : Minimum upper yield stress or proof stress of the material (N/mm^2)

σ_{ES} : σ_{E3} or σ_{E4} obtained from following formulae, whichever is smaller

$$\sigma_{E3} = \frac{0.001EI_{a,net}}{A_{net}\, l^2}$$

E: As specified in **(1)(a)** above

$I_{a\ net}$, : Moment of inertia (cm^4) of the secondary stiffener, including a top flange that has a width equal to the spacing of secondary stiffeners

A_{net} : Cross-sectional area (cm^2) of the secondary stiffener including a top flange that has a width equal to the spacing of secondary stiffeners

l: Span (*m*) of the secondary stiffener

$$\sigma_{E4} = \frac{\pi^2 EI_{w,net}}{10^4 I_{p,net} l^2}\left(m^2 + \frac{K}{m^2}\right) + 0.385E\frac{I_{t,net}}{I_{p,net}}$$

$$K = \frac{Cl^4}{\pi^4 EI_{w,net}} x10^6$$

m: As given by **Table 19.6**

$I_{w\ net}$, : Sectorial moment of inertia (cm^6) of the secondary stiffener about its connection with the plating:

$I_{w,ney} = \frac{h_w^3 t_{w,net}^3}{36} x10^{-6}$ for flat bar secondary stiffeners

$$I_{w,ney} = \frac{t_{f,net} b_f^3 h_w^2}{12} x10^{-6} \text{ for T secondary stiffeners}$$

$$I_{w,ney} = \frac{b_f^3 h_w^2}{12(b_f + h_w)^2} \{t_{f,net}(b_f^2 + 2b_f h_w + 4h_w^2) + 3t_{w,net} b_f h_w\} x10^{-6}$$

for angles and bulb secondary stiffeners

$I_{p,net}$: Polar moment of inertia (cm^4) of the secondary stiffener about its connection with the plating:

$$I_{p,net} = \frac{h_w^3 t_{w,net}}{3} x10^{-4} \text{ for flat bar secondary stiffeners}$$

$$I_{p,net} = \left(\frac{h_w^3 t_{w,net}}{3} + h_w^2 b_f t_{f,net}\right) x10^4$$

$I_{t\,net}$, : St Venant´ s moment of inertia (cm^4) of the secondary stiffener without top flange:

$$I_{t,net} = \frac{h_w t_{w,net}^3}{3} x10^{-4} \text{ for flat bar secondary stiffeners}$$

$$I_{t,net} = \frac{1}{3}\left\{h_w t_{w,net}^3 + b_f t_{f,net}^3 \left(1 - 0.63 \frac{t_{f,net}}{b_f}\right)\right\} x10^{-4} \text{ for flanged secondary stiffeners}$$

h_w : Height (*mm*) of the secondary stiffener web

$t_{w\,net}$, : Net thickness (*mm*) of the secondary stiffener web

b_f : Width (*mm*) of the secondary stiffener bottom flange

$t_{f\,net}$, : Net thickness (*mm*) of the secondary stiffener bottom flange

C: As given by the following:

$$C = \frac{k_p E t_{p,net}^3}{3S\left(1 + \frac{1.33 k_p h_w t_{p,net}^3}{1000 S t_{w,net}^3}\right)} x10^{-3}$$

S: Spacing (*mm*) of secondary stiffeners

k_p : As given by the following, but not less than zero

For longitudinals with flanges, the value is not to be taken as less than 0.1.

$$k_P = 1 - \eta_p$$

$$\eta_p = \frac{\sigma}{\sigma_{E1}}$$

σ_{E1}: As specified in **(1)** above

$t_{p\,net}$, : Net thickness (*mm*) of the hatch cover plate panel

Table 19.6 The value of *m*

	$1 < 4 < 4$	$4 \le K < 36$	$36 \le K \le 144$	$m^2(m-1)^2 \le K < m^2(m+1)^1$
m	1	2	3	*m*

(3) The shear stress in the hatch cover primary supporting members web panels is not to exceed 0.8 *times* the critical buckling stress τ_C, to be evaluated as defined below. For primary supporting members perpendicular to the direction of secondary stiffeners or for hatch covers built without secondary stiffeners, the average shear stress between the values calculated at the ends of this panel is to be considered:

$$\tau_C = \tau_E \text{ when } \tau_E \le \frac{\tau_F}{2}$$

$$\tau_C = \tau_E \text{when } \tau_E > \frac{\tau_F}{2}$$

$$\tau_F = \frac{\sigma_F}{\sqrt{3}}$$

$$\tau_E = 0.9 k_t E \left(\frac{t_{pr,net}}{1000d}\right)^2$$

σ_F and *E*: As specified in **(1)** above

$t_{pr,net}$: Net thickness (*mm*) of primary supporting member

$$k_t = 5.35 + \frac{4.0}{(a/d)^2}$$

a: The greater dimension (*m*) of the web panel of primary supporting member. For primary supporting members perpendicular to the direction of secondary stiffeners or for hatch covers built without secondary stiffeners, the smaller dimension *d* is to be considered

d: Smaller dimension (*m*) of web panel of primary supporting member

7. Deflection limit

The vertical deflection of primary supporting members and portable beams are to be not more than m *l*, where *l* is the greatest span of primary supporting members or portable beams, and m is as specified in **Table 19.5**.

19.2.5 Additional Requirements for Steel Hatch Covers Carrying Cargoes

1. General

(1) The scantlings of steel hatch covers carrying cargoes in exposed positions are to comply with the requirements in **19.2.4** in addition to the requirements in **19.2.5**. When the loading condition or the type of construction differs from the requirements of this paragraph, the calculation method is to be as deemed appropriate by the Society.

(2) The values obtained from the requirements of this paragraph include corrosion addition.

(3) Where concentrated loads are imposed such as in the carriage of container cargoes, direct calculations deemed appropriate by the Society are required.

(4) Where cargo loads and wave loads act jointly due to the height of the loaded cargo or its shape, special consideration is to be required.

2. Design cargo load

The design cargo load *h* (kN/m^2) is not to be less than that obtained from following **(1)** or **(2)**.

(1) *h* is to be equivalent to the standard given by 7 times the height (*m*) from the upper surface of the hatch cover to the deck above measured at the side of the space, or 7 times the height (*m*) from the deck concerned to the upper edge of the hatchway coaming of the deck above. However, *h* may be specified as the maximum design cargo weight per unit area of hatch covers (kN/m^2). In this case, the value of *h* is to be determined by considering the loading height of the cargo.

(2) Where cargoes are intended to be carried on the hatch covers of weather decks, h is to be the maximum design cargo weight per unit area of the hatch covers (kN/m^2).

3. Local plate thickness

For hatch covers carrying cargoes, the thickness of the top plating t is not to be less than that obtained from following formula.

$t = 1.25S\sqrt{Kh} + 2.5\ (mm)$

S: Spacing of stiffeners (m)

h: Design cargo load (kN/m^2) specified in **-2** above

K: Coefficient corresponding to the kinds of steel

e.g. 1.0 for mild steel, the values specified in **1.1.6-2(1)** for high tensile steel

4. Secondary stiffeners

The section modulus of stiffeners supported by girders and subjected to uniformly distributed loads may be obtained from direct strength calculations, or obtained from the following formulae.

$0.71CKSh^2 (cm^3)$

C: Coefficient given below according to the type of end connections of stiffeners;

For lug at both ends: 1.0

For snip at both ends or snip on one end and a lug on the other: 1.5

K: Coefficient corresponding to the kind of steel as specified in the proceeding **-**

S: Spacing of stiffeners (m)

h: Design cargo load (kN/m^2) as specified in **-2** above

l: Unsupported span of stiffeners (m)

5. Scantlings of primary supporting members and of portable beams

The net scantlings of portable beams and primary supporting members of steel hatch covers, which are simply supported between hatch coamings with uniformly distributed loads imposed thereupon are to comply with the following formulae. For steel hatchway covers, S and l are to read as b and S, respectively.

Net section modulus at mid-span of portable beams or primary supporting members:

$C_1 K h_1 S h l^2 (cm^3)$

Net moment of inertia at mid-span of portable beams or primary supporting members:

$C_2 K h l_2 S h l^3 (cm^4)$

Net cross-sectional area of web plates at the ends of portable beams or primary supporting members:

$C_3 KShl\ (cm^2)$

S, b, l, k_1 and k_2: As specified in **19.2.4-5**

C_1, C_2 and C_3: Coefficients given in **Table 19.8**

h: Design cargo loads given by **-2** above

K: Coefficient corresponding to the kind of steel as specified in the proceeding **-3**

Table 19.7 Coefficients C_1, C_2 and C_3

C_1	C_2	C_3
1.07	1.81	0.064*

Note:

*Not applicable to steel hatchway covers.

6. Compressive buckling stress

Steel hatch covers are to satisfy the following formula. However, for double plated steel hatch covers, the plate that actually bears the compressive stress need only comply.

$\sigma_{CR} / \sigma \geq 1.2$

σ_{CR} : Critical compressive buckling stress given by the following formulae.

σ'_{cr} For $\sigma'_{cr} \leq \frac{\sigma_F}{2}$

$\sigma_F \left\{1 - \frac{\sigma_F}{4\sigma'_{er}}\right\}$ For $\sigma'_{cr} > \frac{\sigma_F}{2}$

$\sigma'_{cr} = 0.74(t/S)^2$ (N/mm^2)

t: Thickness of steel plates (mm)

S: Spacing of stiffeners (m)

σ_F : Specified minimum upper yield stress (N/mm^2) of the steel used for fabrication

σ : Compressive stress (N/mm^2) acting on the steel plates

7. Deflection limit

The vertical deflection of primary supporting members and portable beams are to be not more than 0.0035*l*, where *l* is the greatest span of primary supporting members or portable beams.

19.2.6 Special Requirements for Portable Beams, Hatchway Covers, Steel Pontoon Covers and Steel Weathertight Covers

1. Portable beams are to comply with the following **(1)** to **(7)**.

(1) Carriers and sockets for portable beams are to be of substantial construction, having a minimum beaming surface of 75 *mm*, and are to be provided with means for efficient fitting and securing of the beams.

(2) Coamings are to be stiffened in way of carriers and sockets by providing stiffeners from these fittings to the deck or equivalent strengthening.

(3) Where beams of a sliding type are used, the arrangement is to ensure that the beams remain properly in position when the hatchway is closed.

(4) The depth of portable beams and the width of their face plates are to be suitable to ensure lateral stability of the beams. The depth of beams at their ends is not to be less than 0.40 *times* the depth at mid-span or 150 *mm*, whichever is greater.

(5) The upper face plates of portable beams are to extend to the extreme ends of the beams. The web plates are to be increased in thickness to at least twice that at mid-span for at least 180 *mm* at each end or to be reinforced with doubling plates.

(6) Portable beams are to be provided with suitable gear for lifting them without the need for personnel getting on them.

(7) Portable beams are to be clearly marked to indicate the deck, hatchway and position to which they belong.

2. Hatchway covers are to comply with the following **(1)** to **(5)**.

(1) Hatch rests are to be provided with at least a 65 *mm* bearing surface and are to be bevelled, if required, to suit the slope of the hatchways.

(2) Hatchway covers are to be provided with suitable hand grips according to their weight and size, except where the grips are unnecessary due to the construction.

(3) Hatchway covers are to be clearly marked to indicate the deck, hatchway and position to which they belong.

(4) The wood for hatchway covers is to be of good quality, straight grained and reasonably free from knots, sap and shakes.

(5) The ends of all wood covers are to be protected by an encircling steel band.

3. Steel pontoon covers are to comply with the following **(1)** to **(3)**.

(1) The depth of steel pontoon covers at the supports is not to be less than one-third the depth at mid-span or 150 *mm*, whichever is greater.

(2) The width of bearing surface for steel pontoon covers is not to be less than 75 *mm*.

(3) Steel pontoon covers are to be clearly marked to indicate the deck, hatchway and position to which they belong.

4. Steel weathertight covers are to comply with the following **(1)** to **(4)**.

(1) The depth of steel weathertight covers at the supports is not to be less than one-third the depth at mid-span or 150 *mm*, whichever is greater.

(2) The scantlings and construction of small or special types of steel weathertight covers to which the requirements in **(1)**, **19.2.4** and **19.2.5** are not applicable and covers for hatchways that need no coaming under the provisions of **19.2.2-2** will be specially considered by the Society.

(3) The means for securing and maintaining weathertightness are to be to the satisfaction of the Society. The arrangements are to ensure that the weathertightness can be maintained in any sea conditions.

(4) For steel weathertight hatch covers, effective means for stoppers complying with the requirements in **Table 20.8** against the horizontal green sea forces acting on them are to be provided.

19.2.7 Tarpaulins and Securing Arrangements for Hatchways Closed by PorTable overs

1. At least two layers of tarpaulins of Grade A complying with the requirements in **Chapter 7, Part 5** are to be provided for each exposed hatchway on the freeboard or superstructure decks and at least one layer of such a tarpaulin is to be provided for each exposed hatchway elsewhere.

2. Battens are to be efficient for securing the tarpaulins and not to be less than 65 *mm* in width and 9 *mm* in thickness.

3. Wedges are to be of tough wood or other equivalent materials. They are to have a taper not more than 1 in 6 and not to be less than 13 *mm* in thickness at the point.

4. Cleats are to be set to fit the taper of the wedges. They are to be at least 65 *mm* wide and to be spaced not more than 600 *mm* from centre to centre; the cleats along each side are to be arranged not more than 150 *mm* apart from the hatch corners.

5. For all hatchways in the exposed freeboard and superstructure decks, steel bars or other equivalent means are to be provided in order to efficiently secure each section of the hatchway covers after the tarpaulins are battened down.

Hatchway covers of more than 1.5 *metres* in length are to be secured by at least two such securing appliances. At all other hatchways in exposed positions on weather decks, ring bolts or other fittings for lashing are to be provided.

19.2.8 Steel Hatchway Covers for Container Carriers

For container carriers with unusually large freeboards, gaskets and securing devices for steel hatchway covers may be suitably dispensed with at the discretion of the Society upon request by the applicant for classification.

Table 19.8 Strength Requirements for Stoppers

Design pressure	The pressures show in (1) or (2) applies in accordance with ship type (1) For Bulk Carries defined in **1.3.1 (13), Part 1B** of Rules (a) Hatch covers for the foremost cargo hold Longitudinal forces acting on their forward end: $230 kN/m^2$ (Where a forecastle complying with the requirements of **17.4** is fitted, the pressure may be reduced to $175 kN/m^2$). Transverse forces: $175 kN/m^2$ (b) Other hatch covers Longitudinal forces acting on their forward end and transverse forces: $175 kN/m^2$ (2) Ships other than those specified in **(1)** above Following (a) and (b) are to be applied. For ships with unusually large freeboards, the pressure is to be at the discretion of the Society. (a) Hatch covers for the foremost cargo hold Longitudinal forces acting on their forward end: $230 kN/m^2$ (Where a forecastle complying with the requirements of **17.4**, is fitted, the pressure may be reduced to $175 kN/m^2$). Transverse forces: $175 kN/m^2$ (b) Other hatch covers Longitudinal forces acting on their forward end and tranverse forces: $175 kN/m^2$ (Where one forward transverse hatch coaming is protected by the adjacent forward cargo hold cover or other structures effectively against the green sea forces; however, the longitudinal forces acting on their forward end is to be at the discretion of the Society)
Allowable equivalent stress	In stoppers, their support structures and stopper welds (calculated at the throat of the welds), the equivalent stress is not to exceed the allowable value of 0.8 times the yield stress of the material

19.2.9 Steel Hatchway Covers of Deep Tanks

Steel hatchway covers of deep tanks are to comply with the following requirements:

(1) The scantlings of covers, in addition to complying with the requirements for steel weathertight covers are not to be less than that required for deep tank top structures.

(2) The means for securing and maintaining oil and watertightness are to be to the satisfaction of the Society.

19.2.10 Additional Requirement for Small Hatches Fitted on Exposed Fore Deck

Small hatches located on the exposed deck forward of $0.25L_1$ are to be of sufficient strength and weathertightness to resist green sea force if the height of the exposed deck in way of those hatches is less than $0.1L_1$ or 22 *m* above the designed maximum load line, whichever is smaller. The length L_1 is specified in **14.2.1-1**.

19.3 Machinery Space Openings

19.3.1 Protection of Machinery Space Openings

Machinery space openings are to be enclosed by steel casings.

19.3.2 Exposed Machinery Space Casings

1. Exposed machinery space casings are to have scantlings not less than that those required in **18.2.1** and **18.2.2**, taking the *c*-value as 1.0.

2. The thickness of the top plating of exposed machinery space casings is not to be less than that obtained from the following formulae:

Position I: $6.3S + 2.5$ (*mm*)

Position II: $6.0S + 2.5$ (*mm*)

Where:

S : Spacing of stiffeners (*m*)

19.3.3 Machinery Space Casings below Freeboard Deck or within Enclosed Spaces

The scantlings of machinery space casings below the freeboard deck or within enclosed superstructures or deckhouses are to comply with the following requirements:

(1) The thickness of the plating is to be at least 6.5 *mm*; where the spacing of stiffeners is greater than 760 *mm*, the thickness is to be increased at the rate of 0.5 *mm* per 100 *mm* excess in spacing. In accommodation spaces, the thickness of the plating may be reduced by 2 *mm*.

(2) The section modulus of stiffeners is not to be less than that obtained from the following formula:

$1.2Sl^3$ (cm^3)

Where:

l : Tween deck height (*m*)

S : Spacing of stiffeners (*m*)

19.3.4 Access Openings to Machinery Spaces

1. All access openings to machinery spaces are to be located in protected positions as far as possible and provided with steel doors capable of being closed and secured from both sides. Such doors in exposed machinery casings on the freeboard deck are to comply with the requirements in **17.3.1-1**.

2. The sills of doorways in machinery casings are not to be less than 600 *mm* in height above the upper surface of the deck in Position I and 380 *mm* in Position II.

3. In ships having a reduced freeboard, doorways in the exposed machinery casings on the freeboard or raised quarter deck are to lead to a space or passageway which is of a strength equivalent to that of the casing and is separated from the stairway to the machinery spaces by a second steel weathertight door of which the doorway sill is to be at least 230 *mm* in height.

19.3.5 Miscellaneous Openings in Machinery Casings

1. Coamings of any fiddley, funnel and machinery space ventilator in an exposed position on the freeboard or superstructure deck are to be as high above the deck as reasonable and practicable.

2. In exposed positions on the freeboard and superstructure decks, fiddley openings and all other openings in the machinery casings are to be provided with strong steel weathertight covers permanently fitted in their proper positions.

3. Annular spaces around funnels and all other openings in the machinery casings are to be provided with a means of closing capable of being operated from outside the machinery space in case of fire.

19.3.6 Machinery Casings Within Unenclosed Superstructures or Deckhouses

Machinery casings within unenclosed superstructures or deckhouses and doors provided thereon are to be constructed to the satisfaction of the Society, having regard to the degree of protection afforded by the superstructure or deckhouse.

19.4 Companionways and Other Deck Openings

19.4.1 Manholes and Flush Deck Openings

Manholes and flush deck openings in exposed positions on the freeboard and superstructure decks or within superstructures other than enclosed superstructures are to be closed by steel covers capable of being made watertight.

These covers are to be secured by closely spaced bolts or to be permanently fitted.

19.4.2 Companionways

1. Access openings in the freeboard deck are to be protected by enclosed superstructures, or by deckhouses or companionways of equivalent strength and weathertightness.

2. Access openings in exposed superstructure decks or in the top of deckhouses on the freeboard deck which give access to a space below the freeboard deck or a space within an enclosed superstructure are to be protected by efficient deckhouses or companionways.

3. Doorways in deckhouse or companionways such as specified in **-1** and **-2** are to be provided with doors complying with the requirements in **17.3.1-1**.

4. The sills of doorways in companionways specified in **-1** to **-3** are not to be less than 600 *mm* in height above the upper surface of the deck in Position I and 380 *mm* in Position II.

5. For deckhouses or superstructures which protect access openings to spaces below the freeboard deck, the height of sills of doorways on the freeboard deck are not to be less than 600 *mm*. However, where access is provided from the deck above as an alternative to access from the freeboard deck, the height of sills into a bridge or poop or deckhouse may be reduced to 380 *mm*.

6. Where the access openings in superstructures and deckhouses which protect access openings to spaces below the freeboard deck do not have closing appliances in accordance with the requirements of **17.3.1-1**, the openings to spaces below the freeboard deck are to be considered exposed.

19.4.3 Openings to Cargo Spaces

Access and other openings to cargo spaces are to be provided with a means of closing capable of being operated from outside the spaces in case of fire. Such closing means for any opening leading to any other space inboard the ship is to be of steel.

Chapter 20 MACHINERY SPACES AND BOILER ROOMS

20.1 General

20.1.1 Application

The construction of machinery spaces is to be in accordance with the requirements in the relevant Chapters, in addition to this Chapter.

20.1.2 Construction

Machinery spaces are to be sufficiently strengthened by means of web frames, strong beams and pillars or other arrangements.

20.1.3 Supporting Structures for Machinery and Shafting

All parts of the machinery and shafting are to be efficiently supported and adjacent structures are to be adequately stiffened.

20.1.4 Twin Screw Ships and Those with High Power Engines

In twin screw ships and those with high power engines, the structure and attachments of the engines foundations are to be especially strengthened in relation to the engines proportions, weight, power, type, etc.

20.2 Main Engine Foundations

20.2.1 Ships with Single Bottoms

1. In ships with single bottoms, the main engines are to be seated upon thick rider plates laid across the top of deep floors or heavy foundation girders efficiently bracketed and stiffened and having sufficient strength in proportion to the power and size of the engines.

2. The main lines of bolting that hold down the main engines to the rider plates mentioned in **-1** are to pass through the rider plates into the girder plates provided underneath.

3. In ships with longitudinal girders of not excessive spacing beneath the engine which is on the centre line of the hull, the centre keelson may be omitted for the section where the engine is located.

20.2.2 Ships with Double Bottoms

1. In ships with double bottoms, the main engines are to be seated directly upon thick inner bottom plating or thick seat plates on the top of heavy foundations so arranged as to effectively distribute the weight.

2. Additional side girders are to be provided within the double bottom beneath the main lines of bolting and other suitable positions so as to ensure satisfactory distribution of the weight and rigidity of the structure.

20.3 Construction of Boiler Rooms

20.3.1 Boiler Foundations

1. Boilers are to be supported by deep saddle type floors or by transverse or longitudinal girders so arranged as to effectively distribute the weight.

2. Where boilers are supported by transverse saddles or girders, the floors in way of same are to be especially stiffened.

20.3.2 Boiler Location

Boilers are to be so placed as to ensure accessibility and proper ventilation.

20.3.3 Clearance between Boilers and Adjacent Structures

1. Boilers are to be at least 457 *mm* clear of adjacent structures such as tank tops. The thickness of adjacent members is to be increased as may be required where the clearance is unavoidably less. The available clearance is to be indicated on the plans submitted for approval.

2. Hold bulkheads and decks are to be kept well clear of the boilers and uptakes, or provided with suitable insulating arrangements.

3. Side sparrings are to be provided on the bulkheads adjacent to the boilers, keeping suitable clearance on their hold sides.

20.4 Thrust Blocks and Foundations

20.4.1 Thrust Foundations

Thrust blocks are to be bolted to efficient foundations extending well beyond the thrust blocks and so arranged as to effectively distribute the loads into the adjacent structures.

20.4.2 Construction Under Thrust Foundation

Additional girders are to be provided in way of the foundations, as necessary.

20.5 Plummer Blocks and Auxiliary Machinery Seats

20.5.1 General

Plummer blocks and auxiliary machinery seats are to be of ample strength and stiffness in proportion to the weight supported and the height of the foundations.

Chapter 21 TUNNELS AND TUNNEL RECESSES

21.1 General

21.1.1 Arrangement

1. In ships with machinery amidships, the shafting is to be enclosed by a watertight tunnel of sufficient dimensions.

2. Watertight doors are to be provided at the fore end of tunnel. The means of closing and construction of the watertight doors are to be as required in **12.3**.

3. In tunnels which are provided with watertight doors in accordance with the requirement in **-2**, escape trunks are to be provided at a suitable location and they are to lead to the bulkhead deck or above.

21.1.2 Flat Side Plating

The thickness of plating on flat sides of the tunnel is not to be less than that obtained from the following formula:

$$2.9S\sqrt{h} + 2.5\ (mm)$$

Where:

S : Spacing of stiffeners (m)

h : Vertical distance (m) at the mid-length of each hold from the lower edge of the side wall plating to the bulkhead deck at the centre line of the ship

21.1.3 Flat Top Plating

1. The thickness of flat plating of the top of tunnels or tunnel recesses is not to be less than that obtained from the formula in **21.1.2**, h being taken as the height from the top plates to the bulkhead deck at the centre line of the ship.

2. Where the top of tunnels or tunnel recesses form part of the deck, the thickness is to be increased by at least one *mm* above that obtained from the requirements in **-1**, but it is not to be less than that required for the deck plating at the same position.

21.1.4 Curved Top or Side Plating

The thickness of curved top or side plating is to be determined by the requirements in **21.1.2**, using a stiffener spacing reduced by 150 *mm* from the actual spacing.

21.1.5 Top Plating Under Hatchways

Top plating of tunnel under hatchways is to be increased by at least 2 *mm* or to be protected by wood sheathing of not less than 50 *mm* in thickness.

21.1.6 Wood Sheathings

The wood sheathing mentioned in 21.1.5 is to be so secured as to keep watertightness of the tunnel where it might be damaged by cargo. Similar consideration is to be taken where apparatus such as ladder steps are provided in the tunnels.

21.1.7 Stiffeners

1. Stiffeners are to be provided not more than 915 *mm* apart on the top and side plating of tunnels.

2. The section modulus of stiffeners is not to be less than that obtained from the following formula:

$4.0Shl^2$ (cm^3)

Where:

l : Distance (m) from the heel of the lower edge of the side wall to the top of the lat side

S: Spacing of stiffeners (m)

h: Vertical distance (m) at mid-length of each hold from the mid-point of l to the bulkhead deck

3. Where the ratio of the radius of the rounded tunnel top to the height of the tunnel is comparatively large, the section modulus of stiffeners is to be adequately increased over that specified in **-2**.

4. The lower ends of stiffeners over 150 *mm* in depth are to be connected to parts such as the inner bottom plating by lug connections.

21.1.8 Construction Under Masts, Stanchions, and Other Vertical Pieces

Where vertical pieces such as masts and stanchions are attached atop tunnels or tunnel recesses, local strengthening is to be provided in proportion to the weight carried.

21.1.9 Tunnel Top or Tunnel Recess Top Forming part of the Deck

Where the top of tunnels or tunnel recesses forms part of the deck; beams, pillars and girders under the top are to be of the scantlings required for similar members of bulkhead recesses.

21.1.10 Ventilators and Escape Trunks

Escape trunks and ventilators provided in tunnels or tunnel recesses are to be made watertight up to the bulkhead deck and are to be strong enough to withstand the pressure to which they may be subjected.

21.1.11 Tunnels in Water or Oil Tanks

Tunnels in water or oil tanks are to be of equivalent construction and strength to those required for deep tank bulkheads.

21.1.12 Watertight Tunnels

Where watertight tunnels similar to shaft tunnels are provided, they are to be of similar construction to that of the shaft tunnels.

21.1.13 Cylindrical Tunnels

Where cylindrical tunnels pass through deep tanks, the thickness of the plating in way of the tanks is not to be less than that obtained from the following formula:

$$9.1 + 0.134 d_t h \ (mm)$$

Where:

d_t : Diameter of tunnel (*m*)

h : Greater of the vertical distances given below:

Vertical distance (*m*) measured from the bottom of tunnel to the mid-point between the top of tanks and the top of overflow pipes

0.7 times the vertical distance (*m*) measured from the bottom of tunnel to the point 2.0 *metres* above the top of overflow pipes

Chapter 22 BULWARKS, GUARDRAILS, FREEING ARRANGEMENTS, CARGO PORTS AND OTHER SIMILAR OPENINGS, SIDE SCUTTLES, RECTANGULAR WINDOWS, VENTILATORS AND GANGWAYS

22.1 Bulwarks and Guardrails

22.1.1 General

1. Efficient guardrails or bulwarks are to be provided around all exposed decks.

2. Guardrails specified in **-1** above are to comply with the following:

(1) Fixed, removable or hinged stanchions are to be fitted about 1.5 *m* apart. Removable or hinged stanchions are to be capable of being locked in the upright position.

(2) At least every third stanchion is to be supported by a bracket or stay. Alternatively, measures deemed appropriate by the Society are to be taken.

(3) Where necessary for the normal operation of the ship, steel wire ropes may be accepted in lieu of guardrails. The wires are to be made taut by means of turnbuckles.

(4) Where necessary for the normal operation of the ship, chains fitted between two fixed stanchions and/or bulwarks are acceptable in lieu of guardrails.

22.1.2 Dimensions

1. The height of bulwarks or guardrails specified in **22.1.1** is to be at least 1 *metre* from the upper surface of the deck, however, where this height would interfere with the normal operation of the ship and the Society is satisfied that adequate alternative protection is provided; a lesser height may be permitted.

2. The clearance below the lowest course of guardrails on superstructure and freeboard decks is not to exceed 230 *mm*, and those for the other courses are not to be more than 380 *mm*.

3. Guardrails fitted on superstructures and freeboard decks are to have at least three courses. In other locations, guardrails are to have at least two courses.

4. For ships with rounded gunwales, the guardrail supports are to be placed on the flat part of the deck.

22.1.3 Construction

1. Bulwarks are to be strongly constructed and effectively stiffened on their upper edges. The thickness of bulwarks on the freeboard deck is generally to be at least 6 *mm*.

2. Bulwarks are to be supported by stiffened stays connected to the deck in way of beams or at effectively stiffened positions. The spacing of these stays on the freeboard deck is not to be more than 1.8 *m*.

3. Bulwarks on the decks which are designed to carry timber deck cargoes are to be supported by especially strong stays spaced not more than 1.5 *m* apart.

22.1.4 Miscellaneous

1. Gangways and other openings in bulwarks are to be well clear of the breaks of superstructures.

2. Where bulwarks are cut to form gangways or other openings, stays of increased strength are to be provided at the ends of the openings.

3. The plating of bulwarks in way of mooring pipes is to be doubled or increased in thickness.

4. At ends of superstructures, the bulwark rails are to be bracketed either to the superstructure end bulkheads or to the stringer plates of the superstructure decks; or other equivalent arrangements are to be made so that an abrupt change of strength may be avoided.

22.2 Freeing Arrangements

22.2.1 General

1. Where bulwarks on the weather parts of freeboard or superstructure deck form wells, ample provision is to be made for rapidly freeing and draining the decks of water.

2. Ample freeing ports are to be provided for clearing any space other than wells, where water is liable to be shipped and to remain.

3. In ships having superstructures which are open at either or both ends, adequate provisions for freeing the space within superstructures is to be provided.

4. In ships having a reduced freeboard, guardrails are to be provided for at least a half of the length of the exposed parts of the weather deck or other effective freeing arrangements are to be considered, as required by the Society.

22.2.2 Freeing Port Area

1. The freeing port area on each side of the ship for each well on the freeboard and raised quarter decks is not to be less than that obtained from the following formulae. The area for each well on superstructure decks other than the raised quarter deck is not to be less than one-half of that obtained from the formulae.

Where l is not more than 20 m:

$$0.7 + 0.035l + a\ (m^2)$$

Where l is more than 20 m:

$$0.07l + a(m^2)$$

l : Length of bulwark (m), but need not be taken as greater than $0.7L_f$.

a : As obtained from the following formulae.

Where h is more than 1.2 m:

$$0.04l(h - 1.2)(m^2)$$

Where h is not more than 1.2 m, but not less than 0.9 m:

$$0\ (m^2)$$

Where h is less than 0.9 m:

$$-0.04l(0.9 - l)(m^2)$$

h: Average height (m) of bulwarks above the deck

2. In ships either without sheer or with less sheer than the standard, the minimum freeing port area obtained from the formulae in **-1** is to be increased by multiplying with the factor obtained from the following formula:

$$1.5 - \frac{S}{2S_0}$$

S : Average of actual sheer (*mm*)

S_0 : Average of the standard sheer (*mm*) according to the requirements in *ILLC.*

3. Where a ship is provided with a trunk or a hatch side coaming which is continuous or substantially continuous between detached superstructures, the area of the freeing port opening is not to be less than that given by **Table 22.1**.

4. Notwithstanding the requirements in **-1** to **-3**, where deemed necessary by the Society in ships having trunks on the freeboard deck, guardrails are to be provided instead of bulwarks on the freeboard deck in way of trunks for more than half of the length of the trunk.

Table 22.1 Area of Freeing Ports

Breadth of hatchway or trunk	Area of freeing ports in relation to the total of bulwark
$0.41B_f$ or less	0.2
0.75 or more	0.1

Note:

The area of freeing ports at intermediate breadth is to be obtained by linear interpolation.

22.2.3 Arrangement of Freeing Ports

1. Two-thirds of the freeing port area required by 22.2.2 is to be provided in the half of the well near the lowest point of the sheer curve, and the remaining one-third is to be evenly spread along the remaining length of the well.

2. The freeing ports are to have well rounded corners and their lower edges are to be as near the deck as practicable.

22.2.4 Construction of Freeing Ports

1. Where both the length and the height of freeing ports exceed 230 *mm* respectively, freeing ports are to be protected by rails spaced approximately 230 *mm* apart.

2. Where shutters are provided on freeing ports, ample clearance is to be provided to prevent jamming. Hinge pins or bearings of the shutters are to be of non-corrodible materials.

3. The shutters referred to in **-2** are not to be provided with securing appliances.

22.3 Bow Doors and Inner Doors

22.3.1 Application

1. These rules give the requirements for the arrangement, strength and securing of bow doors leading to a complete or long forward enclosed superstructure.

2. In this section, two types of visor and side opening doors (hereinafter collectively referred to as “door(s)”) are provided for.

3. Other types of doors in **-2** are to be specially considered in association with applicable requirements of these rules.

22.3.2 Arrangement of Doors and Inner Doors

1. Doors are to be situated above the freeboard deck. A watertight recess in the collision bulkhead and above the deepest waterline fitted for arrangement of ramps or other related mechanical devices may be regarded as a part of the freeboard deck for the purpose of this requirement.

2. An inner door is to be fitted. The inner door is to be part of the collision bulkhead. The inner door does not need to be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead. Refer to the regulations of **12.1.1**.

3. A vehicle ramp may be arranged as the inner door specified in **-2**, provided that it forms a part of the collision bulkhead and satisfies the requirements for position of the collision bulkhead as stipulated in **12.1.1**.If this is not possible a separate inner weathertight door is to be installed, as far as is practicable within the limits specified for the position of the collision bulkhead.

4. Doors are to be generally weathertight and give effective protection to inner doors.

5. Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with sealing supports on the aft side of the doors.

6. Doors and inner doors are to be arranged so as to preclude the possibility of the door causing structural damage to the inner door or to the bulkhead when damage to or detachment of the door occurs. If this is not possible, a separate inner weathertight door is to be installed, as indicated in **12.1.1**.

7. The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in the stowed position.

22.3.3 Strength Criteria

1. Scantling of primary members and securing and supporting devices of doors and inner doors are to be determined to withstand each design load using the following permissible stresses:

Shearing stress $\tau = \frac{80}{K} (N/mm^2)$

Bending stress $\sigma = \frac{120}{K} (N/mm^2)$

Equivalent stress $\sigma_e = \sqrt{\sigma^2 + 3\tau^2} = \frac{150}{K} (N/mm^2)$

K : Coefficient corresponding to the kind of steel

e.g. 1.0 for mild steel, the values specified in **1.1.6-2(1)** for high tensile steel

2. The buckling strength of primary members is to be verified as being adequate.

3. For steel to steel bearings in securing and supporting devices, the bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed $0.8\sigma_y$, where σ_y is the yield stress of the bearing material.

For other bearing materials, the permissible bearing pressure is to be deemed at the discretion of the Society.

4. The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces.

The maximum tension in way of bolts not carrying support forces is not to exceed:

$$\frac{125}{K}(N/mm^2)$$

K : Coefficient corresponding to the material, as specified in **-1**

22.3.4 Design Loads

1. Doors

(1) The design external pressure Pe , in kN/m^2, to be considered for the scantling of primary members and securing and supporting devices of doors is not to be less than the pressure below:

$$P_e = 2.75(0.22 + 0.15\tan\alpha)\,(0.4V\sin\beta + 0.6\sqrt{L'})^2 (kN/m^2)$$

V : Speed of ship, in *knots*, as specified in **1.2.8, Part 1A**

L' : Length of ship, in *m*, as specified in **1.2.2, Part 1A**, but need not to be greater than 200 *m*

α : Flare angle at the point to be considered

β : Entry angle at the point to be considered

(2) The design external forces F_x , F_y and F_z , considered for the scantlings of securing and supporting devices of doors are not to be less than:

$F_x = P_e A_x$ (kN)

$F_y = P_e A_y$ (kN)

$F_z = P_e A_z$ (kN)

A_x : Area, in m^2, of the transverse vertical projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. In determining the height from the bottom of the door to the upper deck or to the top of the door, the bulwark is to be excluded.

A_y : Area, in m^2, of the longitudinal vertical projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is the lesser.

Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. In determining the height from the bottom of the door to the upper deck or to the top of the door, the bulwark is to be excluded.

A_z : Area, in m^2, of the horizontal projection of the door between the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser

Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. In determining the height from the bottom of the door to the upper deck or to the top of the door, the bulwark is to be excluded.

P_e : External pressure, in kN/m^2, as given in **(1)** with angles a and b defined as follows:

- α : Flare angle measured at a location on the shell $h1/2$ above the bottom of the door and $l/2$ aft of the intersection of the door with the stem
- β : Entry angle measured at a location on the shell $h1/2$ above the bottom of the door and $l/2$ aft of the intersection of the door with the stem
- l : Length, in m, of the door at a height $h1/2$ above the bottom of the door
- w : Breadth, in m, of the door at a height $h1/2$ above the bottom of the door
- h_1 : Height, in m, of the door between the levels of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser

For doors, including bulwark, of unusual form or proportions, e.g. ships with a rounded nose and large stem angles, the area and angles used for determination of the design values of external forces may require special consideration.

(3) For visor doors the closing moment My under external loads is to be taken as:

$$M_y = F_x a + 10W_c - F_z b \ (kN - m)$$

- W : Mass (ton) of the visor door
- a : Vertical distance, in m, from the visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in **Fig. 22.1**
- b : Horizontal distance, in m, from the visor pivot to the centroid of the projected area of the visor door, as shown in **Fig. 22.1**
- c : Horizontal distance, in m, from the visor pivot to the centre of gravity of visor mass, as shown in **Fig. 22.1**

(4) Moreover, the lifting arms of a visor door and its supports are to be dimensioned for the static and dynamic forces applied during lifting and lowering operations, and a minimum wind pressure of 1.5 kN/m^2 is to be taken into account.

2. Inner doors

(1) The design external pressure P_e considered for the scantlings of primary members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of the following:

$P_e = 0.45L'(kN/m^2)$

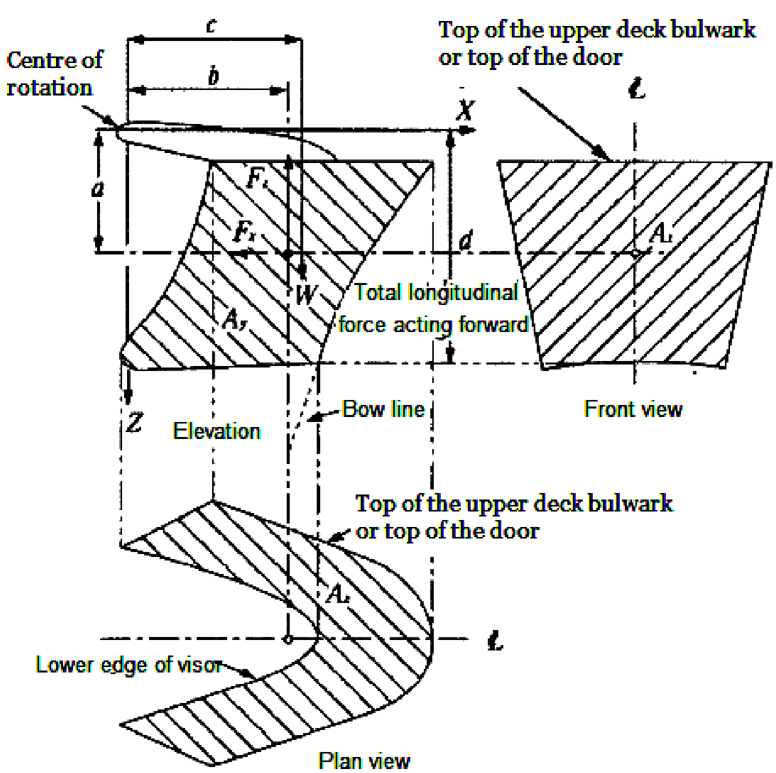
hydrostatic pressure P_h $10h_2 = (kN/m^2)$

h_2 : Distance, in m, from the load point to the top of the cargo space

L' : Length as specified in **-1(1)**

(2) The design internal pressure P_b considered for the scantling devices of inner doors is not to be less than 25 kN/m^2.

Fig. 22.1 Visor type (Upper Hinged Type) Door



22.3.5 Scantlings of Doors

1. General

(1) The strength of the door is to be adequately equivalent to that of the surrounding hull structure.

(2) Adequate strength for opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the ship structure.

2. Plating

The thickness of door plating is not to be less than that required for the side shell plating or the superstructure side shell plating at the position calculated with the stiffener spacing taken as the frame spacing and it is not to be less than the minimum thickness of the shell plating.

3. Secondary stiffeners

(1) Secondary door stiffeners are to be supported by primary members constituting the main stiffening members of the door.

(2) The section modulus of stiffeners of the door is not to be less than that required for frames at the position calculated with the stiffener spacing taken as the frame spacing. Consideration is to be given to differences in fixity between frames and stiffeners.

(3) Stiffener webs are to have a net sectional area, in cm^2, not less than:

$$A = \frac{QK}{10}(cm^2)$$

Q : Shearing force, in kN, in the stiffeners calculated by using uniformly distributed external pressure P_e as given in **22.3.4-1(1)**

K : Coefficient corresponding to the materials as given in **22.3.3-1**

4. Primary structure

(1) The primary members of the door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

(2) Scantlings of primary members are generally to be determined by direct strength calculations in association with the external pressure given in **22.3.4-1(1)**and permissible stresses given in **22.3.3-1**. Normally, formulae for simple beam theory may be applied to determine the bending stress. Members are to be considered to have simply supported end connections.

22.3.6 Scantlings of Inner Doors

1. General

(1) The strength of the inner door is to be equivalent to that of the surrounding hull structure.

(2) The thickness of the inner door is not to be less than that required for plating of the collision bulkhead.

(3) Section modulus of stiffeners of the inner door is not to be less than that required for stiffeners of the collision bulkhead.

(4) Scantlings of primary members are generally to be determined by direct calculations in association with the external pressure given in **22.3.4-2(1)** and permissible stresses in **22.3.3-1.** Normally, formulae for the simple beam theory may be applied.

(5) Stiffeners of the inner door are to be supported by girders.

(6) Where inner doors also serve as vehicle ramps, the scantlings are not to be less than those required for vehicle decks.

(7) The distribution of forces acting on the securing and supporting devices is generally to be determined by direct calculations taking into account the flexibility of the structure and the actual position and stiffness of the supports.

22.3.7 Securing and Supporting of Doors

1. General

(1) Doors are to be fitting with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.

(2) The supporting hull structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

(3) Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered.

(4) Maximum design clearance between securing and supporting devices is generally not to exceed 3 *mm*.

(5) A means is to be provided for mechanically fastening the door and inner door in the open position.

(6) Only active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on these devices. Small and/or flexible devices such as cleats intended to provide local compression of packing material are generally not to be included in the calculations called for in **-2(5)**.

(7) The number of securing and supporting devices are to be the minimum practical whilst taking into account the requirements for redundant provisions given in **-2(6)**, **-2(7)** and the available space for adequate support in the hull structure. Securing devices and supporting devices are to be provided at intervals not exceeding 2.5 *m* and as close to each corner of the door as is practicable.

(8) For visor doors that open outwards, the pivot arrangement is generally to be such that the visor is self closing under external loads, that is $M_y > 0$. Moreover, the closing moment M_y as given in **22.3.4-1(3)** is to be not less than M_{y0} :

$$M_{y0} = 10W_c + 0.1\sqrt{a^2 + b^2}\sqrt{F_x^2 + F_z^2}(kN - m)$$

W, a, b, c, F_x and F_z : As specified in **22.3.4-1**

2. Scantlings

(1) Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in **22.3.3-1**.

(2) For visor doors, the reaction forces applied on the effective securing and supporting devices, assuming the door as a rigid body, are determined for the following combination of external loads acting simultaneously with the self weight of the door:

(a) Case 1: F_x and F_z

(b) Case 2: $0.7F_y$ acting on each side separately together with $0.7F_x$ and $0.7F_z$

Where F_x ,F_y and F_z are determined as indicated in **22.3.4-1(2)** and applied at the centroid of projected areas.

(3) For side-opening doors, the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously with the self weight of the door:

(a) Case 1: F_x ,F_y and F_z acting on both doors

(b) Case 2: 0.7F_x and 0.7F_z acting on both doors and 0.7F_y acting on each door separately,

Where Fx ,Fy and Fz are determined as indicated in **22.3.4-1(2)** and applied at the centroid of projected areas.

(4) The support forces as determined according to **(2)(a)** and **(3)(a)** are to generally give rise to a zero moment about the transverse axis through the centroid of the area A_x . For visor doors, longitudinal reaction forces of pin and/on or wedge supports to the door base contributing to this moment are not to be of the forward direction.

(5) The distribution of the reaction forces acting on the securing and supporting devices may require to be determined by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

(6) The arrangement of securing and supporting devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% of the permissible stresses given in **22.3.3-1**.

(7) For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the permissible stresses given in **22.3.3-1**.

The opening moment M_0 to be balanced by this reaction force is not to be taken as less than:

$$M_0 = 10Wd + 5A_x a \ (kN - m)$$

d : Vertical distance, in m, from the hinge axis to the centre of the door

W, A_x ,a : As defined in **22.3.4-1(3)**

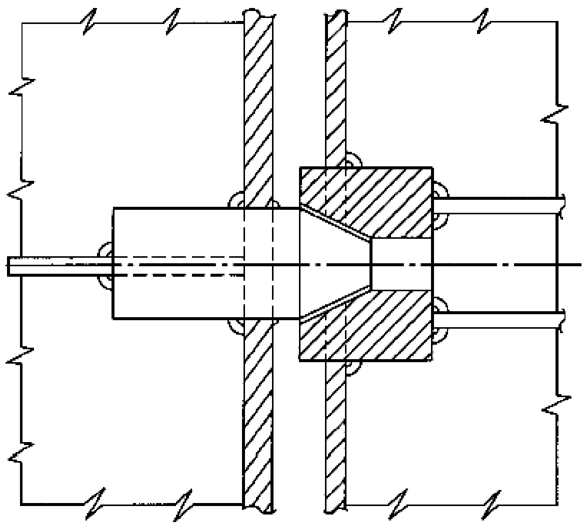
(8) For visor doors, the securing and supporting devices excluding the hinges should be capable of resisting the vertical design forces (F_z -10W) within the permissible stresses given in **22.3.3-1.**

(9) All load transmitting elements in the design load path, from door through securing and supporting devices into the ship structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices.

(10) For side-opening doors, the thrust bearing has to be provided in way of girder ends at the closing of the two leaves to prevent one leaf from shifting towards the other one under the effect of unsymmetrical pressure (*See* example of **Fig. 22.2**). Each part of the thrust bearing has to be kept secured on the other Part by means of securing devices.

(11) Notwithstanding the provision in **(10)**, any other arrangement serving the same purpose may be proposed.

Fig. 22.2 Example of Thrust Bearing



22.3.8 Securing and Locking Arrangement

1. System for operation

(1) Securing devices are to be simple to operate and easily accessible.

(2) Securing devices are to be equipped with a mechanical locking arrangement (self locking or separate arrangement), or to be of the gravity type.

(3) The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

(4) Doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control of the following from a position above the freeboard deck:

  (a) Closing and opening the doors

  (b) Associated securing and locking of every door.

(5) Indication of the open/closed position of every door and every securing and locking device are to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorized persons. A notice plate giving instructions to the effect that all securing devices are to be supplemented by warning indicator lights is to be displayed.

(6) Where hydraulic securing devices are used, the system is to keep the door mechanically closed and locked even in the event of loss of hydraulic fluid. The hydraulic system for securing and locking devices is to be isolated from other circuits, when in the closed position.

2. Systems for indication/monitoring

(1) The separate indicator lights and alarms mentioned in **(a)** and **(b)** below (hereinafter referred to as indication and alarm system) are to be provided at the navigation bridge and on the local operating panel. The indication and alarm system is to be provided with a lamp test function. The indicator light at the navigation bridge is to be designed so as to not be able to be turned off.

(a) Indicator lights to show that the door and inner door are closed and that their securing and locking devices are properly positioned.

(b) In navigation mode, visual and audible alarms to show that the door and inner door are not fully closed and that their securing and locking devices are not properly positioned.

(2) The indication and alarm system specified in **(1)** above is to comply with the following requirements:

(a) The system is to be designed on the fail safe principle.

(b) The power supply for the indication and alarm system is to be independent of the power supply for operating and closing the doors.

(c) The system is to be capable of being supplied from a backup power source.

(d) The sensor of the indication and alarm system is to be protected from water, ice formation and mechanical damage.

(3) The indication and alarm system on the navigation bridge is to be equipped with a mode selecting function that allows selection between “harbour” and “sea voyage”, so that visual and audible alarms specified in **(1) (b)** above will be activated if the vessel leaves a harbour with a door or an inner door unclosed or with any securing device not in the correct position.

(4) A water leakage detection system with audible alarm and television surveillance is to be arranged to provide Indication to the navigation bridge and to the engine control room of leakage through the inner door.

(5) A television surveillance system is to be fitted between the door and inner door with a monitor on the navigation bridge and in the engine control room. The system must monitor the position of the doors and a sufficient number of their securing devices. Special consideration is to be given for lighting and contrasting colour of objects under surveillance.

(6) A drainage system is to be arranged in the area between the door and ramp, or where no ramp is fitted, between the door and inner door. The system is to be equipped with an audible alarm function at the navigation bridge which is set off when the water level in these areas exceeds 0.5 *m* or the high water level alarm, whichever is lesser.

22.3.9 Reinforcement Around Door Openings

1. Shell plating is to be properly rounded at the corners of door openings and is to be reinforced by thicker plate or by doubling plate around the openings.

2. Where frames are cut at the door opening, web frames are to be fitted on both sides of the opening and the structure is to be such that it properly supports the beams above the opening.

22.3.10 Operating and Maintenance Manual

1. An operating and maintenance manual for the door and inner door which is approved by the Society has to be provided on board and contain information on:

(1) Main particulars and design drawings
   (a) Special safety precautions
   (b) Details of vessel, class, statutory certificates
   (c) Equipment and design loading (for ramps)
   (d) Key plan of equipment (doors, inner bow doors and ramps)
   (e) Manufacturer s recommended testing for equipment
   (f) Description of equipment
      i. Doors
      ii. Inner bow doors
      iii. Bow ramp
      iv. Central power pack
      v. Bridge panel
      vi. Engine control room panel

(2) Service conditions
   (a) Limiting heel and trim of ship for loading/unloading
   (b) Limiting heel and trim for door/inner bow door operations
   (c) Doors / Inner bow doors / Ramps operating instructions
   (d) Doors / Inner bow doors / Ramps emergency operating instructions

(3) Maintenance
   (a) Schedule and extent of maintenance
   (b) Trouble shooting and accepable clearances
   (c) Manufacturer s maintenance procedures

(4) Register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

2. Documented operating procedures for closing and securing the door and inner door are to be kept on board and posted at the appropriate places.

22.4 Side Shell Doors and Stern Doors

22.4.1 Application

These rules give the requirements for the arrangement, strength and securing of side shell doors, abaft the collision bulkhead, and stern doors (hereinafter collectively referred to as door(s)) leading into enclosed spaces.

22.4.2 Arrangement of Doors

1. Doors are to be made weathertight.

2. Where the lower edges of any openings of the doors are situated below the freeboard deck, the doors are to be watertight.

3. Notwithstanding the requirements in **-2**, the lower edges of the doors are not to be below a line drawn parallel to the freeboard deck at side, which has at its lowest point at least 230 *mm* above the deepest subdivision draught which correspond to the summer draught assigned to the ship in accordance with the requirements of International Load Line Convention unless additional measures for ensuring watertightness such as the following **(1)** to **(4)** are implemented.

(1) A second door of equivalent strength and watertightness is fitted inside the watertight door

(2) A leakage detection device is provided in the compartment between the two doors

(3) Drainage of this compartment to the bilges is controlled by a readily accessible screw-down valve

(4) The outer door opens outwards

4. The number of door openings is to be kept to the minimum compatible with design and proper operation of the ship.

5. Doors are generally to open outwards.

22.4.3 Strength Criteria

1. Scantlings of primary members and securing and supporting devices of doors are to be determined to withstand the design loads defined in 22.4.4, using the following permissible stresses:

shear stress $\tau = \frac{80}{K} (N/mm^2)$

bending stress $\sigma = \frac{120}{K} (N/mm^2)$

equivalent stress $\sigma_e = \sqrt{\sigma^2 + 3\tau^2} = \frac{150}{K} (N/mm^2)$

K: Coefficient corresponding to the kind of steel

e.g. 1.0 for mild steel, the values specified in **1.1.6-2(1)** for high tensile steel

2. The buckling strength of primary members is to be verified as being adequate.

3. For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed 0.8 Y, where Y is the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be deemed at the discretion of the Society.

4. The arrangements of securing and supporting devices are to be such that threaded bolts do not carry support forces. The maximum tension in way of threads bolts not carrying support forces is not to exceed:

$$\frac{125}{K} (N/mm^2)$$

K : Coefficient corresponding to the material, as specified in **-1**

22.4.4 Design Loads

The design loads for primary members and securing and supporting devices are not to be less than the values given by **Table 22.2** respectively.

Table 22.2 Design Loads

		$F_e(kN)(External\ force)$	$F_i(kN)(Internal\ force)$
Securing and supporting devices	Door opening inwards	$AP_e + F_p$	$F_0 + 10W$
	Door opening outwards	AP_e	$F_0 + 10W + F_p$
Primary Members[1)]		AP_e	$F_0 + 10W$

Notes:

(1) Design loads for primary members is F_e or F_i, whichever is greater.

A : Area (m^2) of the door that bears the actual load in the loading direction.

W : Mass of the door (tons)

F_p : Total packing force (kN). Packing line pressure is normally not to be taken as less than 5 N/mm.

F_0 : The greater of F_c and $5A$ (kN)

F_c : Accidental force (kN) due to loose cargo etc., to be uniformly distributed over the area A and not to be taken as less than $300kN$. Where the area of doors is less than $30m^2$, the valve of F_c may be appropriately reduced to $10A$ (kN).

However, the valve of F_c may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental forces due to loose cargoes.

P_e : External design pressure determined at the centre of gravity of the door opening and not to be taken as less than the value specified in **Table 22.3** (kN/m^2).

Table 22.3 External Design Pressure *Pe*

	$P_e(kN/m^2)$
$ZG < T$	10(T-ZG)+25
$ZG \geq T$	25

Notes:

For stern doors of ships fitted with bow doors, P_e is not to be taken as less than:

$$P_e = 0.6\left(0.8 + 0.6\sqrt{L'}\right)^2$$

T : Draught, in m, at the deepest subdivision load line which correspond to the summer draught assigned to the ship in accordance with the requirements of International Load Line Convention

ZG : Height of the centre of area of the door, in m, above the baseline.

L : Length of ship, in m, as specified in **1.2.2, Part 1A** ,but does not need to be greater than $200m$.

22.4. 5 Scantlings of Doors

1. General

(1) The strength of doors is to be commensurate with that of the surrounding structure.

(2) Doors are to be adequately stiffened and means are to be provided to prevent any lateral or vertical movement of the doors when closed.

(3) Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the ship's structure.

(4) Where doors also serve as vehicle ramps, the design of the hinges should take into account the ship angle of trim and heel which may result in uneven loading on the hinges.

2. Plating

(1) The thickness of door plating is not to be less than the required thickness for the side shell plating or the superstructure side shell plating using the door stiffener spacing, but the thickness of the stern door which is not exposed to direct wave impact by a permanent ramp way provided outside the stern door may be reduced by 20% from the required thickness prescribed above.

(2) Notwithstanding the provision in **(1)** above, the thickness of the door plating is not to be less than the minimum required thickness of shell plating.

(3) Where the doors serve as vehicle ramps, the plating thickness is not to be less than that required for vehicle decks.

3. Secondary stiffeners

(1) The secondary stiffeners are to be supported by primary members constituting the main stiffening of the door.

(2) The section modulus of horizontal or vertical stiffeners is not to be less than that required for frames in the position calculated with the stiffener spacing taken as the frame spacing. Consideration is to be given, where necessary, to differences in fixity between the ship's frames and the door stiffeners.

(3) Where doors serve as vehicle ramps, the stiffener scantlings are not to be less than that required for vehicle decks.

4. Primary structure

(1) Scantlings of primary members are generally to be determined by direct strength calculations in association with the design loads given in **22.4.4** and permissible stresses given in **22.4.3-1**. Normally, formulae for simple beam theory may be applied to determine the bending stress. Members are to be considered to have simply supported end connections.

(2) Webs of primary members are to be properly stiffened in the vertical direction to shell plating.

(3) The primary members and the hull structure in way are to have sufficient stiffness to ensure structural integrity of the boundary of the doors.

(4) Ends of stiffeners and primary members of the doors are to have sufficient rigidity against rotation and the moment of inertia is not to be less than that obtained from the following formula:

$$8d^4F_p \ (cm^4)$$

d : Distance (m) between securing devices

Fp: See Notes for Table **22.2**

(5) Moment of inertia of boundary members of the door which support primary members between securing devices is to be increased in proportion to force.

22.4.6 Securing and Supporting of Doors

1. General

(1) Doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.

(2) The supporting hull structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

(3) Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be as considered appropriate by the Society.

(4) Maximum design clearance between securing and supporting devices is generally not to exceed 3 *mm*.

(5) A means is to be provided for mechanically fastening the door in the open position.

(6) Only active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on these devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material are generally not to be included in the calculations called for in **-2(2)** above.

(7) The number of securing and supporting devices are to be the minimum practical whilst taking into account the requirements for redundant provisions given in **-2(3)** and the available space for adequate support in the hull structure. Securing devices and supporting devices are to be provided at intervals not exceeding 2.5 *m* and as close to each corner of the door as is practicable.

2. Scantlings

(1) Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in **22.4.3-1**.

(2) The distribution of the reaction forces acting on the securing devices and supporting devices may require to be determined by direct calculations taking into account the flexibility of the hull structure and the actual position of the supports.

(3) The arrangement of securing devices and supporting devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% of the permissible stresses given in **22.4.3-1**.

(4) All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship's structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices.

22.4.7 Securing and Locking Arrangement

1. Systems for operation

(1) Securing devices are to be simple to operate and easily accessible.

(2) Securing devices are to be equipped with a mechanical locking arrangement (self locking or separate arrangement), or are to be of the gravity type.

(3) The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

(4) Doors which are located partly or totally below the freeboard deck with a clear opening area greater than 6 m^2 are to be provided with an arrangement for remote control of the following from a position above the freeboard

(a) Closing and opening the doors

(b) Associated securing and locking of every door

(5) For doors which are required to be equipped with a remote control arrangement, indication of the open/closed position of the door and the securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorized persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

(6) Where hydraulic securing devices are used, the system is to keep the door mechanically closed and locked even in the event of loss of hydraulic fluid. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in the closed position.

2. Systems for indication/monitoring

(1) The following requirements apply to doors in the boundary of special category spaces or Ro-Ro spaces through which such spaces may be flooded. For cargo ships, where no part of the door is below the uppermost waterline and the area of the door opening is not greater than 6 m^2, then the requirements of this section need not be applied.

(2) The separate indicator lights and alarms mentioned in **(a)** and **(b)** below (hereinafter referred to as indication and alarm system) are to be provided at the navigation bridge and on the local operating panel. The indication and alarm system is to be provided with a lamp test function. The indicator light at the navigation bridge is to be designed so as to not be able to be turned off.

(a) Indicator lights to show that the door and inner door are closed and that their securing and locking devices are properly positioned.

(b) In navigation mode, visual and audible alarms to show that the door and inner door are not fully closed and that their securing and locking devices are not properly positioned.

(3) The indication and alarm system is to comply with the following requirements:

(a) The system is to be designed on the fail safe principle.

(b) The power supply for the indication and alarm system is to be independent of the power supply for operating and closing the doors;

(c) The system is to be capable of being supplied from a backup power source.

(d) The sensor of the indication and alarm system is to be protected from water, ice formation and mechanical damage.

(4) The indication and alarm system at the navigation bridge is to be equipped with a mode selecting function that allows selection between harbour and sea voyage, so that visual and audible alarms specified in **(2) (b)** above will be activated if the vessel leaves a harbour with a side shell or stern door unclosed or with any securing device not in the correct position.

(5) For passenger ships, a water leakage detection system with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of any leakage through the doors.

(6) A water leakage detection system with visual and audible alarm is to be arranged to provide an indication of any leakage through the doors at the navigation bridge.

22.4.8 Reinforcement Around Door Openings

1. Shell plating is to be properly rounded at the corners of door openings and is to be reinforced by thicker plate or by doubling plate around the openings.

2. Where frames are cut at door openings, adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below.

22.4.9 Operating and Maintenance Manual

1. An approved Operating and Maintenance Manual for the doors is to be provided on board and contain necessary information on:

(1) Main particulars and design drawings
   (a) Special safety precautions
   (b) Details of vessel, class, statutory certificates
   (c) Equipment and design loading (for ramps)
   (d) Key plan of equipment (doors and ramps)
   (e) Manufacturer s recommended testing for equipment
   (f) Description of equipment
      i. Side doors
      ii. Stern doors
      iii. Central power pack
      iv. Bridge panel
      v. Engine control room panel

(2) Service conditions
   (a) Limiting heel and trim of ship for loading/unloading
   (b) Limiting heel and trim for door operations
   (c) Doors/Ramps operating instructions
   (d) Doors/Ramps emergency operating instructions

(3) Maintenance
   (a) Schedule and extent of maintenance

(b) Trouble shooting and accepable clearances

(c) Manufacturer s maintenance procedures

(4) Register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

2. Documented operating procedures for closing and securing doors are to be kept on board and posted at the appropriate places.

22.5 Side Scuttles and Rectangular Windows

22.5.1 General Application

1. The requirements in this chapter apply to side scuttles and rectangular windows on the side shell, superstructures and deckhouses up to the third tier above the freeboard deck. The requirements for the side shell, superstructures and deckhouses above the third tier are to be as deemed appropriate by the Society.

2. Notwithstanding **-1** above, windows on the deckhouse up to the third tier above the freeboard deck may be as deemed appropriate by the Society for windows that do not interfere with the watertightness of the ship and are deemed as necessary for the ship's operation such as those on the navigation bridge.

22.5.2 General Requirement for Position of Side Scuttles

1. No side scuttle is to be provided where its sill is below a line drawn parallel to the freeboard deck at side and having its lowest point 2.5% of the breadth of the ship (*B*') which correspond to the greatest moulded breadth in metres of the ship at or below the deepest subdivision draught. or 500 *mm*, whichever is greater, above the deepest subdivision draught which correspond to the summer draught assigned to the ship in accordance with the requirements of International Load Line Convention.Side scuttles that have their sill below the freeboard deck and which are of a hinged type are to be provided with locking arrangements.

2. No side scuttle is to be provided at any space solely engaged in the carriage of cargoes.

3. The deadlights of side scuttles deemed appropriate by Society may be portable, provided that such scuttles comply with the following requirements **(1)** to **(4)**:

(1) Fitting class *A* side scuttles or class *B* side scuttles is not required.

(2) Such side scuttles are fitted abaft one eighth of the subdivision length (L_s) which correspond to the Subdivision length of the ship (L_s) is the greatest projected moulded length in metres of the ship at or belowdeck or decks limiting the vertical extent of flooding with the ship at the deepest subdivision draught from the forward perpendicular.

(3) Such side scuttles are fitted above a line drawn parallel to the bulkhead deck at side and having its lowest point at a height of 3.7 *m* plus 2.5% of the breadth of the ship (*B*') which correspond to the greatest moulded breadth in metres of the ship at or below the deepest subdivision draught above the deepest subdivision draught which correspond to the summer draught assigned to the ship in accordance with the requirements of International Load Line Convention

(4) Such portable deadlights are to be stowed adjacent to the side scuttles they serve.

4. Automatic ventilating side scuttles is not to be fitted in the shell plating below the freeboard deck.

22.5.3 Application of Side Scuttles

1. Side scuttles inboard are to be class *A* side scuttles, class *B* side scuttles, or class *C* side scuttles complying with the requirements in **Chapter 8, Part 5** or equivalent thereto.

2. Class *A* side scuttles, class *B* side scuttles and class *C* side scuttles are to be so arranged that their design pressure is less than the maximum allowable pressure determined by their nominal diameters and grades. (See **22.5.5**)

3. Side scuttles to spaces below the freeboard deck and those provided to sunken poops are to be class *A* sides cuttles, class *B* side scuttles or equivalent thereto.

4. Side scuttles exposed to direct impact from waves, or that are to spaces within the first tier of side shell or superstructures, first tier deckhouses on the freeboard deck which have unprotected deck openings leading to spaces below the freeboard deck inside, or deckhouses considered buoyant in stability calculations, are to be class *A* side scuttles, class *B* side scuttles or equivalent thereto.

5. Where an opening in the superstructure deck or in the top of the deckhouse on the freeboard deck which gives access to a space below the freeboard deck or to a space within an enclosed superstructure is protected by the deckhouse or companion, the side scuttles fitted to those spaces which give direct access to an open stairway are to be class *A* side scuttles, class *B* side scuttles or equivalent thereto. Where cabin bulkheads or doors separate side scuttles from a direct access leading below the freeboard deck, application of side scuttles is to be as deemed appropriate by the Society.

6. Side scuttles to the spaces in the second tier on the freeboard deck considered buoyant in stability calculations are to be class *A* side scuttles, class *B* side scuttles or equivalent thereto.

7. In ships with an unusually reduced freeboard, side scuttles located below the waterline after flooding into compartments are to be of a fixed type.

22.5.4 Protection of Side Scuttles

All side scuttles in way of the anchor housing and other similar places where they are liable to be damaged are to be protected by strong gratings.

22.5.5 Design Pressure and Maximum Allowable Pressure of Side Scuttles

1. The design pressure of side scuttles is to be less than the maximum allowable pressure (See **Table 22.4**) determined by their nominal diameters and grades. The design pressure *P* is to be determined using the following equation.

$$P = 10ac(bf - y) \quad (kPa)$$

a , b , c and f : As specified in **18.2.1-1**

y : Vertical distance (m) from side scuttle sill to summer load line (or timber load line if given)

2. Notwithstanding the provision of **-1** above, the design pressure is not to be less than the minimum design pressure given in **Table 22.5**.

Table 22.4 Maximum allowable pressure of side scuttles

Class	Nominal Diameter (mm)	Glass thickness (mm)	Maximum allowable pressure (kPa)
A	200	10	328
	250	12	302
	300	15	328
	350	15	241
	400	19	297
B	200	8	210
	250	8	134
	300	10	146
	350	12	154
	400	12	118
	450	15	146
C	200	6	118
	250	6	75
	300	8	93
	350	8	68
	400	10	82
	450	10	65

Table 22.5 Minimum design pressure

	L is 250m and under	L exceeds 250m
Exposed front bulkhead of the first tier superstructure	$25 + L/10 (kPa)$	$50 (kPa)$
Other places	$12.5 + L/20 (kpa)$	$25 (kPa)$

22.5.6 General Requirement for Position of Rectangular Windows

No rectangular window is to be provided to spaces below the freeboard deck, the first tier of superstructures, and the first tier of deckhouses considered buoyant in stability calculations or which protect deck openings leading to spaces below the freeboard deck inside.

22.5.7 Application of Rectangular Windows

1. Rectangular windows inboard are to be class *E* rectangular windows and class *F* rectangular

2. Class *E* rectangular windows and class *F* rectangular windows are to be so arranged that the design pressure is less than the maximum allowable pressure determined by their nominal sizes and grades. (See **22.5.8**)

3. Rectangular windows to spaces in the second tier of the freeboard deck which gives direct access to spaces within the first tier of enclosed superstructures or below the freeboard deck are to be provided with hinged deadlights or externally fixed shutters. Where cabin bulkheads or doors separate the space within the second tier from spaces below the freeboard deck or spaces within the first tier of enclosed superstructures, application of rectangular windows to the spaces within the second tier is to be as deemed appropriate by the Society.

4. Rectangular windows to spaces in the second tier of the freeboard deck considered buoyant in stability calculations are to be provided with hinged deadlights or externally fixed shutters.

22.5.8 Design Pressure and Maximum Allowable Pressure of Rectangular Windows

1. The design pressure of rectangular windows is to be less than the maximum allowable pressure (See**Table 22.6**) determined by their nominal sizes and grades. The design pressure *P* is to be determined using the following equation.

$$P = 10ac(bf - y) \quad (kPa)$$

a , b , c and f : As specified in **18.2.1-1**

y : Vertical distance (m) from the sill of rectangular window to summer load line (or timber load line if given).

2. Notwithstanding the provision of **-1** above, the design pressure is not to be less than the minimum design pressure as given in **Table 22.5**.

22.6 Ventilators

22.6.1 Height of Ventilator Coamings

The height of ventilator coamings above the upper surface of the deck is to be at least 900 *mm* in Position I and 760 *mm* in Position II as specified in **19.1.2**. Where the ship has an unusually large freeboard or where the ventilator serves spaces within unenclosed superstructures, the height of ventilator coamings may be suitably reduced.

22.6.2 Thickness of Ventilator Coamings

1. The thickness of ventilator coamings in Positions I and II leading to spaces below the freeboard deck or within enclosed superstructures is not to be less than that given by Line 1 in **Table 22.7**. Where the height of the coamings is reduced by the provisions in **22.6.1**, the thickness may be suitably reduced.

2. Where ventilators pass through superstructures other than enclosed superstructures, the thickness of ventilator coamings in the superstructures is not to be less than that given by Line 2 in **Table 22.7**.

22.6.3 Connection

Ventilator coamings are to be efficiently connected to the deck and where their height exceeds 900 *mm* are to be specially supported.

Table 22.6 Maximum allowable pressure of rectangular windows

Class	Nominal size Width(*mm*)xheight(*mm*)	Glass thickness (*mm*)	Maximum allowable pressure (*k*Pa)
E	300x425	10	99
	355x500	10	71
	400x560	12	80
	450+630	12	63
	500x710	15	80
F	300X425	8	63
	355X500	8	45
	400X560	8	36
	450X630	8	28
	500X710	10	36
	560X800	10	28
	900X630	12	32
	1000X710	12	25
	1100X800	15	31

Table 22.7 Thickness of Ventilator Coamings

Thickness of coaming plate (*mm*)	Outside diameter of ventilator (*mm*)		
	80 and under	160	230 and over but less than 330
Line 1	6	8.5	8.5
Line 2	4.5	4.5	6

Notes:

1 For intermediate values of outside diameter of ventilator, the thickness of coaming plate is to be obtained by linear interpolation.

2 Where the outside diameter of ventilator is over 330 *mm*, the thickness of coaming plate is to be in accordance with the discretion of the Society.

22.6.4 Cowls

Ventilator cowls are to be fitted closely to coamings and are to have housings of not less than 380 *mm*, except that a smaller housing may be permitted for ventilators of not greater than 200 *mm* in diameter.

22.6.5 Closing Appliances

1. Ventilators to machinery and cargo spaces are to be provided with a means for closing the openings that is capable of being operated from outside the spaces in case of fire.

2. All ventilator openings in exposed positions on the freeboard and superstructure decks are to be provided with efficient weather tight closing appliances. Where the coaming of any ventilator extends to more than 4.5 *m* above the surface of the deck in Position I or more than 2.3 *m*, above the surface of the deck in Position II specified in **19.2.1** such closing appliances may be omitted unless required in **-1**.

3. In ships not more than 100 *m* in length for freeboard, the closing appliances mentioned in **-2** are to be permanently provided; where not so provided in other ships, they are to be conveniently stowed near the ventilators to which they are to be fitted.

22.6.6 Ventilators for Deckhouses

The ventilators for the deckhouses which protect the companionways leading to spaces below the freeboard deck are to be equivalent to those for the enclosed superstructures.

22.6.7 Ventilators for Emergency Generator Room

The coamings of ventilators supplying the emergency generator room is to extend to more than 4.5 *m* above the surface of the deck in Position I, and more than 2.3 *m* above the surface of the deck in Position II specified in **19.1.2**. The ventilator openings are not to be fitted with weathertight closing appliances. However, where due to vessel size and arrangement this requirement is not practicable, the height of ventilator coamings is to be at the discretion of the Society.

22.6.8 Additional Requirement for Ventilators Fitted on Exposed Fore Deck

1. The ventilators located on the exposed deck forward of $0.25L_1$ are to be of sufficient strength to resist green sea force if the height of the exposed deck in way of those ventilators is less than $0.1L_1$ or 22 *m* above the designed maximum load line, whichever is smaller. The length L_1 is specified in **14.2.1-1**.

2. This requirement does not apply to the cargo tank venting systems and inert gas systems of tankers, ships carrying liquefied gases in bulk and ships carrying dangerous chemicals in bulk.

22.7 Gangways

22.7.1 General

Satisfactory means (in the form of guardrails, life lines, gangways or under deck passages, etc.) are to be provided for the protection of the crew in getting to and from their quarters, the machinery space and all other parts used in the necessary work of the ship.

22.7.2 Tankers

1. The requirements in 22.7.2 apply to tankers, ships carrying liquefied gases in bulk and ships carrying dangerous chemicals in bulk (hereinafter referred to as tankers) engaged in international voyages.

2. Tankers are to be provided with the means to enable crew to gain safe access to their bow even in severe weather conditions.

22.8 Means of Embarkation and Disembarkation

22.8.1 General.

1. The wording specially approved by the Society specified in 22.8.1 means those cases where a ship is engaged in voyages between designated ports where appropriate shore accommodation/embarkation ladders (platforms) are provided.

2. With respect to the requirements specified in 22.8.1, the means of embarkation and disembarkation are to be in accordance with the following. However, ships that have small freeboards and are provided with boarding ramps needs not to be in accordance with the following:

(1) Accommodation ladders and gangways are to be constructed based on ISO 5488:1979 *Shipbuilding - accommodation ladders* , ISO 7061:1993 *Shipbuilding - aluminium shore gangways for seagoing vessels* or standards where deemed appropriate by the Society. Accommodation ladder winches are to be constructed based on ISO 7364:1983 *Shipbuilding and marine structures deck machinery accommodation ladder winches* or standards where deemed appropriate by the Society or are to be the one pursuant to aforementioned standards

(2) The structure of the accommodation ladders and gangways and their fittings and attachments are to be such as to allow regular inspection, maintenance of all parts and, if necessary, lubrication of their pivot pin. Special care is to be paid to welding connection.

(3) As far as practicable, the means of embarkation and disembarkation are to be sited clear of the working area and are not to be placed where cargo or other suspended loads may pass overhead. However, in cases where the Society recognizes unavoidable circumstances, the means of embarkation and disembarkation

may be installed within the above mentioned areas or places, provided that safe passage is ensured through description in operation manuals, the installation of warning plates, and so on.

(4) Each accommodation ladder is to be of such a length to ensure that, at a maximum design operating angle of inclination, the lowest platform will be not more than 600*mm* above the waterline in the lightest seagoing condition (in this regard, trim is to be the condition resulting from the loading condition of the lightest seagoing condition), as defined in SOLAS Chapter III, Part A, regulation 3 (13). However, in cases where the height of the embarkation/disembarkation deck exceeds 20*m* above the waterline or is deemed appropriate by the Society, an alternative means of providing safe access to the ship or supplementary means of access to the bottom platform of the accommodation ladder may be accepted.

(5) The arrangement at the head of the accommodation ladder is to provide direct access between the ladder and the ship's deck by a platform securely guarded by handrails and handholds. The ladder is to be securely attached.

Chapter 23 CEILINGS AND SPARRINGS

23.1 Ceilings

23.1.1 Ships with Single Bottoms

1. In ships with single bottoms, close ceilings are to be provided on the floors up to the upper turn of the bilge.

2. The thickness of ceilings is not to be less than 63 *mm*.

3. The ceilings on the flat on the floors are to be laid in portable sections, or other convenient arrangements are to be made for easy removal where required for cleaning, painting or inspection of the bottom.

23.1.2 Ships with Double Bottoms

1. In ships with double bottoms, close ceilings are to be laid from the margin plate to the upper turn of the bilge so arranged as to be readily removable for inspection of the limbers.

2. Ceilings are to be laid on the inner bottoms under hatchways, unless the requirements in **5.5.1-3** and **28.2.4-2** are applied.

3. Ceilings on the top of double bottoms are to be laid on battens not less than 13 *mm* in thickness, or to be bedded on the covering required in **24.1.4**.

4. The thickness of ceilings referred to in **-1** and **-2** is to be as required in **23.1.1-2**.

23.2 Sparrings

23.2.1 Sparrings

1. In all cargo spaces where it is intended to carry general cargo, sparrings not less than 50 *mm* in thickness and not less than 150 *mm* in breadth are to be provided not more than 230 *mm* apart 1bove the bilge ceiling, or equivalent arrangements are to be provided for the protection of framing.

2. In ships intended to carry timbers, hold frames are to be specially protected. However, where it is obvious that the ship is not engaged in the carriage of log cargoes, the protection may be modified.

3. Sparring may be omitted in cargo holds of ships such as coal carriers, bulk carriers, ore carriers and similar ships.

4. General cargo ships may omit sparring only subject to the approval by the Society at the request of owner, in which case the ship is distinguished with the notation "*n.s.*" in the Register Book.

Chapter 24 CEMENTING AND PAINTING

24.1 Cementing

24.1.1 General

The bottom in ships with single bottoms, the bilges in all ships and the double bottoms in the boiler spaces of all ships are to be efficiently protected by Portland cement or other equivalent materials which cover the plates and frames as far as the upper turn of the bilge. However, cement protection may be dispensed with in the bottom of spaces solely used for the carriage of oil.

24.1.2 Portland Cement

Portland cement is to be mixed with fresh water and sand or other satisfactory substances, in the proportion of about one part of cement to two of sand.

24.1.3 Thickness of Cement

The thickness of cement is not to be less than 20 *mm* at the edges.

24.1.4 Special Consideration for Tank Top Plating

The top plating of tanks, where ceiled directly, is to be covered with good tar put on hot and well sprinkled with cement powder, or with other equally effective coatings.

24.2 Painting

24.2.1 General

1. All steel works are to be coated with a suitable paint. Special requirements may be additionally made by the Society in accordance with the kind of ship, purpose of spaces, etc. However, where it is recognized by the Society that the spaces are effectively protected against the corrosion of steel works by means other than painting or due to the properties of the cargoes, etc., painting may be omitted.

2. Steelworks in tanks intended for water may be coated with wash cement in lieu of paint.

3. The surface of steelworks is to be thoroughly cleaned and loose rust, oil and other harmful adhesives are to be removed before being painted. At least the outer surface of shell plating below the load line is to be sufficiently free from rust and mill scale before painting.

24.2.2 Protective Coatings in dedicated seawater ballast tanks and double-side skin spaces

For dedicated seawater ballast tanks of all type of ships of not less than 500 *gross tonnage* engaged on international voyages and double-side skin spaces arranged in bulk carriers engaged on international voyages of 150*m* in length and upwards as defined in **28A.1.2(1)**, the requirements are to be complied with "*PERFORMANCE STANDARD FOR PROTECTIVE COATINGS FOR DEDICATED SEAWATER BALLAST TANKS IN ALL TYPE OF SHIPS AND DOUBLE-SIDE SKIN SPACES OF BULK CARRIERS"* (*IMO Performance Standard for Protective Coatings / IMO* resolution *MSC*.215(82) as may be amended).

Chapter 25 MASTS AND DERRICK POSTS

25.1 General

25.1.1 Masts Without Cargo Gear

1. The outside diameter of steel masts which are not equipped with cargo derricks and are stayed with shrouds as specified in **-4** is not to be less than that obtained from the following formula:

Outside diameter at the uppermost deck at which the mast is supported (hereinafter referred to as the base):

$3.3H\ (cm)$

Outside diameter at the outrigger or at the part to which the upper end of shrouds is connected (hereinafter referred to as the top):

$2.5\ H\ (cm)$

Where:

H : Height (m) of mast from the base to the top

2. The thickness of plating of masts at each part is not to be less than that obtained from the following formula or 5 mm, whichever is greater:

$2.5 + 0.1D_m(mm)$

Where:

D_m : Outside diameter (cm) of masts at each part

3. The base and top of masts are to be properly strengthened.

4. The rigging for the masts is not to be less effective than that obtained from two steel wire shrouds on each side of the ship of the size given in **Table 25.1** so placed that each distance from the forward and after chain plates to the base is not less than one-fourth of the height of the mast from the base to the top or $B/4$, whichever is greater.

Table 25.1 Diameter of Steel Wire Riggings

Height of mast from base to top (m)	9	12	15	18
Diameter of steel wire (mm)	20	22	24	26

Note:

The wire rope is to be No.1 or No.3 wire rope specified in **Chapter 5, Part 5**.

25.1.2 Derrick Posts

The materials, construction and scantlings of masts, derrick posts and stays used for cargo handling will be considered in accordance with the requirements applicable in the "Rules for the Survey and Construction of Cargo Handling Appliances."

Chapter 26 TANKERS

26.1 General

26.1.1 Application

1. The construction and equipment of ships intended to be registered and classed as tankers and intended to carry crude oil, petroleum products having a vapour pressure (absolute pressure) less than 0.28 *MPa* at 37.8°C or other similar liquid cargoes in bulk are to be in accordance with the requirements in this Chapter.

2. The construction, equipment and scantlings of ships intended to carry liquid cargoes having a vapour pressure (absolute pressure) less than 0.28 *MPa* at 37.8 °C in bulk other than crude oil and petroleum products are to be to the satisfaction of the Society, having regard to the properties of the cargoes to be carried.

3. The requirements in this Chapter are for ships with machinery aft having one or more longitudinal bulkheads and single decks with double bottom or with double hull structures or mid-deck.

4. Where the construction of the ship differs from that specified in **-3** and the requirements in this Chapter are considered to be not applicable, matters are to be determined as deemed appropriate by the Society.

5. As regards matters not specifically provided for in this Chapter, the general requirements for the construction and equipment of steel ships are to be applied.

6. In addition to the requirements specified in **-5**, requirements in **Chapter 14 in Part 7**, **Chapter 4 in Part 8**, and **Part 6** of the Rules as applicable according to ship size, navigating area and cargoes carried are to be applied to ships specified in **-1**.

26.1.2 Location and Separation of Spaces

1. In cargo oil spaces, the standard arrangement of bulkheads is to be such that the interval between longitudinal bulkheads or transverse bulkheads does not exceed:

$$1.2\sqrt{L}\ (mm)$$

2. Cofferdams are to be provided in accordance with the following **(1)** to **(3)**:

(1) Cofferdams of air-tight construction with a sufficient width for access are to be provided at fore and aft terminations of cargo oil spaces and the space between cargo spaces and accommodation spaces. However, for oil tankers intended to carry cargo oil having a flash point above 60 °C, the preceding requirements may be suitably modified.

(2) Cofferdams specified in **(1)** may be used as pump rooms.

(3) Fuel oil or ballast water tanks may be concurrently used as the cofferdams to be provided around cargo oil tanks subject to approval by the Society.

3. All areas where there are cargo oil pumps and cargo oil piping are to be segregated by an air-tight bulkhead from areas where stoves, boilers, propelling machinery, electric installations other than those of explosion-proof type in accordance with the requirements in **4.2.4** and **4.3, Part 8** or machinery with a source of ignition is normally present. However, for oil tankers carrying cargo oil having a flash point above 60°C, the requirements may be suitably modified.

4. Ventilation inlets and outlets are to be arranged so as to minimize the possibilities of vapours of cargoes being admitted to an enclosed space containing a source of ignition, or collecting in the vicinity of deck machinery and equipment which may constitute an ignition hazard. Especially, openings of ventilation for machinery spaces are to be situated as far afterwards apart from the cargo spaces as practicable.

5. Ullage openings, sighting ports and tank cleaning openings are not to be arranged in enclosed spaces.

6. The arrangement of openings on the boundaries of superstructures and deckhouses are to be such as to minimize the possibility of accumulation of vapours of cargoes. Due consideration in this regard is to be given to the openings in superstructures and deckhouses when the ship is equipped with cargo piping to load or unload at the stern.

26.2 Minimum Thickness

26.2.1 Minimum Thickness

1. The thickness of structural members in cargo oil tanks and deep tanks such as bulkhead plating, floors, girders including struts, and their end brackets is not to be less than the value determined from **Table 26.1** according to the length of ship.

2. The thickness of structural members in cargo oil tanks and deep tanks is not to be less than 7 *mm*.

Table 26.1 Minimum Thickness

$L(m)$	And over		105	120	135	150	165	180	195	225	275	325	375
	Less than	105	120	135	150	165	180	195	225	275	325	375	
Thickness (*mm*)		8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5

26.3 Bulkhead Plating

26.3.1 Bulkhead Plating in Cargo Oil Tanks and Deep Tanks

1. Thickness t of bulkhead plating is not to be less than the greatest of the values obtained from the following formula when h is substituted with h_1, h_2 and h_3

$$t = C_1 C_2 S\sqrt{h} + 3.5\ (mm)$$

Where:

S: Spacing of stiffeners (m)

h: The following h_1, h_2 and h_3 (m) are to be applied to cargo oil tanks:

h_1: Vertical distance from the lower edge of the bulkhead plating under consideration to the top of hatchway.

For shell plating, a water head corresponding to the minimum draught amidship d_{min} (m) under all operating conditions of the ship may be deducted therefrom. The deductible water head at the top of the keel is to be d_{min}, the value at point d_{min} above the top of the keel, 0, and the value at an intermediate point is to be obtained by linear interpolation.

h_2: As obtained from the following formula:

$$h_2 = 0.85(h_1 + \Delta h)$$

Where:

Δh: Additional water head given by the following formula:

$$\Delta h = \frac{16}{L}(l_t - 10) + 0.25(b_t - 10)(m)$$

l_t : Tank length (m); to be 10, when less than 10 m

b_t : Tank breadth (m); to be 10, when less than 10 m

h_3: As obtained from the following formula:

$$h_3 = 0.3\sqrt{L}$$

The following h_1, h_2, and h_3 (m) are to be applied to deep tanks:

h_1**:** Vertical distance from the lower edge of the bulkhead plating under consideration to the mid-point between the point on the tank top and the upper end of the overflow pipe

For shell plating, a water head corresponding to the minimum draught amidship d_{min} (m) under all operating conditions of the ship may be deducted therefrom. The deductible water head at the top of the keel is to be d_{min} , the value at point d_{min} above the top of the keel, 0, and the value at an intermediate point is to be obtained by linear interpolation.

h_2 : As obtained from the following formula:

$$h_2 = 0.85(h_1 + \Delta h)$$

Δh : As obtained from the formula to determine Δh shown in the section explaining $h2$ for cargo oil tanks.

For tank shapes such as *L-type* and *U-type*, Δh is to be determined as deemed appropriate by the Society.

h_3: Value obtained by multiplying 0.7 by the vertical distance from the lower edge of the bulkhead plating under consideration to the point 2.0 m above the top of overflow pipe

C_1 : Coefficients determined according to values of L as specified below:

1.0, where L is 230 m and below

1.07, where L is 400 m and over

For intermediate values of L, C_1 is to be obtained by linear interpolation.

C_2 : 3.6 $\sqrt{K}$, however, C_2 for h_1 is to be obtained by the following formulae according to the type of bulkhead and stiffening system:

In the case of longitudinal bulkheads of the longitudinal system

$$C_2 = 13.4\sqrt{\frac{K}{27.7 - \alpha K}}$$

However, values of C_2 are not to be less than $3.6\sqrt{K}$.

In the case of longitudinal bulkheads of the transverse system

$$C_2 = 100\sqrt{\frac{K}{767 - \alpha^2 K^2}}$$

In the case of transverse bulkheads

$$C_2 = 3.6\sqrt{K}$$

Where:

K : Coefficient corresponding to the kind of steel

e.g. 1.0 for mild steel, the values specified in **1.1.6-2** for high tensile steel, and the values specified in **1.1.6-3** for stainless steel or stainless clad steel

α : Either α_1 or α_2 according to values of y

However, values of α are not to be less than α_3

when $y_B < y$

$$\alpha_1 = 15.5 f_D \frac{y - y_B}{y_0}$$

when $y \le y_B$

$$\alpha_2 = 15.5 f_B \left(1 - \frac{y}{y_B}\right)$$

$$\alpha_3 = \beta\left(1 - \frac{2b}{B}\right)$$

f_D and f_B : Ratios of section moduli of athwartship section on the basis of mild steel in accordance with the requirements of **Chapter 14** to actual section moduli of athwartship section concerning the strength deck and bottom.

y : Vertical distance (m) from the top of the keel to the lower edge of the bulkhead plating under consideration

y_B : Vertical distance (m) from top of the keel amidship to the horizontal neutral axis of the athwartship section of the hull

y_0 : Greater of the values specified in **14.2.3(5)(a)** or **(b)** ,

β : Coefficient given by the following formulae

For intermediate values of L, β is to be obtained by linear interpolation.

$\beta = \frac{6}{a}$ where L is not more than 230 m

$\beta = \frac{10.5}{a}$ where L is not less than 400 m

a : $\sqrt{K}$ when high tensile steels are used for not less than 80% of side shell plating at the athwartship section amidships, and 1.0 for other parts

b : Horizontal distance (m) from side shell plating to the outer end of the bulkhead plating under consideration

2. In determining the thickness of longitudinal bulkhead plating, coefficient C_2 for h_1 may be gradually reduced for the parts forward and afterward of the midship part, and it may be taken as 3.6 $\sqrt{K}$ in calculations at end parts of the ship.

3. The thickness of shell and deck plating forming cargo oil tanks or deep tanks is not to be less than the thickness obtained through applying the requirements in **-1** and **-2**.

26.3.2 Swash Bulkheads

1. Stiffeners and girders are to be of sufficient strength considering the size of tanks and opening ratios.

2. The thickness of bulkhead plating is not to be less than the value obtained from the following formula:

$$t = 0.3S\sqrt{K(L+150)} + 3.5 \quad (mm)$$

K : As specified in **26.3.1-1**

S : Spacing of stiffeners (m)

3. In determining the thickness of swash bulkhead plating, sufficient consideration is to be given for buckling.

26.3.3 Trunks

The thicknesses of trunk top and side plating are to be determined applying the requirements of **26.3.1** in addition to the requirements in **Chapter 16**.

26.4 Longitudinals and Stiffeners

26.4.1 Longitudinals

1. The section modulus Z of bottom longitudinals is not to be less than the value obtained from the following formula:

$$Z = 100C_1C_2Shl^2 \quad (cm^3)$$

Where:

l : Spacing of girders (m)

S : Spacing of longitudinals (m)

h : Distance (m) from the longitudinals under consideration to the following point above top of keel

$d + 0.026L'$

L': Length of ship (m)

Where, L exceeds 230 m, L' is to be taken as 230 m.

C_1 : As specified in **26.3.1-1**

C_2 : Coefficient given by the following formula:

$$C_2 = \frac{K}{24 - 15.5f_BK}$$

f_B and K : As specified in **26.3.1-1**

2. The section modulus Z of side longitudinals including bilge longitudinals is not to be less than the value obtained from the following formula:

$$Z = 100C_1C_2Sh^2(cm^3)$$

Where:

l and S : As specified in **-1**

h: Distance (m) from the longitudinals under consideration to the following point above the top of keel

$d + 0.038L'$

L': As specified in **-1**

C_1: As specified in **26.3.1-1**

C_2: Coefficient given by the following formula:

$$C_2 = \frac{K}{24 - \alpha K}$$

Where:

K : As specified in **26.3.1-1**

α : $\alpha_1$or α_2 a as given below, whichever is greater

$$\alpha_1 = 15.5f_B\left(1 - \frac{y}{y_B}\right)$$

y : Vertical distance (m) from the top of keel to the longitudinals under consideration

f_B and y_B : As specified in **26.3.1-1**

α_2: Coefficient as given below determined by values of L:

$\alpha_2 = \frac{6}{a}$ when L is not more than 230 m

$\alpha_2 = \frac{10.5}{a}$ When L is not less than 400 m

For intermediate values of L, α_2 is to be obtained by linear interpolation.

a : $\sqrt{K}$ when high tensile steels are used in the athwartship sections of the midship hull for 80% or more of side shell plating, and 1.0 for other cases.

However, the section modulus does not need to exceed that of bottom longitudinals specified in **-1**, but is not to be less than the value obtained from the following formula:

$$Z = 2.9K\sqrt{L}\,Sl^2(cm^3)$$

3. For side longitudinals, sufficient consideration is to be given for fatigue strength.

4. For parts forward and afterward of the midship part, the scantlings of longitudinals may be gradually reduced and at the end parts they may be reduced by 15% of the value obtained from the requirements in **-1** and **-2**. However, the scantlings of longitudinals are not to be less than those required in **-1** and **-2** under any circumstances for the part between the point 0.15L from the fore end and the collision bulkhead.

26.4.2 Bulkhead Stiffeners in Cargo Oil Tanks and Deep Tanks

1. Section modulus Z of stiffeners is not to be less than the value obtained from the following formula:

$$Z = 125C_1C_2C_3Shl^2\ (cm^3)$$

Where:

S : Spacing of stiffeners (m)

h : As specified in **26.3.1-1**

Where the lower edge of the bulkhead plating under consideration is to be construed as the mid-point of the stiffener under consideration for vertical stiffeners; and as the stiffener under consideration for horizontal stiffeners; and side shell plating is to be construed as stiffener attached to side shell plating.

l : Spacing of girders (m)

C_1 : As specified in **26.3.1-1**

C_2 : $\frac{K}{18}$, however, C_2 for h_1 is to be in accordance with the following:

Values of C_2 for h_1 are to be as obtained from the following formulae according to the stiffening system: $C_2 = \frac{K}{24-\alpha K}$ for the longitudinal system

However, the value of C_2 is not to be less than $\frac{K}{18}$.

$C_2 = \frac{K}{18}$ for the transverse system or transverse bulkheads

α and K : As specified in **26.3.1-1**

However, "the lower edge of the bulkhead plating under consideration" and "the bulkhead plating under consideration" are to be construed as "the stiffener under consideration" in applying the requirements for y and b.

C_3 : As determined from **Table 26.2** according to the fixity condition of stiffener ends:

Table 26.2 Value of C_3

The other end	One end			
	Rigid fixity by bracket	Soft fixity by bracket	Supported by girders or lug-connection	Snip
Rigid fixity by bracket	0.70	1.15	0.85	1.30
Soft fixity by bracket	1.15	0.85	1.30	1.15
Supported by girders or lug-connection	0.85	1.30	1.00	1.50
Snip	1.30	1.15	1.50	1.50

Notes:

1 Rigid fixity by bracket means the fixity in the connection between the double bottom plating or comparable stiffeners within adjoining planes and brackets, or equivalent fixity (*see* **Fig. 12.1** (a)).

2 Soft fixity by bracket means the fixity in the connection between beams, frames, etc., which are crossing members, and brackets (*see* **Fig. 12.1** (b) of the Rules).

2. In determining the section modulus of stiffeners attached to bulkhead plating, coefficient C_2 for h_1 may be gradually reduced, and at the end parts C_2 may be as $K/18$.

26.4.3 Buckling Strength

1. Buckling strength of longitudinal frames, beams and stiffeners is to be in accordance with the requirements **(1)** to **(3)** below. The Society may request detailed assessments if deemed necessary according to the materials, scantlings, geometries and arrangement of these structural members.

(1) Longitudinal beams, side longitudinals attached to sheer strakes and longitudinal stiffeners attached to the longitudinal bulkhead within $0.1D$ from the strength deck are to have a slenderness ratio not exceeding 60 at the midship Part as far as practicable.

(2) As for flat bars used for longitudinal beams, frames and stiffeners, the ratio of depth to thickness is not to exceed 15.

(3) The full width of face plates of longitudinal beams, frames and stiffeners is not to be less than that obtained from the following formula:

$$b = 69.6\sqrt{d_0 l}\ (mm)$$

Where:

d_0 : Depth of web (m) of longitudinal beam, frame or stiffener

l : Spacing of girders (m)

2. Where assembled members, special shape steels or flanged plates are used for frames, beams or stiffeners in cargo oil tanks and deep tanks whose scantlings are specified only in terms of the section modulus, the thickness of the web is not to be less than that obtained from the following formula. However, where the depth of the web is intended to be greater than the required level due to reasons other than strength, it may be suitably modified.

$$t = 15K_0 d_0 + 3.5\ \ (mm)$$

Where:

d_0 : Depth of web (m)

K_0 : As specified below:

$K_0\sqrt{\frac{1}{4}\left(3f_B + \frac{1}{K}\right)}$ for bottom longitudinals located not more than $0.25D$ above top of the keel

$K_0 = \sqrt{\frac{1}{4}\left(3f_D + \frac{1}{K}\right)}$ for deck longitudinal located not more than $0.25D$ below deck

$K_0 = \sqrt{\frac{1}{4}\left(3 + \frac{1}{K}\right)}$ for other structural members

f_B , f_D and K : As specified in **26.3.1-1**

26.4.4 Other Precautions

The section modulus of longitudinal beams is not to be less than that obtained by applying the requirements of **9.3.3**. The section modulus of bottom longitudinals, side longitudinals and longitudinal beams in cargo oil tanks or deep tanks is not to be less than that obtained by applying the requirements of **26.4.2**.

26.5 Girders

26.5.1 General

1. The double bottom and double side hull structures and the arrangements and scantlings of girders in cargo oil spaces are to be determined based upon direct calculations.

2. Notwithstanding the requirement in **-1**, the scantlings of girders may be determined in accordance with the requirements in **26.5.3** through **26.5.8** for tankers with L less than 200 m. Specifically, tankers with double bottom structures having longitudinal bulkheads only on the centreline (see Type A specified in **Fig. 14.6**, hereinafter referred to as Type A tankers), tankers with double hull structures having no longitudinal bulkheads on the centreline (see Type C specified in **Fig. 14.6**, hereinafter referred to as Type C tankers), and tankers with double hull structures having longitudinal bulkheads only on the centreline (see Type D specified in **Fig. 14.6**, hereinafter referred to as Type D tankers). The arrangement of primary members in the double bottom, double side hull and cargo oil tank of the cargo tank area are to be determined based on the structural types shown in the following **(1)** through **(5)**. However, in tankers that do not use partial loading conditions such as half-loading or alternate loading, the spacing of girders and floors in the double bottom and stringers and transverses in the double side hull may be increased.

(1) (The height of the double bottom in cargo oil spaces is not to be less than B/20 (m).

(2) The width of the double side hull is not to be less than D/9 (m).

(3) In double bottoms in cargo oil spaces, girders are to be provided at a spacing not exceeding $0.9\sqrt{l_T}\ (m)$and floors are to be provided at a spacing not exceeding $0.55\sqrt{B}\ (m)$ or $0.75\sqrt{D}\ (m)$, whichever is smaller.

(4) In the double side hull, stringers are to be provided at a spacing not exceeding $1.1\sqrt{l_T}\ (m)$

(5) Transverses in the double side hull, cargo oil tanks and deep tanks are to be provided in line with the floors in the double bottom.

3. Notwithstanding the requirement in **-1**, the arrangement and scantling of girders in the double bottom and double side hull of tankers less than 200 m in length except Type A, Type C and Type D tankers are to be to the satisfaction of the Society. However, the scantling of girders in cargo oil tanks and deep tanks of these tankers may be determined by applying the requirements from **26.5.5** to **26.5.8**.

26.5.2 Direct Calculations of Girders

The structural models, loads, allowable stress levels, etc. for determining the arrangement of girders and scantlings based upon direct calculations are to be as deemed appropriate by the Society.

26.5.3 Scantlings of Girders and Floors in Double Bottom

1. The thickness of centre girders and side girders in the double bottom is not to be less than the greatest of either the value t_1 specified in the following **(1)**, or t_2 or t_3 specified in the following **(2)**. However, the thickness of centre girders of tankers having the longitudinal bulkheads on the centreline (Type *A* and Type *D* tankers) are to be determined using only t_3.

(1) The thickness is not to be less than those obtained by the following **(a)**, **(b)** or **(c)** according to the type of tanker:

(a) Type *A* tankers

The thickness obtained from the following formula according to each location in the cargo oil tank:

$$t_1 = C_1 K \frac{S h_B X}{d_0 - d_1} + 2.5 \ (mm)$$

Where:

S : Distance (m) between the centres of two adjacent spaces from side girder under consideration to the adjacent girders or the inner end of tank side brackets

h_B : The greater of the values obtained from the following formulae:

$0.6d + 0.026L\ (m)$

$h' - (d - 0.026L)(m)$

h': Vertical distance (m) from the top of the inner bottom plating to the top of hatches

d_0 : Depth (m) of side girder under consideration

d_1 : Depth (m) of opening at the point under consideration

Where vertical webs attached to the transverse bulkhead are provided in the cargo oil tank, opening in girders provided between the transverse bulkhead and the inner end of brackets of the lower vertical webs may be omitted unless deemed necessary by the Society.

x : Longitudinal distance (m) between the centre of l_T of each cargo oil tank and the point under consideration

Where vertical webs attached to the transverse bulkhead are provided in the cargo oil tank, x may be calculated as the distance up to the inner end of the bracket attached to the lower vertical webs.

Where x is under 0.25 l_T , x is to be taken as 0.25 l_T .

l_T : Length (m) of the cargo oil tank under consideration

C_1 : Coefficient obtained from **Table 26.3** depending on b / l_T .

For intermediate values of b / l_T , C_1 is to be obtained by linear interpolation.

b : Distance (m) between the side shell plating and the longitudinal bulkhead on the centreline of the hull at the top of the inner bottom plating at the midship part

K : As specified in **26.3.1-1**

Table 26.3 Coefficient C_1

$\frac{b}{l_t}$	0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_1	0.045	0.054	0.061	0.068	0.073	0.076	0.079	0.081	0.082

(b) Type *C* tankers

The thickness obtained from the following formula according to each location in cargo oil tank:

$$t_1 = C_1 K \frac{S h_B x}{d_0 - d_1} + 2.5 \ (mm)$$

Where:

S : Distance (m) between the centres of two adjacent spaces from the centre girder or side girder under consideration to the adjacent girders

d_0 : Depth (m) of centre girders or side girder under consideration

x : Longitudinal distance (m) between the centre of l_T of each cargo oil tank and the point under consideration

Where vertical webs attached to the transverse bulkhead are provided in the cargo oil tank, x may be calculated as the distance up to the inner end of the bracket attached to the lower vertical webs.

Where x is under 0.25 l_T , x is to be taken as 0.25 l_T .

C_1 : Coefficient obtained from **Table 26.4** depending on b / l_T

For intermediate values of b / l_T , C_1 is to be obtained by linear interpolation.

b : Distance (m) between the inner ends of the longitudinal bulkheads (when bilge hopper tanks are provided, between the inner ends of hoppers) of the hull at the top of the inner bottom plating at the midship part

h_B , d_1 and l_T are to be in accordance with the requirements of **(a)**.

K : As specified in **26.3.1-1**

Table 26.4 Coefficient C_1

$\frac{b}{l_T}$	1.0 and under	1.2	1.4	1.6 and over
C_1	0.073	0.079	0.082	0.083

(c) Type *D* tankers

The thickness obtained from the following formula according to each location in the cargo oil tank:

$$t_1 = C_1 K \frac{S h_B x}{d_0 - d_1} + 2.5 \ (mm)$$

Where:

S : Distance (m) between the centres of two adjacent spaces from the side girder under consideration to the adjacent girders

x : Longitudinal distance (m) between the centre of l_T of each cargo oil tank and the point under consideration. However, if vertical webs attached to the transverse bulkhead are provided in the cargo oil tank, x may be calculated as the distance up to the inner end of the bracket attached to the lower vertical webs. If x is under $0.25 l_T$, x is to be taken as $0.25 l_T$.

C_1 : Coefficient obtained from **Table 26.5** depending on b / l_T

For intermediate values of b / l , C_1 is to be obtained by linear interpolation.

b : Distance (m) between the longitudinal bulkhead of the double side hull (when bilge hopper tanks are provided, point of the inner end of hopper) and the longitudinal bulkhead on the centreline at the top of the inner bottom plating at the midship part h_B , d_0 , d_1 and l_t are to be in accordance with the requirements of **(a)**.

K : As specified in **26.3.1-1**

Table 26.5 Coefficient C_1

$\frac{b}{l_T}$	0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_1	0.037	0.044	0.051	0.059	0.065	0.070	0.074	0.076	0.079

(2) The thickness is to be greater than those obtained from the following formulae according to the location in the cargo oil tank, irrespective of the type of ship:

$$t_2 = 8.6 \sqrt[3]{\frac{H^2 a^2}{C_1' K}(t_1 - 2.5)} + 2.5 \quad (mm)$$

$$t_3 = \frac{C_1'' a}{\sqrt{K}} + 2.5 \quad (mm)$$

Where:

a : Depth (m) of girders at the point under consideration

However, if horizontal stiffeners are provided on the depth of girders in a lengthwise direction, a is the distance (m) from the horizontal stiffener to the bottom shell plating or inner bottom plating or an adjacent horizontal stiffener.

t_1: Thickness (mm) of girders calculated under the requirements of **(1)** according to the type of tanker.

C_1': Coefficient obtained from **Table 26.6** according to the ratio between a and spacing S_1 (m) of stiffeners provided in the direction of the depth of girders

For intermediate values of S_1/a, C_1' is to be determined by linear interpolation.

H : Value obtained from the following formulae:

(a) Where the girder is provided with an unreinforced opening:

$$1 + 0.5\frac{\emptyset}{\alpha}$$

Where:

$\emptyset$: Major diameter of the openings (m)

α : The greater of a or S_1 (m)

(b) In cases other than **(a)**, H = 1.0.

C_1'' : Coefficient obtained from **Table 26.7** depending on S_1/a

For intermediate values of S_1/a, C_1'' is to be obtained by linear interpolation.

K : As specified in **26.3.1-1**

Table 26.6 Coefficient C_1'

$\frac{S_1}{a}$	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_1''	64	38	25	19	15	12	10	9	8	7

Table 26.7 Coefficient C_1''

$\frac{S_1}{a}$		0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6 and over
C_1''	Centre girder	4.4	5.4	6.3	7.1	7.7	8.2	8.6	8.9	9.3	9.6	9.7
	Side girder	3.6	4.4	5.1	5.8	6.3	6.7	7.0	7.3	7.6	7.9	8.0

2. The thickness of floors in the double bottom is not to be less than the greatest of either the value t_1 specified in the following **(1)**, or t_2 or t_3 specified in the following **(2)**:

(1) The thickness is not to be less than those obtained by the following **(a)**, **(b)** or **(c)** according to the type of tanker:

(a) Type A tankers

The thickness obtained from the following formula according to each location in the cargo oil tank:

$$t_1 = C_2 K \frac{S b h_B}{d_0 - d_1}\left(1 - \frac{4}{3}\frac{y}{b'}\right) + 2.5 \quad (mm)$$

Where:

S : Spacing of floors (m)

h_B : The greater of the values obtained from the following formula

However, for tankers without abnormal loading conditions such as half-loading or alternate loading, h_B specified in **-1(1)(a)** may be used.

$d + 0.026L(m)$

$h' - (0.6d - 0.026L)(m)$

d_0 : Height (m) of floors at the point under consideration.

d_1 : Depth (m) of opening at the point under consideration

However, if transverses attached to the longitudinal bulkhead or side transverses attached to the side shell plating are provided in the cargo oil tank, openings in floors between the longitudinal bulkhead or side shell plating and the inner end of the brackets of the lower transverses under consideration may be omitted except when deemed necessary by the Society.

b' : Distance (m) between the side shell plating and the longitudinal bulkhead on the centreline of the hull at the top of the inner bottom plating at the floors under consideration

y : Athwartship distance (m) at the floors under consideration from centreline of the hull to the point under consideration

However, if transverses attached to the longitudinal bulkhead are provided in the cargo oil tank, y may be calculated as the distance up to the inner end of the bracket under consideration for spaces between the longitudinal bulkhead and the inner end of the bracket of lower transverses.

If y exceeds 0.3 b', y is to be taken as 0.3 b'.

C_2 : Coefficient obtained from **Table 26.8** depending on b / l_t

For intermediate values of b / l_t, C_2 is to be obtained by linear interpolation.

b, h' and l_t are to be in accordance with the requirements of **-1(1)(a).**

K : As specified in **26.3.1-1**

Table 26.8 Coefficient C_2

$\frac{b}{l_T}$	0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_2	0.047	0.048	0.047	0.046	0.045	0.043	0.041	0.039	0.037

(b) Type C tankers

The thickness obtained from the following formula according to each location in the cargo oil tank:

$$t_1 = C_2 K \frac{Sbh_B}{d_0 - d_1} \frac{2y}{b'} + 2.5\ (mm)$$

Where:

d_1 : Depth (m) of opening at the point under consideration

However, if brackets attached to the lower transverses of the double side hull are provided, the openings in floors between the longitudinal bulkhead and the inner end of the brackets under consideration may be omitted except when deemed necessary by the Society.

b': Distance (m) between the inner ends of the longitudinal bulkheads (between the inner ends of hopper, if bilge hopper tanks are provided) at the top of inner bottom plating at the floors under consideration

y : Athwartship distance (m) at the floors under consideration from the centreline of the hull to the point under consideration

Where brackets attached to the lower transverses of the double side hull are provided, y may be calculated as the distance up to the inner end of the bracket under consideration. Where y is under $0.25b'$, y is to be taken as $0.25b'$

C_2 : Coefficient obtained from **Table 26.9** depending on b/l_T

For intermediate values of b/l_T, C_2 is to be obtained by linear interpolation.

S, h_B and d_0 are to be in accordance with the requirements of **(a)**.

l_T: As specified in **-1(1)(a)**

b : As specified in **-1(1)(b)**

K : As specified in **26.3.1-1**

Table 26.9 Coefficient C_2

$\frac{b}{l_T}$	1.0 and under	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6 and over
C_2	0.036	0.033	0.031	0.28	0.026	0.024	0.022	0.021	0.019

(c) Type D tankers

The thickness obtained from the following formula according to each location in the cargo oil tank:

$$t_1 = C_2 K \frac{Sbh_B}{d_0 - d_1} \frac{2y}{b'} + 2.5\ (mm)$$

Where:

d_1 : Depth (m) of opening at the point under consideration.

However, if brackets attached to the lower transverses of the double side hull or the lower transverses of the longitudinal bulkhead on the centreline of the hull in the cargo oil tank are provided, the openings in floors between the longitudinal bulkhead of the double side hull or the longitudinal bulkhead on the centreline of the hull and the inner end of the brackets under consideration may be omitted except when deemed necessary by the Society.

b' : Distance (m) between the longitudinal bulkhead of the double side hull (between the inner ends of the hopper, when bilge hopper tanks are provided) and the longitudinal bulkheads on the centerline of the hull at the top of the inner bottom plating at the floors under consideration

y : Athwartship distance (m) at the floors under consideration from the centre of b' to the point under consideration

Where brackets attached to the lower transverses of the double side hull or the lower transverses of the longitudinal bulkhead on the centreline of the hull in the cargo oil tank are provided, y may be calculated respectively as the distance up to the inner end of the bracket attached the lower transverses of the double side hull or up to the inner end of the bracket attached to the lower transverses of longitudinal bulkhead on the centreline of the hull. Where y is under $0.25b'$, y is to be taken as $0.25\ b'$

C_2 : Coefficient obtained from **Table 26.10** depending on b/l_T

For intermediate values of b/l_T, C_2 is to be obtained by linear interpolation.

S, h_B and d_o are to be in accordance with the requirements of **(a)**.

l_T : As specified in **-1(1)(a)**

b : As specified in **-1(1)(c)**

K : As specified in **26.3.1-1**

Table 26.10 Coefficient C_2

$\frac{b}{l_T}$	0.6 and under	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_2	0.042	0.041	0.041	0.040	0.039	0.038	0.036	0.035

(2) Greater of the thicknesses obtained from the following formulae according to the location in the cargo oil tank, irrespective of the type of ship:

$$t_2 = 8.6\sqrt[3]{\frac{H^2a^2}{C_2'K}(t_1 - 2.5)} + 2.5\ (mm)$$

$$t_3 = \frac{8.5S_2}{\sqrt{K}} + 2.5\ (mm)$$

Where:

a : Depth (m) of floors at the point under consideration

Where horizontal stiffeners are provided on the depth of floors in a lengthwise direction, a is the distance (m) from the horizontal stiffener to the bottom shell plating or the inner bottom plating or an adjacent horizontal stiffener.

t_1 : Thickness (mm) of floors calculated under the requirements of **(1)** according to the type of tanker

C_2': Coefficient obtained from **Table 26.11** according to the ratio between a and spacing S_1 (m) of stiffeners provided in the direction of the depth of floors

For intermediate values of S_1/a, C_2' is to be determined by linear interpolation.

H : Value obtained from the following formulae:

(a) Where the floor is provided with an unreinforced opening:

$$1 + 0.5\frac{\emptyset}{\alpha}$$

Where:

$\emptyset$: Major diameter (m) of the openings

α : The greater of a or S_1 (m)

(b) In cases other than **(a)**, H = 1.0

S_2 : The smaller of S_1 or a (m)

K : As specified in **26.3.1-1**

Table 26.11 Coefficient C_2'

$\frac{S_1}{a}$	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_2'	64	38	25	19	15	12	10	9	8	7

26.5.4 Scantlings of Stringers and Transverses in Double Side Hull

1. The thickness of stringers in the double side hull is not to be less than the greatest of either the value t_1 specified in the following **(1)**, or t_2 or t_3 specified in the following **(2)**:

(1) 0.5 thicknesses obtained by the following **(a)** or **(b)** according to the type of tanker:

(a) Type C tankers

The thickness obtained from the following formula according to each location in the cargo oil tank:

$$t_1 = C_3 K \frac{S h_S x}{d_0 - d_1} + 2.5\ (mm)$$

Where:

S : Breadth (m) of Part supported by stringers

h_S : The greater of the values obtained from the following formulae:

$(0.6d - d_3) + 0.038L\ (m)$

$h'\ (m)$

d_3 : Height (m) of double bottom at ship's sides (however, to include the vertical distance up to the upper end of bilge hopper, if provided)

h' : Vertical distance (m) from the upper end of the bilge hopper, if provided, or the top of the inner bottom plating to the top of hatches

d_0 : Depth of stringers (m)

d_1 : Depth (m) of opening at the point under consideration

where horizontal girders attached to the transverse bulkhead are provided in the cargo oil tank, openings in stringers between the transverse bulkhead and the inner end of the bracket at the end of horizontal girders under consideration may be omitted except when deemed necessary by the Society.

x : Longitudinal distance (m) between the centre of l_T of each cargo oil tank and the point under consideration.

Where horizontal girders attached to the transverse bulkhead are provided in the cargo oil tank, x may be calculated as the distance up to the inner end of the bracket attached to the end of horizontal girders under consideration. Where x is under 0.25 l_T , x is to be taken as 0.25 l_T.

l_T : Length (m) of the cargo oil tank under consideration

C_3 : Coefficient obtained from **Table 26.12** depending on D'/l_T

For intermediate values of D'/l_T, C_3 is to be obtained by linear interpolation.

D': Value obtained from the following formula:

$$D' = D - d_3\ (m)$$

K : As specified in **26.3.1-1**

Table 26.12 Coefficient C_3

$\frac{D'}{l_T}$	0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_3	0.013	0.019	0.025	0.030	0.034	0.037	0.039	0.042	0.045

(b) Type D tankers

The thickness obtained from the following formula according to each location in the cargo oil tank:

$$t_1 = C_3 K \frac{S h_S x}{d_0 - d_1} + 2.5\ (mm)$$

Where:

x : Longitudinal distance (m) between the centre of l_T of each cargo oil tank and the point under consideration Where horizontal girders attached to the transverse bulkhead are provided in the cargo oil tank, x may be calculated as the distance up to the inner end of the bracket attached to the end of horizontal girders under consideration. Where x is under 0.25 l_T , x is to be taken as 0.25 l_T .

C_3 : Coefficient obtained from **Table 26.13** depending on D'/l_T

For intermediate values of D'/l_T, C_3 is to be obtained by linear interpolation.

S, l_T, h_S ,d_0, d_1, D' and K are to be in accordance with the requirements of **(a)**.

K : As specified in **26.3.1-1**

Table 26.13 Coefficient C_3

$\frac{D'}{l_T}$	0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_3	0.020	0.024	0.028	0.032	0.035	0.038	0.040	0.042	0.045

(2) Greater of the thicknesses obtained from the following formulae according to the location in the cargo oil tank, irrespective of the type of ship:

$$t_2 = 8.6\sqrt[3]{\frac{H^2 a^2}{C_3' K}(t_1 - 2.5)} + 2.5\ (mm)$$

$$t_3 = \frac{8.5 S_2}{\sqrt{K}} + 2.5\ (mm)$$

Where:

a : Depth (m) of stringers at the point under consideration

Where horizontal stiffeners are provided on the depth of stringers in a lengthwise direction, a is the distance (m) from the horizontal stiffener to the side shell plating or adjacent horizontal stiffener or the longitudinal bulkhead of the double side hull.

t_1 : Thickness (mm) of stringers calculated under the requirements of **(1)** according to the type of tanker.

C_3': Coefficient obtained from **Table 26.14** according to the ratio between a and spacing S_1 (m) of stiffeners provided in the direction of the depth of stringers

For intermediate values of S_1/a, C_3' is to be obtained by linear interpolation.

H : Value obtained from the following formulae:

(a) Where the stringer is provided with an unreinforced opening:

$$1 + 0.5\frac{\emptyset}{\alpha}$$

Where:

$\emptyset$: Major diameter (m) of the openings

α: The greater of a or S_1 (m)

(b) In cases other than **(a)**, $H = 1.0$

S_2 : The smaller of S_1 or a (m)

K : As specified in **26.3.1-1**

Table 26.14 Coefficient C_3'

$\frac{S_1}{a}$	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_3'	64	38	25	19	15	12	10	9	8	7

2. The thickness of transverses in the double side hull is not to be less than the greatest of either the value t_1 specified in the following **(1)**, or t_2 or t_3 specified in the following **(2)**:

(1) Not to be less than either of the thickness obtained by the following **(a)** or **(b)** according to the type of tanker:

(a) Type *C* tankers

The thickness obtained from the following formula according to each location in the cargo oil tank:

$$t_1 = C_4 K \frac{SD' h_s}{d_0 - d_1}\left(1 - 1.75\frac{z}{D'}\right) + 2.5(mm)$$

Where:

S : Breadth (m) of Part supported by transverses

h_S : The value obtained from the following formulae, whichever is the greater

However, for tankers without abnormal loading conditions such as half-loading or alternate loading,

h_S specified in **-1(1)(a)** may be used.

$(d - d_3) + 0.038L$ (m)

h' (m)

d_0 : Depth of transverses (m)

d_1 : Depth (m) of opening at the point under consideration

However, if brackets attached to the lower transverses of the double side hull are provided, the openings in transverses between the top of the inner bottom plating and the inner end of the bracket under consideration may be omitted except when deemed necessary by the Society.

z : Distance (m) in the direction of the ship's depth between the top of the inner bottom plating or the top of the bilge hopper, if provided, and the point under consideration

Where brackets attached to the lower transverses of the double side hull are provided, z may be calculated as the distance at the inner end of the bracket under consideration for spaces between the top of the inner bottom plating and the inner end of the bracket. Where z exceeds $0.4D'$, z is to be taken as $0.4D'$.

C_4 : Coefficient obtained from **Table 26.15** depending on D' / l_T

For intermediate values of D' / l_T, C_4 is to be obtained by linear interpolation.

D', h', d_3 and l_T are to be in accordance with the requirements of **-1(1)(a)**.

K : As specified in **26.3.1-1**

Table 26.15 Coefficient C_4

$\frac{D'}{l_T}$	0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_4	0.052	0.051	0.049	0.046	0.043	0.041	0.038	0.036	0.0034

(b) Type *D* tankers

The thickness obtained from the following formula according to each location in the cargo oil tank:

$$t_1 = C_4 K \frac{SD'h_s}{d_0 - d_1}\left(1 - 1.75\frac{z}{D'}\right) + 2.5\ (mm)$$

Where:

z : Distance (*m*) in the direction of the ship's depth between the top of the inner bottom plating or the top of the bilge hopper, if provided, and the point under consideration.

Where brackets attached to the lower transverses of the double side hull are provided, *z* may be calculated as the distance at the inner end of the bracket under consideration for spaces between the top of inner bottom plating and the inner end of the bracket under consideration. Where *z* exceeds $0.4D'$, *z* is to be taken as $0.4D'$.

C_4 : Coefficient obtained from **Table 26.16** depending on D'/l_T

For intermediate values of D'/l_T, C_4 is to be obtained by linear interpolation.

S, h_S , d_0 and d_1 are to be in accordance with the requirements of **(a)**.

D' and l_T are to be in accordance with the requirements in **-1(1)(a)**.

K : As specified in **26.3.1-1**

Table 26.16 Coefficient C_4

$\frac{D'}{l_T}$	0.8 and under	0.9	1.0	1.1	1.2	1.3 and over
C_4	0.034	0.033	0.033	0.032	0.031	0.030

(2) Greater of the thicknesses obtained from the following formulae according to the location in the cargo oil tank, irrespective of the type of ship:

$$t_2 = 8.6\sqrt[3]{\frac{H^2 a^2}{C_4' K}(t_1 - 2.5)} + 2.5\ (mm)$$

$$t_3 = \frac{8.5 S_2}{K} + 2.5\ (mm)$$

Where:

a : Depth (*m*) of transverses at the point under consideration

Where vertical stiffeners are provided on the depth of transverses in a lengthwise direction, a is the distance (m) from the vertical stiffener to the side shell or an adjacent vertical stiffener or the longitudinal bulkhead of the double side hull.

t_1: Thickness of transverses calculated under the requirements of **(1)** according to the type of tanker (mm)

C_4': Coefficient obtained from **Table 26.17** according to the ratio between a and spacing S_1 (m) of stiffeners provided in the direction of the depth of transverses

For intermediate values of S_1/a, C_4' is to be obtained by linear interpolation.

H : Value obtained from the following formulae:

(a) Where the stringer is provided with an unreinforced opening:

$$1 + 0.5\frac{\emptyset}{\alpha}$$

Where:

$\emptyset$: Major diameter (m) of the openings

a : The greater of a or S_1 (m)

(b) In cases other than **(a)**, H = 1.0

S_2 : The smaller of S_1 or a (m)

K : As specified in **26.3.1-1**

Table 26.17 Coefficient C_4'

$\frac{S_1}{a}$	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_4'	64	38	25	19	15	12	10	9	8	7

26.5.5 Girders and Transverses in Cargo Oil Tanks and Deep Tanks

1. The section modulus Z of girders is not to be less than that obtained from the following formula:

$$Z = 7.13C_1KShl_0^2\,(cm^3)$$

Where:

S : Width (m) of the area supported by the girders

h : As specified in **26.3.1-1**

However, from the lower edge of the bulkhead plating under consideration is to be construed as from the midpoint of S for horizontal girders, and as from the midpoint of l_o for vertical girders in applying the value of h.

l_0 : Length of girders obtained from the following formula:

$l_0 = kl$ (m)

l : Total length of girders (m), and where conjoined with other girders and transverses, the distance (m) to the inner surface of face plates of the girder

k : Correction factor for brackets to be as obtained from the following formula:

$$k = 1 - \frac{0.65(b_1 + b_2)}{l}$$

b_1 and b_2 : Arm length (m) of brackets, at respective ends of girders and transverses

K : As specified in **26.3.1-1**

C_1 : Coefficient determined by L as given below:

C_1 = 1.0, where L is not more than 230 m

C_1 = 1.20, where L exceeds 400 m

For intermediate values of L, C_1 is to be obtained by linear interpolation.

2. The moment of inertia of girders is not to be less than that obtained from the following formula. However, the depth of girders is not to be less than 2.5 times the depth of slots.

$$I = 30hl_0^4 (cm^4)$$

Where:

h, l_0 : As specified in **-1**

3. The thickness of girders is not to be less than the greatest of the following t_1, t_2 or t_3:

$$t_1 = 0.0417 \frac{C_1 C_2 KShl_0}{d_1} + 3.5\ (mm)$$

$$t_2 = 1.74 \sqrt[3]{\frac{C_1 C_2 Shl_0 S_1^2}{d_1}} + 3.5\ (mm)$$

$$t_3 = \frac{C_3}{\sqrt{K}} d_0 + 3.5\ (mm)$$

Where:

S, h, l_0, C_1 and K : As specified in **-1**

S_1: Spacing (m) of stiffeners of girders or the depth (m) of girders, whichever is smaller

d_1: Depth (m) of the girder under consideration minus the depth (m) of openings

C_2: Coefficient as obtained from the following formula. It is not to be less than 0.5 under any circumstances:

$$C_2 = \left|1 - 2\frac{x}{l_0}\right| \text{ for horizontal girders}$$

$$C_2 = \left|1 + \frac{1}{5}\frac{l_0}{h} - \left[2 + \frac{l_0}{h}\right]\frac{x}{l_0} + \frac{l_0}{h}\left[\frac{x}{l_0}\right]^2\right|$$

x : Distance (m) from the end of l_0 to the sectional area under consideration, and from the lower end of l_0 for vertical girders

d_0 : Depth of web plate (m) (where stiffeners are parallel to the face plate on the mid part of web plates, d_0 is the distance (m) between the stiffener and the shell plating or the face plate or adjacent stiffener)

C_3 : Coefficient which is to be taken as follows:

(1) Where the webs of girders situated above the position approximately 0.25 D below the lower edge of the deck at the ship's sides, C3 is determined according to the ratio of S' to d_0 as follows, where S' (m) is the spacing of stiffeners on web plates provided in a depthwise direction:

Where $\frac{S'}{d_0} \geq 1.0: C_3 = 11.0$

Where $\frac{S'}{d_0} < 1.0: C_3 = 11.0\sqrt{\frac{S'}{d_0}}$

(2) For webs of girders and transverses other than those specified in **(1)**, C_3 is given in **Table 26.18** according to the ratio of S' to d_0. For intermediate values of S'/d_0, C_3 is to be obtained by interpolation. Where the webs of girders situated higher than $D/3$ above the top of the keel or the lower edge of the face plate at the lower side of the second cross tie from the deck, whichever is the lower, C_3 may be as given in **Table 26.18** multiplied by 0.85, subject to the requirements in i) and ii) below:

(a) Where no stiffener is provided in parallel with the face plates: α_1

However, where there are slots, α_2 is to be used and is not to be less than that obtained by applying the requirement in i)

(b) Where stiffeners are provided in parallel with the face plates, for the panel between the face plate and the stiffener or between the stiffeners: α_3

However, the thickness need not exceed the value obtained by using coefficient α_1, assuming no slots or stiffeners parallel with the face plate are provided.

For the panel between the stiffener and the shell plating: α_2

i) Where slots are provided on webs with no reinforcement, α_1, α_2 and α_3 are to be multiplied bythe following factor:

$$\sqrt{4.0\frac{d_1}{S'} - 1.0}$$

Where d_1/S' is 0.5 or less, the multiplier is to be taken as 1.0.

Where:

d_1: Depth of slots (m)

ii) Where openings are provided on webs with no reinforcement, α_1, α_2 and α_3 are to be multiplied by the following factor:

$$1 + 0.5\frac{\emptyset}{a}$$

Where:

a : Length (m) at the longer side of the panel surrounded by web stiffeners

$\emptyset$: Diameter of openings (m)

Where openings are oblong, $\emptyset$ is to be the length (m) of the longer diameter.

Table 26.18 α_1, α_2 and α_3

$\frac{S'}{d_0}$	0.2 and under	0.4	0.6	0.8	1.0	1.5	2.0	2.5 and over
α_1	2.6	4.5	5.6	6.4	7.1	7.8	8.2	8.4
α_2	2.1	3.7	4.9	5.8	6.6	7.4	7.8	8.0
α_3	3.7	6.7	8.6	9.6	9.9	10.3	10.4	10.4

4. Effective steel plates used for calculating the actual moment of inertia of girders and section modulus are to be as specified in **1.1.11-3**. Where stiffeners are provided within the effective width, they may be included with the effective steel plates.

5. The thickness of webs at the root of struts for girders and transverses where struts are provided is not to be less than that obtained from the following formula. Where slots are provided in webs at the root of struts, they are to be covered effectively with collar plates.

$$t = 16\sqrt{\frac{C_1 S b_S h_s}{A}} S_1 \quad (mm)$$

Where:

S : Spacing (m) of transverses

b_S : Width (m) supported by struts

h_S : Distance from mid-point of b_S to the following point above top of the keel:

$d + 0.038L'(m)$

L': As specified in **26.4.1-1**

C_1 : As specified in **-1**

S_1 : Spacing (m) of stiffeners provided depthwise on the web plates of transverses at the portion where cross ties are connected

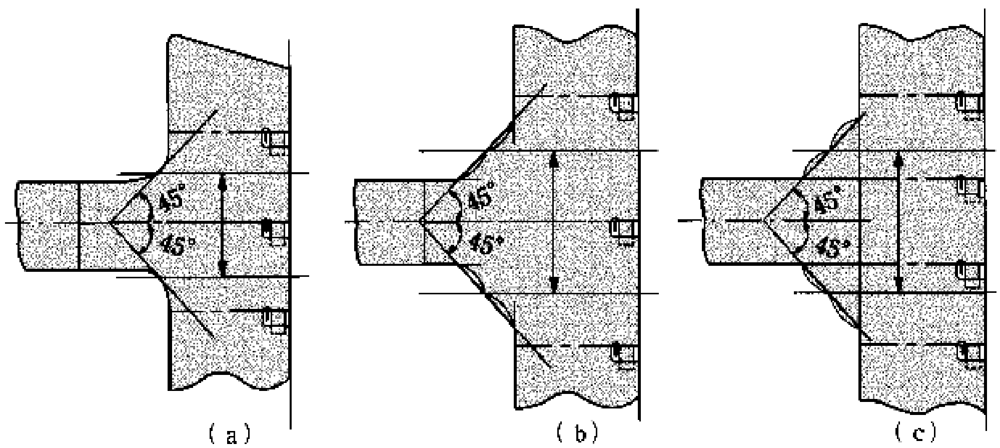
A : Sectional area (cm^2) effective to support the axial force from cross ties, which is to be taken as follows:

(a) Where the face plates of cross ties are continuous to the face plates of transverses and form an arc (or similar curve), A is the total sum of the sectional area of the web plate of the transverse and the stiffeners provided in the axial direction of the cross tie on the web plate between two points, and 0.5 times the sectional area of the face plates at these points. Each point is located on its respective arc where the tangent makes an angle of 45° to the axial direction of the cross tie (*See* **Fig. 26.1** (a)).

(b) Where the face plates of cross ties are continuous to the face plates of transverses and form a straight line with rounded corners, A is the total sum of the sectional area of the web plate of the transverse and the stiffeners provided in the axial direction of the cross tie on the web plate between two points, and 0.5 times the sectional area of the face plates at these points. Each point is located at the midpoint between the intersections of the line that makes an angle of 45° to the axial direction of the cross tie and touches the inner surface plate, and the extensions of the lines of the face plates of the cross tie and transverse (*See* **Fig. 26.1** (b)).

(c) Where the face plates of cross ties are joined directly to the face plates of transverses at (or nearly at) right angles with brackets, and stiffeners are provided on the web plate of the transverse on the extensions of the lines of the face plates of the cross tie, *A* is the total sum of the sectional area of the web plate of the transverse between two points, and the sectional area of the stiffeners mentioned above. Each point is located at the midpoint between the intersections of the line that makes an angle of 45° to the axial direction of the cross tie and touches the free edge line of the bracket, and the face plates of the cross tie and transverse (*See* **Fig. 26.1** (c)).

Fig. 26.1 Extent for Total Sectional Area



6. The thickness of face plates forming a girder is to be greater than the thickness of the web, and the total width is not to be less than that obtained from the following formula:

$85.4\sqrt{d_0 l}\ (mm)$

Where:

d_0 : Depth of girders (m)

l : Distance (m) between supporting points of girders

Where effective tripping brackets are provided, they may be regarded as supporting points.

26.5.6 Girders of Ships Without Double Side Hull

1. In addition to the requirements in **26.5.5**, depth of the side transverse d and the section modulus of transverse Z are not to be less than that obtained from the following formulae:

$d = 0.15l\ (mm)$

$Z = 8.7KShl_0^2\ (cm^3)$

Where:

l : Total length (m) of side transverses, and where conjoined with other transverses, distance (m) to the inner surface of the transverses

l_0 : As given below:

$l_0 = kl$ (m)

k : As specified in **26.5.5-1**

S : Spacing of transverses (m)

h : Distance from the mid-point of l_0 to the following point above top of the keel

$d + 0.038L'$ (m)

L': As specified in **26.4.1-1**

K : As specified in **26.3.1-1**

2. The scantlings of deck transverses are to be as given in **(1)** and **(2)** below:

(1) Section modulus Z of deck transverses of a ship without trunks is not to be less than that obtained from the following formula:

$$Z = 3KS\sqrt{Ll_0^2}\,(cm^3)$$

S, K and l_0 : As specified in **-1**

(2) For ships with trunks, the construction of providing continuous deck transverses across the trunks is to be considered as the standard. The depth of the deck transverses that can be regarded as those supported by trunks may be $0.03B$.

3. For transverses provided on the centreline bulkhead, the requirements for side transverses specified in **-1** are to be applied correspondingly. The scantlings are not to be less than 0.8 times the coefficient in each formula.

26.5.7 Stiffeners Attached to Girders in Cargo Oil Tanks and Deep Tanks

The thickness of flat bar stiffeners and tripping brackets provided on girders and transverses, and stiffeners attached to the bulkhead is not to be less than that obtained from the following formula. The thickness does not need to exceed the thickness of the webs of the girder to which they are provided.

$$t = 0.5\sqrt{L} + 3.5\ (mm)$$

26.5.8 Cross Ties

1. Cross ties in ships having two or more rows of longitudinal bulkheads, where they are effectively connected with longitudinal bulkhead transverses in cargo oil tanks are to be in accordance with the requirements in **26.5.8**.

2. The sectional area of cross ties interconnecting longitudinal bulkhead transverses in cargo oil tanks is not to be less than that obtained from the following formula:

$$A = C_1 C_2 KSb_S h\ (cm^2)$$

Where:

S, b_S, C_1 : As specified in **26.5.5-5**

h : h_S when cross ties are provided in wing cargo oil tanks or vertical distance (m) from mid-point of b_S to the top of hatchways of adjacent cargo oil tanks where struts are provided in centre cargo oil tanks

K : As specified in **26.3.1-1**

C_2 : Coefficient obtained from the following formula:

Where $\frac{l}{k} > 0.6$;

$$C_2 = \frac{0.77}{1 - 0.5\frac{l}{k\sqrt{K}}}$$

Where $\frac{l}{k} < 0.6$;

$$C_2 = 1.1$$

l: Length (m) of cross ties measured between the inner edges of the vertical webs on longitudinal bulkheads

k: As given below:

$$k = \sqrt{\frac{I}{A}} \quad (cm)$$

I : The least moment of inertia (cm^4) of cross ties

A : Sectional area (cm^2) of cross ties

26.6 Structural Details

26.6.1 General

1. The principal structural members are to be arranged so that continuity of strength can be secured throughout the cargo area. In forward and afterward parts of the cargo area, the structures are to be effectively strengthened so that continuity of strength is not sharply impaired.

2. Sufficient consideration is to be given to the fixity at the ends of principal structural members and their supporting and stiffening systems against out-of-plane deflections, and their construction is to minimize local stress concentrations.

26.6.2 Frames and Stiffeners

Longitudinal beams, frames and stiffeners are to be of continuous structures, or to be connected securely so that their sectional areas at the ends can be properly maintained providing sufficient resistance against bending moments.

26.6.3 Girders and Cross Ties

1. Girders provided within the same plane are to be arranged to avoid sharp changes in strength and rigidity.Brackets of a suitable size are to be provided at the ends of girders, and bracket toes are to be sufficiently rounded.

2. Where the depth of longitudinal girders is large, stiffeners are to be arranged in parallel with the face plates.

3. Brackets are to be provided at the ends of cross ties to connect to transverses or girders.

4. Transverses and vertical webs are to be provided with tripping brackets at the junctions with cross ties.

5. Where the breadth of face plates forming cross ties exceeds 150 *mm* on one side of the web, stiffeners are to be provided at proper intervals to support the face plates as well.

6. Tripping brackets are to be provided on the web plate transverses at the inner edge of end brackets and at the connecting part of cross ties, etc. and also at the proper intervals in order to support transverses effectively. Where the width of face plates of each girder exceeds 180 *mm* on one side, the tripping brackets shown above are to support face places as well.

7. Webs for the upper and lower end brackets of side transverses and longitudinal bulkhead transverses and areas in the vicinity of their inner ends and those in the vicinity of the roots of cross ties are to be stiffened specifically by closer spacing.

26.7 Special Requirements for Corrosion

26.7.1 Thickness of Shell Plating

1. In application of the requirements in **Chapter 15,** the thickness of shell plating forming the casing of cargo oil tanks planned to carry ballast water (except tanks for carrying ballast water only in heavy weather conditions) in ships without a double side hull is not to be less than 0.5 *mm* more than the thickness obtained from the formula given in **15.3.2**.

2. In application of the requirements in this **Chapter**, the thickness of shell plating may be 0.5 *mm* less than the thickness obtained from the formula given in **26.3.1**.

26.7.2 Thickness of Deck Plating

1. In application of the requirements in this **Chapter**, the thickness of freeboard deck plating may be 0.5 *mm* less than the thickness obtained from the formula given in **26.3.1**.

2. In application of the requirements in **Chapter 16**, the thickness of freeboard deck plating in spaces carrying cargo oil is not to be less than 0.5 *mm* more than the thickness obtained from the formula given in **16.3**.

26.7.3 Thickness of Tank Top Plating

The thickness of tank top plating in cargo oil tanks and deep tanks is not to be less than 1.0 *mm* more than the thickness obtained from the formula given in **26.3.1**. However, such an addition is not required for the thickness of the inner bottom plating.

26.7.4 Section Modulus of Longitudinal Beams, Frames and Stiffeners

1. The section modulus of longitudinal beams provided on deck plating in spaces carrying cargo oil is not to be less than 1.1 times that calculated according to the requirements of **9.3.3**.

2. The section modulus of frames and stiffeners provided on shell plating and bulkheads forming cargo oil tanks planned to carry ballast water (except tanks for carrying ballast water only in heavy weather conditions) is not to be less than 1.1 times that calculated in accordance with the requirements in **26.4.1** and **26.4.2**.

26.7.5 Thickness of Plate Members in Ballast Tanks Adjacent to Cargo Oil Tanks

1. The thickness of bulkhead plating at the boundaries between ballast tanks and cargo oil tanks is not to be less than 1.0 *mm* more than the thickness specified in **26.2**.

2. Where the adjacent cargo oil tanks are equipped with heating systems, the thickness of bulkhead plating at the boundaries between ballast tanks and cargo oil tanks is not to be less than 1.0 *mm* more than the thickness determined in **-1**.

26.7.6 Thickness of Deck Plating in Cargo Oil Tanks

1. The thickness of deck plating in cargo oil tanks is not to be less than 1.0 *mm* more than the thickness specified in **26.2**.

26.7.7 Thickness of Inner Bottom Plating in Cargo Oil Tanks

1. The thickness of inner bottom plating of cargo oil tanks is to be sufficient considering the effects of pitting corrosion.

2. The thickness of inner bottom plating in the vicinity of suction bellmouths in cargo oil tanks, and the thickness of suction wells, when provided, are not to be less than 2.0 *mm* more than the thickness obtained by the requirements in **26.3.1-1** for the appropriate area of application.

26.8 Special Requirements for Tankers with Mid-Decks

26.8.1 Application

The structural members of tankers having mid-decks penetrating longitudinally through cargo areas are to comply with the requirements in **26.1** through **26.7** in addition to the requirements in **26.8**.

26.8.2 Loads

Values of h_1, h_2 and h_3 are to be as specified in **Table 26.19** where the scantlings of structural members in cargo oil tanks below the mid-deck are obtained from the formulae specified in **26.3.1**, **26.4.2** and **26.5.5**.

Table 26.19 Loads

Loads	Provisions		
	26.3.1	26.4.2	26.5.5
h_1	Vertical distance (*m*) from the lower edge of bulkhead plating to the mid-deck	Vertical distance (*m*) from mid-length of *l* for vertical stiffeners, and from mid-point between the upper and lower stiffeners for horizontal stiffeners to the mid-deck	Vertical distance (*m*) from mid-length of S for horizontal girders, and from mid-length of *l* for vertical girders to the mid-deck
h_2	$0.85(h_1 + \Delta h)$ (m) Δh is to be as specified in 26.3.1-1	$0.85(h_1 + \Delta h)$ (m) Δh is to be as specified in 26.3.1-1	$0.85(h_1 + \Delta h)$ (m) Δh is to be as specified in 26.3.1-1
h_3	0.7 times the vertical distance (*m*) from the lower edge of bulkhead plating to the top of hatchway	0.7 times the vertical distance (*m*) from mid-length of *l* for vertical stiffeners, and from mid-span of the upper and lower stiffeners for horizontal stiffeners to the top of hatchway	0.7 times the vertical distance (*m*) from mid-length of S for horizontal girders, and from mid-length of *l* for vertical girders to the top of hatchway

26.8.3 Mid-Deck

Where the thickness of mid-deck plating is counted as the top plating of the lower cargo oil tank, it is not to be less than 1.0 *mm* more than the thickness obtained from the formula given in 26.3.1 using the loads specified in 26.8.2.

26.9 Special Requirements for Forward Wing Tanks

26.9.1 Application

For tankers of not less than 200 *m* in length, the structural members in wing tanks which become empty in the full loaded condition for spaces 0.15*L* from the bow to the collision bulkhead are to comply with the requirements in 26.1 through 26.8 in addition to the requirements in 26.9

26.9.2 Side Longitudinals

1. The section modulus of side longitudinals is not to be less than that obtained from the following formula:

$Z = 9C_1KShl^2\ (cm^3)$

Where:

l : Spacing of transverses (m)

S : Spacing of side longitudinals (m)

h : Distance (m) from the longitudinals under consideration to the point above top of keel obtained from the following formula:

$h = 0.7d + 0.05L$

h (m) is not to be less than that obtained from the following formula:

$h = 0.2\sqrt{L} + 0.03L$

C_1 , K : As specified in **26.3.1-1**

2. Where side longitudinals are connected to transverses by brackets, the section modulus may be determined by multiplying the value obtained from the following formula by the formula specified in **-1**:

$(1- C)^2$

Where:

C : As obtained from the following formulae:

Where brackets are provided at both ends:

$$C = \frac{b_1 + b_2 - 0.3}{l}$$

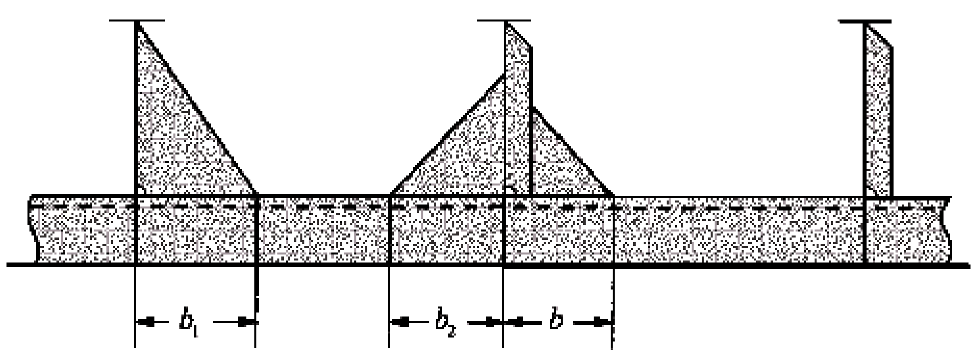
Where a bracket is provided at one end:

$$C = \frac{b - 0.15}{l}$$

b_1, b_2, b : Length (m) of bracket arms along longitudinals

Where the value of C is negative, C = 0 (See **Fig. 26.2**)

Fig. 26.2 Measurement of b, b_1 and b_2



26.10 Construction and Strengthening of the Forward Bottom

Strengthening of the forward bottom is to comply with the requirements in **6.8** and **15.4.4**.

26.11 Special Requirements for Hatchways and Freeing Arrangements

26.11.1 Ships Having Unusually Large Freeboards

Ships considered to have an unusually large freeboard may be given special consideration in regards to the requirements in **26.11**.

26.11.2 Hatchways to Cargo Oil Tanks

1. Thickness of coaming plates is not to be less than 10 *mm*. Where the length and coaming height of a hatchway exceed 1.25 *metres* and 760 *mm* respectively, vertical stiffeners are to be provided to the side or end coamings, and the upper edge of coamings is to be suitably stiffened.

2. Hatch covers are to be of steel or other approved materials. The construction of steel hatch covers is to comply with the following requirements. The construction of hatch covers of materials other than steel is to be at the discretion of the Society.

(1) The thickness of cover plates is not to be less than 12 *mm*.

(2) Where the area of a hatchway exceeds 1 m^2 but does not exceed 2.5 m^2, cover plates are to be stiffened by flat bars of 100 *mm* in depth spaced not more than 610 *mm* apart. Where the cover plates are 15 *mm* or more in thickness, the stiffeners may be dispensed with.

(3) Where the area of a hatchway exceeds 2.5 m^2, cover plates are to be stiffened by flat bars of 125 *mm* in depth spaced not more than 610 *mm* apart.

(4) The covers are to be secured by fastenings spaced not more than 457 *mm* apart in circular hatchways or 380 *mm* apart and not more than 230 *mm* from the corners in rectangular hatchways.

26.11.3 Hatchways to Spaces Other Than Cargo Oil Tank

In exposed positions on the freeboard and forecastle decks or on the top of expansion trunks, hatchways serving spaces other than cargo oil tanks are to be provided with steel watertight covers having scantlings complying with the requirements in **19.2.4** and **19.2.5**.

26.11.4 Freeing Arrangement

1. Ships with bulwarks are to have open rails for at least half the length of the exposed part of the freeboard deck orto have other effective freeing arrangements. The upper edge of the sheer strake is to be kept as low as practicable.

2. Where superstructures are connected by trunks, open rails are to be provided for the whole length of exposed parts of the freeboard deck.

3. Gutter bars greater than 300 *mm* in height fitted around the weather decks of tankers in way of cargo manifolds and cargo piping are to be treated as bulwarks. Freeing ports are to be arranged in accordance with the requirements in **22.2**. Closures attached to the freeing ports for use during loading and discharge operations are to be arranged in such a way that jamming cannot occur while at sea.

26.12 Welding

26.12.1 Application

The welding in tankers is to be in accordance with the requirements given in **Table 1.5** unless specified otherwise in **26.12**.

26.12.2 Fillet Welding

1. The application of fillet welding to structural members within the cargo areas is to be as given in **Table 26.20**.

2. The leg length of fillet welds in areas given in **(1)** and **(2)** below is to be at least 0.7 times the plate thickness as specified in the requirements in this Chapter.

(1) Fillet welds at the connections between the outermost girders in the double bottom and floors

(2) Fillet welds at the connections between the lowermost girders in the double side hull and transverses

Table 26.20 Application of Fillet Welding

<table>
<tr><th>Column</th><th colspan="2">Item</th><th>Application</th><th>Kind of weld</th></tr>
<tr><td>1</td><td rowspan="6">Girders and Tranverses</td><td rowspan="3">Web plates</td><td>Shell, deck, longitudinal bulkhead or inner bottom plating</td><td>F1</td></tr>
<tr><td>2</td><td>Web plates</td><td>F1</td></tr>
<tr><td>3</td><td>Face plates</td><td>F2</td></tr>
<tr><td>4</td><td>Slots in web plates</td><td>Web plates of longitudinal frames, beams and horizontal stiffeners on longitudinal bulkheads</td><td>F2</td></tr>
<tr><td>5</td><td rowspan="2">Tripping brackets and stiffeners provided on web plates</td><td>Web plates</td><td>F3</td></tr>
<tr><td>6</td><td>Longitudinal frames, beams and horizontal stiffeners on longitudinal bulkheads</td><td>F1</td></tr>
<tr><td>7</td><td colspan="2">Longitudinal frames, beams and horizontal stiffeners on longitudinal bulkheads</td><td>Shell, deck or longitudinal bulkhead plating</td><td>F3</td></tr>
<tr><td>8</td><td colspan="2" rowspan="2">Cross ties</td><td>Members forming cross ties (web plates to face plates)</td><td>F3</td></tr>
<tr><td>9</td><td>Face plates of transverses or girders</td><td>F1</td></tr>
</table>

Note:

Where the radius at the toe of end brackets is small, it is recommended that *F*1 be used for the appropriate length at the toe of the bracket.

Chapter 27 ORE CARRIERS

27.1 Construction and Equipment

27.1.1 Application

1. The construction and equipment of ships intended to be registered and classed as “ore carriers” are to be in accordance with the requirements in this Chapter or equivalent thereto.

2. Items not covered in this Chapter are to be in accordance with the general requirements for the construction and equipment of steel ships.

3. The requirements in this Chapter are for ships not greater than 230 *m* in length of usual form, having a single deck, machinery aft, two rows of longitudinal watertight bulkheads, and having double bottoms under ore holds and decks and bottoms with longitudinal framing.

4. Where the construction of the ship differs from that specified in **3** or the length of the ship exceeds 230 *m* and the requirements in this chapter are considered to be not applicable, matters are to be determined as deemed appropriate by the Society.

27.1.2 Subdivision

1. The distance between longitudinal bulkheads and the ship’s sides is not to be less than that obtained from the following formula even at the narrow parts at the ends of the ship:

$4L + 500$ (*mm*)

2. At least one transverse watertight bulkhead is to be provided between the longitudinal watertight bulkheads at a position somewhat forward of the middle of the length of the ore cargo space, except where the Society is satisfied with the omission of such a bulkhead.

27.1.3 Direct Calculation

Where approved by the Society, the scantlings of structural members may be determined based upon direct calculation. Where the scantlings determined by direct calculation exceed the required scantlings in this Chapter, theformer is to be adopted.

27.1.4 Double Bottoms

1. The height of double bottoms is to be determined in such a manner that the centre of gravity of the ship is sufficiently high in full load condition. The standard height is $0.2D$ (*m*).

2. The thickness of centre girders is not to be less than that obtained from the following formula:

$0.04L + 7.0$ (*mm*)

3. Floor plates or bottom transverses are to be arranged at the positions of bulkheads or transverses in wing tanks or void spaces.

4. Where longitudinal framing is adopted in the inner bottom, the thickness of floor plates is not to be less than that obtained from the following formula. The sum of the depths of lightening holes, slots, etc. is not to exceed a half of the depth of the floor at the part 2/4 or more from the ends of the floor and a quarter of the depth of the floor at *b*/8 from the ends of floor. Where suitable reinforcement is provided, lightening holes over the preceding limits may be permitted.

$$0.0625\frac{SbH}{d_0} + 2.5\ (mm)$$

Where:

S : Spacing (m) of floor plates

b : Breadth (m) of floor plates

H : Value obtained from the following formulae:

$2h - d$: where only floor plates are arranged

$1.6h - d$: where one transverse is arranged between adjacent floor plates to support inner bottom longitudinals

h : Vertical distance (m) from the upper surface of inner bottom plates to the upper deck measured at the centre line of the ship

d_0 : Depth (m) of floor plates

5. Stiffeners are to be provided on the centre girder plates and floor plates in the spacing not greater than that obtained from the following formula:

$$100t - 250\ (mm)$$

Where:

t : Thickness (mm) of centre girder plates or floor plates

6. The thickness of inner bottom plates is not to be less than that obtained from the following formulae, whichever is greater.

$$6.6S\sqrt{h} + 5.0\ (mm)$$

$$19\sqrt{S} + 5.0\ (mm)$$

Where:

S : Spacing (m) of inner bottom longitudinals

h : As specified in **-4**

7. The section modulus of inner bottom longitudinals is not to be less than that obtained from the following formula:

$$21Shl^2\ (cm^3)$$

Where:

S : Spacing (m) of inner bottom longitudinals

h : As specified in **-4**

l : Spacing (m) of floor plates or transverses

27.1.5 Construction and Scantlings of Wing Tanks or Void Spaces

1. Longitudinal frames and beams are to be as required in the provisions of **26.5** and **26.10**.

2. Construction and scantlings of transverses, girders, webs and cross ties are to be as required in the following provisions:

(1) The thickness of transverses, girders, webs and cross ties are not to be less than that given by **Table 26.1** according to the length of the ship.

(2) Girders and transverses in the same plane are to be so arranged that abrupt changes in strength and rigidity are avoided; they are to have brackets of sufficient scantlings and with properly rounded corners at their ends.

(3) The depth of girders and transverses is not to be less than 2.5 times that of slots for frames, beams and stiffeners.

(4) For the face plates composing girders, the thickness is not to be less than that of web plates and the full width is not to be less than that obtained from the following formula:

$$85.4\sqrt{d_0 l}\ (mm)$$

d_0 : Depth of girder (m)

Where the girder is a balanced girder, d_0 is the depth (m) from the surface of the plate to the face plate.

l : Distance (m) between supports of girders

Where effective tripping brackets are provided, they may be taken as supports.

(5) Transverses are to be effectively stiffened according to **(a)** to **(c)** below.

(a) The depth of flat bar stiffeners provided on transverses is not to be less than $0.08d_0$. However, where the stiffeners range throughout the full depth of the transverse, d_0 is to be taken as the depth of transverse, and where the stiffeners are fitted in parallel with face plates, d_0 is to be taken as the spacing of the tripping brackets. The depth and thickness of the flat bar stiffeners which support longitudinals penetrating transverses are to be as required in **1.1.12-3**.

(b) Tripping brackets are to be provided on the web of transverses at the inner edge of end brackets and at the intersectional part with cross ties, etc. and also at the proper intervals in order to support transverses effectively. Where the breadth of the face plate exceeds 180 *mm* on either side of the web plate, these brackets are to be so arranged as to support the face plate as well.

(c) Lower brackets of transverses on longitudinal bulkheads and side shell and web plates in the vicinity of the edge of the brackets are to be provided with closely-spaced stiffeners.

(6) The construction and scantlings of transverses on the side shell are to be as required in the following provisions:

(a) The following definitions are used in **(6)**:

$$Q = Shl_0$$

h : Distance (m) from the mid-point of l_0 to the point H_2 above the top of the keel

h_s : Distance (m) from the mid-point of b_s to the point H_2 above the top of the keel

$$H_2 = d + 0.038L\ (m)$$

l_0 : Overall length (m) of side transverses, which is equal to the distance between the inner surfaces of face plates of bottom transverses and deck transverses (*See* **Fig. 27.1**)

S : Spacing (m) of transverses

S_1 : Spacing (m) of stiffeners provided depthwise on the web plates of transverses at the portion where cross ties are connected

K : Coefficient corresponding to the kind of steel

e.g. 1.0 for mild steel, the values specified in **1.1.6-2(1)** for high tensile steel

k : Correction factor for brackets, and to be as obtained from the following formula:

$$k = 1 - \frac{0.65(b_1 + b_2)}{l_0}$$

b_1 and b_2 : Arm length (m) of brackets, at respective ends of girders and transverses

b : Arm length (m) of lowest bracket

The upper end of the bracket is to be the intersection of the tangent of the free edge of the bracket that makes an angle of 45 degrees to the base line, and the extension of the line of the inner edge of the side transverse. (*See* **Fig. 27.1**)

b_s : Width (m) of the area supported by cross ties (*See* **Fig. 27.1**)

d_0': Depth (m) of side transverses at the inner edge of the lowest bracket (*See* **Fig. 27.1**)

a : Depth (m) of slot in the vicinity of inner edge of the lowest bracket. Where the slots are provided with collar plates, a may be taken as zero.

A : Sectional area (cm^2) effective to support the axial force from cross tie, which is to be taken as follows:

i) Where the face plates of cross ties are continuous to the face plates of transverses and form an arc (or a similar curve), A is the total sum of the sectional area of the web plate of the transverse and the stiffeners provided in the axial direction of the cross tie on the web plate between two points, and 0.5 times the sectional area of the face plates at these points. Each point is located on its respective arc where the tangent makes an angle of 45° to the axial direction of the cross tie (*See* **Fig. 27.2(a)**).

ii) Where the face plates of cross ties are continuous to the face plates of transverses and form a straight line with rounded corners, A is the total sum of the sectional area of the web plate of the transverse and the stiffeners provided in the axial direction of the cross tie on the web plate between two points, and 0.5 times the sectional area of the face plates at these points. Each point is located at the midpoint between the intersections of the line that makes an angle of 45° to the axial direction of the cross tie and touches the inner surface plate, and the extensions of the lines of the face plates of the cross tie and transverse (*See* **Fig. 27.2(b)**).

iii) Where the face plates of cross ties are joined directly to the face plates of transverses at (or nearly at) right angles with brackets, and stiffeners are provided on the web plate of the transverse on the extensions of the lines of the face plates of the cross tie, A is the total sum of the sectional area of the web plate of the transverse between two points, and the sectional area of the stiffeners mentioned above. Each point is located at the midpoint between the intersections of the line that makes an angle of 45° to the axial direction of the cross tie and touches the free edge line of the bracket, and the face plates of the cross tie and transverse (*See* **Fig. 27.2(c)**).

C_0, C_1 and C_2 : Coefficients given in **Table 27.1** according to the number of cross ties respectively

Fig. 27.1 Measurement of l_0, d_0', b, b_s, etc.

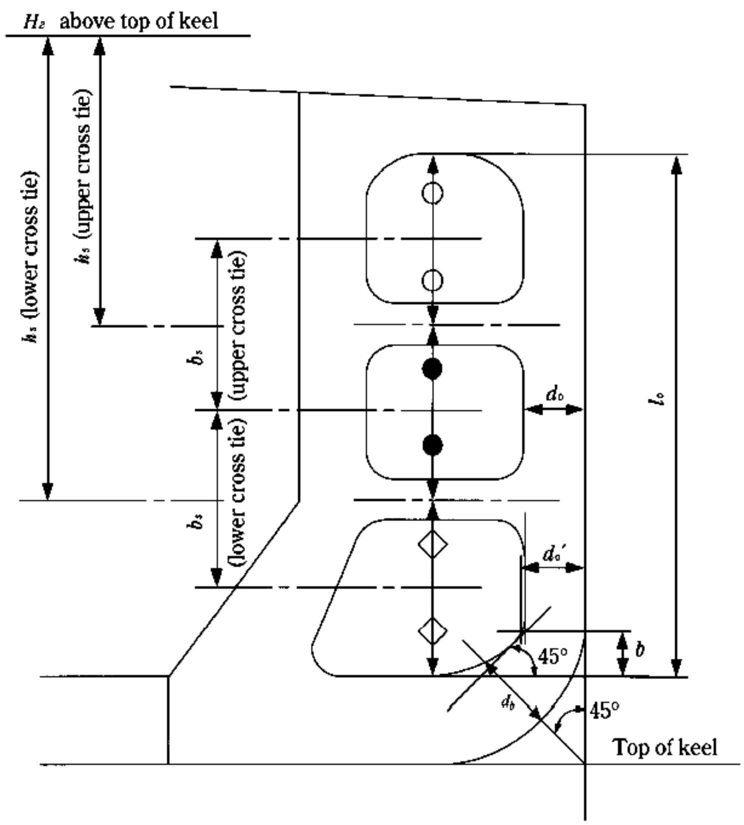


Fig. 27.2 Extent for Total Section Area

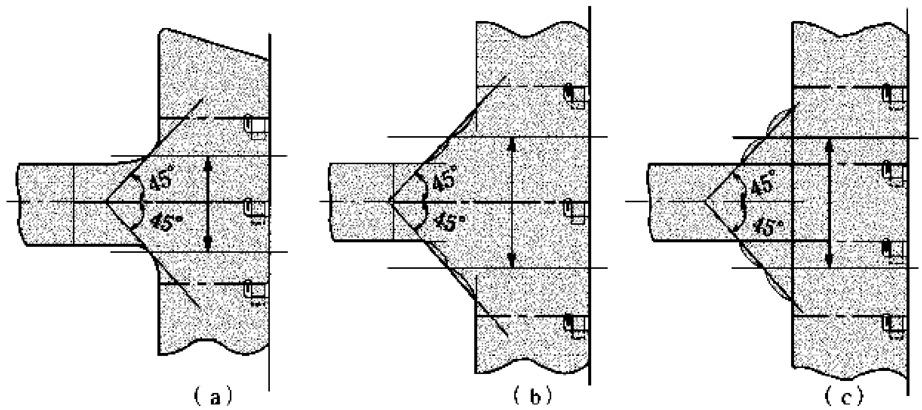


Table 27.1 Coefficients C_0, C_1, C_2 and C_2'

Number of cross ties	C_0	C_1	C_2	C_2'
0	0.150	55.7	5.07	7.14
1	0.110	44.8	2.70	4.42
2	0.100	39.4	2.28	3.74
3	0.095	36.2	2.12	3.49

(b) The depth (m) of transverses is not to be less than $C_0 l_0$ at the mid-point of l_0. Where the transverses are tapered, the reduction in depth at the upper end is not to exceed 10% of the depth at the mid-point of l_0, and the rate of increase in depth at the lower end is not to be less than that of the reduction at the upper end.

(c) The web thickness of transverses at the inner edge of brackets at the lower ends is not to be less than that obtained from the following formula:

$$t = \frac{C_1 - 148\dfrac{b}{l_0}}{1000} \frac{QK}{d_0' - a} + 3.5\ (mm)$$

(d) The web thickness of transverses at the portion where cross ties are connected is not to be less than that obtained from the following formula. Where slots are provided in the web at the portion where cross ties are connected, the slots are to be effectively covered with collar plates.

$$t = 16\sqrt{\frac{S b_S h_S}{A} S_1}\ (mm)$$

(e) The section modulus of transverses at the span is not to be less than that obtained from the following formula:

$Z = C_2 k^2 K Q l_0 (cm^3)$

(7) The scantlings of transverses on longitudinal bulkheads are not to be less than those obtained from applying provisions **(6)(b)** to **(e)** above correspondingly. For transverses without cross ties, h is to be the distance from the mid-point of l_0 to the top of the cargo hatch.

(8) The scantlings of bottom transverses are to be as required in the following provisions:

(a) The rigidity of bottom transverses is to be well balanced with that of side transverses.

(b) The section modulus of transverses at the span is not to be less than that obtained from the following formula:

$Z = 9.3 k^2 K S h_1 l^2 (cm^3)$

k, K and S : As specified in **(6)** above

h_1 : As given by the following formula;

$h_1 = d + 0.026L$ (m)

l : Overall length of bottom transverses (m), which is equal to the distance between the inner surface of face plates of bottom transverses and that of transverses on longitudinal bulkheads.

(c) The section modulus of bottom transverses at the bilge and at the lower end of longitudinal bulkheads is not to be less than that obtained from the following formula. In calculating the section modulus, the neutral axis of the section is to be taken as located at the middle of the depth d_b (*See* **Fig. 27.1**) of the transverse.

$Z = C_2' K Q l_0 \ (cm^3)$

K, Q and l_0: As specified in **(6)** above

C_2': Coefficient given in **Table 27.1** according to the number of cross ties

(9) The scantlings of deck transverses are to be as required in the following provisions:

(a) The rigidity of deck transverses is to be well balanced with that of side transverses.

(b) The section modulus of deck transverses at the span is not to be less than that obtained from the following formula:

$Z = 3k^2 KS\sqrt{L l_2^2} \ (cm^3)$

K, k and S: As specified in **(6)** above

L_2: Overall length (m) of deck transverses, which is equal to the distance between the inner surface of face plates of side transverses and that of transverses on longitudinal bulkheads

(10) The web thickness of transverses is not to be less than that obtained from the formula for t_3 given in **26.5.5-3.**

(11) Where side transverses and transverses on longitudinal bulkheads are connected with cross ties, the cross ties are to be as required in the following provisions:

(a) The construction of cross ties is to be as required in the following provisions.

i. Brackets are to be provided at the ends of cross ties to connect cross ties with transverses.

ii. Where the breadth of face plates forming cross ties exceeds 150 mm on one side of the web, stiffeners are to be provided at proper intervals to support the face plates as well.

(b) The scantlings of cross ties are to comply with the requirements in **26.5.8**.

3. The construction and scantlings of bulkheads are to comply with the requirements in **26.2** and **26.3**. When applying the requirements in **26.3**, h_1, h_2, and h_3 are to be substituted for those applicable to the deep tank bulkhead.

4. The thickness of longitudinal watertight bulkhead plating at the lower part of the ore hold is to be properly increased in relation to the thickness of inner bottom plating.

5. The thickness of longitudinal watertight bulkheads is to be in accordance with the requirements in **14.3.2** and **14.3.3** as well as **14.4**.

27.1.6 Transverse Bulkheads in Ore Holds

1. The scantlings of the members of the transverse bulkheads in ore holds are to be in accordance with the requirements in **13.2**. However, where h in the formula is to be substituted for 0.72 h' in application of these requirements, h' is to be in accordance with the following.

(a) Bulkhead plating:

Vertical distance (m) from the lower edge of the bulkhead plate to the upper deck at the centre line of the ship

(b) Stiffeners:

Vertical distance (m) from the mid-point of l for vertical stiffeners, and from the mid-point of S for horizontal stiffeners to the upper deck at centre line However, where the distance is less than 6 *metres*, h' is to be at least 0.8 times the distance plus 1.2 m. S and l is as specified in **13.2.3**.

(c) Girders:

Vertical distance (m) from the mid-point of l for vertical girders or from the mid-point of S for horizontal girders, to the upper deck at centre line However, where the distance is less than 6 *metres*, h' is to be at least 0.8 times the distance plus 1.2 m. l and S are as specified in **13.2.5**

2. Notwithstanding the requirements in **-1**, the thickness of the transverse bulkhead plating is not to be less than 7 *mm*.

3. The thickness of the lowest strake of bulkhead plating is to be appropriately increased according to the thickness of the inner bottom plating.

27.1.7 Relative Deformation of Wing Tanks

Where the value obtained from the following formula exceeds 0.18, special consideration is to be given to the structure of the wing tanks

$$\frac{2h - 0.65d}{n_b K_b + n_s \eta_s K_s + n_t \eta_t K_t} \cdot \frac{a}{b} l$$

Where:

h : Vertical distance (m) between the top of inner bottom plating and the upper deck at the centre line of the ship

l : Length of one ore hold (m)

a : Half-breadth of cargo hold (*m*)

b : Breadth of wing tank (*m*)

$n_{b,}$ n_s and n_t: Numbers of transverse bulkheads, swash bulkheads and transverse rings in wing tanks located within *l*, respectively

The bulkheads at the fore and after ends of *l* are to be counted as 1/2, respectively.

η_s and η_t: Values given in **Table 27.2** in accordance with the opening ratio

For intermediate values of the opening ratio, η_s and η_t are to be obtained by interpolation.

K_b, K_s , and K_t : Values obtained from the following formula:

$$81.0\frac{Dt}{\alpha b}$$

t : Mean thickness (*mm*) of transverse bulkhead plating in wing tanks in obtaining K_b value

Mean thickness (*mm*) of swash bulkhead plating in wing tanks in obtaining K_S value

Mean thickness (*mm*) of transverse rings in wing tanks in obtaining K_t value

α : Value obtained from the following formula, where transverse bulkheads or swash bulkheads in wing tanks are of corrugated form, in accordance with whether the corrugation is vertical or horizontal

For vertical corrugation:

$$\frac{l_{ath}}{b}$$

l_{ath} : Girth length (*m*) of bulkheads in athwartship direction

For horizontal corrugation:

$$\frac{l_{dep}}{D}$$

l_{dep} : Girth length (*m*) of bulkheads in depthwise direction

For cases other than the above, the value is to be 1.0

Table 27.2 Coefficients η_s and η_t

Opening ratio %	0	5	10	20	30	40	50	60	70
η_s, η_t	1.00	0.95	0.80	0.55	0.35	0.23	0.15	0.10	0.06

27.1.8 Drainage of Ore Holds

1. In general, one bilge suction opening is to be arranged on each side of the ship at the after end of the ore hold. Where the length of the ore hold in ships having only one hold exceeds 66 *metres*, an additional bilge suction opening is to be arranged in a suitable position in the forward half-length of the hold.

2. Bilge wells are to be arranged at suitable positions so as to protect the cover plates from direct impact by ore. They are to be provided with strum boxes or other suitable means so that the suction openings are not choked by ore dust or other particles.

3. Where bilge pipes are led through double bottoms, side tanks or void spaces, non-return valves or stop valves capable of being closed from a readily accessible position are to be provided at their open ends.

4. Bilge suction branch pipes may be of an inside diameter obtained from the formula in **13.5.3-1**, **Part 7**, taking *B* as the mean breadth of the ore hold.

27.1.9 Ore/Oil Carriers

1. Ore carriers that intend to carry oils in the ore holds and/or wing tanks (hereinafter referred to as "ore/oil carriers") are to comply with the relevant requirements in **Chapter 26**, in addition to those in this Chapter.

2. In addition to the requirements in this Chapter, special requirements may be specified as deemed necessary for ore/oil carriers by the Society.

27.1.10 Slop Tanks in Ore/Oil Carriers

1. Cofferdams are to be provided between slop tanks and machinery spaces in accordance with the requirements in **26.1.2-2**. In addition, cofferdams are to be provided between slop tanks and ore holds, except where the slop tanks are cleaned and freed of gas at any time prior to loading ore cargoes.

2. The cofferdams specified in -1 are to be capable of being flooded, except where the cofferdams are used concurrently as pump rooms, fuel oil tanks or water ballast tanks, or cargo oil tanks (in case of cofferdams between slop tanks and ore holds only).

3. Adequate ventilation is to be provided for the spaces surrounding slop tanks.

4. Notice boards are to be erected at suitable points detailing the precautions to be observed prior to loading or unloading, or whilst carrying ore cargo with oily water in the slop tanks.

5. It is recommended to provide an inert gas system for the slop tanks.

Chapter 28 BULK CARRIERS

28.1 General

28.1.1 Application

1. The construction and equipment of ships intended to be registered as "bulk carriers" are to be in accordance with the requirements in this Chapter or equivalent thereto.

2. Except where required otherwise in this Chapter, the general requirements for the construction and equipment of steel ships are to be applied.

3. The requirements in this Chapter are for ships having typical hull form with a single deck, machinery aft, bilge hopper tanks and topside tanks, a double bottom under cargo holds, and longitudinal framing on decks and bottom.

4. Where the construction of the ship differs from that given above, and the requirements in this Chapter are not considered to be applicable, matters are to be at the discretion of the Society.

28.1.2 Ship Types and Applicable Requirements

1. Ships with a length L_1 of not less than 150 *m* are to be categorized into one of the following types and comply with the requirements of this Chapter. L_1 is the length of ship (*m*) specified in **1.2.2, Part 1 A** or 0.97 *times* the length of ship (*m*) on the designed maximum load line, whichever is smaller.

(1) BC-A: Bulk carriers designed to carry bulk cargoes with a bulk cargo density (defined in **28A.1.2-1(6)**) of 1.0 t/m^3 and above with specified holds empty at designed maximum load draught (hereinafter referred to as alternately loaded condition) and with all ballast tanks empty.

(2) BC-B: Bulk carriers designed to carry bulk cargoes with a bulk cargo density of 1.0 t/m^3 and above in a homogeneously loaded condition at designed maximum load draught with all ballast tanks empty.

(3) BC-C: Bulk carriers designed to carry bulk cargoes with a bulk cargo density of less than 1.0 t/m^3 in a homogeneously loaded condition at designed maximum load draught with all ballast tanks empty.

2. Ships of less than 150 *m* in length L_1 are to be at the discretion of the Society.

28.1.3 Capacity of Ballast Tanks

1. Ships are to have ballast tanks of sufficient capacity that fulfil the ballast conditions specified in **(1)** and **(2)**.

(1) Normal ballast condition is a ballast (no cargo) condition with any cargo hold or holds adapted for the carriage of water ballast at sea empty and where:

- (a) The propeller is to be fully immersed
- (b) The trim is to be by the stern and is not to exceed 1.5% of the length between perpendiculars of the ship

(2) Heavy ballast condition is a ballast (no cargo) condition where:

- (a) The propeller is to be immersed such that the perpendicular distance from the centreline of the propeller to the waterline is not less than 60% of the propeller diameter

(b) The trim is to be by the stern and is not to exceed 1.5% of the length between perpendiculars of the ship

(c) The moulded forward draught is not to be less than 3% of the length between perpendiculars of the ship or 8 *m*, whichever is smaller

2. Ships in the ballast conditions specified in **-1(1)** and **(2)** above are to meet the requirements of construction and strengthening of the forward bottom specified in **5.8** and **15.4.4**, longitudinal strength specified in **Chapter 14** and intact stability specified in **Part 4**.

3. Where any ballast tanks (except cargo holds adapted for the carriage of water ballast at sea in the normal ballast condition specified in **-1(1))** is empty in the ballast conditions specified in **-1**, ships in the condition with all ballast tanks 100% full are to meet the longitudinal strength requirements in **Chapter 14**.

28.1.4 Plans and Documents for Approval

1. Plans and documents submitted for approval are to indicate kinds of cargo and/or ballast, loading capacity, level of liquid, etc. in each of the holds at service.

2. Where direct calculation of strength is used according to the specifications in **28.1.5**, the data necessary for the calculation is to be submitted.

28.1.5 Direct Calculation

When determining the scantlings of structural members by direct calculation according to the provisions of **1.1.20**, the subject members, load conditions, scope of calculations, and allowable stress are to be as deemed appropriate by the Society.

28.1.6 Minimum Thickness

1. The thickness of inner bottom plating, bulkhead plates, floor plates, girders and bracket plates in the double bottom, bilge hopper tanks, topside tanks, side tanks, hold tanks, etc. is not to be less than that given in **Table 28.1** according to the length of the ship.

Table 28.1 Minimum Thickness of Structural Members in Tanks

L (m)											
L (m)	and over		105	120	135	150	165	180	195	225	275
	less than	105	120	135	150	165	180	195	225	275	
Min. thickness (mm)		8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5

2. The thickness of webs and upper brackets of hold frames is not to be less than that obtained from the following formula. The thickness of lower brackets of hold frames is not to be less than 2.0 *mm* greater than that obtained from the following formula:

$$C(0.03L_0 + 7.0)\ (mm)$$

L_0 : Length of ship specified in**1.2.2, Part 1 A** or 0.97 *times* the length of ship on the designed maximum load line, whichever is smaller

However, where the value exceeds 200 *m*, L_0 is to be taken as 200 *m*.

C : Coefficient given by the following:

1.15: for the webs of hold frames in way of the foremost hold

1.00: for the webs of hold frames in way of other holds

3. For single side skin bulk carriers, the thickness of side shell plating located between top side tanks and bilge hopper tanks is not to be less than that obtained from the following formula:

$$\sqrt{L_1}\,(mm)$$

L : Length of ship specified in **1.2.2, Part 1 A** or 0.97 *times* the length of ship on the designed maximum load line, whichever is smaller

28.2 Double Bottoms

28.2.1 General

1. Except where required in **1.2.2, Part 1 A**of the Rules the requirements in **Chapter 5** are also to be applied.

2. The scantlings of members in double bottom tanks intended to be deep tanks are also to be in accordance with the requirements in **Chapter 13**.

However, the thickness of inner bottom plating need not be increased by 1 *mm* as given in **13.2.7** for the top plating of deep tanks.

3. The specific gravity of cargoes γ_D , γ_{Full}, γ_H , γ_{HD} and γ_B described in this Chapter are as defined by the following formula:

$$\gamma_D = \frac{M_D}{V}$$

$$\gamma_{Full} = \frac{M_{Full}}{V}$$

$$\gamma_H = \frac{M_H}{V}$$

$$\gamma_{HD} = \frac{M_{HD} + 0.1M_H}{V}$$

$$\gamma_B = \frac{M_B}{V}$$

M_D : The maximum cargo mass (*t*) given for each cargo hold

M_{Full} : The cargo mass (*t*) in the cargo hold corresponding to cargo with virtual density (homogeneous mass / volume of the hold including its hatchway, minimum 1.0 t/m^3) filled to the top of the hatch coaming

M_{Full} is not to be less than M_H.

M_H : The cargo mass (*t*) in the cargo hold corresponding to a homogeneously loaded condition at designed maximum load draught

M_{HD} : The maximum cargo mass (t) allowed to be carried in a cargo hold according to the design in an alternately loaded condition

M_B : The maximum mass (t) of water in the cargo hold when the cargo hold is used to carry water ballast (hereinafter referred to as hold ballast condition), if applicable

V : Volume (m^3) of the hold excluding its hatchway

4. The coefficient, k, specified in **28.2** is to be obtained from the following formula. However, where the angle between the hopper plate and the horizontal line, β, is very large, the value of k is to be at the discretion of the Society. (*See* **Fig. 28.1**)

$$2.1\frac{l l_H}{e^2\left(1+\frac{d_1}{d_0}\right)^2}$$

l_H : Length of hold (m)

Where stools are provided at transverse bulkheads, l_H may be taken as the distance between the toes.

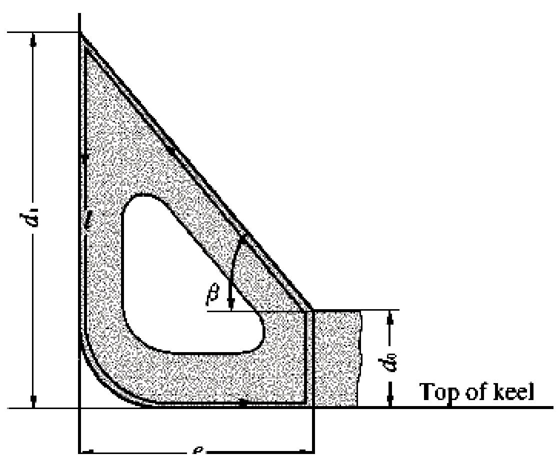
l : Total girth length (m) of hopper plate, side girder and shell plating composing the bilge hopper

e : Width of bilge hopper (m)

d_1 : Distance (m) from the top of keel to the top of the bilge hopper at side

d_0 : Depth of centre girder (m)

Fig. 28.1 Measurement of *l*, *e*, d_0, d_1 and β



28.2.2 Centre Girders and Side Girders

1. Side girders are to be provided at the toes of bilge hoppers. In addition, side girders are to be arranged between the centre girder and the side girder at the toe of bilge hoppers at intervals not exceeding the distance obtained from the following formula. However, where the value given by the formula exceeds 4.6 m, the distance is to be taken as 4.6 m.

For loaded holds: $5.7 - 1.6\gamma_D$ (m)

For holds to be left empty when the ship is fully loaded: 3.5 (m)

γ_D : As defined in 28.2.1-3.

2. Except where specially approved by the Society, the depth of centre girders is not to be less than that obtained from the following formula. However, the depth is not to be less than $B/20$.

$$15\sqrt{\frac{L_H BD}{m}} \quad (mm)$$

L_H : Total length (m) of all cargo holds, excluding pump rooms and cofferdams

m : Number of holds included in the cargo space

3. The thickness of centre girder plates and side girder plates is not to be less than the greater of the values given by the following requirements in **(1)** and **(2)**:

(1) The thickness obtained from the following formula according to the location in the hold:

$$C_1 \frac{SBd}{d_0 - d_1}\left(2.6\frac{x}{l_H} - 0.17\right)\left\{1 - 4\left(\frac{y}{B}\right)^2\right\} + 2.5\ (mm)$$

S : Distance (m) between the centres of two adjacent spaces from the centre or side girder under consideration to the adjacent longitudinal girders

d_0 : Depth (m) of the centre or side girder under consideration

d_1 : Depth (m) of the opening at the point under consideration

l_H : Length defined in 28.2.1-4

x : Longitudinal distance (m) between the centre of l_H of each hold and the point under consideration However, where x is less than $0.2l_H$, x is to be taken as $0.2l_H$, and where x exceeds $0.45l_H$, x may be taken as $0.45l_H$.

y : Transverse distance (m) from the centre line of ship to the longitudinal girder

C_1 : Coefficient given by the following formula: nab

n and a : Coefficients given in Table 28.2

However, where ${B}/{l_H}$ exceeds 1.8, ${B}/{l_H}$ is to be taken as 1.8, and where ${B}/{l_H}$ is less than 0.5, ${B}/{l_H}$ is to be taken as 0.5. For special loading conditions other than those presumed in Table 28.2, these coefficients are to be deemed as appropriate by the Society.

b : Value given in Table 28.3 depending on k and $\frac{B}{l_H}$ specified in 28.2.1-4

For intermediate values of k, b is to be obtained by linear interpolation.

(2) The thickness obtained from the following formula:

$$C_1' d_0 + 2.5 + (mm)$$

d_0: Depth (m) of the girder at the point under consideration

However, where horizontal stiffeners are provided in way of the depth of girder, d_0 is the distance (m) from the horizontal stiffener to the bottom shell plating or inner bottom plating or the distance between the horizontal stiffeners.

C_1': Coefficient given in Table 28.4 according to S_1/d_0

For intermediate values of S_1/d_0, C_1' is to be obtained by linear interpolation.

S_1: Spacing (m) of brackets or stiffeners provided on the centre girders or side girders under consideration

Table 28.2 Coefficient of "*n*" and "*a*"

<table>
<tr><th></th><th></th><th>n</th><th>a</th></tr>
<tr><td>1</td><td>Homogeneously loaded condition</td><td>$\frac{1}{3}\left(7-2\frac{B}{l_H}\right)$</td><td>$\frac{h\gamma_{Full}}{d}-1+\frac{0.026L'}{d}$</td></tr>
<tr><td>2</td><td>Condition with slacked hold</td><td>$\frac{1}{3}\left(\alpha\left(2-\frac{B}{l_H}\right)+5-\frac{B}{l_H}\right)$</td><td>$1+\frac{0.026L'}{d}-\frac{0.5h\gamma_H}{d}$</td></tr>
<tr><td>3</td><td>Ballast condition</td><td>$\frac{1}{3}\left(7-2\frac{B}{l_H}\right)$</td><td>$\frac{d_{act}+0.026L'^{*4}}{d}$</td></tr>
<tr><td rowspan="3">4[*1]</td><td>Condition loaded/unloaded in multiple ports</td><td rowspan="3">$\frac{1}{3}\left(\alpha\left(2-\frac{B}{l_H}\right)+5-\frac{B}{l_H}\right)$</td><td rowspan="2">$\frac{H\gamma_{Full}}{d}-0.67+\frac{0.026L'}{d}$</td></tr>
<tr><td>Loaded hold at assumed draught of 67% of d</td></tr>
<tr><td>Empty hold at assumed draught of 8.3% of d</td><td>$0.83+\frac{0.026L'}{d}$</td></tr>
<tr><td rowspan="3">5[*2]</td><td>Alternately loaded condition</td><td rowspan="3">1.0</td><td rowspan="2">$\frac{h\gamma_{HD}}{d}-1+\frac{0.026L'}{d}$</td></tr>
<tr><td>Loaded hold</td></tr>
<tr><td>Empty hold</td><td>$1+\frac{0.026L'}{d}$</td></tr>
<tr><td rowspan="3">6[*3]</td><td>Hold ballast condition</td><td rowspan="3">$\frac{1}{3}\left(\alpha\left(2-\frac{B}{l_H}\right)+5-\frac{B}{l_H}\right)$</td><td rowspan="2">$\frac{h\gamma_B}{d}-\frac{d_{act}-0.026L'}{d}$</td></tr>
<tr><td>Cargo hold adapted for the carriage of water ballast</td></tr>
<tr><td>Other cargo holds</td><td>$\frac{d_{act}-0.026L'}{d}$</td></tr>
<tr><td>7</td><td>Loading/unloading condition (Assumed draught is 67% of d)</td><td>$\frac{1}{3}\left(\alpha\left(2-\frac{B}{l_H}\right)+5-\frac{B}{l_H}\right)$</td><td>$\frac{h\gamma_D}{d}-0.67$</td></tr>
</table>

h : Vertical distance (m) from the top of inner bottom plating to the upper deck at centre line

L' : Length of ship (m). However, where L' exceeds 230 m, L' is to be taken as 230 m.

γ_D , γ_{Full}, γ_H , γ_{HD} and γ_B: As specified in 28.2.1-3.

α : Ratio of the load difference between the cargo load per unit area on the double bottom of the adjacent hold and the bottom water pressure including added variable wave pressure (pressure corresponding to wave height given as 0.026L' , however, the value of 0 may be used for conditions in port) to the similar load difference of the hold under consideration. The largest value of this ratio within the expected range of bottom water pressure is to be taken. This value is not to be less than -1.0 or greater than 1.0.

d_{act} : Actual draught corresponding to the loading condition specified in Table 28.2 (m)

Notes:

*1 These conditions only apply to ships designed for loading and/or unloading at multiple ports.

*2 These conditions only apply to ships of BC-A type.

*3 These conditions only apply to ships designed for hold ballast condition.

*4 The value of a is not to be less than $0.45 + \frac{0.026L'}{d}$

Table 28.3 Coefficient *b*

k	B/l_H						
	And over		1.4	1.6	1.8	2.0	2.2	2.4
	Less than	1.4	1.6	1.8	2.0	2.2	2.4	
10.0 and over		0.017	0.016	0.015	0.014	0.013	0.012	0.011
5.0		0.016	0.015	0.014	0.013	0.012	0.011	0.011
2.0		0.015	0.015	0.014	0.013	0.012	0.011	0.011
1.0		0.014	0.014	0.014	0.013	0.012	0.011	0.011
0.0		0.013	0.013	0.013	0.012	0.012	0.011	0.011

Table 28.4 Coefficient C_1'

$\frac{S_1}{d_0}$		0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6 and over
C_1'	Centre Girders	4.4	5.4	6.3	7.1	7.7	8.2	8.6	8.9	9.3	9.6	9.7
	Side Girders	3.6	4.4	5.1	5.8	6.3	6.7	7.0	7.3	7.6	7.9	8.0

4. Where a partial intermediate side girder with suitable thickness is provided between a transverse bulkhead (or the base of the stool at the base of the bulkhead) and the solid floor located 20% or more of the hold length l_H away from the end of l_H, 35% of the sectional area of the intermediate side girder may be used in the calculation of the sectional areas of adjacent girders. Where there is a stool at the base of the transverse bulkhead, a separate side girder is to be provided under the stool to counterbalance the partial intermediate side girder.

5. Where duct keels are provided, their spacing is not to be larger than 1.8 m. Sufficient consideration is to be paid to the strength continuity of solid floors and the stiffness of shell plating and inner bottom plating between duct keels.

6. Where the distance from the top of the inner bottom plating to the top of the overflow pipes is more than 15 m, brackets are to be provided at both ends of the vertical stiffeners on watertight side girders and they are to be connected with the inner bottom plating and bottom longitudinals.

28.2.3 Floor Plates

1. Solid floors are to be provided with spacing not more than that obtained from the following formula. However, where the value obtained exceeds 3.65 *m*, the spacing is not to be more than 3.65 *m*; where the value obtained is less than 2.5 *m*, the spacing may be 2.5 *m*. Solid floors are to be provided at the foot of the sloping plates of lower stools attached to transverse bulkheads.

For loaded holds: $5.6 - 2.8\gamma_D$ (*m*)

For holds to be empty under full load condition: 2.5 (*m*)

γ_D : As defined in **28.2.1-3**

2. The thickness of solid floors is not to be less than the greater of the values obtained from the following requirements in **(1)** and **(2)**:

(1) The thickness obtained from the following formula according to the location in the hold:

$$C_2 \frac{SB'd}{d_0 - d_1}\left(\frac{2y}{B''}\right)\left\{1 - 2\left(\frac{x}{l_H}\right)^2\right\} + 2.5\ (mm)$$

S : Spacing of solid floors (*m*)

B': Distance (*m*) between the lines of toes of bilge hoppers at the top of inner bottom plating at the midship part

B'': Distance (*m*) between the lines of toes of bilge hoppers at the top of inner bottom plating at the position of the solid floor under consideration

l_H : Length defined in **28.2.1-4**

y : Transverse distance (*m*) from the centre line of ship to the point under consideration at the position of the solid floor under consideration

However, where y is less than $\frac{B''}{4}$, y is to be taken as $\frac{B''}{4}$, and where y exceeds $\frac{B''}{2}$, y may be taken as $\frac{B''}{2}$.

x : Longitudinal distance (*m*) from the middle of l_H of the respective hold to the floor under consideration

d_0 : Depth (*m*) of the solid floor at the point under consideration

d_1 : Depth (*m*) of the opening at the point under consideration

C_2 : Coefficient obtained from the following formula

However, for adjacent holds simultaneously loaded or empty, the value obtained from the following formula may be multiplied by 0.9:

ab

a : Coefficient specified in **28.2.2-3**

b : Value given in **Table 28.5** according to k and B / l_H , which are defined in **28.2.1-4**

For intermediate values of k, the value of b is to be determined by linear interpolation.

Table 28.5 Coefficient *b*

k	B/l_H											
	and over		0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4
	less than	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	
10.0 and over		0.040	0.038	0.034	0.031	0.026	0.023	0.021	0.018	0.016	0.015	0.014	0.012
5.0		0.040	0.040	0.037	0.033	0.030	0.026	0.024	0.022	0.018	0.018	0.016	0.015
2.0		0.041	0.040	0.038	0.035	0.033	0.030	0.028	0.025	0.023	0.021	0.018	0.017
1.0		0.041	0.040	0.040	0.039	0.037	0.034	0.032	0.029	0.026	0.024	0.023	0.021
0		0.041	0.041	0.041	0.041	0.041	0.040	0.037	0.033	0.032	0.030	0.026	0.025

(2) The thickness obtained from the following formula according to the location in the hold:

$$8.6\sqrt[3]{\frac{H^2 d_0^2}{C_2'}(t_1 - 2.5)} + 2.5\ (mm)$$

t : Thickness given by the requirements in **(1)**

d_0 : Depth defined in **(1)**

C_2': Coefficient given in **Table 28.6** according to the ratio of the spacing of stiffeners $S_1(m)$ to d_0

For intermediate values of S_1/d_0, C_2' is to be determined by linear interpolation.

H : Value obtained from the following formula:

(a) Where slots without reinforcement are provided on solid floors, H is given by the following formula. However, where d_2/S_1 is less than 0.5, H is to be taken as 1.0.

$$\sqrt{4.0\frac{d_2}{S_1} - 1.0}$$

d_2 : The depth (m) of slots without reinforcement in the upper part of solid floors or the depth (m) of slots without reinforcement in the lower part of solid floors, whichever is greater.

(b) Where openings without reinforcement are provided on solid floors, H is given by the following formula:

$$1 + 0.5\frac{\phi}{d_0}$$

$\emptyset$: Major diameter of the openings (m)

(c) Where slots without reinforcement and openings without reinforcement are provided on solid floors, H is a product of the values given by **(a)** and **(b)**.

(d) Except for **(a)**, **(b)** and **(c)**, H is to be taken as 1.0.

Table 28.6 Coefficient C_2'

$\frac{S_1}{d_0}$	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_2'	64	38	25	19	15	12	10	9	8	7

3. Where a partial intermediate solid floor with suitable thickness is provided between the outermost side girder inside the bilge hopper and a side girder located not less than 20% of B' ' away, 35% of the sectional area of the intermediate solid floor may be used in the calculation of the sectional areas of adjacent solid floors. Diaphragms, girders or brackets are to be provided in the bilge hopper tank to counterbalance this partial intermediate solid floor.

28.2.4 Inner Bottom Plating

1. The thickness of inner bottom plating is not to be less than the greater of the values obtained from the following formula:

$$\frac{C_3}{1000}\frac{B^2 d}{d_0} + 2.5\ (mm)$$

$$C_3' S\sqrt{h} + 2.5\ (mm)$$

d_0: Height (m) of centre girders

S: Spacing (m) of inner bottom longitudinals

h: Vertical distance (m) from the top of inner bottom plating to the upper deck at centre line

C_3: Coefficient given by the following formula

However, for adjacent holds simultaneously loaded or empty, and especially short holds, the value obtained from the following formula is to be multiplied by 1.2:

ab

a : As specified in **28.2.2-3**

b : b_0 or 1 ab_1 given below according to the value of $\frac{B}{l_H}$

b_0 : for $\frac{B}{l_H} < 0.8$

b_0 or αb_1 , whichever is greater: for $0.8 \leq \frac{B}{l_H} < 1.2$

αb_1 : for $1.2 \leq \frac{B}{l_H}$

b_0 and b_1 : As given in **Table 28.7** according to the values of k and $\frac{B}{l_H}$

For intermediate values of k, b_0 and b_1 are to be obtained by linear interpolation.

k and l_H : As specified in **28.2.1-4** respectively

α: As given by the following formula:

$$\frac{13.8}{24 - 11\, f_B}$$

f_B : Ratio of the section modulus of transverse section of hull required in **Chapter 14** to the actual section modulus of transverse section of hull at the bottom

C_3': Coefficient given by the following formula, according to the value of $\frac{l}{S}$ **:**

$$\left(0.46\frac{l}{S} + 2.64\right)\sqrt{\gamma} : for\ 1 \leq \frac{l}{S} < 3.5$$

$$4.25\sqrt{\gamma}: for\ 3.5 \le \frac{l}{S}$$

l : Distance between floors (m)

γ : γ_{D}, γ_{Full} , or γ_{B} as specified in 28.2.1-3 applicable to the cargo hold, whichever is greatest

Table 28.7 Coefficient b_0 and b_1

B/l_H	and over		0.4	0.6	0.8		1.0		1.2	1.4	1.6	1.8	2.0	2.2
	less than	0.4	0.6	0.8	1.0		1.2		1.4	1.6	1.8	1.8	2.0	
b_0 or b_1		b_0	b_0	b_0	b_0	b_1	b_0	b_1	b_1	b_1	b_1	b_1	b_1	b_1
k	10.0 and over	4.6	4.1	3.4	2.3	2.3	1.7	2.2	2.0	1.8	1.5	1.3	1.1	1.0
	5.0	3.9	3.5	2.9	2.1	2.0	1.5	1.9	1.8	1.6	1.4	1.2	1.1	1.0
	2.0	3.3	3.0	2.4	1.9	1.7	1.5	1.7	1.6	1.5	1.4	1.2	1.1	1.0
	1.0	2.7	2.4	2.1	1.7	1.4	1.4	1.6	1.4	1.4	1.3	1.2	1.1	1.0
	0	2.0	2.0	1.9	1.5	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.1	1.0

2. The thickness of inner bottom plating under hatchways, where no ceiling is provided, is to be 2 *mm* more than the thickness obtained from the second formula in **-1** or that specified in 28.2.1-2, whichever is greater, except where the provision in **-3** is applied.

3. In ships whose cargoes are regularly handled by grabs or similar mechanical appliances, the thickness of inner bottom plating is to be 2.5 *mm* more than that specified in **-1** or in 28.2.1-2, whichever is greater, except where a ceiling is provided.

28.2.5 Longitudinals

1. The section modulus of bottom longitudinals is not to be less than that obtained from the following formula:

$$\frac{100C}{24 - 15.5f_B}(d + 0.026L')Sl^2(cm^3)$$

f_B : As specified in 28.2.4-1

C : Coefficient given below:

a) Where the struts specified in 28.2.6 are not provided midway between floors: 1.0

b) Where the struts specified in 28.2.6 are provided midway between floors: 0.625 (for lower parts of deep tanks and holds which become empty in fully loaded condition)

$0.3\gamma + 0.2$ (elsewhere)

C is not to be less than 0.50. Furthermore, where the width of vertical stiffeners provided on floors and that of struts are especially large, the coefficient may be properly reduced.

γ: γ_D , γ_{Full}, or γ_B as specified in 28.2.1-3 applicable to the cargo hold, whichever is greatest

l : Spacing of solid floors (m)

S : Spacing of bottom longitudinals (m)

L': Length of ship (m)

However, where L exceeds 230 m, L' is to be taken as 230 m.

2. The section modulus of inner bottom longitudinals is not to be less than that obtained from the following formula. However, the section modulus of inner bottom longitudinals is not to be less than 0.75 *times* that of the bottom longitudinals at the same location.

$$\frac{100CShl^2}{24-12f_B}\ (cm^3)$$

f_B : As specified in **28.2.4-1**

C : Coefficient given below:

a) Where the struts specified in **28.2.6** are not provided midway between floors: γ

C is not to be less than 0.9.

b) Where the struts specified in **28.2.6** are provided midway between floors: 0.6 γ

C is not to be less than 0.54. Furthermore, where the width of vertical stiffeners provided on floors and that of struts are especially large, the coefficient may be properly reduced.

γ: γ_D , γ_{Full}, or γ_B as specified in **28.2.1-3** applicable to the cargo hold, whichever is greatest

h : As specified in **28.2.4-1**

l : Spacing (m) of solid floors

S : Spacing (m) of inner bottom longitudinals

28.2.6 Vertical Struts

1. Where vertical struts are provided, they are to be rolled sections other than flat bars or bulb plates and are to overlap the webs of bottom and inner bottom longitudinals sufficiently.

2. The sectional area of the above-mentioned vertical struts is not to be less than that obtained from the following formula. Where the double bottom is deep, sufficient care is to be taken against buckling.

$$1.8CSbh\ (cm^2)$$

S : Spacing (m) of longitudinals

b : Breadth (m) of the area supported by the strut

h : As obtained from the following formula:

$$\frac{d+0.026L'+h_i}{2}\ m$$

h is nt to be less than d.

L' : As specified in **28.2.5-1**

h_i : γ times the value of h specified in **28.2.4-1** (m)

However, under deep tanks, h is not to be less than the vertical distance (m) from the upper surface of the inner bottom to the mid-point between the top of the overflow pipe and the top of the inner bottom or 0.7 *times* the vertical distance from the upper surface of the inner bottom to the point 2.0 m above the top of the overflow pipe, whichever is greater.

γ: γ_D , γ_{Full} or γ_B as specified in **28.2.1-3** applicable to the cargo hold, whichever is greatest

C : Coefficient obtained from the following formula:

$$\frac{1}{1 - 0.5\frac{l_S}{k}}$$

The value of the coefficient is not to be less than 1.43.

l_S : Length (m) of strut

k : Minimum radius (cm) of gyration of vertical struts, obtained from the following formula

$$\sqrt{\frac{I}{A}}(cm)$$

I : The least moment of inertia (cm^4) of the strut

A : Sectional area (cm^2) of the strut

28.2.7 Double Bottom Structure Under Lower Stools at Bulkheads

The inner bottom plating, centre girders, side girders and bottom longitudinals under lower stools at transverse bulkheads are to be connected to the extensions of those of holds just before and behind the bulkheads. The floors are to be equivalent to those of holds.

28.3 Bilge Hopper Tanks

28.3.1 General

1. Compartments of bilge hopper tanks are to be in coincidence with those of holds as far as practicable.

2. Sufficient care is to be taken for the continuity of strength at fore and after ends of bilge hopper tank structure.

3. The scantlings of structural members in bilge hopper tanks are to be in accordance with the requirements in **28.3** and those in **Chapter 13**.

28.3.2 Thickness of Hopper Plates

1. Thickness of hopper plates of bilge hopper tanks is not to be less than that obtained from the following formula.

$$CS\sqrt{h} + 2.5(mm)$$

S : Length (m) of the shorter side of the panel enclosed by stiffeners, etc.

h : Vertical distance (m) from the lower end of the hopper plate to the upper deck at centre line

C : Coefficient obtained from the following formula

However, it is not to be less than 3.2.

$$4.25C_1C_2\sqrt{\gamma}$$

C_1 : Coefficient obtained from the following formula:

Where $1 \leq \frac{l}{S} < 3.5: 0.615 + 0.11l/S$

Where $3.5 \leq l/S: 1.0$

l : Length (m) of the longer side of the panel enclosed by stiffeners, etc.

C_2 : Coefficient obtained from the following formula:

Where $\beta \leq 40^\circ$: 1.0

Where $40^\circ < \beta < 80^\circ$: $1.4 - 0.01\beta$

Where $80^\circ \leq \beta$: 0.6

β: Angle of hopper plate to the horizontal as specified in 28.2.1-4

γ: γ_D , γ_{Full} or γ_B as specified in 28.3.1-3 applicable to the cargo hold, whichever is greatest

2. In ships whose cargoes are regularly handled by grabs or similar mechanical appliances, the greater of the thicknesses of the hopper plate determined in **-1** above or in 28.3.1-3 is to be increased by the following thicknesses.

Hopper plate under hatchway: 2.5 *mm*

Hopper plate other than the above: 1.0 *mm*

3. Where transverse stiffeners are provided on the hopper plates of bilge hopper tanks, the thickness of hopper plates is to be sufficient against buckling.

28.3.3 Stiffeners

1. The section modulus of longitudinal stiffeners provided on hopper plates is not to be less than that obtained from the following formula:

$CShl^2 (cm^3)$

S : Spacing (m) of stiffeners

h : Vertical distance (m) from the stiffener to the upper deck at centre line

l : Length (m) of longitudinal stiffener between transverse webs

C : Coefficient obtained from the following formula:

$$\frac{\alpha}{24 - 15.5 f_B \frac{y}{y_B}}$$

α: Coefficient obtained from the formula given in Table 28.8 according to β , the acute angle

f_B : Ratio of the section modulus of the transverse section of the hull required in Chapter 14 to the actual section modulus of the transverse section of the hull at bottom

y : Vertical distance (m) from the neutral axis of the transverse section of the hull to the longitudinal stiffener concerned

y_B : Vertical distance (m) from the neutral axis of the transverse section of the hull to the top of the keel

Table 28.8 Coefficient α

Angle β	α
$\beta \leq 40^\circ$	130γ
$40^\circ < \beta < 80^\circ$	$(214 - 2.1\beta)\gamma$
$\beta \geq 80^\circ$	46γ

2. The section modulus of transverse stiffeners provided on hopper plates is not to be less than that obtained from the following formula:

$CShl^2 (cm^3)$

S : Spacing (m) of transverse stiffeners

l : Distance (m) between the supports of stiffeners

h : Vertical distance (m) from the mid-point of l to the upper deck at centre line

C : Coefficient obtained from the formula given in **Table 28.9** according to β , the acute angle between the hopper plate and the horizontal plate in terms of γ specified in **28.3.2-1**

Table 28.9 Coefficient *C*

Angle β	C
$\beta \leq 40^{\circ}$	7.8γ
$40^{\circ} < \beta < 80^{\circ}$	$(12.8 - 0.125\beta)\gamma$
$\beta \geq 80^{\circ}$	2.8γ

3. Bottom longitudinals in bilge hopper tanks are to be in accordance with the requirements in **5.4.3**. Side longitudinals are to be in accordance with the requirements in **6.4.1-1**, where l in the formula is to be taken as the distance between transverse webs in *metres*. The section modulus of bilge longitudinals need not exceed that specified for bottom longitudinals.

28.3.4 Transverse Webs

1. In bilge hopper tanks, a transverse web or diaphragm is to be provided at every solid floor.

2. The depth of transverse webs provided on hopper plates is not to be less than 1/5 of l specified in -3 or 2.5 times the depth of slots for longitudinal stiffeners, whichever is greater.

3. The thickness of transverse webs provided on hopper plates is not to be less than the greater of the values obtained from the following formulae:

$$10d_0 + 2.5\ (mm)$$

$$\frac{C}{1000}\frac{Shl}{d_0 - a} + 2.5\ (mm)$$

d_0 : Depth (m) of transverse web

a : Depth (m) of slot

Where effective collar plates are provided within 0.25l from each end of l, a may be modified according to the size of collar plates. a may be taken as zero for 0.5l at the middle part of l.

S : Breadth (m) of the area supported by transverse web

h : Vertical distance (m) from the mid-point of l to the upper deck at centre line

l : Overall length (m) of transverse web

Where the transverse webs are connected with effective brackets at the ends, l may be modified in accordance with the requirements in **1.1.16**.

C : Coefficient obtained from the formulae in **Table 28.10** according to b , the acute angle between the hopper plate and the horizontal plane in terms of γ specified in **28.3.2-1**

Table 28.10 Coefficient *C*

Angle β	C
$\beta \leq 40^{\circ}$	41.7γ
$40^{\circ} < \beta < 80^{\circ}$	$(68.5 - 0.67\beta)\gamma$
$\beta \geq 80^{\circ}$	14.9γ

Notes:

1 Where γ is less than 0.7, γ is to be taken as 0.7.

2 Where the value C obtained from the above formula is less than 27.8, C is to be taken as 27.8.

4. The section modulus of transverse webs provided on hopper plates is not to be less than that obtained from the following formula:

$CShl^2 (cm^3)$

S, h and l : As specified in **-3**

C : Coefficient obtained from the formula given in **Table 28.11** according to β , the acute angle between the hopper plate and the horizontal plate, in terms of γ specified in **28.3.2-1**

The thickness of face plates is not to be less than that of webs and the breadth is not to be less than that obtained from the following formula:

$85.4\sqrt{d_0 l_1} (mm)$

d_0 : Depth of web (m)

l_1 : Distance (m) between supports of transverse web

Where effective tripping brackets are provided, they may be taken as supports.

Table 28.11 Coefficient *C*

Angle β	C
$\beta \leq 40^{\circ}$	7.1γ
$40^{\circ} < \beta < 80^{\circ}$	$(11.5 - 0.11\beta)\gamma$
$\beta \geq 80^{\circ}$	2.7γ

Notes:

1 Where γ is less than 0.7, γ is to be taken as 0.7.

2 Where the value C obtained from the above formula is less than 4.75, C is to be taken as 4.75.

3 Where an effective support is provided at the mid-point of a girder, one-half of C obtained from the above formula may be taken as C.

5. Flat bar stiffeners are to be provided on transverse webs or diaphragms at the positions through which longitudinals pass and tripping brackets are to be provided at a spacing of approximately 3 m.

28.4 Topside Tanks

28.4.1 General

1. Compartments of topside tanks are to be in coincidence with those of holds as far as practicable. Except for the foremost hold, one topside tank compartment may be in coincidence with two adjacent hold compartments.

2. Sufficient care is to be taken for the continuity of strength at the fore and after ends of topside tank structure

3. The scantlings of structural members in topside tanks are to be in accordance with the requirements in **28.4** and those in **Chapter 13**. However, in application of the requirements in **Chapter 13**, h is not to be less than one-half of the breadth of tanks at the midship part.

4. For flat bars used for longitudinal stiffeners, the ratio of the depth to the thickness is not to be greater than 15.For longitudinal stiffeners near the strength deck, the slenderness ratio is not to exceed 60 at midship Part as far as is possible.

28.4.2 Thickness of Sloping Plates

1. The thickness of sloping plates of topside tanks is not to be less than that obtained from the following formula:

$$4.6S\sqrt{h} + 2.5\ (mm)$$

S : Spacing (m) of longitudinal or transverse stiffeners.

h : Vertical distance (m) from the lower edge of the sloping plate to the top of the overflow pipe or one-half of the breadth of the topside tank at the midship part, whichever is greater.

2. Where transverse stiffeners are provided on the sloping plates of topside tanks, the thickness of sloping plates is to be sufficient against buckling.

28.4.3 Stiffeners Provided on Sloping Plates

1. The section modulus of longitudinal stiffeners provided on the sloping plates of topside tanks is not to be less than that obtained from the following formula:

$$CShl^2 (cm^3)$$

S : Spacing (m) of longitudinal stiffeners

h : Vertical distance (m) from the stiffener to the top of the overflow pipe or one-half of the breadth of the topside tank at the midship part, whichever is greater

l : Length (m) of longitudinal stiffeners between transverse webs

C : Coefficient obtained from the following formula:

$$\frac{100}{24-15.5 f_D \frac{y}{y_D}}$$

f_D : Ratio of the section modulus of the transverse section of the hull required in Chapter 14 to the actual section modulus of the transverse section of the hull at deck

y_D : Vertical distance (m) from the neutral axis of the transverse section of the hull to the top of the beams at side

y: Vertical distance (m) from the neutral axis of the transverse section of the hull to the longitudinal stiffener concerned

2. The section modulus of transverse stiffeners provided on the sloping plates of topside tanks is not to be less than that obtained from the following formula:

$6.8Shl^2$ (cm^3)

S : Spacing (m) of transverse stiffeners

l : Unsupported length (m) of stiffener

h : Vertical distance (m) from the mid-point of l to the top of the overflow pipe or one-half of the breadth of the topside tank at the midship part, whichever is greater.

28.4.4 Longitudinal Beams

The section modulus of longitudinal beams in topside tanks is not to be less than that obtained according to the requirements in 9.3.3, where h is the deck load (kN/m^2) specified in 9.2 or one-half of the breadth of the topside tank at the midship part multiplied by 9.81, whichever is greater.

28.4.5 Side Frames

1. The section modulus of side longitudinals in topside tanks is not to be less than that obtained from the formula in 6.4.1-1, taking l and h as follows:

l : Distance (m) between transverse webs

h : As specified in 6.4.1-1, but is not to be less than one-half of the breadth (m) of the topside tank at the midship part

2. Where transverse frames are provided on the side shell plating in way of topside tanks, the section modulus is not to be less than that obtained from the following formula:

$6Shl^2$ (cm^3)

S : Spacing (m) of frames

l : Vertical distance (m) from the bottom of the sloping plate of the topside tank to the upper deck at side

h : Vertical distance (m) from the mid-point of l to the point $d+0.038L'$ above the top of the keel, or one-half of the breadth of the topside tank at the midship part, whichever is greater

Where the value is less than $0.3\sqrt{L}$ (m), h is to be taken as $0.3\sqrt{L}$ (m)

L' : Length of ship (m)

However, where L exceeds 230 m, L' is to be taken as 230 m.

28.4.6 Transverse Webs

1. Transverse webs or diaphragms are to be provided at a spacing not exceeding 5 m in topside tanks.

2. Where effective struts are provided at an intermediate position on transverse webs, the depth of transverse webs is not to be less than 1/6 of l specified in **-3**. Otherwise, the depth is not to be less than 1/5 of l, or 2.5 *times* the depth of slots through which longitudinals pass, whichever is greater.

3. The thickness of webs is not to be less than the greater of the values obtained from the following formulae

$$10d_0 + 2.5\ (mm)$$

$$0.0417\frac{Shl}{d_0 - a} + 2.5\ (mm)$$

d_0 : Depth (m) of transverse web

a : Depth (m) of slot

Where effective collar plates are provided within $0.25l$ from each end of l, a may be modified according to the size of the collar plates. a may be taken as zero for $0.5l$ at the middle of l.

S : Breadth (m) of the area supported by transverse web

h : Vertical distance (m) from the mid-point of l to the top of the overflow pipe, or one-half of the breadth of the topside tank at the midship part, whichever is greater

l : Overall length (m) of transverse web

Where a longitudinal diaphragm is provided at an intermediate position on the transverse web, l is the distance (m) from the longitudinal diaphragm to the heel of the bracket provided at the end of the transverse web. Where effective brackets are provided, l may be modified as specified in **1.1.16**.

4. The section modulus of transverse webs is not to be less than that obtained from the following formula. Where an effective strut is provided at an intermediate position on the transverse web, the coefficient 7.13 may be taken as 3.57**.**

$$7.13Shl^2\ (cm^3)$$

S, h and l : As specified in **-3**

The thickness of face plates is not to be less than that of webs and the breadth is not to be less than that obtained from the following formula.

$$85.4\sqrt{d_0 l_1}\ (mm)$$

d_0 : Depth (m) of web

l_1 : Distance (m) between supports of transverse web

Where effective tripping brackets are provided, those locations may be taken as supports.

5. Flat bar stiffeners are to be provided on transverse webs or diaphragms at the positions through which longitudinals pass and tripping brackets are to be provided at a spacing of approximately 3 m.

6. Where heavy cargoes are loaded on the deck, web plates or diaphragms are to be suitably reinforced.

28.4.7 Large Topside Tanks

1. Where topside tanks are large, special consideration is to be given to the structure such as providing longitudinal diaphragms around the mid-point of the breadth of topside tanks.

2. The thickness of longitudinal diaphragms, where provided, is not to be less than that specified in **28.1.4** or that obtained from the following formula, whichever is greater:

$$19.8\sqrt{\frac{y}{D}} + 2.5\ (mm)$$

S : Spacing (*m*) of longitudinal stiffeners

y : Vertical distance (*m*) from the point *D*/2 above the top of the keel to the mid-point of the panel between the stiffeners.

3. Where longitudinal stiffeners are provided on longitudinal diaphragms, the depth of stiffeners is not to be less than 0.06*l*, where *l* is the distance between the girders provided on the longitudinal diaphragms. Where longitudinal stiffeners are connected with tripping brackets at the ends, the depth of the stiffeners may be properly reduced.

4. Where transverse stiffeners are provided on longitudinal diaphragms, the thickness of the longitudinal diaphragms is to be sufficient against buckling. The scantlings of the stiffeners are to be equivalent to those specified in **-3**.

28.5 Transverse Bulkheads and Stools

28.5.1 Transverse Bulkheads

1. The scantlings of structural members of transverse bulkheads are to be in accordance with the requirements in **13.2**. In application of these requirements, h in the formulae is to be substituted by $0.36\gamma h'$, where γ is as specified in **28.3.2-1**. However, where γ is less than 1.5, γ is to be taken as $1.5h'$ is to be in accordance with the following.

(1) For bulkhead plating, the vertical distance (*m*) from the lower edge of the bulkhead plate to the upper deck at the centre line of the ship

(2) For vertical stiffeners on the bulkhead, the vertical distance (*m*) from the mid-point of *l* to the upper deck at the centre line of the ship

For horizontal stiffeners on the bulkhead, the vertical distance (*m*) from the mid-point of *S* to the upper deck at the centre line of the ship *l* is as specified in **13.2.3.**

(3) For vertical webs supporting stiffeners, the vertical distance (*m*) from the mid-point of *l* to the upper deck at the centre line of the ship

For horizontal girders supporting stiffeners the vertical distance (*m*) from the mid-point of *S* to the upper deck at the centre line of the ship *l* and *S* are as specified in **13.2.5**.

2. Notwithstanding the requirements in **-1**, the scantlings of structural members of transverse bulkheads are not to be less than that specified in **Chapter 12**.

3. Single strakes of transverse bulkheads adjacent to the side shell plating are to be reinforced appropriately.

4. For transverse bulkheads without lower stools, the thickness of the lowest strake of bulkhead plating is to be appropriately increased according to the thickness of the inner bottom plating.

5. Plating of transverse bulkheads to which the sloping plates of topside tanks are connected, is to be properly strengthened by increasing its thickness or by other means.

28.5.2 Lower and Upper Stools at Transverse Bulkheads

1. Thickness of the hopper plate of the lower stool of the transverse bulkhead is not to be less than that obtained from the formula in **28.3.2-1** using the value of coefficient *C* reduced by 10%. In ships whose cargoes are regularly handled by grabs or similar mechanical appliances, the thickness is to be increased by 1 *mm*.

2. The section modulus of horizontal stiffeners provided on the sloping plates of lower stools is not to be less than that obtained from the formula given in **28.3.3-1**, where the coefficient, *C*, is to be reduced by 10%. Where vertical stiffeners are provided, the section modulus is not to be less than that obtained in accordance with the requirements in **28.3.3-2**.

3. In lower stools, girders are to be provided at the centre girder and side girders of the double bottom. The scantlings of girders are not to be less than that obtained in accordance with the requirements in **28.3.4**.

4. Where holds are so designed as to be loaded with ballast water, cargo oil or heavy cargo, girders specified in **-3** are to be sufficient against shearing by taking measures such as adopting

5. For *BC-A*, *BC-B* or *BC-C* ships and ships designed for loading and/or unloading in multiple ports, upper stools deemed as appropriate by the Society are to be provided on vertical corrugated type transverse bulkheads.

6. The scantlings of structural members of the upper and lower stools of transverse bulkheads are not to be less than that determined in **Chapter 12**.

28.6 Hold Frames

28.6.1 Hold Frames

1. The section modulus of hold frames between $0.15L$ from the fore end and the after peak bulkhead is not to be less than that obtained from the following formula:

$CShl^2 (cm^3)$

S: Spacing (*m*) of frames

h: Vertical distance (*m*) from a point $d + 0.038L'$ above the top of the keel to the top of the bilge hopper at side

L': Length (*m*) of ship

However, where L exceeds 230 *m*, L' is to be taken as 230 *m*.

l: Distance (*m*) between the top of the bilge hopper at side and the bottom of the top side tank (*See* **Fig. 28.2**)

C: Coefficient obtained from the following formula:

$C_1 + C_2$

$$C_1 = 3.3 - 2.5\frac{l}{h}$$

$$C_2 = (25.7\lambda_1 + 44.5)\alpha\frac{d}{h}$$

$$\lambda_1 = l_1/l$$

l_1: Vertical distance (*m*) from the mid-point of the depth of the centre girder to the top of the bilge hopper at side (*See* **Fig. 28.2**)

α : Coefficient given in **Table 28.12**

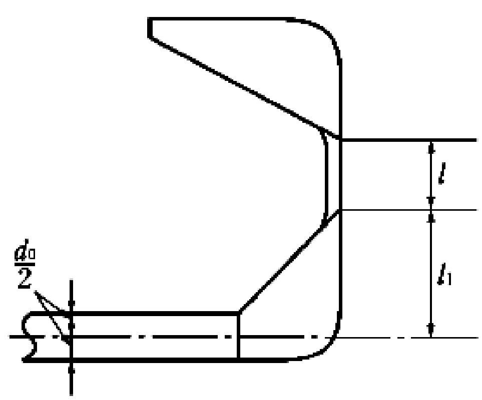
For intermediate values of B / l_H , the value of a is to be determined by linear interpolation. For the holds which are empty in fully loaded condition, the value of a is to be 1.8 *times* the value determined from the Table.

l_H : As specified in **28.2.1-4**

Table 28.12 Coefficient α

B/l_H	0.4 and under	0.6	0.8	1.0	1.2	1.4	1.6	1.8 and over
α	0.0288	0.0207	0.0144	0.0099	0.0069	0.0048	0.0034	0.0025

Fig. 28.2 Measurement of *l* and *l*₁



2. The section modulus of hold frames between 0.15L from the fore end and the collision bulkhead is not to be less than that obtained from the formula in **-1**, using the coefficient of 1.25C instead of C.

3. The thickness of webs near the top and bottom end connections of hold frames is to be sufficient against shearing.

4. In ships less than 190 *m* in length, mild steel hold frames may be asymmetric. In this sub-paragraph, length of ship means L_1 (*m*) as specified in **28.1.6-3**.

5. In ships other than ships specified in **-4** above, hold frames of asymmetrical section are to be fitted with tripping brackets in way of the foremost hold.

6. The web depth to thickness ratio of hold frames is not to exceed the following values:

60 for symmetrically flanged hold frames

50 for asymmetrically flanged hold frames

7. For hold frames with asymmetrical section or flanged hold frames, the outstanding face or flange is not to exceed 10 *times* the flange thickness.

8. For holds loaded with cargoes of an especially large specific gravity, precautions are to be taken such as increasing scantlings of hold frames specified in **-1** and **-2**.

28.6.2 Upper and Lower End Connections of Hold Frames

1. Upper and lower ends of hold frames are to be connected with top side tanks and bilge hopper tanks by brackets.

Structural continuity with the upper and lower end connections of hold frames is to be ensured within top side tanks and bilge hopper tanks by connecting brackets. The toes of brackets connecting frames with hopper plates and top side tank sloping plates are not to coincide with connecting bracket ends in the tanks.

2. The connecting brackets in top side tanks and bilge hopper tanks specified in **-1** above are to be stiffened against buckling.

3. The scantlings of side longitudinals and longitudinal stiffeners fitted on the hopper plates and top side tank sloping plates which support the connecting brackets in top side tanks and bilge hopper tanks specified in **-1** above are to be in accordance with the requirements in **28.3.3-1**, **28.3.3-3**, **28.4.3-1** and **28.4.5-1**. However, in application of these requirements, l in the formulae is to be taken as the distance (m) between transverse webs regardless of the arrangement of the connecting brackets.

4. In ships not less than 190 m in length, hold frames are to be fabricated with integral upper and lower brackets. In this sub-paragraph, length of ship means L_1 (m) specified in **28.1.6-3**.

5. The thickness of upper and lower brackets attached to hold frames is not to be less than the thickness of the webs of those hold frames.

6. The section modulus of the hold frame and bracket or integral bracket, and associated shell plating, at the locations of Z_{BKT} *section* shown in **Fig. 28.3** is not to be less than twice the section modulus required by **28.6.1-1** and **-2**.

7. The dimensions of the upper and lower brackets of hold frames are to comply with the following requirements:

(1) The vertical depths of the brackets (l_{BKT}) from the R end (of the lower bracket) to the intersection of the side shell and the hopper plates, and from the R end (of the upper bracket) to the intersection of the side shell and the top side tank sloping plates are not to be less than those obtained from the following formula: (*See* **Fig. 28.4**)

$0.125\, l$ (m)

l : As specified in **28.6.1-1**

(2) The horizontal depths of the brackets (d_{BKT}) on the horizontal line through the intersection of the side shell and the hopper plates, and the intersection of the side shell and the top side tank sloping plates are not to be less than those obtained from the following formula: (*See* **Fig. 28.4**)

$$1.5d_{WEB}\ (m)$$

d_{WEB}: The web depth (m) of the hold frame fitted with the mentioned bracket

8. For hold frames with integral upper and lower brackets, the hold frame flange is to be curved (not knuckled) at the connection with the upper and lower brackets. The radius (R) of curvature is not to be less than that obtained from following formula (*See* **Fig 28.3**):

$$\frac{0.4b_f^2}{t_f}\ (mm)$$

b_f: The flange width (mm) of the bracket

t_f: The flange thickness (mm) of the bracket

28.6.3 Welding of Hold Frames

1. Double continuous fillet welding is to be adopted for the connection of hold frames and brackets to the side shell, top side tanks and bilge hopper tanks and webs to face plates. The throat thickness is to be greater than that obtained from following formulae according to the location of the weld.

(1) For connections of the upper and lower brackets to the hopper plates and top side tank sloping plates and the parts within $0.25l$ from each end of l (*See "zone A"* in **Fig. 28.3**):

$$0.44t\ (mm)$$

(2) For the parts within $0.5l$ amidspan of l (*See "zone B"* in **Fig. 28.3**):

$$0.4t\ (mm)$$

l: As specified in **28.6.1-1**

t: The thinner of the two connected members

2. Where the shape of the hull is such that it prohibits effective fillet welding, edge preparation of the web of hold frames and brackets may be required in order to ensure the same efficiency as the weld connection specified in **-1** above.

Fig 28.3 Hold Frames and Upper and Lower Brackets

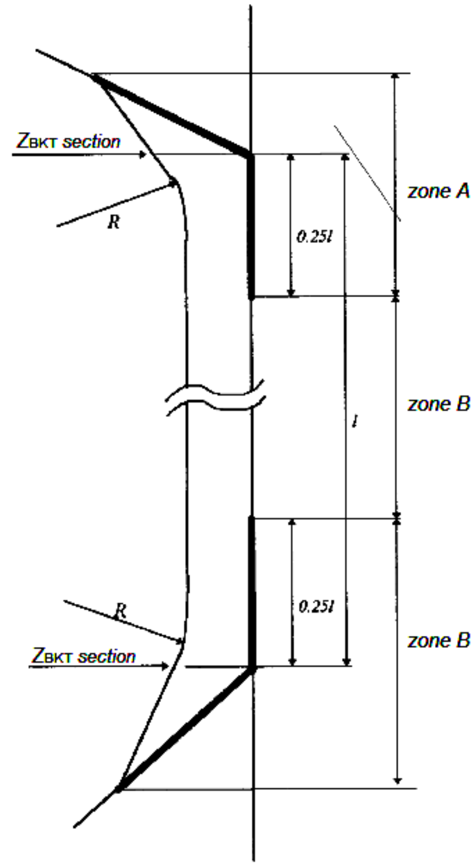
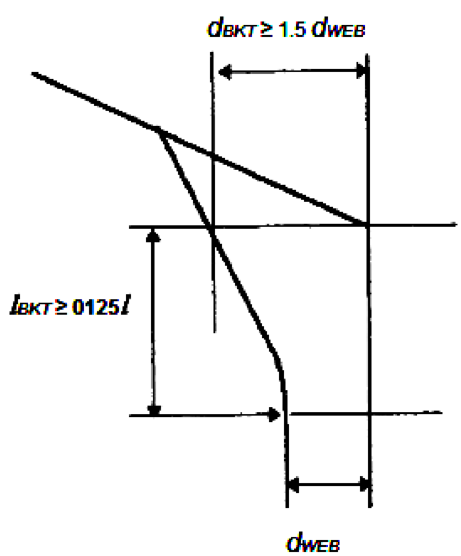


Fig 28.4 Dimension of Upper and Lower Brackets



28.7 Decks, Shell Plating and Miscellaneous

28.7.1 Deck Plating Outside the Line of Openings

The cross sectional area of deck plating outside the line of openings, where topside tanks are not provided, is to be determined in consideration of the continuity of longitudinal strength.

28.7.2 Deck Plating Inside the Line of Openings

1. Hatch end coamings are to be provided in coincidence with the positions of girders in topside tanks. If not coincident, sufficient care is to be taken for the continuity of strength at the connections of hatch end coamings with topside tanks.

2. Deck plating inside the line of openings is recommended to be provided with transverse beams. Where longitudinal beams are provided, special care is to be taken against buckling.

3. Special consideration for deck plating inside the line of openings, even if a transverse framing system is applied to the deck, is to be taken against buckling when loading high-density cargoes such as ore.

28.7.3 Bottom Shell Plating

The thickness of bottom shell plating of cargo holds in way of the double bottom is not to be less than that obtained from the formula in **15.3.4** or from the first formula in **28.2.4-1**, whichever is greater. However, in application of the latter formula, α is to be as given by the following formula:

$$\frac{13.8}{24 - 15.5 f_B}$$

f_B : As specified in **28.2.4-1**

28.7.4 Scuppers

1. One bilge suction pipe is to be provided, as a rule, on each side of the ship at the after end of each hold.

2. Bilge wells are to be provided at suitable positions so as to protect the cover plates from direct impact from bulk cargoes, and to be provided with mud boxes or other suitable means so that the suction openings are not choked by dust.

3. Where bilge pipes pass through double bottoms or bilge hopper tanks, non-return valves or stop valves capable of being closed down from a readily accessible position are to be provided at their open ends.

4. Overboard discharges from top side tanks are to be in accordance with the requirements of **13.4.1-6** and **-7 of Part 7**.

28.7.5 Coal Transportation

For ships intended for the transport of coal, care is to be taken regarding the following:

(1) The structure between holds and other compartments is to be airtight.

(2) Trimming hatches are recommended to be provided on the outside of superstructures and deckhouses.

(3) Ventilation of holds is to be made by a ventilation system provided on the weather part.

28.8 Supplementary Provisions for Carriage of Liquid in Holds

28.8.1 General

1. Bulk carriers whose holds are loaded with cargo oil (hereinafter referred to as *B*/*O* carriers) are to be in accordance with the requirements in this Chapter and also those for oil tankers.

2. Other important items required for *B*/*O* carriers than those specified in **28.8** are to be at the discretion of the Society.

3. Where holds are loaded with cargo oil or ballast water, the scantlings of plates, stiffeners and girders composing bilge hopper tanks, topside tanks, transverse bulkheads and their stools as well as side structures are not to be less than that obtained from the relevant formulae, where the value of h specified in **13.1.5** is applied.

28.8.2 Holds Half-Loaded with Cargo Oil

Where holds are half-loaded with cargo oil, special care is to be taken to avoid synchronization of the natural period of oscillation of liquid in the holds with the natural periods of rolling and pitching of the ship. Where synchronization is not avoidable, plating, stiffeners and girders of transverse bulkheads and topside tanks are to be especially strengthened.

Chapter 28A ADDITIONAL REQUIREMENTS FOR NEW BULK CARRIERS

28A.1 General

28A.1.1 Application

1. This Chapter applies to bulk carriers defined in **28A.1.2 (1)**.

2. Except where required otherwise in this chapter, the requirements of **Chapter 27** and **Chapter 28** and the general requirements for construction and equipment of steel ships, as applicable, are to be applied.

28A.1.2 Definitions

Terms used in this chapter are defined as follows:

(1) Bulk carrier means a ship which is intended primarily to carry dry cargo in bulk, including such types as ore carriers and combination carriers.

(2) Bulk carrier of single-side skin construction means a bulk carrier as defined in **(1)**, other than bulk carriers of double-side skin construction as defined in **(3)**.

(3) Bulk carrier of double-side skin construction means a bulk carrier as defined in **(1)**, in which all cargo holds are bounded by a double-side skin as defined in **(4)**.

(4) Double-side skin means a configuration where each ship side is constructed by the side shell and a longitudinal bulkhead connecting the double bottom and the deck. Hopper side tanks and top-side tanks may, where fitted, be integral parts of the double-side skin configuration.

(5) Solid bulk cargo means any material, other than liquid or gas, consisting of a combination of particles, granules or any larger pieces of material, generally uniform in composition, which is loaded directly into the cargo spaces of a ship without any intermediate form of containment.

(6) Bulk cargo density or Bulk density (t/m^3) means the ratio of the loaded cargo mass to the volume which is assumed to be occupied by the loaded cargo including empty spaces within the bulk cargo, notwithstanding the specific gravity of the cargoes defined in **28.2.1-3**.

(7) Permeability of a space means the ratio of the volume within the space which is assumed to be occupied by water to the total volume of the space under consideration. In this chapter, the value given in **Table 28A.1.1** may be used as standard according to the kind of cargo. For cargoes other than those given in **Table 28A.1.1**, the values of permeability are to be at the Society s discretion.

(8) Angle of repose means the maximum slope angle between a horizontal plane and a cone slope of free-flowing bulk cargo. In this chapter, the value given in **Table 28A.1.2** may be used as standard according to the kind of cargo. For cargoes other than those given in **Table 28A.1.2**, the angles of repose are to be at the Society's discretion.

Table 28A.1.1 Permeability

Cargo and etc.	Permeability
Iron Ore	0.3
Cement	0.3
Coal	0.3
Empy Space	0.95

Table 28A.1.2 Angle of repose

Cargo	Angle of repose
Iron ore	35˚
Cement	25˚
Coal	35˚

28A.2 Damage Stability

28A.2.1 Survivability

1. Bulk carriers, coming under the following **(1)** or **(2)**, of not less than 150 *m* in length L_f, designed to carry solid bulk cargoes having a density of not less than 1.0 ton/m^3 are to, when loaded to the summer load line, be able to withstand flooding of any one cargo hold in all loading conditions and remain afloat in a satisfactory condition of equilibrium, as specified in **-2** below. However where deemed necessary by the Society, plural cargo holds are to be assumed to be flooded.

(1) Bulk carriers of single-side skin construction

(2) Bulk carriers of double-side skin construction in which any part of a longitudinal bulkhead is located within B/5 or 11.5 *m*, whichever is less, inboard from the ship's side at right angles to the centreline at the assigned summer load line

2. The condition of equilibrium after flooding is to be in accordance with the following:

(1) The final water line after flooding, taking into account sinking, heel, and trim, is to be below the lower edge of any opening through which progressive flooding may take place. Such openings are to include air pipes, ventilators and openings which are closed by means of weathertight doors or hatch covers. The openings closed by means of manhole hatch covers and flush scuttles, watertight hatch covers, remotely operated sliding watertight doors and side scuttles of the non- opening type, may be excluded.

(2) Where pipes, ducts or tunnels are situated within the assumed extent of damage penetration, arrangements are to be made so that progressive flooding does not extend to compartments other than those assumed to be flooded.

(3) The metacentric height in the flooded condition is to be positive.

(4) The righting lever curve is to have a minimum range of 20 *degrees* beyond the position of equilibrium and a maximum righting lever of at least 0.1 *m* within this range. The area under the righting lever curve within this range is to be not less than 0.0175 *m-radian*. Unprotected openings are not to be immersed within this range except where the corresponding compartments are assumed to be flooded.

3. The ships whose assigned freeboards are of "*B-60*" or "*B-100*" type specified in *ILLC* are to be treated as complying with **-1** and **-2** above.

28A.3 Transverse Watertight Bulkheads in Cargo Holds

28A.3.1 General

1. The requirements in this section apply to vertically corrugated watertight bulkheads in cargo holds of bulk carriers, coming under the following **(1)** or **(2)**, of not less than 150 *m* in length L_f, designed to carry solid bulk cargoes having a density of not less than 1.0 ton/m^3

(1) Bulk carriers of single-side skin construction

(2) Bulk carriers of double-side skin construction in which any part of a longitudinal bulkhead is located within *B*/5 or 11.5 *m*, whichever is less, inboard from the ship's side at right angles to the centreline at the assigned summer load line

2. In this section, "homogeneous loading condition" means a loading condition in which the ratio between the highest and lowest filling ratio, evaluated for each hold, does not exceed 1.20, to be corrected for different cargo densities.

3. The most severe combinations of cargo induced loads and flooding loads are to be used for examining the scantlings of the bulkheads, depending on the following loading conditions included in the loading manual:

(1) Homogeneous loading conditions;

(2) Non-homogeneous loading conditions.

In any case, the pressure due to the flood water alone needs to be considered when making calculations. Non-homogeneous loading conditions associated with multiport loading and unloading operations that occur before a homogeneous loading condition is reached does not need to be considered according to the requirements in this section.

4. Holds carrying bound cargoes such as steel mill products are to be considered as empty holds for examining the scantlings of the bulkhead.

5. The thickness of bulkheads excluding the corrosion margin (hereinafter referred to as net thickness), *tnet*, is to be used for examining the scantlings of the bulkhead. The actual scantlings of the bulkhead are to be at least *tnet* plus the corrosion margin which is not less than 3.5 *mm*.

6. Unless the ship is intended to carry, in non-homogeneous conditions, only iron ore or cargo having a bulk density not less than 1.78 t/m^3, the maximum mass of cargo which may be carried in the hold is to be considered as cargo that fills the hold up to the upper deck level at the centre line.

7. For ships of not less than 190 *m* of length L_1, bulkheads are to be fitted with a lower stool and generally with a upper stool. For ships other than the above, corrugations may extend from the inner bottom to the deck. L_1 is the length of ship specified in **1.2.2, Part 1** or 0.97 *times* the length of ship on the designed maximum load line, whichever is smaller.

28A.3.2 Load Model

1. The flooding head h_f (*m*) is to be the distance measured vertically with the ship in the upright position, from the calculation point to a level located at a distance d_f (*m*) from the baseline equal to (see Fig. **28A.3.1**):

(1) General:

(a) D (*m*) for the aft bulkhead in the foremost cargo hold

(b) $0.9D$ (*m*) for the other bulkheads

Where the ship is to carry cargoes having a bulk density of less than 1.78 t/m^3 in non-homogeneous conditions, the following values can be assumed:

(a) $0.95D$ (*m*) for the aft bulkhead in the foremost cargo hold

(b) $0.85D$ (*m*) for the other bulkheads

(2) For ships less than 50,000 *tonnes* deadweight with a type B freeboard:

(a) $0.95D$ (*m*) for the aft bulkhead in the foremost cargo hold

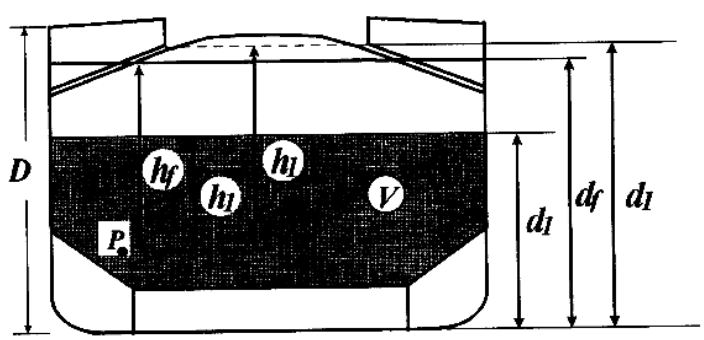
(b) $0.85D$ (*m*) for the other bulkheads

Where the ship is to carry cargoes having a bulk density of less than 1.78 t/m^3 in non-homogeneous conditions, the following values can be assumed:

(a) $0.9D$ (*m*) for the aft bulkhead in the foremost cargo hold

(b) $0.8D$ (*m*) for the other bulkheads

Fig. 28A.3.1



V = Volume of Cargo
P = calculation Point

2. In a non-flooded hold loaded with cargo, the pressure and force acting on the corrugated bulkhead are to be obtained from following **(1)** and **(2)**.

(1) At each point of the bulkhead, the pressure p_c is given by the following:

$$P_c = \rho_c g h_1 \tan^2 \gamma \ (kN/m^2)$$

Where:

ρ_c: Bulk cargo density (t/m^3)

g : Gravity acceleration; 9.81(m/s^2)

h_1 : Vertical distance (m) from the calculation point to the horizontal plane corresponding to the top of the cargo when levelled out located at the distance d_1 from the baseline (see **Fig. 28A.3.1**)

γ: $45° - \frac{\phi}{2}$

ϕ: Angle of repose defined in **28A.1.2(8)**

(2) The force F_c acting on the corrugation is given by the following:

$$F_c = \rho_c g s_1 \frac{(d_1 - h_{DB} - h_{LS})^2}{2} tan^2\gamma \ (kN)$$

Where:

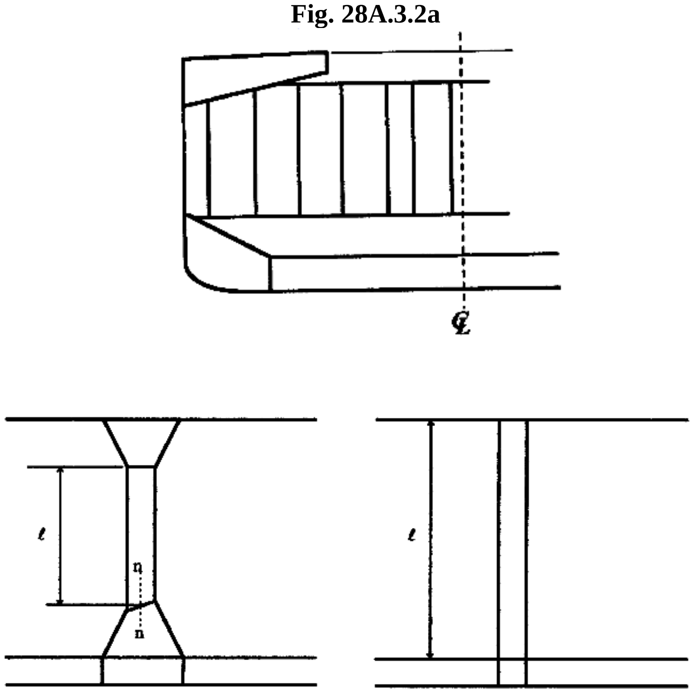
P_c , g, d_1 and γ : As specified in **(1)** above

S_1 : Spacing (m) of corrugation (see **Fig. 28A.3.2a**)

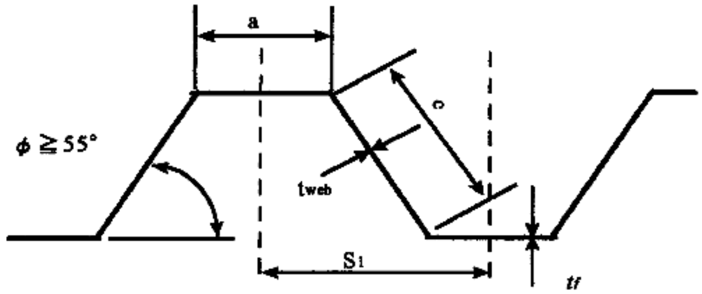
h_{DB} : Height (m) of the double bottom

h_{LS} : Height (m) of the lower stool from the inner bottom

Fig. 28A.3.2a



n= Neutral Axis of the corrugations



3. The pressure and force acting on the bulkhead in a loaded cargo hold under flooded conditions at the point considered are to be obtained from the following **(1)** and **(2)** according to the relation between the flooding head d_f and cargo height d_1 calculated in **-1** and **-2** above. (See **Fig. 28A.3.1**)

(1) For $d_f \geq d_1$

(a) At each point of the bulkhead located at a distance between d_f and d_1 from the baseline, the pressure $p_{c,f}$, is given by the following:

$$p_{c,f} = \rho g h_f (kN/m^2)$$

Where:

ρ : Sea water density; 1.025(t/m^3)

g : As specified in **-2** above

h_f : As specified in **-1** above

(b) At each point of the bulkhead located at a distance lower than d_1 from the baseline, the pressure $p_{c\,f}$, is given by the following:

$$p_{c,f} = \rho g h_f + [\rho_c - \rho(1 - perm)] g h_1 tan^2 y \qquad (kN/m^2)$$

Where:

ρ : As specified in **(a)** above

h_f: As specified in **-1** above

ρ_c, g, h_1 and γ: As specified in **-2** above

perm: Permeability defined in **28A.1.2(7)**

(c) The force $F_{c,f}$ acting on the corrugation is given by the following:

$$F_{c,f} = s_1 \left[\rho g \frac{(d_f - d_1)^2}{2} + \frac{\rho g (d_f - d_1) + (p_{c,f})_{le}}{2} (d_1 - h_{DB} - h_{LS)} \right] (kN)$$

Where:

ρ: As specified in **(a)** above

s_1 , g, d_1 , h_{DB} and h_{LS} : As specified in **-2** above

d_f : As specified in **-1** above

$(p_{c,f})_{le}$: Pressure at the lower end of the corrugation (kN/m^2)

(2) For $d_f < d_1$

(a) At each point of the bulkhead located at a distance between d_f and 1 d from the baseline, the pressure $p_{c,f}$, is given by the following:

$$p_{c,f} = \rho_c g h_1 \tan^2\gamma \ (kN/m^2)$$

Where:

ρ_c, g, h_1 and γ specified in **-2** above

(b) At each point of the bulkhead located at a distance lower than d_f from the baseline, the pressure p_{cf}, is given by the following:

$$p_{c,f} = pgh_f + [p_c h_1 - p(1 - perm)h_f] \tan^2\gamma \ (kN/m^2)$$

Where:

ρ and $perm$: As specified in **(1)** above

h_f : As specified in **-1** above

ρ_c, g, h_1, and γ: As specified in **-2** above

(c) The force $F_{c,f}$ acting on the corrugation is given by the following:

$$F_{c,f} = S_1 \left[\rho_c g \frac{(d_1 - d_f)^2}{2} \tan^2\gamma + \frac{\rho_c g (d_1 d_f) \tan^2\gamma + (p_{c,f})_{le}}{2} (d_f - h_{DB} - h_{LS}) \right] (kN)$$

Where

s_1, ρ_c, g, d_1, h_{DB} and h_{LS} : As specified in **-2** above

d_f : As specified in **-1** above

$(p_{c,f})l_e$: As specified in **(1)** above

4. The pressure and force acting on the bulkhead in an empty cargo hold under flooded conditions at the point considered are to be obtained from following **(1)** and **(2).**

(1) At each point of the bulkhead, the hydrostatic pressure p_f induced by flooding is to be a flooding head h_f as calculated in **-1** above.

(2) The force F_f acting on the corrugation is given by the following:

$$F_f = S_1 \rho g \frac{(d_f - h_{DB} - h_{LS})^2}{2} \quad (kN)$$

Where:

s_1, g, h_{DB} and h_{LS} : As specified in **-2** above

ρ : As specified in **-3** above

d_f : As specified in **-1** above

5. The resultant pressure p and force F at each point of the bulkhead used for calculating its scantlings are to be calculated based on the values attained from **-1** to **-4** above according to the loading conditions by the following formulae:

(1) For homogeneous loading

$$p = p_{c,f} - 0.8 p_c (kN/m^2)$$

$$F = F_{c,f} - 0.8 F_c (kN)$$

(2) Non-homogeneous loading

$p = p_{c,f}\ (kN/m^2)$

$F = F_{c,f}(kN/m^2)$

28A.3.3 Bending Moment and Shear Force in Bulkhead Corrugations

1. The design bending moment M for bulkhead corrugations is given by the following:

$$M = \frac{Fl}{8}(kN \cdot m)$$

F : As calculated in 28A.3.2-5

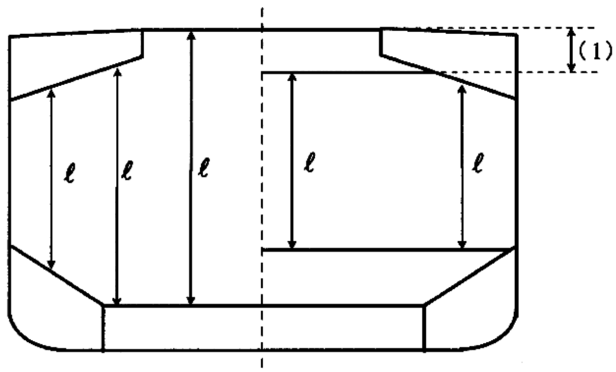
l : Span (m) of the corrugation as shown in Fig. 28A.3.2a and Fig. 28A.3.2b

2. The shear force Q at the lower end of the bulkhead corrugations is given by the following:

$Q = 0.8F\ (kN)$

F : As calculated in 28A.3.2-5

Fig. 28A.3.2b



l : Span of the corrugation

Where the upper stool is the provided, the upper end of *"l"* may be the bottom of the upper stool. However, the distance between the upper end of *"l"* and the upper deck at the centre line (1) is not to be greater than the following values;

(a) 3 times the depth of the corrugations, in general

(b) 2 times the depth of corrugations, for rectangular stool.

28A.3.4 Strength Criteria

1. The section modulus at the lower end of the corrugation is to be calculated with the following considerations.

(1) The width of the compressive corrugation flange to be used for the calculation of the section modulus is not to exceed the effective width b_{ef} obtained by the following.

$b_{ef} = C_e a\ (m)$

C_e: $\frac{2.25}{\beta} - \frac{1.25}{\beta^2}$ For $\beta > 1.25$

1.0 For $\beta \leq 1.25$

Where:

$\beta: 10^3 \dfrac{a}{t_f}\sqrt{\dfrac{\sigma_F}{E}}$

t_f : Net flange thickness (*mm*)

a : Width (*m*) of corrugation flange (See **Fig. 28A.3.2a**)

σ_F : Yield stress (N/mm^2) of the material

E : Modulus of elasticity, 2.06 x10^5 (N/mm^2)

(2) Where the webs of corrugation are not supported by local brackets below the stool top (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs to be 30% effective.

(3) Provided that effective shedder plates as defined in **28A.3.5-5** are fitted (see **Fig. 28A.3.3a** and **Fig. 28A.3.3b**), the area of flange plates may be increased by the following formula when calculating the section modulus of corrugations (see cross-section (1) in **Fig. 28A.3.3a** and **Fig. 28A.3.3b**), but it is not to be greater than $2.5at_f$

$2.5a\sqrt{t_f t_{sh}}\ (cm^2)$

Where:

a : Width (*m*) of corrugation flange (See **Fig. 28A.3.2a**)

t_{sh} : Net shedder plate thickness (*mm*)

t_f : Net corrugation flange thickness (*mm*)

Fig. 28A.3.3a

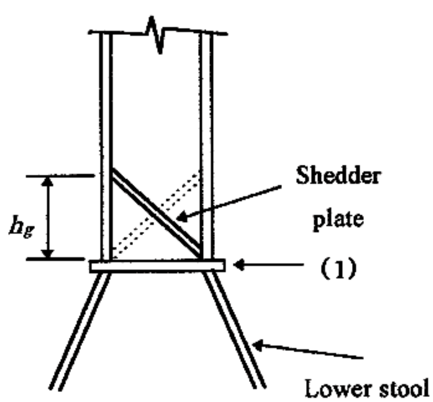
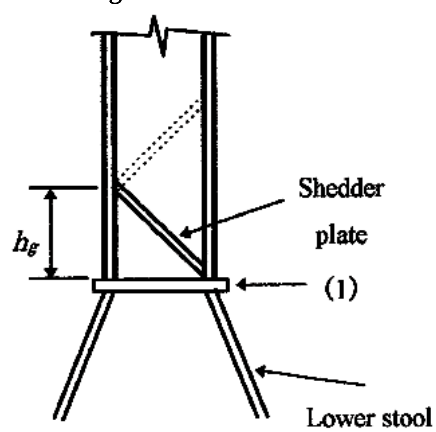


Fig. 28A.3.3b



(4) Provided that effective gusset plates as defined in **28A.3.5-6** are fitted (see **Fig. 28A.3.4a** and **Fig. 28A.3.4b**),the area of flange plates may be increased by the following formula when calculating the section modulus of corrugations (see cross-section (1) in **Fig. 28A.3.4a** and **Fig. 28A.3.4b**).

$7h_g t_f (cm^2)$

Where:

h_g : Height (*m*) of gusset plate, but not to be greater than $10S_{gu}$ / 7 (See **Fig. 28A.3.4a** and **Fig. 28A.3.4b**)

S_{gu} : Width (*m*) of gusset plate

t_f : Net flange thickness (*mm*)

Fig. 28A.3.4.a

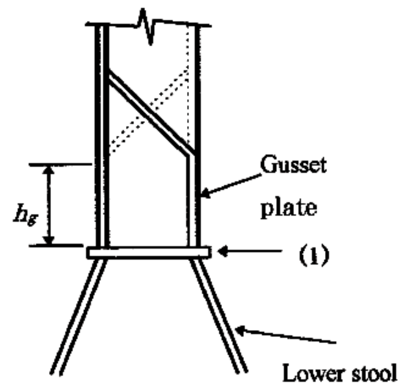
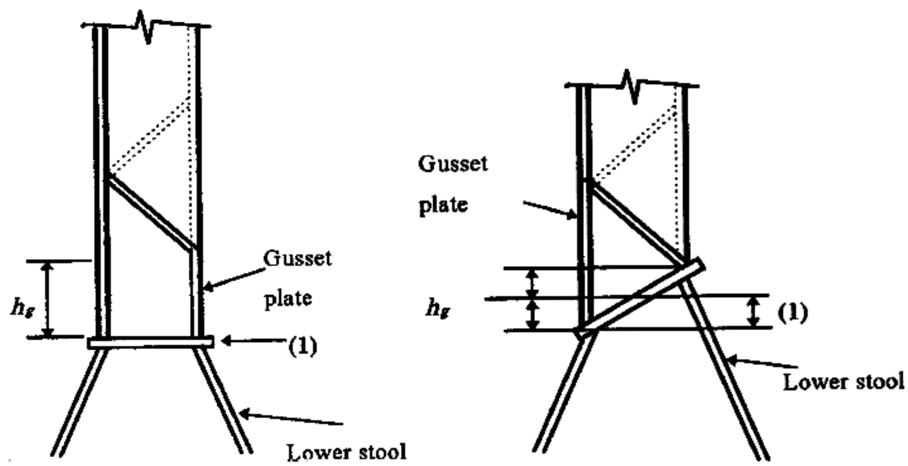


Fig. 28A.3.4.b



(5) If the corrugation webs are welded to sloping stool top plates which have an angle of not less than 45° with the horizontal plane, the section modulus of the corrugations may be calculated taking the corrugation webs as fully effective. For angles less than 45°, the effectiveness of the web may be obtained by linear interpolation between 30% (for 0°) and 100% (for 45°). (See **Fig. 28A.3.4b**)

Where effective gusset plates are fitted, the area of flange plates may be increased as specified in (4) above when calculating the section modulus of corrugations. This is not applicable if only shedder plates are fitted.

2. Provided that effective gusset plates or shedder plates as defined in **28A.3.5-5**, and **28A.3.5-6** are fitted (see **Fig. 28A.3.4a** and **Fig. 28A.3.4b**), the section modulus of corrugations at the lower end Z_{le} is to be not greater than Z'_{le} obtained from the following formula:

$$Z'_{le} = Z_g + 10^3 x \frac{Qh_g - 0.5h_g^2 s_1 p_g}{\sigma_a} (cm^3)$$

Z_g : Section modulus (cm^3) of corrugation according to **-3.** in way of the upper end of shedder plates or gusset plates

Q : Shear force (kN) as given in **28A.3.3-2**

h_g : Height (m) of shedder plates or gusset plates (See **Fig. 28A.3.3a**, **Fig. 28A.3.3b**, **Fig. 28A.3.4a** and **Fig. 28A.3.4b**)

s_1 : As given in **28A.3.2-2**

p_g : Resultant pressure (kN/m^2) as defined in **28A.3.2-5**, calculated in way of the middle of the shedder plates or gusset plates

σ_a : Yield stress of material (N/mm^2)

3. The section modulus of corrugations at a cross-section other than the lower end calculated in **-1** and **-2** is ated with the corrugation webs considered effective and the compressive flange having an effective flange width b_{ef} not greater than as given in **-1** above**.**

4. The bending capacity of corrugation is to be in accordance with the following:

$$10^3 x \frac{M}{0.5Z_{le}\sigma_{a,le} + Z_m \sigma_{a,m}} \leq 0.95$$

Where

M : Bending moment ($kN \cdot m$) as given in **28A.3.3-1**

Z_{le} : Section modulus (cm^3) of corrugation at the lower end as calculated in **-1**

Z_m : Section modulus (cm^3) of corrugation at the mid-span of corrugation as calculated in **-3**

Z_m is not to be greater than $1.15 \cdot Z_{le}$.

$\sigma_{a,le}$: Yield stress (N/mm^2) of the material to be used for the lower end of corrugations

$\sigma_{a,m}$: Yield stress (N/mm^2) of the material to be used for the mid-span of corrugations

5. Shearing stress of corrugation is to be in accordance with the following: (See **Fig. 28A.3.2a**)

$$\tau_a \geq \frac{Qx10^3}{A_w \sin \emptyset} (N/mm^2)$$

t_a : $0.5\sigma_F$ (N/mm^2)

σ_F : Yield stress of material (N/mm^2)

Q : Shear force (kN) as given in **28A.3.3-2**

A_w : Sectional area (mm^2) of corrugation web at the lower end

$\emptyset$: Angle (°) between the web and the flange

6. The buckling strength of the corrugation is to fulfil the following formula so that the shearing stress t for the web plates at the ends do not exceed the critical value τ_c.

$$\tau_c = \tau_E \quad when \;\; \tau_E \leq \frac{\tau_F}{2} (N/mm^2)$$

$$\tau_c = \tau_F \left(1 - \frac{\tau_F}{4\tau_E}\right) \quad when \;\; \tau_E > \frac{\tau_F}{2} (N/mm^2)$$

Where:

t_F: $\frac{\sigma_F}{\sqrt{3}}$ (N/mm^2)

σ_F: Yield stress of material (N/mm^2)

τ_E: $0.9k_tE\left(\frac{t}{1000c}\right)^2$ $(\mathrm{N/mm^2})$

k_t : Coefficient as 6.34

E : Modulus of elasticity of material as 2.06 x 10^5 (N/mm^2)

t : Net thickness (mm) of corrugation web

c : Width (m) of corrugation web (See **Fig. 28A.3.2a**)

7. The corrugation local net plate thickness t is to comply with the following:

$$t = 14.9\ Sw\sqrt{\frac{1.05p}{\sigma_F}}(mm)$$

S_w: Plate width (m) to be taken equal to the width of the corrugation flange or web, whichever is the greater (see **Fig. 28A.3.2a**)

p : Resultant pressure (kN/m^2) at the bottom of each strake of bulkhead plating calculated in **28A.3.2-5**; in all cases, the net thickness of the lowest strake is to be determined using the resultant pressure at the top of the lower stool, or at the inner bottom if no lower stool is fitted, or at the top of shedders if shedder or gusset/shedder plates are fitted.

σ_F: Yield stress of material (N/mm^2)

For built-up corrugation bulkheads, of which the thickness of the flange and web are different, the thickness of the narrower plating is to be not less than t_n given by the following:

$$t_n = 14.9Sn\sqrt{\frac{1.05p}{\sigma_F}}(mm)$$

S_n : Width (m) of the narrower plating

The net thickness of the wider plating t_w is to be taken not less than t_{w1} and t_{w2} obtained from following formula:

$$t_{wl} = 14.9Sw\sqrt{\frac{1.05p}{\sigma_F}}(mm)$$

$$t_{w2} = \sqrt{\frac{440S_w^2 \cdot 1.05p}{\sigma_F} - t_{np}^2}\ (mm)$$

t_{np} : The value (mm) not greater than the net thickness of the narrower plating and t_{w1}

28A.3.5 Structural Details

1. The corrugation angle $\emptyset$ shown in **Fig. 28A.3.2a** is not to be less than 55°

2. The thickness of the lower part of the corrugations calculated in **28A.3.4-1**, -**2**, -**4** and -**5** are to be maintained for a distance of not less than 0.15l from the inner bottom (if no lower stool is fitted) or the top of the lower stool.

3. The thickness of the middle part of the corrugations calculated in **28A.3.4-3**, **-4** and **-5** are to be maintained for a distance of not less than $0.30l$ from the deck (if no upper stool is fitted) or the bottom of the upper stool.

4. The section modulus of the corrugation in the upper part of the bulkhead other than those specified in **-2** and **-3** is not to be less than 75% of that required for the middle part in **-3**, and to be corrected for the yield stresses of different materials.

5. Where shedder plates are fitted, they are to comply with the following so as to maintain their effectiveness.

(1) Not be knuckled

(2) Be welded to the corrugation and the top plate of the lower stool by one-side penetration welds or equivalent

(3) Have a min. slope of 45° and their lower edge is to be in line with the stool side plating

(4) Have a thickness of not less than 75% of that of the corrugation flange, and have material properties at least equivalent to those used for the corrugation flanges

6. Where gusset plates are fitted, they are to comply with the following so as to maintain their effectiveness.

(1) Be in combination with the shedder plates of **-5** above

(2) Have a height of not less than half of the corrugation flange width

(3) Be fitted in line with the stool side plating

(4) Have a thickness and material properties at least equivalent to those used for the corrugation flanges

(5) Be welded to the top of the lower stool by either full penetration or deep penetration welds (see **Fig. 28A.3.6**) and to the corrugations and shedder plates by one side penetration welds or equivalent.

7. Where lower stools are fitted with the bulkheads, the structure and arrangements are to be in accordance with the following. For ships less than 190 *m* in length L_1, the following **(1)** and **(6)** are standard.

(1) The height of the lower stool is generally to be not less than 3 times the depth of the corrugations.

(2) The thickness and material of the lower stool top plate is not to be less than those required for the bulkhead plating at the lower end of the corrugation in **28A.3.4**.

(3) The thickness and material of the upper part of the slant stool side plating with a depth equal to the corrugation flange width from the stool top is not to be less than those required for the bulkhead plating at the lower end of the corrugation stipulated in **28A.3.4**..

(4) The ends of stool side vertical stiffeners are to be attached to brackets at the upper and lower ends of the stool.

(5) The distance from the edge of the stool top plate to the surface of the corrugation flange is to be not less than the thickness of the flange (see **Fig. 28A.3.5**).

(6) The stool bottom is to be installed in line with double bottom floors and is to have a width of not less than 2.5 times the mean depth of the corrugation.

(7) The stool is to be fitted with diaphragms in line with the longitudinal double bottom girders for effective support of the corrugated bulkhead.

(8) Scallops in the brackets and diaphragms in way of the connections to the stool top plate are to be avoided.

(9) Flanges and webs of corrugated bulkhead plating are to be connected to the stool top plate by full penetrationwelds. The stool side plating is to be connected to the stool top plate and the inner bottom

plating by either full penetration or deep penetration welds (see Fig. 28A.3.6). The supporting floors are to be connected to the inner bottom by either full penetration or deep penetration welds (see Fig. 28A.3.6).

Fig. 28A.3.5

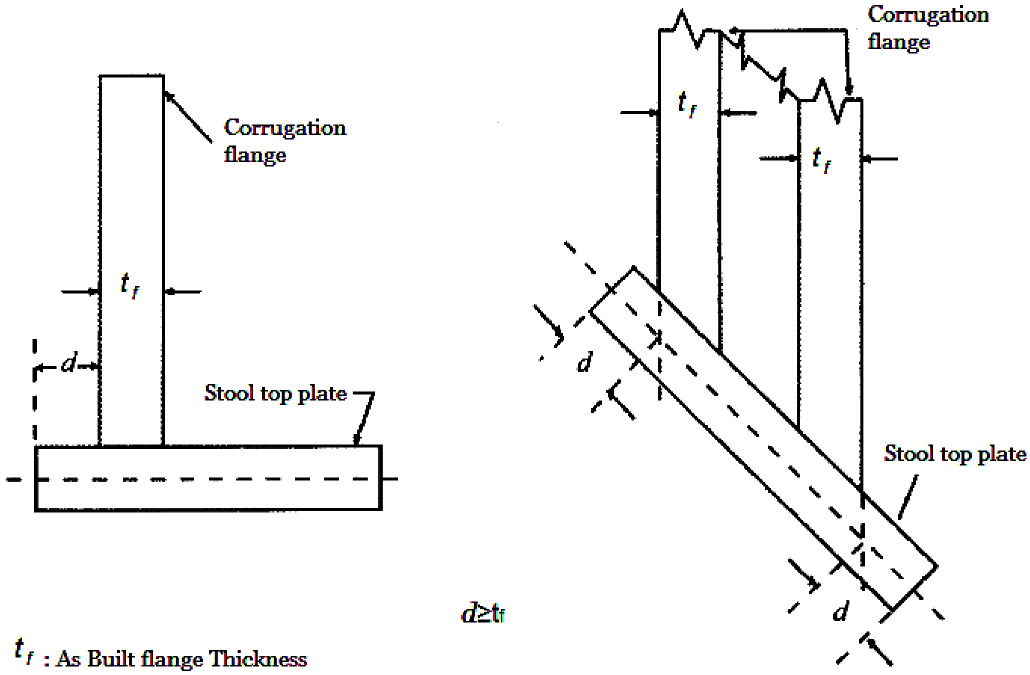
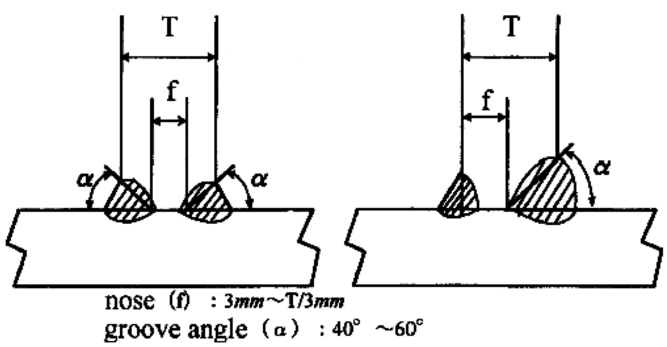


Fig. 28A.3.6



8. Where upper stools are fitted with the bulkheads, the structure and arrangements are to be in accordance with the following. For ships less than 190 *m* of length L_1 , the following **(1)** and **(4)** are standard:

(1) The upper stool, where fitted, is to have a height generally between 2 to 3 times the depth of corrugations. When measured at the hatch side girder, the height of rectangular stools from the deck is to be generally equal to 2 times the depth of corrugations.

(2) The upper stool is to be properly supported by girders or deep brackets between the adjacent hatch-end beams.

(3) The width of the stool bottom plate is generally to be the same as that of the lower stool top plate.

(4) The stool top of non-rectangular stools is to have a width of not less than 2 times the depth of corrugations.

(5) The thickness and material of the stool bottom plate are to be the same as those of the bulkhead plating below.

(6) The thickness of the lower portion of stool side plating is not to be less than 80% of that required for the upper part of the bulkhead plating where the same material is used.

(7) The ends of stool side stiffeners are to be attached to brackets at upper and lower ends of the stool.

(8) Diaphragms are to be fitted inside the stool in line with and effectively attached to longitudinal deck girders extending to the hatch end coaming girders for effective support of the corrugated bulkhead.

(9) Scallops in the brackets and diaphragms in way of the connection to the stool bottom plate are to be avoided.

9. Where no stools are fitted, the following precautions are to be taken.

(1) Where no upper stools are fitted, two transverse reinforced beams are to be fitted in line with the corrugation flanges at the deck. The thickness and material of the beams are not to be less than those required for the bulkhead plating at the upper end of the corrugation, and the height of the beams are to be generally not less than half the depth of the corrugations.

(2) Where no lower stools are fitted, the corrugation flanges are to be in line with the supporting floors. Flanges and webs of corrugated bulkhead plating are to be connected to the inner bottom plating by full penetration welds.

The plating of supporting floors is to be connected to the inner bottom by either full penetration or deep penetration welds (see **Fig. 28A.3.6**). The thickness and material properties of the supporting floors are to be at least equal to those of the corrugation flanges.

(3) The scallops for connections of the inner bottom longitudinals to the double bottom floors in (2) above are to be closed by collar plates. The supporting floors are to be connected to each other by suitably designed shear plates, as deemed appropriate by the Society.

10. The design of local details is to be for the purpose of transferring the force and moment acting on the corrugation to boundary structures, in particular to the double bottom and cross-deck structures.

28A.3.6 Renewal Thickness for Ship in Operation

Structural drawings of corrugated bulkheads complying with the requirements of **28A.3.4** are to indicate the renewal thickness ($t_{renewal}$) for each structural element, given by the following formula in addition to the as built thickness ($t_{as\text{-}built}$). If the thickness for voluntary addition is included in the as built thicknesses, the value may be at the discretion of the Society.

$$t_{renewal} = t_{as-biult} - 3.0\ (mm)$$

28A.4 Allowable Hold Loading on Double Bottom

28A.4.1 General

1. Bulk carriers, coming under the following **(1)** or **(2)**, of not less than 150 *m* in length L_f, designed to carry solid bulk cargoes having a density of not less than 1.0 ton/m^3 are to have sufficient double bottom strength to withstand flooding of any one cargo hold in all designed loading and ballast conditions. Evaluation of the double bottom strength is to be in accordance with **28A.4.3**.

(1) Bulk carriers of single-side skin construction

(2) Bulk carriers of double-side skin construction in which any part of a longitudinal bulkhead is located within *B*/5 or 11.5 *m*, whichever is less, inboard from the ship's side at right angles to the centreline at the assigned summer load line

28A.4.2 Notes for Evaluation of Strength

1. The maximum bulk cargo density is of importance when considering the cargo load acting on the double bottom of a cargo hold that is flooded.

2. In calculating the shear strength, the net thickness t_{net} of floors and girders is to be used, as given by the following:

$$t_{net} = t - 2.5\ (mm)$$

t : As built thickness of floors and girders (*mm*)

3. The shear capacity of the double bottom is defined as a sum of the shear strengths at each end of the following members:

(1) All floors adjacent to both hoppers, less one half of the strength of the two floors adjacent to each stool, or transverse bulkheads if no stool is fitted (See **Fig. 28A.4.1**)

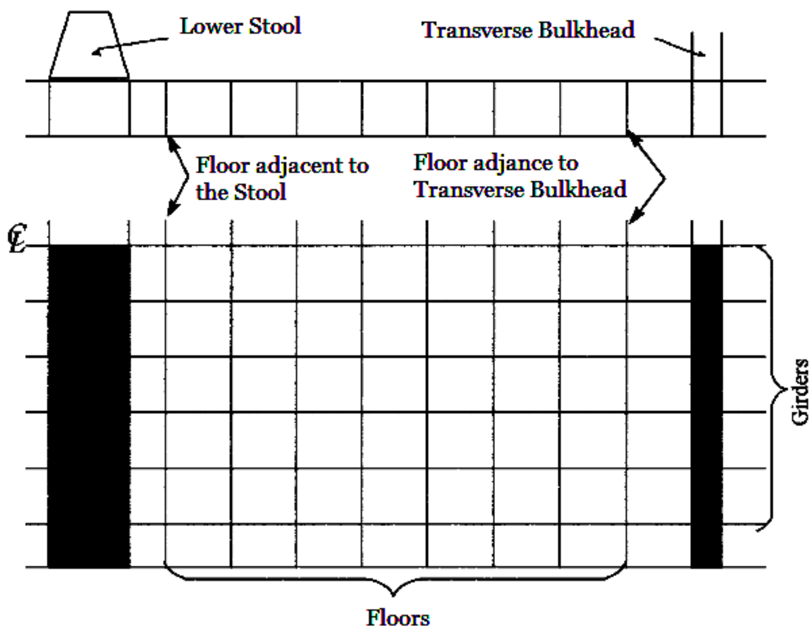
(2) All double bottom girders adjacent to stools or transverse bulkheads if no stool is fitted

4. The strength of girders or floors of end holds which do not directly attach to boundary stools or hopper girders are to be evaluated at one end only.

5. The floors and girders to be considered are those inside the hold boundaries formed by the hoppers and stools (or transverse bulkheads if no stool is fitted). The hopper side girders and the floors directly below the connection of the bulkhead stools (or transverse bulkheads if no stool is fitted) to the inner bottom are not to be included.

6. When the shape and/or structural arrangement of the double bottom are deemed inadequate by the Society as stipulated above, the shear capacity of the double bottom is to be calculated at the discretion of the Society

Fig. 28A.4.1 Floors and Girders to be calculated



28A.4.3 Strength Criteria

1. Shear capacity of double bottom C_h and C_e are to comply with the following formulae:

$$C_h = Z \cdot A_{DB,h}\ (kN)$$

$$C_e = Z \cdot A_{DB,e}\ (kN)$$

Where:

The variables in the above formulae are to be in accordance with the following **-2** through **-4**.

2. Shear capacities of the double bottom C_h and C_e are to be obtained from the following formulae:

$$C_h = \sum min\left(S_{f1}, S_{f2}\right) + \sum min\left(S_{g1}, S_{g2}\right)(kN)$$

$$C_e = \sum S_{f1} + \sum min\left(S_{g1}, S_{g2}\right)(kN)$$

S_{f1} and S_{f2}: The floor shear strength in way of the floor panel adjacent to hoppers, and the shear strength in way of the openings in the outmost bay (i.e. the bay closest to hoppers) are given by the following:

$$S_{f1} = 10^{-3} A_f \frac{\tau_a}{\eta_{f1}}(kN)$$

$$s_{f2} = 10^{-3} A_{f,h} \frac{\tau_a}{\eta_{f2}}(kN)$$

Where:

A_f: Sectional area (mm^2) of the floor panel adjacent to hoppers

$A_{f,h}$: Net sectional area (mm^2) of the openings in the outmost bay (i.e. the bay closest to hoppers)

τ_a : Allowable shear stress to be taken equal to the lesser of the following formula (however, τ_a maybe taken as $\frac{\sigma_F}{\sqrt{3}}$ for floors adjacent to stools or transverse bulkheads):

$$\frac{162 \cdot \sigma_F^{0.6}}{\left(\frac{s}{t_{net}}\right)^{0.8}} \quad or \quad \frac{\sigma_F}{\sqrt{3}} \quad (N/mm^2)$$

σ_F: Yield stress (N/mm^2) of the material

S: Spacing (mm) of stiffening members of panel under consideration

η_{f1} : 1.10

η_{f2} : 1.20; may be reduced to 1.10, where appropriate reinforcements are fitted to the Society's satisfaction.

S_{g1} and S_{g2}: The girder shear strength in way of the girder panel adjacent to stools (or transverse bulkheads, if no stool fitted) and the girder shear strength in way of the largest openings in the outmost bay (i.e. the bay closest to stools, or transverse bulkheads, if no stool fitted) are given by the following:

$$S_{g1} = 10^{-3} A_g \frac{\tau_a}{\eta_{g1}} (kN)$$

$$S_{g2} = 10^{-3} A_{g,h} \frac{\tau_a}{\eta_{g2}} (kN)$$

Where:

A_g : Sectional area (mm^2) of the girder panel adjacent to stools (or transverse bulkheads, if no stool fitted)

$A_{g,h}$: Net sectional area (mm^2) of the largest openings in the outmost bay (i.e. the bay closest to stools, or transverse bulkheads, if no stool fitted)

η_{g1} : 1.10

η_{g2} : 1.15; may be reduced to 1.10, where appropriate reinforcements are fitted to the Society's satisfaction.

3. The load Z acting on the double bottom for flooded hold condition is to be obtained from the following formulae:

For $h_1 < h_f$

$$Z = \rho g \{h_1(perm - 1) - E + h_f\} + \rho_c g h_1 \ (N/mm^2)$$

For $h_1 \geq h_f$

$$Z = \rho_c g h_1 - \rho g (E - h_f \, perm) \ (N/mm^2)$$

Where:

h_1 : Vertical distance (m) from the inner bottom to the horizontal plane corresponding to the top of the cargo of volume V when levelled out in each cargo hold

V : Cargo volume (m^3) in each cargo hold as given by the following:

$$V = \frac{F \cdot W}{\rho_c}$$

F : 1.1 in general

1.05 for steel mill products

W : Cargo mass (t) loaded in each hold

ρ_c: Bulk cargo density (t/m^3) (the density for steel is to be used for steel mill products)

h_f : Flooding head (m) in each hold as given by the following (see **Fig. 28A.3.1**)

$h_f = d_f - h_{DB}$

d_f: Distance measured vertically with the ship in the upright position, from the baseline to the level as given by the following (see **Fig. 28A.3.1**)

In general;

D (m) for the foremost cargo hold

0.9D (m) for the other holds

For ships less than 50,000 *tonnes* deadweight with type B freeboard;

0.95D (m) for the foremost cargo hold

0.85D (m) for the other holds

h_{DB} : Height of double bottom

ρ: Sea water density; 1.025 (t/m^3) ver

g : Acceleration due to gravity; 9.81 (m/s^2)

perm : Permeability of cargo as specified in **28A.1.2(7);** but is to be taken as 0 for steel mill products.

E : Ship immersion for flooded hold condition as given by;

$E = d_f - 0.1D\ (m)$

4. The areas $A_{DB,h}$, and $A_{DB,e}$, of the double bottom on which the loads are acting is to be calculated by the following:

$$A_{DB,h} = \sum_{i=l}^{n} S_i \cdot B_{DB,i}\ (m^2)$$

$$A_{DB,e} = \sum_{i=l}^{n} S_i \cdot (B_{DB-}\ S_l)(m^2)$$

Where:

n : Numbers of floors between stools (or transverse bulkheads, if no stool fitted)

S_1 : Space (m) of i-th floor

$B_{DB,i}$: $B_{DB} - S_l(m)$, for floors whose shear strength is calculated by S_{f1}in **-2** above**.**

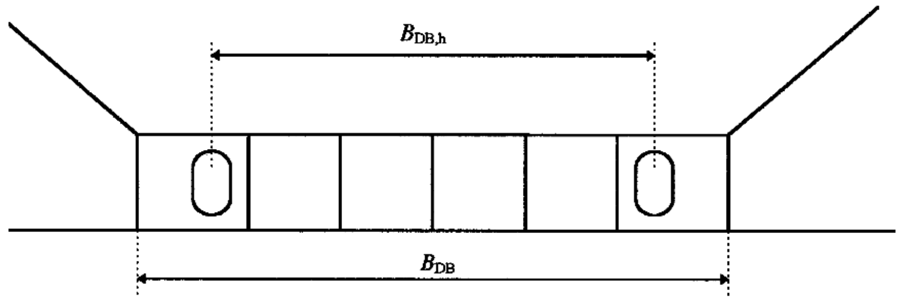
$B_{DB,i}$: $B_{DB,h}\ (m)$, for floors whose shear strength is calculated by S_{f2} in **-2** above.

B_{DB} : Breadth (m) of double bottom between hoppers (See **Fig. 28A.4.2**)

$B_{DB,h}$: Distance (m) between the two considered openings (See **Fig. 28A.4.2**)

S_l: Spacing (m) of double bottom longitudinals adjacent to hoppers

Fig.28A.4.2 B_{DB} and $B_{DB,h}$



28A.5 Longitudinal Strength in Flooded Condition

28A.5.1 General

1. The requirements in this section apply to bulk carriers, coming under the following **(1)** or **(2)**, of not less than 150 *m* in length L_f, designed to carry solid bulk cargoes having a density of not less than 1.0 ton/m^3.

(1) Bulk carriers of single-side skin construction

(2) Bulk carriers of double-side skin construction in which any part of a longitudinal bulkhead is located within *B*/5 or 11.5 *m*, whichever is less, inboard from the ship's side at right angles to the centreline at the assigned summer load line

2. Ships are to have sufficient longitudinal hull girder strength to withstand flooding of any one cargo hold in the following conditions. The loads in flooded holds are to be in accordance with **28A.5.2** and the evaluation of longitudinal strength is to be in accordance with **28A.5.3**.

(1) Ballast condition (at departure and arrival)

(2) Homogeneous loading condition (at departure and arrival)

(3) All specific non-homogeneous loading conditions (at departure and arrival)

(4) Other loading conditions deemed necessary by the Society

28A.5.2 Loads in Flooded Holds

1. The load to be considered for evaluation of longitudinal strength is the sum of cargo induced loads and flooding loads in the condition where each cargo hold is individually flooded up to the equilibrium waterline.

2. For the calculation of flooded water weight, the following are to be assumed.

(1) The permeability of empty cargo holds and volume left in loaded cargo spaces is to be taken as 0.95.

(2) The permeability for bulk cargoes are to be in accordance with **28A.1.2 (7)**. For steel mill products such as steel coil, permeability is to be taken as 0.

28A.5.3 Strength Criteria

1. The section modulus Z_f of the transverse section of the hull girder under consideration at the midship part is not to be less than the following W_z so that it has sufficient strength after flooding in all specific loading and ballast conditions:

$$W_z = 5.72\left|M_{sf} + 0.8M_w(+)\right|(cm^3)$$

$$W_z = 5.72\left|M_{sf} + 0.8M_w(-)\right|(cm^3)$$

Where:

M_{sf} : Still water bending moment (*kN-m*) in the flooded condition for the section under consideration See **15.2.1** for calculation method.

M_w : Wave induced bending moment (*kN-m*) for the section under consideration, as given by **14.2.1-1**

Z_f : Actual section modulus (cm^3) for the section under consideration as calculated in **14.2.3**

2. At sections other than the midship part, the section moduli may be required to fulfill requirements deemed necessary by the Society.

3. The thickness t of side shell plating under consideration is to be not less than the value obtained from the following formulae in order to have sufficient strength after flooding in all specific loading and ballast conditions:

$$t = 0.455\left|F_{sf} + 0.8F_w(+)\right|\frac{m}{I}(mm)$$

$$t = 0.455\left|F_{sf} + 0.8F_w(-)\right|\frac{m}{I}(mm)$$

Where:

F_{sf} : Still water shear force (*kN*) in the flooded condition for the section under consideration See **15.3.1** for calculation method.

F_w : Wave induced shear force (*kN*) for the section under consideration, as given in **14.3.1-1**.

I and m : As specified in **14.3.1-1**

4. When calculating bending and shearing strength after flooding, the damaged structure is assumed to remain fully effective in resisting the applied load.

5. Axial stress buckling stress is to be assessed in accordance with **14.3.1-1**.

28A.6 Double-side Skin Construction and Cargo Hold Construction

28A.6.1 Double-side Skin Construction

1. Bulk carriers of not less than 150 *m* in length L_f are to comply with the following requirements **(1)** to **(6)** in all areas with double-side skin construction.

(1) Primary stiffening structures of the double-side skin are not to be placed inside the cargo hold space.

(2) The distance between the outer shell and the inner shell at any transverse section is not to be less than 1,000 *mm* measured perpendicular to the side shell. The double-side skin construction is to be such as to allow access for inspection as provided in **Chapter 32**.

(3) The minimum width of the clear passage through the double-side skin space in way of obstructions such as piping or vertical ladders is not to be less than 600 *mm*.

(4) Where the inner and/or outer skins are transversely framed, the minimum clearance between the inner surfaces of the frames is not to be less than 600 *mm*.

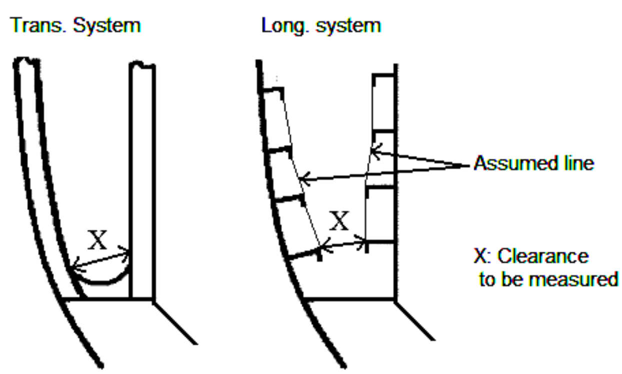
(5) Where the inner and outer skins are longitudinally framed, the minimum clearance between the inner surfaces of the frames is not to be less than 800 *mm*. Outside the parallel part of the cargo hold, this clearance may be reduced where necessitated by the structural configuration, but is not to be less than 600 *mm*.

(6) The minimum clearances referred to in **(3)** to **(5)** above are to be the shortest distance measured between assumed lines connecting the inner surfaces of the frames on the inner and outer skins. (See **Fig. 28A.6.1**.) Such clearances need not be maintained in way of cross ties, upper and lower end brackets of transverse framing or end brackets of longitudinal framing.

2. Double-side skin spaces and dedicated seawater ballast tanks arranged in bulk carriers of not less than 150 *m* in length L_f are to comply with corrosion prevention systems deemed appropriate by the Society.

3. The double-side skin spaces, with the exception of top-side wing tanks are not to be used for the carriage of cargo.

Fig. 28A.6.1 Clearance Inside Double-side Skin Construction



28A.6.2 Cargo Hold Construction

1. In bulk carriers of not less than 150 *m* in length L_f, carrying solid bulk cargoes having a density of not less than 1.0 ton/m^3, the construction of the cargo hold is to comply with the following requirements.

(1) The structure of cargo holds is to be such that all contemplated cargoes can be loaded and discharged by standard loading/discharge equipment and procedures without damage which may compromise the safety of the structure.

(2) Effective continuity between the side shell structure and the rest of the hull structure is to be assured.

(3) The structure of cargo areas is to be such that localized mechanical damage of one stiffening structural member will not lead to immediate consequential failure of other structural items potentially leading to the collapse of entire stiffened panel.

Chapter 28B ADDITIONAL REQUIREMENTS FOR EXISTING BULK CARRIERS

28B.1 General

28B.1.1 Application

1. The requirements in this chapter apply to cargo ships of not less than 500 *gross tonnage* engaged on international voyages.

2. Bulk Carriers defined in **1.3.1(13) of Part 1B** with single side skin construction, which fulfil all the following conditions, are to be in accordance with the provisions of **28B.1.2**, **28B.1.3**, **28B.2**, **28B.3** and **28B.4** so as to withstand flooding of the foremost cargo hold.

(1) Ships which are contracted for construction prior to 1 July 1998, and the keels of which are laid or that are at a similar stage of construction prior to 1 July 1999.

The term a similar stage of construction means the stage at which assembly of the ship commenced comprising at least 50 *tonnes* or 1% of the estimated mass of all structural material, whichever is less.

(2) Ships of not less than 150 *m* in length for freeboard.

(3) Ships carrying solid bulk cargoes having a bulk density of not less than 1.78 t/m^3

3. The strength of cargo hold frames and brackets of Bulk Carriers defined in **1.3.1(13), Part 1 B** with single side skin construction, which have been contracted for construction prior to 1 July 1998, are to comply with the provisions of **28B.5**.

4. For ships constructed or converted with a single deck, top-side tanks and hopper side tanks in the cargo area and intended primarily to carry dry cargoes in bulk, which are contracted for construction prior to 1 January 2004, the securing devices and stoppers for steel weather tight hatch covers are to comply with the provisions of **28B.6**.

5. Bulk carriers defined in **1.3.1(13), Part 1 B** of not less than 150 *m* in length L_f, of single-side skin construction, carrying cargoes having a density of not less than 1.78 ton/m^3, which was at the beginning stage of construction before 1 July 1999, are to comply with the provisions of **28B.7** when operating with any hold empty.

6. Except where especially required in this chapter, the general requirements for construction and equipment in **Chapter 28** and of steel ships are to be applied.

28B.1.2 Definitions

1. Terms used in this chapter are defined as follows:

(1) "Bulk cargo density" or "Bulk density" (t/m^3) means the ratio of the loaded cargo mass to the volume which is assumed to be occupied by the loaded cargo including empty spaces within the bulk cargo, notwithstanding the specific gravity of the cargoes defined in **28.2.1-3**.

(2) "Permeability" of a space means the ratio of the volume within the space which is assumed to be occupied by water to the total volume of the space under consideration. In this chapter, the value given in **Table**

28B.1.1, may be used as standard according to the kind of cargo. For cargoes other than those given in Table 28B.1.1, the values of permeability are to be at the Society s discretion.

Table 28B.1.1 Permeability

Cargo and etc.	Permeability
Iron Ore	0.3
Cement	0.3
Coal	0.3
Empty Space	0.95

(3) "Angle of repose" means the maximum slope angle between a horizontal plane and a cone slope of free-flowing bulk cargo. In this chapter, the value given in Table 28B.1.2 may be used as standard according to the kind of cargo. For cargoes other than those given in Table 28B.1.2, the angles of repose are to be at the Society's discretion.

Table 28B.1.2 Angle of repose

Cargo	Angle of repose
Iron Ore	35°
Cement	25°
Coal	35°

28B.1.3 Implementation Schedule

1. Ships are to comply with the requirements of 28B.2, 28B.3 and 28B.4 by the date required in Table 28B.1.3 according to the ship's age on 1 July 1998.

Table 28B.1.3 Implementation Time Table for Existing Ships

Ship`s Age on 1 July 1998: A	Implementation Scheme
$20\ years\ \leq A$	By the due date of the first Intermediate Survey or Special Survey to be held after 1 July 1998, whichever comes first
$15\ years\ \leq A < 20\ years$	By the due date of the first Special Survey to be held after 1 July 1998, but not later than 1 July 2002
$10\ years\ \leq A < 15\ years$	By the due date of the first Intermediate Survey or Special Survey to be held after the date on which the ship reaches 15 years of age but not later than the date on which the ship reaches 17 years of age
$5\ years\ \leq A < 10\ years$	By the due date, after 1 July 2003, of the first Intermediate Survey or Special Survey after the date on which the ship reaches 10 years of age, whichever occurs first
$A < 5\ years$	By the date on which to ship reaches 10 years of age

Note:

The due date of the Intermediate Survey may be taken as that of the Second Annual Survey or the Third Annual Survey.

28B.2 Damage Stability

28B.2.1 Survivability

1. Ships are to be able to withstand flooding of the foremost cargo hold in all loading conditions when loaded to the summer load line and remain afloat in satisfactory condition of equilibrium as required in **28A.2.1-2.**

2. Ships not capable of complying with the requirements in **28B.2.1-1** are to take measures deemed appropriate by the Society. The requirements specified in **28B.3** and **28B.4** do not need to be applied to the ships which are subject to this requirement.

3. The Ships whose assigned freeboards are of "*B-60*" or "*B-100*" type specified in *ILLC*, are to be treated as complying with the preceding **-1** and **-2**.

28B.3 Transverse Watertight Corrugated Bulkhead

28B.3.1 General

1. The requirements in this section apply to the vertically corrugated watertight bulkhead abaft the foremost hold.

2. In this section, homogeneous loading condition means a loading condition in which the ratio between the highest and lowest filling ratio, evaluated for two foremost holds, does not exceed 1.20, to be corrected for different cargo densities.

3. The most severe combinations of cargo induced loads and flooding loads are to be used for examining the scantlings of the bulkheads, depending on the loading conditions included in the loading manual:

(1) Homogeneous loading conditions;

(2) Non-homogeneous loading conditions.

In any case, the pressure due to the flood water alone needs to be considered when making calculations.

Non-homogeneous loading conditions associated with multiport loading and unloading operations that occur before a homogeneous loading condition is reached does not need to be considered according to the requirements in this section.

4. The thickness of bulkheads excluding the corrosion margin (hereinafter referred to as "net thickness"), t_{net}, is to be used for examining the scantlings of the bulkhead.

28B.3.2 Load Model

1. The flooding head $h_f(m)$ is to be the distance measured vertically with the ship in the upright position, from the calculation point to a level located at a distance $d_f(m)$ from the baseline equal to (see **Fig. 28A.3.1**):

(1) General:

D (m)

(2) For ships less than 50,000 *tonnes* deadweight with type B freeboard:

$0.95D$ (m)

(3) For ships operated at an assigned load line draught T_r less than the permissible load line draught T, the flooding head d_f defined in the preceding (1) and (2) may be reduced by $T - T_r$.

2. The cargo height loaded in the foremost hold d_1 measuring from the base line is to be obtained from the following formula:

$$d_1 = \frac{M_c}{\rho_c l_c B} + \frac{V_{LS}}{l_c B} + (h_{HT} - h_{DB})\frac{b_{HT}}{B} + h_{DB} \quad (m)$$

Where:

M_c : Mass of cargo in foremost hold (t)

ρ_C: Bulk cargo density (t/m^3)

l_c : Length (m) of foremost hold

B : Ship's breadth amidship (m)

v_{LS} : Volume (m^3) of the bottom stool above the inner bottom

h_{HT} : Height (m) of the hopper tanks amidships from base line

h_{DB} : Height (m) of the double bottom

b_{HT} : Breadth (m) of the hopper tanks amidships

3. In a hold loaded with cargo, the pressure and force acting on the bulkhead at the point considered in a flooded condition are to be obtained from the following **(1)** and **(2)**, according to the relation between the flooding head d_f and the cargo height d_1 calculated respectively in **-1** and **-2** above. (See Fig. 28A.3.1)

(1) For $d_f > d_1$

(a) At each point of the bulkhead located at a distance between d_f and d_1 from the baseline, the pressure p_{cf}, is given by the following:

$$p_{cf} = \rho g h_f, (kN/m^2)$$

(b) At each point of the bulkhead located at a distance less than $d1$ from the baseline, the pressure p_{cf}, is given by the following:

$$p_{c,f} = \rho g h_f + [\rho_c - \rho(1 - perm)] g h_1 tan^2 y \ (kN/m^2)$$

(c) The force $F_{c,f}$ acting on the corrugation is given by the following:

$$F_{c,f} = S_1 \left[\rho g \frac{(d_f - d_1)^2}{2} + \frac{\rho g (d_f - d_1) + (p_{c,f})_{le}}{2} (d_1 - h_{DB} - h_{LS}) \right] (kN)$$

Where:

h_f and d_f : As specified in - **1** above

d_1, h_{DB} : As specified in -**2** above

ρ: Sea water density (t/m^3)

g : Gravity acceleration 9.81 (m/s^2)

ρ_C: Bulk cargo density (t/m^3)

perm : Permeability defined in 28B.1.2-1(2)

h_1 : Vertical distance (m) between the point considered and the top of the cargo height d_1 (given in **-2** above)

γ: $45^\circ - \frac{\emptyset}{2}$

$\emptyset$: Angle of repose defined in 28B.1.2-1(3)

S_1 : Spacing (m) of corrugation in 1/2 pitch (see Fig. 28A.3.2a)

$(P_{cf})_{le}$: Pressure (kN/m^2) at the lower end of the corrugation

h_{LS} : Height (m) of the lower stool from the inner bottom

(2) For $d_f < d_1$

(a) At each point of the bulkhead located at a distance between d_f and d_1 from the baseline, the pressure p_{cf}, is given by the following:

$$P_{c,f} = \rho_c g h_1 tan^2\gamma \qquad (kN/m^2)$$

(b) At each point of the bulkhead located at a distance less than d_f from the baseline, the pressure $p_{c.f}$, is given by the following:

$$p_{c,f} = \rho g h_f + [\rho_c h_1 - \rho(1 - perm)h_f]g tan^2\gamma \quad (kN/m^2)$$

(c) The force $F_{c,f}$, acting on the corrugation is given by the following:

$$F_{c,f} = S_1 \left[\rho_c g \frac{(d_1 - d_f)^1}{2} tan^2\gamma + \frac{\rho_c g(d_1 - d_f)tan^2\gamma + (p_{c,f})_{le}}{2}(d_f - h_{DB} - h_{LS})\right] (kN)$$

Where:

d_f: As specified in **-1** above

d_1 and h_{DB} : As specified in **-2** above

ρ_c, g, h_1, γ, ρ, h_f, *perm*, s_1, $(p_{c,f})_{le}$ and h_{LS} : As specified in (1) above

4. In an empty hold, the pressure and force at the point considered acting on the bulkhead in a flooded condition are to be obtained from the following **(1)** and **(2)**.

(1) At each point of the bulkhead, the hydrostatic pressure p_f induced by flooding is to be a flooding head h_f calculated in **-1** above.

(2) The force F_f acting on the corrugation is given by the following:

$$F_f = s_1 \rho g \frac{(d_f - h_{DB} - h_{LS})^2}{2} \qquad (kN)$$

Where:

s_1, ρ, g, d_f, h_{DB} and h_{LS} : As specified in preceding **-3**

5. In a hold loaded with cargo that is not flooded, the pressure and force at the point considered acting on the bulkhead are to be obtained from following **(1)** and **(2)**.

(1) At each point of the bulkhead, the pressure P_c is given by the following:

$$p_c = \rho_c g h_1 tan^2\gamma \ (kN)$$

Where:

ρ_c, g, h_1 and γ: As specified in **-3** above

(2) The force F_c acting on the corrugation is given by the following:

$$F_c = \rho_c g s_1 \frac{(d_1 - h_{DB} - h_{LS})^2}{2} tan^2\gamma (kN)$$

Where:

ρ_c , g, s_1,d_1 ,h_{LS} ,h_{DB} and γ: As specified in **-3** above.

6. Resultant pressure p and force F at each point of the bulkhead to be used for examining the scantlings of the bulkhead are to be calculated from the pressure and force obtained from **-3** through**-5** above according to the loading conditions, by the following formulae:

(1) For homogeneous loading

$$P = P_{c,f} - 0.8P_c \, (kN/m^2)$$

$$F = F_{c,f} - 0.8F_c (kN)$$

(2) Non-homogeneous loading

$$P = P_{c,f} (kN/m^2)$$

$$F = F_{c,f} (kN)$$

(3) Where the foremost hold is not allowed to be loaded in a non-homogeneous loading condition.

$$P = P_f (kN/m^2)$$

$$F = F_f (kN)$$

28B3.3 Bending Moment and Shear Force in Bulkhead Corrugations

1. The design bending moment M for bulkhead corrugations is given by the following:

$$M = \frac{Fl}{8} (kN \cdot m)$$

F : As calculated in **28B.3.2-6.**

l : Span (m) of the corrugation to be taken as in **Fig. 28A.3.2a** and **Fig. 28A.3.2b**

2. The shear force Q at the lower end of the bulkhead corrugations is given by the following:

$$Q = 0.8F \; (kN)$$

F : As calculated in **28B.3.2-6.**

28B.3.4 Strength Criteria

1. The section modulus at the lower end of the corrugation is to be calculated with the following considerations.

(1) The width of compressive corrugation flange to be used for the calculation of section modulus is not to exceed the effective width b_{ef} obtained by the following.

$$b_{ef} = C_e a \; (m)$$

$$C_e: \frac{2.25}{\beta} - \frac{1.25}{\beta^2} \; for \; \beta > 1.25$$

$$1.0: For \; \beta < 1.25$$

Where:

$\beta: 10^3 \dfrac{a}{t_f}\sqrt{\dfrac{\sigma_F}{E}}$

t_f: Net flange thickness (mm)

a : Width (m) of corrugation flange (See **Fig. 28A.3.2a**)

σ_F : Yield stress (N/mm^2) of the material

E : Modulus of elasticity, 2.06 x 10^5 (N/mm^2)

(2) Where the webs of the lower part of the corrugation are not supported by local brackets below the stool top (or below the inner bottom), the section modulus of the corrugations is to be calculated taking the corrugation webs as 30% effective.

(3) Provided that effective shedder plates as defined in **28B.3.5-4** are fitted (see **Fig. 28A.3.3a** and **28A.3.3b**), the area of the flange plates may be increased by the following formula when calculating the section modulus of the lower end of corrugations (cross-section (1) in **Fig. 28A.3.3a** and **28A.3.3b**), but it is not be greater than $2.5a\,t_f$.

$$2.5a\sqrt{t_f t_{sh}}\sqrt{\frac{\sigma_{Fsh}}{\sigma_{Ffl}}} \quad (cm^2)$$

Where:

a : Width (m) of corrugation flange (See **Fig. 28A.3.2a**))

t_{sh} : Net shedder plate thickness (mm)

t_f: Net corrugation flange thickness (mm)

σ_{Fsh}: Yield stress (N/mm^2) of the material used for the shedder plates

σ_{Ffl} : Yield stress (N/mm^2) of the material used for the corrugation flanges

(4) Provided that effective gusset plates as defined in **28B.3.5-5** are fitted (see **Fig. 28A.3.4a** and **28A.3.4b**), the area of flange plates may be increased by the following formula when calculating the section modulus of the lower end of corrugations (cross-section (1) in **Fig. 28A.3.4a** and **28A.3.4b**).

$7h_g\, t_{gu}$ (cm^2)

Where:

h_g : Height (m) of gusset plate, but not to be greater than 10 S_{gu} /7 (See **Fig. 28A.3.4a** and **28A.3.4b**)

S_{gu} : Width (m) of gusset plate

t_{gu} : Net gusset thickness (mm), but not to be greater than t_f specified in (3) above

(5) If the corrugation webs are welded to sloping stool top plates, which have an angle of not less than 45° with the horizontal plane, the section modulus of the corrugations may be calculated taking the corrugation webs as fully effective. For angles less than 45°, the effectiveness of the web may be obtained by linear interpolation between 30% (for 0°) and 100% (for 45°). (See **Fig. 28A.3.4b**)

Where effective gusset plates are fitted, the area of the flange plates may be increased as specified in (4) above when calculating the section modulus of corrugations. This is only applicable if shedder plates are fitted.

2. Provided that effective gusset plates or shedder plates as defined in **28B.3.5-4**, and **28B.3.5-5** are fitted (see **Fig. 28A.3.4a** and **28A.3.4b**), the section modulus of corrugations at the lower end Z_{le} is to be not greater than Z'_{le} obtained from the following formula:

$$Z'_{le} = Z_g + 10^3 \text{x} \frac{Qh_g - 0.5h_g^2 s_1 P_g}{\sigma_a} \qquad (cm^3)$$

Z_g : Section modulus (cm^3) of corrugation according to **-3.** in way of the upper end of shedder plates or gusset plates

Q: Shear force (kN) as given in **28B.3.3-2**

h_g: Height (m) of shedder plates or gusset plates (See **Fig. 28A.3.3a**, **28A.3.3b**, **28A.3.4a** and **28A.3.4b**)

S_1 : As given in **28B.3.2-3**

P_g: Resultant pressure (kN/m^2) as defined in **28B.3.2-6**, calculated in way of the shedder plates or gusset plates.

σ_a : Yield stress of the material (N/mm^2)

3. The section modulus of corrugations at a cross-section other than the lower end calculated in **-1** and **-2** is to be calculated with the corrugation webs considered effective and the compressive flange having an effective flange width b_{ef} , not greater than as given in **-1** above**.**

4. The bending capacity of corrugation is to be in accordance with the following:

$$10^3 x \frac{M}{0.5 Z_{le}\sigma_{a,le} + Z_m \sigma_{a,m}} \leq 1.0$$

Where:

M : Bending moment (kN-m) as given in **28B.3.3**

Z_{le} : Section modulus (cm^3) of corrugation at the lower end as calculated in **-1.**

Z_m : Section modulus (cm^3) of corrugation at the mid-span of corrugation as calculated in **-3.** Z_m is not to be greater than $1.15 \cdot Z_{le}$.

$\sigma_{a,le}$: Yield stress (N/mm^2) of the material to be used for the lower end of corrugations

$\sigma_{a,m}$: Yield stress (N/mm^2) of the material to be used for the mid-span of corrugations

5. Shearing stress of corrugation is to be in accordance with the following: (See **Fig. 28A.3.2a**)

$$\tau_a \geq \frac{Q}{A_w \sin \emptyset \, x 10^3} \qquad (N/mm^2)$$

$$\tau_a = 0.5\sigma_F (N/mm^2)$$

σ_F: Yield stress of material (N/mm^2)

Q : Shear force as given in **28A.3.3-2**. (kN)

A_w : Sectional area (mm^2) of corrugation web at the lower end

$\emptyset$: Angle (°) between the web and the flange

6. The buckling strength of the web plates at the ends of the corrugations is to fulfil the following formula so that the shearing stress τ for the web plates do not exceed the critical value τ_c .

$$\tau_c = \tau_E \quad when \quad \tau_E \leq \frac{\tau_F}{2} \quad (N/mm^2)$$

$$\tau_c = \tau_F \left(1 - \frac{\tau_F}{4\tau_E}\right) \quad when \quad \tau_E > \frac{\tau_F}{2} \quad (N/mm^2)$$

Where:

$$\tau_F = \frac{\sigma_F}{\sqrt{3}} (N/mm^2)$$

σ_F : Yield stress of material (*N/mm*^{2})

$$\tau_E = 0.9 k_t E \left(\frac{t}{1000c}\right)^2 (N/mm^2)$$

k_t : Coefficient as 6.34

E : Modulus of elasticity of material as 2.06 x 10^5 (*N/mm*^{2})

t : Net thickness (*mm*) of corrugation web

c : Width (*m*) of corrugation web (See **Fig. 28A.3.2a**)

7. The corrugation local net plate thickness t is to comply with the following:

$$t = 14.9 S_w \sqrt{\frac{P}{\sigma_F}} \quad (mm)$$

S_w : Plate width (*m*) to be taken equal to the width of the corrugation flange or web, whichever is the greater (See **Fig. 28A.3.2a**)

P : Resultant pressure (*kN/m*^{2}) at the bottom of each strake of bulkhead plating as calculated in **28B.3.2-6**; in all cases, the net thickness of the lowest strake is to be determined using the resultant pressure at the top of the lower stool, or at the inner bottom if no lower stool is fitted, or at the top of shedders if shedder or gusset/shedder plates are fitted.

σ_F: Yield stress of material (*N/mm*^{2})

For built-up corrugation bulkheads, when the thickness of the flange and web are different, the net thickness of the narrower plating is to be not less than t_n given by the following:

$$t_n = 14.9 S_n \sqrt{\frac{P}{\sigma_F}} \quad (mm)$$

S_n : width of the narrower plating (*m*)

The net thickness of the wider plating t_w is not to be taken less than t_{w1} and t_{w2} obtained from following formula:

$$t_{w1} = 14.9 S_w \sqrt{\frac{P}{\sigma_F}} \quad (mm)$$

$$t_{w2} = \sqrt{\frac{440 S_w^2 p}{\sigma_F} - t_{np}^2} \quad (mm)$$

t_{np} : The value (*mm*) not greater than the net thickness of the narrower plating and t_{w1}

28B.3.5 Structural Details

1. Where the corrugation angle ∅ shown in **Fig. 28A.3.2a** is less than 50, the horizontal row of staggered shedder plates is to be fitted at approximately mid-depth of the corrugation in order to help preserve dimensional stability of the bulkhead under flooding loads. The shedder plates are to be welded to the corrugations by double continuous welding, but they are not to be welded to the side shell.

2. The thickness of the lower part of the corrugations calculated in **28B.3.4-1**, -**2**, -**4** and -**5** are to be maintained for a distance of not less than 0.15*l* from the inner bottom (if no lower stool is fitted) or the top of the lower stool

3. The thickness of the middle part of the corrugations calculated in **28B.3.4-3**, -**4** and -**5** are to be maintained in a distance of not less than 0.30*l* from the deck (if no upper stool is fitted) or the bottom of the upper stool .

4. Where shedder plates are fitted, they are to comply with the following so as to maintain their effectiveness.

(1) Not be knuckled

(2) Be welded to the corrugation and the top plate of the lower stool by one-side penetration welds or equivalent

(3) Have a min. slope of 45° and their lower edge is to be in line with the stool side plating

5. Where gusset plates are fitted, they are to comply with the following so as to maintain their effectiveness.

(1) Be fitted in line with the stool side plating

(2) Have material properties at least equivalent to those used for the corrugation flanges

6. The design of local details is to be for the purpose of transferring the force and moment acting on the corrugation to boundary structures, in particular to the double bottom and cross-deck structures.

28B.3.6 Corrosion Addition, Steel Renewal and Reinforcement

The corrugated bulkhead is to be renewed or reinforced by measures deemed appropriate by the Society, according to the relationship between the actual gauged thickness and the net thickness required in this section.

28B.4 Allowable Hold Loading on Double Bottom

28B.4.1 General

1. The load in the foremost cargo hold is not to exceed the allowable hold load in flooded condition calculated in **28B.4.4**, using the flooding head given in **28B.4.2** and the shear capacity of the double bottom given in **28B.4.3**.

2. The most severe combinations of cargo induced loads and flooding loads are to be used, depending on the following loading conditions described in the loading manual:

(1) Loading condition of all bulk cargoes except cargoes such as steel mill products

(2) Loading condition of cargoes such as steel mill products

For each loading condition, the maximum bulk cargo density is to be considered in calculating the allowable hold limit.

28B.4.2 Flooding Head

1. The flooding head h_f (m) is to be the distance measured vertically with the ship in the upright position, from the calculation point to the point located at a distance d_f (m) from the baseline given by the following (See **Fig. 28A.3.1**):

D (m) in general

$0.95D$ (m) for ships less than 50,000 *tonnes* deadweight with type B freeboard

28B4.3 Shear Capacity

1. The shear capacity C_k and C_e of the double bottom of the foremost hold is defined as the sum of the shear strength at the each end of the following members:

(1) All floors adjacent to both hoppers, less one half of the strength of the two floors adjacent to each stool, or transverse bulkheads if no stool is fitted. (See **Fig. 28A.4.1**)

(2) All double bottom girders adjacent to both stools or transverse bulkheads if no stool is fitted.
The strength of girders or floors which do not directly attach to boundary stools or hopper girders are to be evaluated at one end only.

2. The floors and girders to be considered are those inside the hold boundaries formed by the hoppers and stools (or transverse bulkheads if no stool is fitted). The hopper side girders and the floors directly below the connection of the bulkhead stools (or transverse bulkheads if no stool is fitted) to the inner bottom are not to be included.

3. In calculating the shear strength, the net thickness t_{net} of floors and girders is to be used, as given by the following:

$$t_{net} = t - t_c \quad (mm)$$

t : As built thickness (mm) of floors and girders

t_c : Corrosion diminution, equal to 2 mm in general; however, the lower value may be used, provided the measurement is deemed appropriate by the Society.

4. When the shape and/or structural arrangement of the double bottom are deemed inadequate by the Society for the provisions in **-2**, the shear capacity of the double bottom is to be calculated at the discretion of the Society.

5. Shear capacity of double bottom C_h and C_e are to be obtained from the following formulae:

$$C_h = \sum min\left(S_{f1,}S_{f2}\right) + \sum min\left(S_{g1,}S_{g2}\right) \quad (kN)$$

$$C_e = \sum S_{f1} + \sum min\left(S_{g1}, S_{g2}\right) \quad (kN)$$

S_{f1} and S_{f2} : The floor shear strength in way of the floor panel adjacent to hoppers, and the shear strength in way of the openings in the outmost bay (i.e. that bay which is closest to hopper) are given by the following respectively:

$$S_{f1} = 10^{-3} A_f \frac{\tau_a}{\eta_{f1}} \quad (kN)$$

$$S_{f2} = 10^{-3} A_{f,h} \frac{\tau_a}{\eta_{f2}} \quad (kN)$$

Where:

A_f: Sectional area (mm^2) of the he floor panel adjacent to hoppers

$A_{f\,h}$, : Net sectional area (mm^2) of the openings in the outmost bay (i.e. that bay which is closest to hopper)

τ_a: Allowable shear stress;$\frac{\sigma_F}{\sqrt{3}}$ (N/mm^2)

σ_F: Yield stress of the material (N/mm^2)

η_{f1}=1.10

η_{f2}=1.20; may be reduced to 1.10, where appropriate reinforcements are fitted to the Society's satisfaction.

S_{g1} and $S_{g\,2}$: The girder shear strength in way of the girder panel adjacent to stools (or transverse bulkheads, if no stool fitted) and the girder shear strength in way of the largest openings in the outmost bay (i.e. that bay which is closest to stool, or transverse bulkheads, if no stool fitted) are given by the followings:

$$S_{g1} = 10^{-3} A_g \frac{\tau_a}{\eta_{g1}} \quad (kN)$$

$$S_{g2} = 10^{-3} A_{g,h} \frac{\tau_a}{\eta_{g2}} \quad (kN)$$

Where:

A_g : Sectional area (mm^2) of the girder panel adjacent to stools (or transverse bulkheads, if no stool fitted)

$A_{g\,h\,,}$: Net sectional area (mm^2) of the largest openings in the outmost bay (i.e. that bay which is closest to stool, or transverse bulkheads, if no stool fitted)

η_{g1}=1.10

η_{g2}=1.20; may be reduced to 1.10, where appropriate reinforcements are fitted to the Society's satisfaction

28B.4.4 Allowable Hold Loading Weight

1. Allowable hold loading weight W in the foremost hold is to be calculated by the following formulae, but not to exceed the maximum designed hold loading weight in intact condition:

$$W = \rho_c V \frac{1}{F} \quad (t)$$

Where:

F = 1.05 in general

F = 1.0 for steel mill products

ρ_c: Bulk cargo density (t/m^3); for steel mill products, is taken as density of steel

V : Volume (m^3) occupied by cargo when levelled out at height h_1

h_1 : As given by the following

$$h_1 = \frac{X}{\rho_c g} \quad (m)$$

WHere:

X : The lesser of the following X_1 and X_2, however, it may be taken as X_1 using perm = 0 for steel mill products:

$$X_1 = \frac{Z + \rho g(E - h_f)}{1 + \frac{\rho}{\rho_c}(perm - 1)} \ (kN/m^2)$$

$$X_2 = Z + \rho g\left(E - h_f perm\right) \ \ (kN/m^2)$$

Where:

ρ: Sea water density; 1.025 (t/m^3)

g : Acceleration due to gravity; 9.81 (m/s^2)

E : d_f - 0.1D (m)

d_f : As specified in **28B.4.2**

h_f : As specified in **28B.4.2**

perm : Permeability of cargo as specified in **28A.1.2-1(2)** is to be taken as 0 for steel mill products.

Z : The lesser of Z_1 and Z_2 given by the following:

$$Z_1 = \frac{C_h}{A_{DB,h}} \quad (kN/m^2)$$

$$Z_2 = \frac{C_e}{A_{DB,e}} \quad (kN/m^2)$$

C_h ,C_e : As specified in **28B.4.3**

$A_{DB,h}$, $A_{DB,e}$: As given by the following:

$$A_{DB,h} = \sum_{i=1}^{n} S_i \cdot B_{DB,i} \quad (m^2)$$

$$A_{DB,e} = \sum_{i=1}^{n} S_i \cdot (B_{DB} - S_1) \ \ (m^2)$$

n : Numbers of floors between stools (or transverse bulkheads, if no stool fitted)

S_i : Space (m) of i-th floor

$B_{DB\,i}$, : B_{DB} - S_l (m), for floors whose shear strength is calculated by $S_{f\,1}$ in **28B.4.3-5.**

$B_{DB\,i}$, : $B_{DB\,h}$, (m), for floors whose shear strength is calculated by $S_{f\,2}$ in **28B.4.3-5.**

B_{DB} : Breadth (m) of double bottom between hoppers (See **Fig. 28A.4.2**)

$B_{DB\,,h}$, : Distance (m) between the two considered openings (See **Fig. 28A.4.2**)

S_l : Spacing (m) of double bottom longitudinals adjacent to hoppers.

28B.5 Hold Frames

28B.5.1 Implementation Schedule

Bulk Carriers which have been contracted for construction prior to 1 July 1998, are to comply with the requirements of **28B.5.2** and **28B.5.3** by the date required in **Table 28B.5.1** corresponding to the ships age on 1 January 2004.

Table 28B.5.1 Implementation Time Table for Existing Ships

Ship´s age on 1 January 2004: *A*	Implementation scheme
$15\ years\ \leq A$	By the due date of the first Intermediate Survey or Special Survey to be held after 1 January 2004
$10\ years\ \leq A < 15\ years$	By the due date of the first Special Survey to be held after 1 January 2004*1
$A < 10\ years$	By the due date on which the ship reaches 10 years of age*2

Notes:

*1 Where the due date of the first special survey is later than the date when the ship reaches15 *years* of age, the implementation is to be made by the due date of the first intermediate or special survey after the date when the ship reaches 15 *years* of age, whichever comes first.

*2 Where the due date of the first intermediate or special survey does not fall between 1 January 2004 and the date when the ship reaches 10 *years* of age, the implementation may be made by the due date of the first intermediate or special survey after the ship reaches 10 *years* of age.

28B.5.2 Steel Renewal Criteria and Reinforcing Measures

1. Steel renewal of the webs of side shell frames and brackets is to be done when $t_M \leq t_{REN}$, where t_M is the measured thickness, in *mm*, and t_{REN} is the renewal thickness, in *mm*, defined as the maximum value of the following **(1)** through **(4)**.

(1) $t_{REN} = t_{COAT} - t_c$

t_{COAT}: $0.75 t_{s12}$ (mm)

t_C : The value (*mm*) specified in **Table 28B.5.2**

t_{S12} : Web of hold frame and web of bracket thickness (*mm*) required according to **28.1.6-2** and **28.6.2-5**

(2) $t_{REN} = 0.75 t_{AB}$

t_{AB} : As built thickness (*mm*)

(3) $t_{REN} = t_{REN,d/t}$

$t_{REN,d/t}$: Web thickness, in *mm*, which satisfies the following web depth to thickness ratio for frames and brackets (applicable only to Zones *A* and *B* as shown in **Fig. 28B.5.1**). However, regardless of the web depth to thickness ratio, $t_{REN,d/t}$ for lower integral brackets is not to be taken as less than $t_{REN,d/t}$

for the frames as specified in **(a)**. The following **(a)** may be disregarded, provided that tripping brackets are fitted in accordance with **-6**.

(a) Web depth to thickness ratio for frames at section *b*) (See **Fig. 28B.5.2**)

Below 65 $\sqrt{K}$ for symmetrically flanged frames

Below 55$\sqrt{K}$ for asymmetrically flanged frames

(b) Web depth to thickness ratio for the lower brackets at section *a*) (See **Fig. 28B.5.2**)

Below 87$\sqrt{K}$ or symmetrically flanged frames

Below 73$\sqrt{K}$ for asymmetrically flanged frames

Coefficient corresponding to the kind of steel

e.g. 1.0 for mild steel, the values specified in **1.1.6-2(1)** for high tensile steel

When calculating the web depth to thickness ratio of lower brackets, the web depth of the lower bracket may be measured from the intersection between the sloped bulkhead of the hopper tank and the side shell plate, perpendicularly to the face plate of the lower bracket (See **Fig. 28B.5.3**). Where stiffeners are fitted on the lower bracket plate, the web depth may be taken as the distance between the side shell and the stiffener, between adjacent stiffeners or between the stiffeners and the face plate of the brackets, whichever is the largest.

For side frames, including the lower bracket, located immediately abaft the collision bulkheads, whose scantlings are increased in order that their moment of inertia is such to avoid undesirable flexibility of the side shell, when their web as built thickness t_{AB} is greater than 1.65 *times* of $t_{REN,S,}$ defined by **28B.5.3-4** the thickness $t_{REN,d/t}$, may be taken as the value $t_{REN,d/t}$ obtained from the following equation.

$$T'_{REN,d/t} = \sqrt[3]{{t_{REN,d/t}}^2 \cdot t_{REN,S}}$$

(4) $t_{REN} = t_{REN,S}$, (When $t_M \leq t_{COAT}$ in the lower part of side frames as defined in **Fig. 28B.5.1**)

$t_{REN\,S}$, : As specified in **28B.5.3-4**

When the lower bracket length or depth does not comply with the requirements of **28.6.2-7**, a strength check in accordance with **28B.5.3-5** is to be carried out and renewals or reinforcements effected as required therein.

Table 28B.5.2 t_C values (*mm*)

Ship´s length $L_1(m)$	Holds other than No. 1		Hold No. 1	
	Span and upper brackets	Lower brackets	Span and upper brackets	Lower brackets
≤ 100	2.0	2.5	2.0	3.0
150	2.0	3.0	3.0	3.5
≥ 200	2.0	3.0	3.0	4.0

Note: For intermediate ship lengths, t_C is obtained by linear interpolation between the above values

Fig. 28B.5.1 Lower Part and Zones of Side Frame

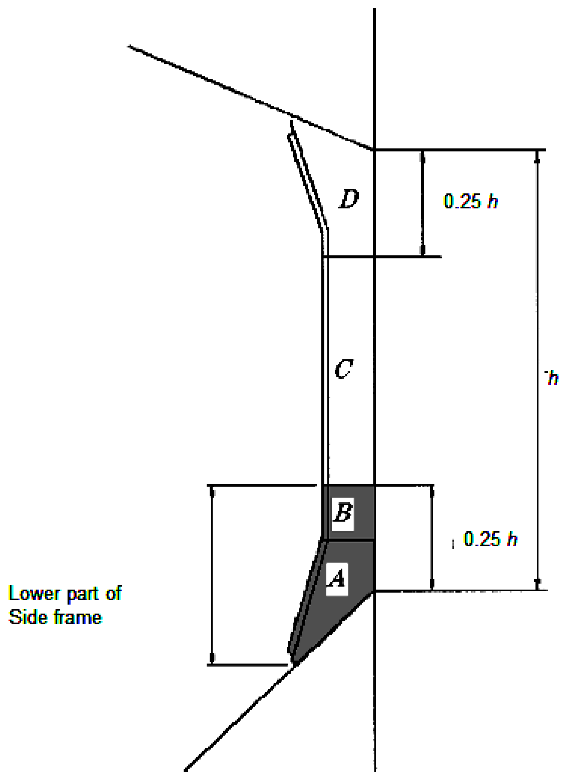


Fig. 28B.5.2 Sections *a*) and *b*)

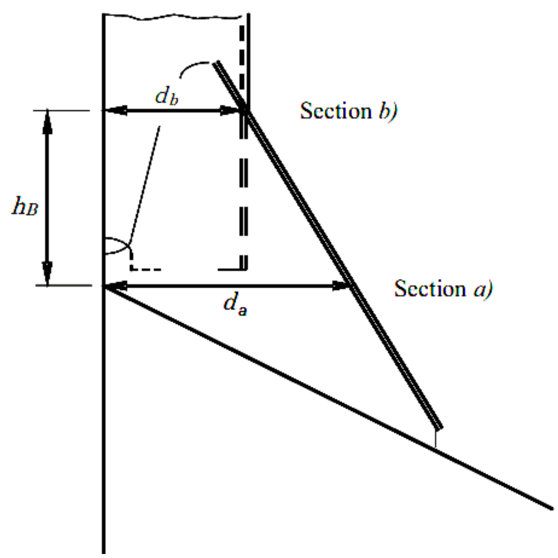
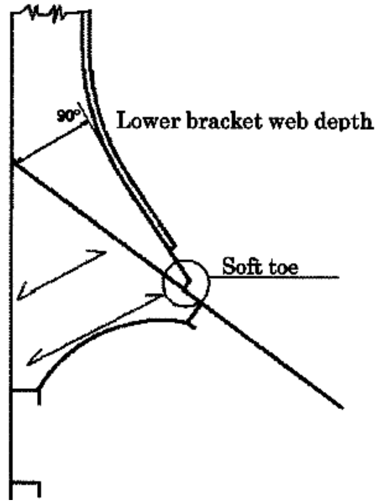


Fig. 28B.5.3 Definition of the Lower Bracket Web Depth for Determining $t_{REN,\ d/t}$



2. When lower brackets are not fitted with face plates or flanges, the lower brackets are to be flanged or fitted with face plates. The thickness of face plate or flange is not to be less than the thickness of the web of the lower bracket.

3. When steel renewal is required, the renewal webs are to be of a thickness not less than t_{AB}, $1.2t_{COAT}$ or $1.2t_{REN}$, whichever is the greatest. Where steel renewal is conducted, the welded connections are to comply with the requirements of **28.6.3**.

4. When $1.2t_{REN} < t_M \leq t_{COAT}$, measures consisting of all the following **(1)** through **(3)** are to be taken. However, the measures may be waived if the structural members show no thickness diminution with respect to the as built thicknesses and the coating is in an "as-new" condition (*i.e.* without breakdown or rusting).

When the measured frame webs t_M is such that $1.2t_{REN} < t_M \leq t_{COAT}$ and the coating is in Good condition, the coating as required in the following (1) may be waived even if not found in an as-new condition, provided that tripping brackets are fitted and the coating damaged in way of the tripping bracket welding is repaired.

(1) Sand blasting, or equivalent, and coating (see **-5**)

(2) Installation of tripping brackets (see **-6**), when the above condition occurs for any of the side frame zones *A*, *B*, *C* and *D*, shown in **Fig. 28B.5.1**

(3) Maintenance of coating in an as-new condition (*i.e.* without breakdown or rusting) at Special and Intermediate Surveys

5. Thickness measurements, steel renewal, sand blasting and coating

(1) For the purpose of steel renewal, sand blasting and coating, four zones *A*, *B*, *C* and *D* are defined, as shown in **Fig. 28B.5.1**. Representative thickness measurements are to be taken for each zone and are to be assessed against the criteria in **-1** and **-3**.

(2) In the case of integral brackets, when the criteria in **-1** or **-3** are not satisfied for zone *A* or *B*, steel renewal, sand blasting and coating, as applicable, are to be done for both zones *A* and *B*.

(3) In the case of separate brackets, when the criteria in **-1** or **-3** are not satisfied for zone *A* or *B*, steel renewal, sand blasting and coating is to be done for each of these zones, as applicable.

(4) When steel renewal is required for zone *C*, according to **-1**, it is to be done for both zones *B* and *C*. When sand blasting and coating is required for zone *C* according to **-3**, it is to be done for zones *B*, *C* and *D*.

(5) When steel renewal is required for zone *D* according to **-1**, it needs only be done for this zone. When sand blasting and coating is required for zone *D* according to **-3**, it is to be done for both zones *C* and *D*.

(6) Notwithstanding the requirements specified in **(2)** through **(5)** above, special consideration may be given by the Society to zones previously renewed or re-coated, if found in an as-new condition (i.e. without breakdown or rusting).

(7) In regards to the renewal thickness criteria in **-1** and **-3**(1) above, the coating is to be applied in compliance with the requirements of **24.2.1**, as applicable.

(8) Where a limited number of side frames and brackets are shown to require coating over part of their length in accordance with the requirements in **(7)** above, the following criteria apply.

(a) The part to be coated is to include:

i. The web and the face plate of the side frames and brackets,

ii. The hold surface of side shell, hopper tank and topside tank plating over a width not less than 100 *mm* from the web of the side frame, as applicable.

(b) Epoxy coating or equivalent is to be applied.

(9) In all cases, all the surfaces to be coated are to be sand blasted prior to coating application.

(10) When hold frames with asymmetrical section or flanged hold frames are renewed, the outstanding breath to thickness ratio of face or flange is to comply with **28.6.1-7**.

6. Reinforcing measures

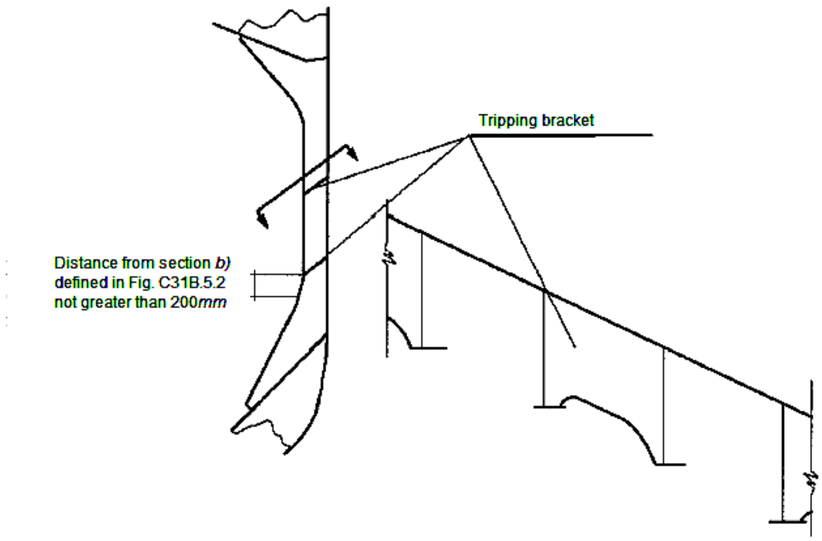
(1) Reinforcing measures are constituted by tripping brackets, located at the lower part and at midspan of side frames (see **Fig. 28B.5.4**). Tripping brackets may be located at every two frames, but lower and midspan brackets are to be fitted in line between alternate pairs of frames.

(2) The thickness of the tripping brackets is to be not less than the as-built thickness of the side frame webs to which they are connected.

(3) Double continuous welding is to be adopted for the connections of tripping brackets to the side shell frames and shell plating.

7. When all frames in one or more holds are required to be renewed, the compliance with requirements in **28.6** may be accepted in lieu of the compliance with the requirements in this Chapter.

Fig. 28B.5.4 Tripping Brackets



28B.5.3 Strength Check Criteria

1. In general, loads are to be calculated for the following loading conditions and strength checks are to be carried out for the aft, middle and forward frames of each hold. The scantlings required for frames in intermediate positions are to be obtained by linear interpolation between the results obtained for the above frames. When scantlings of side frames vary within a hold, the required scantlings are also to be calculated for the mid frame of each group of frames having the same scantlings. The scantlings required for frames in intermediate positions are to be obtained by linear interpolation between the results obtained for the calculated frames.

(1) Homogeneous loaded conditions with heavy cargoes (bulk cargo density is not less than 1.78 t/m^3), if carrying such heavy cargoes

(2) Homogeneous loaded conditions with light cargoes (bulk cargo density is less than 1.78 t/m^3)

(3) Non homogeneous loaded conditions with heavy cargoes, if applicable (multi-port loading/unloading conditions need not be considered.)

2. Load model

The forces $P_{fr\,a}$, and $P_{fr\,b}$, in kN, to be considered for the strength checks at sections a) and b) of side frames specified in **Fig. 28B.5.2** (in the case of separate lower brackets, section b) is at the top of the lower bracket) are given by:

$$P_{fr,a} = P_S + \max\ (P_1, P_2)$$

$$P_{fr,b} = P_{fr,a} \cdot \frac{h - 2h_B}{h}$$

P_S : Still water force, in kN, obtained from the following **(1)** or **(2)**.

(1) When the upper end of the side frame span h (see **Fig. 28B.5.1**) is below the load water line

$$sh\left(\frac{p_{S,U}+P_{S,L}}{2}\right)$$

(2) When the upper end of the side frame span h (see **Fig. 28B.5.1**) is at or above the load water line

$$sh'\left(\frac{p_{S,L}}{2}\right)$$

P_1 : Wave force, in *kN*, in head sea

$$sh\left(\frac{p_{1,U}+p_{1,L}}{2}\right)$$

P_2 : Wave force, in *kN*, in beam sea

$$sh\left(\frac{p_{2,U}+p_{2,L}}{2}\right)$$

h , h_B : Side frame span and lower bracket length, in *m*, defined in **Fig. 28B.5.1** and **Fig. 28B.5.2**, respectively

h': Distance, in *m*, between the lower end of side frame and the load water line

s : Frame spacing, in *m*

$p_{S,U}$, $p_{S,L}$: Still water pressure, in kN/m^2, at the upper and lower end of the side frame span h (see **Fig. 28B.5.1**), respectively

$p_{1,U}$, $p_{1,L}$, : Wave pressure, in kN/m^2, as defined in **(1)** below for the upper and lower end of the side frame span h, respectively

$p_{2,U}$, $p_{2,L}$, : Wave pressure, in kN/m^2, as defined in **(2)** below for the upper and lower end of the side frame span h, respectively

(1) Wave pressure p_1

(a) The wave pressure p_1 , in kN/m^2, at and below the waterline is given by:

$$p_1=1.5\left[p_{11}+135\frac{B}{2(B+75)}-1.2(d-z)\right]$$

$$p_{11}=3k_sC+k_f$$

(b) The wave pressure p_1, in kN/m^2, above the water line is given by:

$$p_1=p_{1wl}-7.5(z-d)$$

(2) Wave pressure p_2

(a) The wave pressure p_2 , in kN/m^2, at and below the waterline is given by:

$$p_2=13\left[0.5B\frac{50C_r}{2(B+75)}+C_B\frac{0.5B+k_f}{14}\left(0.7+2\frac{z}{d}\right)\right]$$

(b) The wave pressure p_2 , in kN/m^2, above the water line is given by:

$$p_2=p_{2wl}-5(z-d)$$

p_{1wl}: p_1 wave sea pressure at the waterline

p_{2wl}: p_2 wave sea pressure at the waterline

L_1 : Length of ship, in *m*, specified in **14.2.1-1**

B : Breadth of ship, in *m*, specified in **1.2.4, Part 1A**

C_B : Block coefficient $C'b$ specified in **14.2.1-1**

d : Designed maximum load draught, in *m*, specified in **1.2.12, Part 1A**

C : Coefficient defined as follows:

$10.75 - \left(\frac{300 - L_1}{100}\right)^{1.5}$ $for\ 90 \le L_1 \le 300m$

10.75 $for\ \ L_1 > 300m$

c_r : $\left(1.25 - 0.025\frac{2k}{\sqrt{GM}}\right)k$

k = 1.2 for ships without bilge keel

k = 1.0 for ships with bilge keel

k_r : Roll radius of gyration. If the actual value of kr is not available, the following value of (1) or (2) is to be used.

(1) 0.39B for ships with even distribution of mass in transverse section (*e.g.* alternate heavy cargo loading or homogeneous light cargo loading)

(2) 0.25B for ships with uneven distribution of mass in transverse section (*e.g.* homogeneous heavy cargo distribution)

GM : 0.12B if the actual value of GM is not available

z : Vertical distance, in m, from the baseline to the load point

k_s: $C_B + \frac{0.83}{\sqrt{C_B}}$ at aft end of L_1

C_B between 0.2 L_1 and 0.6 L_1 from aft end of L_1

$C_B + \frac{1.33}{C_B}$ at forward end of L_1

Between the specified points above, k_s is to be interpolated linearly.

$k_f = 0.8C$

3. Allowable stresses

The allowable normal and shear stresses σ_a and $\tau_a (kN/mm^2)$ in the side shell frames and brackets are given by:

$\sigma_a = 0.9\sigma_F$

$\tau_a = 0.4S\sigma_F$

Where σ_F s is the minimum upper yield stress (N/mm^2) of the material specified in **Part 10**

4. Shear strength check

When $t_M \le t_{COAT}$ in the lower part of side frames as shown in **Fig. 28B.5.1**, the shear strength check is to be carried out in accordance with the following. The thickness $t_{REN,S}$ in mm, is the greater of the thicknesses $t_{REN,Sa}$ and $t_{REN,Sb}$, obtained from the shear strength check at sections a) and b) (see **Fig. 28B.5.2** and **-2** above) given by the following, but it does not need to be in excess of $0.75t_{S12}$

At section a): $t_{REN,Sa} = \frac{1000k_S P_{fr,a}}{d_a \sin\emptyset\tau_a}$

At section b): $t_{REN,Sb} = \frac{1000k_S P_{fr,b}}{d_b \sin\emptyset\tau_b}$

Where:

k_S : Shear force distribution factor, to be taken equal to 0.6

$P_{fr,a}$, $P_{fr,b}$, : Forces specified in **-2** above

d_a , d_b : Bracket and frame web depth, in *mm*, at sections *a*) and *b*) (see **Fig. 28B.5.2**)

In case of separate (non integral) brackets, d_b is to be taken as the minimum web depth deducing possible scallops.

$\emptyset$: Angle between frame web and shell plate

τ_a: Allowable shear stress, in N/mm^2, specified in **-3** above

5. Bending strength check

(1) When the lower bracket length or depth does not comply with the requirements of **28.6.2-7**, the actual section modulus, in cm^3, of the brackets and side frames at sections *a*) and *b*) is to be not less than:

At section a): $$Z_a = \frac{1000 P_{fr,a} h}{m_a \sigma_a}$$

At section b): $$Z_b = \frac{1000 P_{fr,a} h}{m_b \sigma_a}$$

Where:

$P_{fr,a} h$: Force defined in **-2** above

h : Side frame span, in *m*, defined in **Fig. 28B.5.1**

σ_a : Allowable normal stress, in N/mm^2, defined in **-3** above

m_a, m_b : Bending moment coefficients defined in **Table 28B.5.3**

(2) The actual section modulus of the brackets and side frames is to be calculated about an axis parallel to the attached plate, based on the measured thicknesses. For precalculations, alternative thickness values may be used, provided they are not less than:

(a) t_{REN} for the web thickness

(b) The minimum thicknesses allowed by the Society for renewal criteria for flange and attached plating

(3) The attached plate breadth is equal to the frame spacing, measured along the shell at midspan *h*.

(4) If the actual section moduli at sections *a*) and *b*) are less than the values Z_a and Z_b, the frames and brackets are to be renewed or reinforced in order to obtain actual section moduli not less than 1.2 Z_a and 1.2Z_b ,respectively. In this case, renewal or reinforcements of the flange are to be extended over the lower part of side frames, as shown in **Fig. 28B.5.1**.

Table 28B.5.3 Bending Moment Coefficients m_a and m_b

	m_a	m_b		
		$h_B \leq 0.08h$	$h_B = 0.1h$	$h_B \geq 0.125h$
Empty holds of ships approved to operate in non homogeneour loading conditions	10	17	19	22
Other cases	12	20	22	26
Note 1: Non homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling ratio, evaluated for each hold, exceeds 1.20 corrected for different cargo densities. Note 2: For intermediate values of the bracket length h_B, the coefficient m_b is obtained by linear interpolation between the table values.				

28B.6 Steel Weathertight Hatch Covers

28B.6.1 Implementation Schedule

For ships constructed or converted with a single deck, top-side tanks and hopper side tanks in cargo area and intended primarily to carry dry cargoes in bulk, which are contracted for construction prior to 1 January 2004, steel weathertight hatch covers for cargo hold hatchways which are located wholly or partially within $0.25L_1$ of the fore end of L_1 are to comply with the requirements of **28B.6.2** and **28B.6.3** in accordance with the schedule shown in **Table 28B.5.1**. Notwithstanding the provisions above, hatch covers other than those for the foremost and second cargo holds need not apply to these requirements. The length L_1 is a length specified in **14.2.1-1**.

28B.6.2 Securing Devices

Effective devices deemed appropriate by the Society for securing weathertightness are to be provided for steel weathertight hatch covers.

28B.6.3 Stoppers

For steel weathertight hatch covers, effective means deemed appropriate by the Society for stoppers against the horizontal forces acting on their forward end and the side are to be provided.

28B.7 Restrictions for Sailing with Any Hold Empty

28B.7.1 General

1. Bulk carriers of not less than 150 m in length L_f of single-side skin construction, carrying cargoes having a density of not less than 1.78 ton/m^3, which was at beginning stage of construction before 1 July 1999, are not to sail with any hold empty when in full load condition, after reaching 10 years of age. For the application of this requirement, any hold empty in full load condition means that at least one cargo hold is loaded to less than 10% of the hold s maximum allowable cargo weight when the ship is carrying a load equal to or greater than 90% of the Ships deadweight at the relevant assigned freeboard.

2. Notwithstanding the provisions of **-1** above, bulk carriers meeting the structural strength requirements for withstanding flooding of any one cargo hold as specified in **28A.3**, **28A.4** and **28A.5** and having a side construction deemed appropriate by the Society, may continue sailing with any hold empty in full load condition.

Chapter 29 CONTAINER CARRIERS

29.1 General

29.1.1 Application

1. The construction and equipment of ships intended to be registered as container carriers are to be in accordance with the requirements in this Chapter.

2. Except where especially required in this Chapter, the general requirements for the construction and equipment of steel ships are to be applied.

3. The requirements in this Chapter are for ships which have a single deck, double bottoms in cargo holds, and decks and bottoms framed longitudinally.

4. Container carriers with a different construction from that specified in **-3** above, to which the requirements in this Chapter are not applicable, are to be at the discretion of the Society.

29.1.2 Direct Calculation

Where approved by the Society, scantlings of structural members may be determined based upon direct calculation. Where the scantlings determined based upon direct calculation exceed the scantlings required in this Chapter, the former is to be adopted.

29.2 Longitudinal Strength

29.2.1 Bending Strength

The section modulus of the athwartship section of the hull is to be as given in **15.2**. However, in case the athwartship section changes greatly in shape, adequate care is to be taken against deflection of the hull.

29.2.2 Torsional Strength

Where the width of the hatchway at the midship exceeds $0.7B$, special considerations are to be made to additional stresses and deformation of hatchway openings due to torsion. However, where the ship has two or more rows of hatchways, the distance between the outermost lines of hatchway openings is to be taken as the width of the hatchway.

29.3 Double Bottom Construction

29.3.1 General

1. The construction of the double bottom in holds which are exclusively loaded with containers is to be in accordance with the requirements in **31.3**. Unless otherwise specified in **31.3**, such construction is also to be in accordance with the requirements in **Chapter 5**.

2. Side girders or solid floors are to be provided in the double bottoms under corner fittings, or double bottoms are to be constructed so as to effectively support the loads of the containers.

29.3.2 Longitudinals

1. The section modulus of bottom longitudinals is not to be less than that obtained from the following formula:

$$Z = \frac{90CK}{24 - 15.5f_B K}\left\{d + 0.013L'\left(\frac{2}{B}y + 1\right) + h_1\right\}Sl^2 \quad (cm^3)$$

Where:

C : Coefficient given below:

Where no strut specified in **29.3.3** is provided midway between floors C=1.0

Where a strut specified in **29.3.3** is provided midway between floors C=0.625

However, where the widths of the vertical stiffeners provided on floors and those of struts are especially large, the coefficient may be appropriately reduced.

h_1: As given in (I) or (II)

(I) For 0.3L from the fore end:

$$h_1 = \frac{3}{2}(17 - 20C_b')\,(1 - x)$$

C_b': Block coefficient

Where C_b excedes 0.85, C_b' is to taken as 0.85

(II) For elsewhere:

0

x: As given by the following formula

$$\frac{X}{0.3L}$$

X: Distance (m) from the fore end for side shell plating. However, where X is less than that 0.1L, X is to be taken as 0.1L and where X exceeds 0.3L, X is to be taken as 0.3L.

f_B : Ratio of the section modulus of the transverse section of the hull required in **Chapter 14** to the actual section modulus of the transverse section of the hull at the bottom.

K: Coefficient corresponding to the kind of steel

e.g. 1.0 for mild steel, the values specified in **1.1.6-2** for high tensile steel

L': Length of ship (m)

Where L exceeds 230 m, L' is to be taken as 230 m.

l : Spacing of solid floors (m)

S : Spacing of longitudinals (m)

2. The section modulus of inner bottom longitudinals is not to be less than 75% of that specified for the bottom longitudinals at the same place.

$$Z = 100C_1C_2Shl^2 \quad (cm^3)$$

Where:

C_1: Coefficient given in the following formula, however, for h_2 and h_3, C_1 is to be taken as $\frac{K}{18}$

$C_1 = \frac{K}{24-\alpha K}$, however, the value of C_1 is not to be less than $\frac{K}{18}$

α: As obtained from the following formula:

$$\alpha = 15.5 f_B \left(1 - \frac{z}{z_B}\right)$$

K and f_B: As specified in **-1** above

z: Vertical distance (m) from the top of the keel to the bottom of inner bottom plating.

z_B: Vertical distance (m) from the top of the keel amidships to the horizontal neutral axis of the transverse section.

C_2: As determinated from **Table 29.1**

S: Spacing of stiffeners (m)

h: The following h_1, h_2 and h_3, however, where the double bottom space is void, h is to be taken as h_1

h_1: Vertical distance (m) from the mid point between the bottom of inner bottom plating and the upper end of the overflow pipe.

h_2: As obtained from the following formula:

$$h_2 = 0.85(h_1 + \Delta h) \quad (m)$$

Δh: As obtained from the following formula:

$$\Delta h = \frac{16}{L}(l_t - 10) + 0.25(b_t - 10) \quad (m)$$

l_t: Tank length (m)

It is not to be less than 10 m

b_t: Tank breadth (m)

It is not to be less than 10 m

h_3: Value obtained by multiplying 0.7 by the vertical distance from the tank top plating to the point 2.0 m above the top of overflow pipe.

l: Spacing of girders (m)

Table 29.1 Value of C_2

Other end	One end		
	Rigid connection by bracket	Soft connection by bracket	Supported by girders or lug-connection
Rigid connection by bracket	0.70	1.15	0.85
Soft connection by bracket	1.15	0.85	1.30
Supported by girders or lug-connection	0.85	1.30	1.00

Notes:

1. "Rigid connection by bracket" is a connection by bracket of the stiffener to the double bottom or to a stiffener of equivalent strength attached to the face plates of adjacent members, or a connection of equivalent strength. **(See Fig. 12.1(a)).**

2. **"**Soft connection by bracket" is a connection by bracket of the stiffener to transverse member such as beams, frames, or the equivalent thereto. **(See Fig. 12.1(b)).**

29.3.3 Vertical Struts

Where vertical struts are provided, the sectional area is not to be less than that obtained from the following formula:

$$A = 0.9CKSb\left(d + 0.026L'\right) \quad (cm^2)$$

Where:

C: Coefficient obtained from the following formula, but *C* is not to be less than 1.43

$$C = \frac{1}{1 - 0.5\frac{l_s}{k\sqrt{K}}}$$

K: As specified in **29.3.2-1**

ls : Length of struts (*m*)

k : Minimum radius (*cm*) of gyration of struts obtained from the following formula:

$$k = \sqrt{\frac{I}{A}}$$

I : The least moment of inertia of struts (cm^4)

A : Sectional area of struts (cm^2)

S : Spacing of longitudinals (*m*)

b : Width (*m*) of the area supported by struts

29.3.4 Thickness of Inner Bottom Plating

1. The thickness of inner bottom plating is to be in accordance with the requirement in **5.5.1-1.** However, in the application of the second formula in the requirement, *h* is to be obtained from the following formula:

$$h = 1.13(d - d_0)$$

Where:

d_0: Height of centre girder (*m*)

2. Notwithstanding the requirement in **-1**, the thickness *t* of inner bottom plating is to be not less than obtained from the following formula.

$$t = 3.6CS\sqrt{Kh} + 3.0 \ \ (mm)$$

S: Spacing of stiffeners (*m*)

h: As specified in **29.3.2-2**

K: As specified in **29.3.2-1**

C: Coefficient given in the following formula according to the stiffening system of inner bottom plating used, however, for h_2 and h_3, *C* is to be taken as 1.

(a) For transverse system

$$C = \frac{27.7}{\sqrt{767 - \alpha^2 K^2}}$$

α: As specified in 29.3.2-1

(b) For longitudinal system

$C = \frac{3.72}{\sqrt{27.7 - \alpha K}}$, However, C is not to be less than 1.0

α: As specified in 29.3.2-2

3. The inner bottom plating with which the lower ends of corner fittings of containers are in contact is to be strengthened by means of doubling or by other appropriate means.

29.3.5. Bottom Shell Plating

1. The thickness t of bottom shell plating is not to be less than that obtained from the following formulae **(1)** and **(2)** or from the requirements in 5.5.5, whichever is greater. However, in the application of the requirements in 5.5.5, the thickness need not apply to the formula in requirement of 15.3.4

(1) In ships with transverse framing, the thickness is not to be less than that obtained from the following formula:

$$t = C_1 C_2 S \sqrt{d + 0.0175L'\left(\frac{2}{B}y + 1\right) + h_1} + 2.5 \quad (mm)$$

Where:

S: Spacing (m) of tranverse frames

L', y, h_1: As specified in 32.3.2-1

C_1: Coefficient given below:

Where L is 230 *metres* and under: 1.0

Where L is 400 *metres* and over: 1.07

For intermediate values of L, C_1 is to be obtained by linear interpolation.

C_2: Coefficient given below:

$$C_2 = \frac{91}{\sqrt{576 - (15.5 f_B x)^2}}$$

x: As given by the following formula

$$\frac{X}{0.3L}$$

X: Distance (m) from the end for side shell plating afore the midship, or from the after end for side shell plating after the midship. However, where X is less than that 0.1L, X is to be taken as 0.1L and where X exceeds 0.3L, X is to be taken as 0.3L.

(2) In ships with longitudinal framing, the thickness of side shell plating is not to be less than that obtained from the following formula:

$$t = C_1 C_2 S \sqrt{d + 0.0175L'\left(\frac{2}{B}y + 1\right)h_1} + 2.5 \quad (mm)$$

Where:

S: Spacing (m) of longitudinal frames

L', C_1 and h_1: As given in **(1)**

C_2: Coefficient given by the following formula, but it is not be less than $3.78\sqrt{K}$

$$C_2 = 13\sqrt{\frac{K}{24 - 15.5 f_B K x}}$$

x: As given in **(1)**

2. Notwithstanding the requirement in **-1**, the thickness *t* of bottom shell plating is to be not less than obtained from the following formula.

$$t = \sqrt{KL'} \quad (mm)$$

L': Length (m) of ship

However, where L exceeds 330 m, L' is to be taken as 330 m

K: As specified in **29.3.2-1**

3. The breadth and thickness of plate keels are to be in accordance with the requirement of **15.2.1**. However, in the application of the requirement of **15.2.1-2**, **15.3.4** is to be read as **29.3.5**

29.4 Double Side Construction

29.4.1 General

1. The side construction of holds is to be of double hull construction as far as practicable and is to be thoroughly stiffened by providing side transverse girders and side stringers within the double hull.

2. Double side construction is to be in accordance with the requirements in **Chapter 12**, unless otherwise specified in **29.4**.

3. Double side shell structures, the interiors of which are used as deep tanks, are to be in accordance with the requirements in **Chapter 13** in addition to those in **29.4**.

4. Side stringers are to be spaced appropriately according to the depths of holds. Side transverse girders are to be provided at solid floors in double bottoms.

5. Where the width of the double side shell changes in the bilge part, the scantlings are to be at the discretion of the Society.

6. Where structures effectively support deck structures and side shell structures in the midway of holds, the requirements in **29.4** may be appropriately modified.

7. Where the height from the designed maximum load line to the strength deck is especially large, the scantlings are to be at the discretion of the Society.

8. Where the inner hull plating and the inner bottom plating are combined, considerations are to be made to their structural arrangement so as not to cause stress concentration.

9. At the fore and aft ends of the double side structure, sufficient considerations are to be made to the continuity of construction and strength.

29.4.2 Side Transverse Girders and Side Stringers

1. The thickness of side transverse girders is not to be less than that obtained from the following formulae, whichever is the greatest:

$$t_1 = 0.083\frac{CKSl_H}{d_1 - a}\left(d + 0.083L'\right) + 2.5 \quad (mm)$$

$$t_2 = 8.6\sqrt[3]{\frac{d_1^2(t_1 - 2.5)}{kK}} + 2.5 \quad (mm)$$

$$t_3 = \frac{8.5}{\sqrt{K}}S_2 + 2.5 \quad (mm)$$

Where:

C : As obtained from the following formula:

$$C = (C_1 + \beta_T C_2)C_3$$

C_1 and C_2: As obtained from **Table 29.2** in accordance with the value of h/l_h

For intermediate values of h/l_h, the values of C_1 and C_2 are to be determined by linear interpolation.

h : Vertical distance (m) from the top of inner bottom to the strength deck at side

l_h : Length of hold (m)

β_T : As obtained from the following formula:

$$\beta_T = 1 + \frac{0.42\left(\frac{B}{D_s}\right)^2 - 0.5}{0.59\frac{D_s - \frac{d_0}{2}}{B - d_1}\left(\frac{d_0}{d_1}\right)^2 + 1.0}$$

d_0 : Height of centre girder (m)

d_1 : Depth of side transverse girder (m)

Where the depth of the web is divided by stiffeners attached in the direction of the length of the girder, d_1 in the formulae for t_2 and t_3 may be taken as the divided depth.

C_3 : As obtained from the following formula, but not to be less than 0.2:

$$C_3 = 1 - 1.8\frac{y}{h}$$

y : Distance (m) from the lower end of h to the location under consideration

K: As specified in **29.3.2-1**

S : Width (m) of the area supported by the side transverse girders

a : Depth (m) of the openings at the location under consideration

L' : Length of ship (m).

However, where L exceeds 230 m, L' is to be taken as 230 m.

k : Coefficient obtained from **Table 29.2** in accordance with the ratio of the spacing S_1 (m) of the stiffeners provided on the web of side transverse girders in the direction of the depth of the girders and d_1

For intermediate values of S_1/d_1, the value of k is to be determined by linear interpolation.

S_2 : S_1 or d_1, whichever is smaller.

However, t_3 can be determined by other analytical measures against compressive buckling strength of the girder

Table 29.2 Coefficients, C_1 and C_2

h/l_H	0.50 and under	0.75	1.00	1.25	1.50	1.75 and above
C_1	0.18	0.21	0.24	0.25	0.26	0.27
C_2	0.05	0.08	0.09	0.10	0.11	0.12

Table 29.3 Coefficient k

S_1/d_1	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0 and above
k	60.0	40.0	26.8	20.0	16.4	14.4	13.0	12.3	11.1	10.2

2. The thickness of side stringers is not to be less than that obtained from the following formula, whichever is the greatest:

$$t_1 = 0.083\frac{CKSl_H}{d_1 - a}\left(d + 0.083L'\right) + 2.5\ (mm)$$

$$t_2 = 8.6\sqrt[3]{\frac{d_1^2(t_1 - 2.5)}{kK}} + 2.5\ (mm)$$

$$t_3 = \frac{8.5}{\sqrt{K}}S_2 + 2.5\ (mm)$$

Where:

C : As obtained from the following formula:

$$C = (C_1 - \beta_L C_2)C_3$$

C_1 and C_2 : As obtained from **Table 29.4**, in accordance with the value of h/l_H

For intermediate values of h/l_H, the values of C_1 and C_2 are to be determined by linear interpolation.

β_L : As obtained from the following formula:

$$\beta_L = 1 + \frac{0.18\left(\frac{B}{D_S}\right)^2 - 0.5}{0.59\frac{D_S - \frac{d_0}{2}}{B - d_1}\left(\frac{d_0}{d_1}\right)^2 + 1.0}$$

h , l_H , d_0 and L' : As specified in **-1** above

d_1 : Depth of side stringers (m)

However, where the depth of the web is divided by stiffeners attached in the direction of the length of the stringer, d_1 in the formulae for t_2 and t_3 may be taken as the divided depth.

C_3 : As obtained from the following formula:

$$C_3 = \left|1 - \frac{2x}{l_H}\right|$$

x : Distance (m) from the end of l_H to the location under consideration

K: As specified in **29.3.2-1**

S : Width (m) of the area supported by the side stringers

a : Depth (m) of the openings at the location under consideration

k : Coefficient obtained from **Table 29.3** in accordance with the ratio of the spacing S_1(m) of the stiffeners provided on the web of the side stringer in the direction of the depth of the stringer and d_1

For intermediate values of S_1/d_1, the value of k is to be determined by linear interpolation.

S_2 : S_1 or d_1, whichever is smaller

However, t_3 can be determined by other analytical measures against compressive buckling strength of the girder.

Table 29.4 Coefficients C_1 and C_2

h/l_H	0.50 and under	0.75	1.00	1.25	1.50 and above
C_1	0.20	0.24	0.26	0.26	0.26
C_2	0.07	0.05	0.03	0.01	0.00

29.4.3 Inner Hull Construction

The thickness t of inner hull plating where the interior of the double side structure is used as deep water tanks, and the section modulus Z of longitudinal stiffeners are not to be less than those obtained from the following formulae, respectively:

(1) Thickness of inner hull plating

$$t = 3.6CS\sqrt{Kh} + 2.0 \quad (mm)$$

Where:

S : Spacing of stiffeners (m)

K: As specified in **29.3.2-1**

h : The following h_1, h_2 and h_3, however, where the double bottom space is void, h is to be taken as h_1

h_1: Vertical distance (m) from the lower edge of the bulkhead plating under consideration to the mid-point between the point on the tank top and the upper end of the overflow pipe.

h_2: As obtained from the following formula:

$h_2 = 0.85(l_t + \Delta h)\ \ (mm)$

Δh: As obtained from the following formula:

$\Delta h = \frac{16}{L}(l_t - 10) + 0.25(b_t - 10)\ \ \ (mm)$

l_t: Tank length (m)

It is not to be less than 10 m

b_t: Tank breadth (m)

It is not to be less than 10 m

h_3: Value obtained by multiplying 0.7 by the vertical distance from the lower edge of the bulkhead plating under consideration to the point 2.0 m above the top of overflow pipe.

C: Coefficient given in the following formulae according to the stiffening system of inner hull plating used, however, for h_2 and h_3, C is to be taken as 1:

(a) For transverse system

$$C = \frac{27.7}{\sqrt{767 - \alpha^2 K^2}}$$

Where:

α : As obtained from the following formulae, whichever is greater:

$\alpha = 15.5 f_B \left(1 - \frac{z}{z_B}\right)$ where $z \leq z_B$

$\alpha = 15.5 f_D \left(\frac{z - z_B}{Z'}\right)$ where $z_B < z$

$\alpha = \frac{1}{9.81}\frac{M_H}{I_H} y_H \times 10^5$

f_B: As specified in **29.3.2-1**

z: Vertical distance (m) from the top of the keel to the lower edge of inner hull plating

z_B : As specified in **29.3.2-2**

f_D : Ratio of the section modulus of the transverse section of hull required in **Chapter 14** to the actual section modulus of the hull at the strength deck.

Z': The greater of the values specified in **14.2.3(5)(a)** or **(b)**

M_H: As given by the following formula

$M_H = 0.45 C_1 L^2 d (C_b + 0.05) C_H\ \ (kN - m)$

C_1: As given by the following formula

$10.75 - \left(\frac{300 - L_1}{100}\right)^{1.5}$	for $L_1 \leq 300m$
10.75	for $300m < L_1 \leq 350m$

$10.75 - \left(\frac{L_1 - 350}{150}\right)^{1.5}$ for $350m < L_1$

L_1: Length (m) of ship specified in **1.2.2, Part 1A** or 0.97 *times* the length of ship on the designed maximum load line, whichever is smaller.

C_H: Coefficient, as given in **Table 29.5**, based on the ratio of L to x, where x is the distance (m) from the aft end of L to the section under consideration.

Intermediate values are to be determined by interpolation.

l_H: Moment of inertia (cm^4) of the cross section about the vertical neutral axis of the transverse section under consideration

y_H: Horizontal distance (m) from the vertical neutral axis to the evaluation position

(b) For longitudinal system

$C = \frac{3.72}{\sqrt{27.7 - \alpha K}}$, however, C is not to be less tan 1.0

Where:

α : As specified in **(a)**

(2) Section modulus Z of longitudinal stiffeners on inner hull plating

$Z = 100 C_1 C_2 S h l^2 (cm^3)$

Where:

C_1 : Coefficient given in the following formula, however, for h_2 and h_3, C_1 is to be taken as $\frac{K}{18}$

$C_1 = \frac{K}{24 - \alpha K}$, however, the value of C_1 is not to be less than $\frac{K}{18}$

α: As specified in **(a)**

C_2: As specified in **29.3.2-2**

S: Spacing of stiffeners (m)

h: As specified in **(a)**

Where "the lower edge of the bulkhead plating under consideration" is to be construed as "the stiffener under consideration".

l: Spacing of girders (m)

Table 29.5 Coefficient C_H

x/L	0.0	0.4	0.7	1.0
C_H	0.0	1.0	1.0	0.0

29.4.4 Brackets

Brackets are to be provided on the upper and lower corners inside the double side structure, at every frame where transversely stiffened and at an appropriate spacing between side transverse girders where longitudinally stiffened.

29.4.5 Side Shell plating

1. The side shell plating below the strength deck is to be in accordance with the requirements in **29.4.5.** Unless otherwise specified in **29.4.5**, such plating is also to be in accordance with the requirements in **Chapter 15.**

2. The thickness t of side shell plating other than the sheer strake specified in **15.3.3** is to be as required in the following **(1)** and **(2)** in addition to the requirements in **14.3.1** and **14.3.2.**

(1) In ships with transverse framing, the thickness of side shell plating is not to be less than that obtained from the following formula:

$$t = C_1 C_2 S\sqrt{d - z' + 0.05L' + h_1} + 2.0 \ \ (mm)$$

Where:

S: spacing (m) of tranverse frames

L', C' and h_1: As specified in **29.3.5-1(1)**

z': Vertical distance (m) from the top of the keel to the upper turn of the bilge at midship. The upper turn of the bilge is a point of the end of curvature at upper turn of the bilge on the side shell.

C_2: Coefficient given below:

$$C_2 = 91\sqrt{\frac{K}{576 - \alpha^2 K^2 x^2}}$$

K: As specified in **29.3.2-1**

α: As given in following formula, whichever is greater

$$\alpha = 15.5 f_B\left(1 - \frac{z}{z_B}\right)$$

$$\alpha = \frac{1}{9.81}\frac{M_H}{I_H} y_H \times 10^5$$

z_B: As specified in **29.3.2-2**

z: Vertical distance (m) from the top of keel to the lower edge of the side shell plating under consideration.

f_B: As specified in **29.3.2-1**

M_H, I_H and y_H: As specified in **29.4.3(1)(a)**

x: As specified **29.3.5-1(1)**

(2) In ships with longitudinal framing, the thickness of side shell plating is not to be less than that obtained from the following formula:

$$t = C_1 C_2 S\sqrt{d - z' + 0.05L' + h_1} + 2.0 \ \ (mm)$$

Where:

S: Spacing (m) of longitudinal frames

z', L', C_1 and h_1: As specfieid in **(1)**

C_2: Coefficient given by the following formula, but it is not to be less than $3.78\sqrt{K}$

$$C_2 = 13\sqrt{\frac{K}{24 - \alpha K x}}$$

K, α and x: As specified in **(1)**

3. Notwithstanding the requirement in **-2,** the thickness t of side shell plating below the strength deck is to be not less than obtained from the formula in **29.3.5-2.**

29.4.6 Side Longitudinals

1. The section modulus Z of side longitudinals below the freeboard deck is not to be less than that obtained from the following formulae **(1)** and **(2)**, whichever is greater:

(1) $Z = 90CShl^2 \quad (cm^3)$

Where:

S: Spacing (m) of longitudinals

l: Spacing of girders (m)

h: Vertical distance (m) from the side longitudinal concerned to a point $d + 0.038L' + h_1$ above the top of keel.

h_1, K and L: As specified in **29.3.2-1**

C: Coefficient given by the following formula:

$C = \frac{K}{24-\alpha K}$, however, the value of C is not to be less than $\frac{K}{18}$

α: As obtained from the following formula, whichever is greater:

$\alpha = 15.5 f_B\left(1 - \frac{z}{z_B}\right)$ where $z \le z_B$

$\alpha = 15.5 f_D \frac{z - z_B}{z'}$ where $z \le z_B$

$$\alpha = \frac{1}{9.81}\frac{M_H}{I_H} y_H \times 10^5$$

z: Vertical distance (m) from the top of keel to the longitudinal under consideration

z_B: As specified in **29.3.2-2**

f_B, f_D and Z': As specified in **29.4.3(1)(a)**

M_H, I_H and y_H: As specified in **29.4.3(1)(a)**

(2) $Z = 2.9K\sqrt{L'}Sl^2 \quad (cm^3)$

K, L', S and l: As specified in **(2)**

2. The section modulus Z of side longitudinals where the interior of the double side structure is used as deep water tanks are to be in accordance with the requirement in **29.4.3(2).**

29.5 Transverse Bulkheads

29.5.1 Construction

Transverse bulkheads are to be constructed so as to be sufficiently supported at the deck. Where the width of the bulkhead is especially large, the upper parts of transverse bulkheads are to be appropriately strengthened by providing box-shaped structures or by other means.

29.5.2 Partial Bulkheads

Where non-watertight partial bulkheads are provided in cargo holds, the construction and scantlings are to be of sufficient strength and rigidity based on factors such as the size of the cargo hold and the depth of the bulkheads.

29.6 Deck Construction

29.6.1 Decks Inside the Line of Deck Openings

The scantlings of decks inside the line of deck openings in relation to bending in the deck plane are not to be less than those obtained from the following formulae. When calculating the section modulus and moment of inertia, the deck inside the line of deck openings is to be regarded as a web and the hatch end coaming as a flange. Where the construction is box-shaped or of similar construction, the second term of the formula for the thickness of deck plating is to be taken as 5.0.

(1) Thickness of deck plating (including the bottom plate in case of box-shaped construction)

$$0.00417C_1K\left(\frac{l_v^2 l_c}{w_c}\right) + 2.5\ \ (mm)$$

Where:

K: As specified in **29.3.2-1**

l_v : Distance (m) from the top of inner bottom plating to the bulkhead deck at the centre line of the ship

l_c : Width of hatchway (m)

Where two or more rows of hatchways are provided, the width of the widest hatchway is to be taken.

w_c : Width (m) of deck inside the line of deck openings

C_1: As obtained from **Table 29.6** in accordance with the value of α

For intermediate values of a, the values of C_1 are to be determined by linear interpolation.

α : As obtained from the following formula:

$$\alpha = 0.5l_c \sqrt[4]{\frac{3}{4SI_v^3}\frac{I_v}{I_c}}$$

S : Spacing (m) of vertical webs provided on transverse bulkheads

I_v : Moment of inertia (cm^4) of vertical webs provided on transverse bulkheads

I_c : Moment of inertia (cm^4) of decks inside the line of deck openings

(2) Section modulus Z

$$Z = 1.43 C_2 K l_v^2 l_c^2 \quad (cm^3)$$

Where:

C_2 : As obtained from **Table 29.4** in accordance with the value of α

For intermediate values of α, the values of C_2 are to be determined by linear interpolation.

α, l_v and l_c : As specified in **(1)**

(3) Moment of inertia

$$I = 0.38 \frac{l_c^4}{S l_v^3} I_v \quad (cm^4)$$

Where:

S , l_c ,l_v and I_v : As specified in **(1)**

Table 29.6 Coefficients, C_1 and C_2

α	0.50 and under	1.50 and above
C_1	1.00	0.37
C_2	0.50	0.10

29.6.2 Crossties

1. Where the length of the hatchway is large in comparison with the width, crossties are to be provided in the hatchway opening at an appropriate spacing.

2. Where structures effectively supporting the loads from the side and deck of the ship are not provided at the location of crossties in holds, special considerations are to be made regarding the scantlings of crossties.

29.6.3 Continuity of Thickness of Deck Plating

Consideration is to be made to the continuity in the thickness of deck plating, and to the avoidance of remarkable differences between the thicknesses inside and outside the line of deck openings.

29.7 Container Supporting Arrangements

29.7.1 General

1. Container supporting arrangements are to be constructed so as to effectively transmit the loads to the double bottom structure, side construction and transverse bulkheads.

2. The strength of container supporting arrangements is to be sufficient for the loads from the bottom and side of the ship and the loads due to the containers.

29.8 Strength at Large Flare Locations

29.8.1 Shell Plating

For side shell plating where the flare is especially large, sufficient consideration is to be made regarding reinforcement against forces acting on the bow such as wave impact pressure.

29.8.2 Frames

The frames that are fitted where the bow flare is considered to endure large wave impact pressure are to be properly strengthened and particular attention is to be paid to the effectiveness of their end connections.

29.8.3 Girders

The girders that are fitted where the bow flare is considered to endure large wave impact pressure are to be properly strengthened and particular attention is to be paid to the effectiveness of their end connections.

29.9 Welding

29.9.1 Application

1. Fillet welding is to be applied to longitudinals with a web plate thickness above 40*mm* and up to 80*mm*, which are used for the strength deck or for side shell plating and longitudinal bulkheads that extend upwards from a position 0.25*D* below the strength deck.

2. Where longitudinals with a web plate thickness above 80*mm* are used, the kind and size of the weldings are to be at the discretion of the Society.

29.9.2 Fillet Welding

1. Fillet welding is to be continuous.

2. The size of fillet is to be not less than 8*mm*.

Chapter 30 DAMAGE CONTROL FOR DRY CARGO VESSELS

30.1 General

30.1.1 Application

1. The requirements in this part apply to dry cargo vessels of not less than 500 *gross tonnage* which are engaged in international voyages.

2. Dry cargo vessel is defined as a cargo ship that does not engage in carrying liquids.

30.2 Damage Control

30.2.1 Watertight Doors

1. For watertight doors in the watertight bulkhead, except those permanently closed at sea, position indicators showing whether the doors are open or closed are to be provided on the bridge and at all operating positions.

2. Electrical installations for watertight doors specified in **-1** except those of a waterproof type approved by the Society are not to be provided under the freeboard deck.

30.2.2 Cargo Ports and Other Similar Openings

For bow doors, stern doors or shell doors required to be watertight, indicators showing whether the doors are opened or closed are to be provided on the navigation bridge. However, where it is deemed appropriate by the Society, this requirement may be dispensed with.

30.3 Booklet and Plan for Damage Control

30.3.1 Damage Control Plan

1. A Damage control plan approved by the Society is to be permanently exhibited or readily available on the navigation bridge, for the guidance of the officer in charge of the ship.

2. The damage control plan is to show clearly for each deck and hold, the boundaries of the watertight compartments, the openings therein with their means of closure (including the position of any controls thereof), and the arrangements for the correction of any list due to flooding.

30.3.2 Booklet

1. The Booklet is to contain the information shown in the damage control plan.

2. The Booklet is to be provided at a suitable place which is made available to the officers of the ship.

Chapter 31 LOADING MANUAL AND LOADING COMPUTER

31.1 General

31.1.1 General

1. In order to enable the ship master to arrange for the loading of cargo and ballasting to avoid the occurrence of unacceptable stress in the ship's structure, ships are to be provided with a loading manual approved by the Society.

2. For ships of not less than length L_f 100 *m*, which fall under the following **(1)** or **(2)**, a loading computer approved by the Society is to be provided.

(1) Ships conforming to **Chapter 26** to **Chapter 29**, *IGC Code- IMO* or *IGC Code- IMO*

(2) Other ships deemed necessary by the Society

31.1.2 Loading Manual

1. The Loading manual is to include at least the following items.

(1) The loading conditions on which the design of the ship has been based, including permissible limits of longitudinal still water bending moment and still water shearing force

(2) Results of calculations of longitudinal still water bending moment and still water shearing force corresponding to the loading conditions

(3) Allowable limits of local loads applied to hatch covers, deck, double bottom construction, etc., where deemed necessary by the Society

31.1.3 Loading Computer

1. The Loading computer is to be capable of readily computing longitudinal still water bending moment and still water shearing force working on the ship corresponding to all the loading conditions of the cargo and ballast. The computer has the performance and functions deemed appropriate by the Society.

2. The Loading computer is to be capable of producing the specified performance and functions on installation.

3. The operation manual for the computer is to be available on board.

31.2 Additional Requirements for Newly-built Bulk Carriers

31.2.1 General

1. Bulk carriers, coming under the following **(1)** or **(2)**, of not less than 150 *m* in length L_f are to be provided with a loading manual and a loading computer in accordance with the requirements in **31.2.2** and **31.2.3**.

(1) Bulk carriers as defined in **1.3.1(13), Part 1B**, which are contracted for construction on or after 1 July 1998

(2) Bulk carriers as defined in 28A.1.2(1), which are at the beginning stage of construction on or after 1 July 2006

2. Notwithstanding the provisions of **-1**, bulk carriers defined in 28A.1.2(1) but not coming under the definition of bulk carriers as specified in 1.3.1(13), Part 1B, need not comply with the requirements of 31.2.2-1(4), 31.2.2-2(4) and 31.2.3(2). In addition, the requirements of 31.2.2-1(3) may be modified so that loading manuals are to include the maximum allowable load per hold. The requirements of 31.2.2-2(7) and (8) may be also modified so that loading manuals are to include general restrictions and/or instructions for loading, unloading, ballasting and de-ballasting with regard to the strength of the ship's structures.

3. Bulk carriers coming under the provisions of **-1(2)** above, of less than 150 *m* in length L_f are to be provided with a loading manual in accordance with the requirements in 31.2.2. Notwithstanding the above, items to be included in the loading manual may be in accordance with the provisions of **-2** above.

31.2.2 Loading Manual

1. The Loading manual is to include, in addition to the requirements given in 31.1.2, the following items.

(1) For bulk carriers conforming to 28A.5, envelope results and permissible limits of still bending moments and shear forces in the hold flooded condition according to the requirements given in 28A.5

(2) However, results deemed by the Society as too small to affect the strength of the ship may be The cargo holds or combination of cargo holds that might be empty at full draught

Where no cargo hold is allowed to be empty at full draught, this is to be clearly stated in the loading manual.

(3) Maximum allowable and minimum required mass of cargo and double bottom contents of each hold as a function of the draught at mid-hold position

(4) Maximum and minimum required mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught

This mean draught may be calculated by averaging the draught of the two mid-hold positions.

(5) Maximum allowable tank top loading together with specification of the nature of the cargo for cargoes other than bulk cargoes

Where the ship is not approved to carry cargoes other than bulk cargoes, this is to be clearly stated in the loading manual.

(6) Maximum allowable load on deck and hatch covers

Where the ship is not approved to carry loads on deck and hatch covers, this is to be clearly stated in the loading manual.

(7) Maximum rate of ballast change together with the advice that a load plan is to be agreed with the terminal on the basis of the achievable rates of change of ballast

(8) Bulk cargo density for strength requirements in accordance with Chapter 28A

It is to be clearly stated in the loading manual as follows, "Where cargoes of a bulk cargo density greater than that specified are to be loaded, the interaction of the load with the strength of the hull is to be reviewed before loading".

The latest date for implementation for requirements in **(4)** is 1 July 1999.

2. The Loading manual is to include, in addition to the requirements given in **33.1.2**, the following conditions; subdivided into departure and arrival conditions. Where the design of the ship is based on conditions **(1)**, **(4)**, **(5)**,**(6)**, and **(8)**, these are to be included in the loading manual.

(1) Alternate light and heavy cargo loading conditions at maximum draught

(2) Homogeneous light and heavy cargo loading conditions at maximum draught

(3) Ballast conditions

Ships having ballast holds adjacent to topside wing, hopper, and double bottom tanks are to have sufficient structural strength to allow the ballast holds to be filled when these topside wing, hopper, and double bottom tanks are empty.

(4) Short voyage conditions where the ship is to be loaded to maximum draught but with a limited amount of bunkers

(5) Multiple port loading/unloading conditions

(6) Deck cargo conditions

(7) Typical loading/unloading sequences

This is to detail the loading sequence from the commencement of cargo loading to when the ship reaches full deadweight capacity and the unloading sequence from full deadweight capacity to empty conditions. These sequences are to be developed paying attention to the loading rate, ship strength, and de-ballasting capability.

(8) Typical sequences for change of ballast at sea

31.2.3 Loading Computer

1. In addition to the requirements in **31.1.3**, the Loading computer is to be capable of ascertaining that the following values are within permissible limits.

(1) The mass of cargo and double bottom contents in way of each hold as a function of the draught at mid-hold position

(2) The mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds

(3) For bulk carriers conforming to **28A.5**, the still water bending moment and shear forces in holds flooded conditions

The latest date for implementation for the requirements in **(2)** is 1 July 1999.

31.3 Additional Requirements for Existing Bulk Carriers, Ore Carriers, and Combination Carriers

31.3.1 Loading Manual

1. In addition to the requirements in **31.1.2**, the loading manual with typical loading/unloading sequences given in **31.2.2-2(7)** is to be approved by the Society for single side skin bulk carriers of not less than 150 *m* length which are contracted for construction before 1 July 1998. Bulk carriers are to be provided with this manual including the sequences before 1 July 1999. The bulk carriers referred to in this sub-paragraph and **31.3.2** refer to ships of single deck construction with top-side tanks and hopper side tanks in cargo spaces.

31.3.2 Loading Computer

1. Bulk carriers, ore carriers and combination carriers of not less than length L_f 150 m conforming to **Chapter 27** or **Chapter 28** are to be provided with a loading computer as specified in **31.1.3**, except ships for which the application for classification survey during construction is submitted to the Society on or after 1 January 1994.

Chapter 32 MEANS OF ACCESS

32.1 General Rules

32.1.1 General

1. Peak tanks, deep tanks, cofferdams, cargo oil tanks, cargo holds with relative high bilge hopper tanks, and other similar enclosed spaces are to be provided with means of access, i.e., stages, ladders, steps or other similar facilities for internal examinations in safety. However, such means are not required in aft peak tanks and deep tanks which are exclusively loaded with fuel oil or lubrication oil.

2. Notwithstanding **-1** above, spaces specified in 32.2 are to comply with the requirements of 32.2.

32.1.2 Means of Access to Spaces

1. Safe access to peak tanks, deep tanks, cofferdams, cargo oil tanks, cargo holds and other similar enclosed spacesis to be, in general, direct from the open deck and served by at least one access hatchway or manhole and ladder.

2. Notwithstanding **-1** above, safe access to lower spaces of spaces divided vertically, may be from other spaces, subject to consideration of ventilation aspects.

3. Notwithstanding **-1** above, the provision of fixed ladders is not required for spaces not greater than 1.5 *m* in height measuring from the bottom to the top of the open deck on ships of less than 300 *gross tonnage*.

32.1.3 Means of Access within Spaces

1. Peak tanks, deep tanks, cofferdams, cargo oil tanks, cargo holds and other similar enclosed spaces are to be provided with means of access to hull structures for examination.

2. Where unavoidable obstructions such as hull structural members of not less than 600 *mm* in height impedes access to hull structures within the space, appropriate facilities such as ladders or steps are to be fitted.

32.1.4 Specifications of Means of Access and Ladders

1. Means of access are to be safe to use.

2. Permanent means of access are to be of robust construction.

32.1.5 Plans for Means of Access

Plans showing the arrangement of means of access to peak tanks, deep tanks, cofferdams, cargo oil tanks, cargo holds with relative high bilge hopper tanks, and other similar enclosed spaces are to be kept on board.

32.2 Special Requirements for Oil Tankers and Bulk Carriers

32.2.1 Application

This section (**32.2**) applies to each space within the cargo area and fore peak tanks of oil tankers (as defined in **1.3.1(11) of Part 1B**, of not less than 500 *gross tonnage*) and bulk carriers (as defined in **1.3.1(13) of Part 1B**, of not less than 20,000 *gross tonnage*), in place of the requirements in **32.1**. Notwithstanding the above, the provisions in this section, except **32.2.3-1** and **-2** and **32.2.5-5**, **-6** and **-7** in relation to access to tanks/spaces, does not need to apply to cargo tanks of combined oil/chemical tankers which are to comply with the requirements for ships carrying dangerous chemicals in bulk as defined in **1.2.43 of Part 1A**.

32.2.2 General

Each space within the cargo area and fore peak tanks are to be provided with means of access to enable overall and close-up examinations and thickness measurements of the ship's structures to be carried out safely.

32.2.3 Means of Access to Spaces

1. Safe access to each space within the cargo area and fore peak tanks is to be direct from the open deck and in accordance with the following **(1)** to **(3)** corresponding to the kind of the space.

(1) Tanks, cofferdams and subdivisions of tanks and cofferdams, having a length of not less than 35 *m*, are to be fitted with at least two access hatchways or manholes and ladders, as far apart as is practicable.

(2) Tanks and cofferdams less than 35 *m* in length are to be served by at least one access hatchway or manhole and ladder.

(3) Each cargo hold is to be fitted with at least two access hatchways or manholes and ladders that are as far apart as is practicable. In general, these accesses are to be arranged diagonally, for example one access near the forward bulkhead on the port side, the other one near the aft bulkhead on the starboard side. At least one of the two required ladders is to be of the inclined type except as specified in **-3** below.

2. Notwithstanding **-1** above, safe access to double bottom spaces, forward ballast tanks or lower spaces of sections divided vertically, may be from a pump-room, deep cofferdam, pipe tunnel, cargo hold, double hull space or similar compartment not intended for the carriage of oil or hazardous cargoes, subject to consideration of ventilation aspects.

3. The uppermost entrance section of the ladder providing access from the deck to a tank or cofferdam is to be vertical for not less than 2.5 *m*, but not in excess of 3.0 *m* measured clear of the overhead obstructions in way of the tank entrance, and be connected to a ladder linking platform which is to be displaced to one side of the vertical ladder.

However, where there is a longitudinal or athwartship permanent means of access fitted within 1.6 *m* and 3 *m* below the deck head, the uppermost section of the ladder may stop at this means of access.

4. For oil tankers, access ladders to cargo tanks and other spaces in the cargo area (excluding fore peak tanks) are to be in accordance with the following.

(1) Where two access hatchways or manholes and ladders are required as in **-1(1)** above, at least one ladder is to be of the inclining type. However, the uppermost entrance section of the ladder is to be vertical in accordance with the provisions of **-3** above.

(2) Where ladders not required to be of the inclined type as specified in **(1)** above, maybe of a vertical type. Where the vertical distance is more than 6 *m*, vertical ladders are to be connected by one or more ladder linking platforms, generally spaced not more than 6 *m* apart vertically and displaced to one side of the ladder. The uppermost entrance section of the ladder is to be in accordance with the provisions of **-3** above.

(3) Where one access hatchway or manhole and ladder is required as in **-1(2)** above, an inclined ladder is to be used in accordance with the provisions of **(1)** above.

(4) In double hull spaces of less than 2.5 *m* width, access to the space may be made by means of vertical ladders that are connected to one or more ladder linking platforms generally spaced not more than 6 *m* apart vertically and displaced to one side of the ladder. Adjacent sections of ladder are to be laterally offset from each other by at least the width of the ladder. The uppermost entrance section of the ladder is to be in accordance with the provisions of **-3** above.

(5) Access from the deck to a double bottom space may be made by means of a vertical ladder through a trunk. The vertical distance from the deck to a resting platform, between resting platforms, or a resting platform and the tank bottom is generally not to be more than 6 *m* unless approved otherwise by the Society.

5. For bulk carriers, access ladders to cargo holds and other spaces in the cargo area are to be in accordance with the following.

(1) Either a vertical ladder or an inclined ladder may be used where the vertical distance between the upper surface of adjacent decks or between the deck and the bottom of the cargo space is not more than 6 *m*.

(2) An inclined ladder or a series of inclined ladders at one end of the cargo hold is to be used where the vertical distance between the upper surface of adjacent decks or between the deck and the bottom of the cargo space is more than 6 *m*, except for the uppermost 2.5 *m* of the cargo space measured clear of overhead obstructions and the lowest 6 *m* may have vertical ladders, provided that the vertical extent of the inclined ladder or ladders connecting the vertical ladders is not less than 2.5 *m*.

(3) Means of access at the end of the cargo hold other than those specified in **(2)** above, may be formed by a series of staggered vertical ladders, which is to be connected to one or more ladder linking platforms spaced not more than 6 *m* apart vertically and displaced to one side of the ladder. Adjacent sections of ladder are to be laterally offset from each other by at least the width of the ladder. The uppermost entrance section of the ladder directly exposed to a cargo hold is to be vertical for a distance of 2.5 *m* measured clear of overhead obstructions and connected to a ladder-linking platform.

(4) A vertical ladder may be used as a means of access to topside tanks, where the vertical distance between the deck and the longitudinal means of access in the tank, the stringer, or the bottom of the space immediately below the entrance is not more than 6 *m*. The uppermost entrance section of the ladder of the tank is to be vertical for a distance of 2.5 *m* measured clear of overhead obstructions and be connected to a ladder linking platform, unless the landing on the longitudinal means of access, the stringer, or the bottom is within 2.5 *m* and is displaced to one side of the vertical ladder.

(5) Unless specified in **(4)** above, an inclined ladder is to be used for access to a tank or space where the vertical distance is greater than 6 *m* between the deck and a stringer immediately below the entrance, between stringers,or between the deck or a stringer and the bottom of the space immediately below the entrance.

(6) In the case of **(5)** above, the uppermost entrance section of the ladder is to be vertical for a distance of 2.5 *m* clear of overhead obstructions and connected to a landing platform. Another ladder is to continue down from the platform. Inclined ladders are not to be more than 9 *m* in actual length and the vertical height is not normally to be more than 6 *m*. The lowermost section of the ladder may be vertical for a distance of 2.5 *m*.

(7) In double-side skin spaces of less than 2.5 *m* width, access to the space may be made by means of vertical ladders that connects to one or more ladder linking platforms spaced not more than 6 *m* apart vertically and displaced to one side of the ladder. Adjacent sections of ladder are to be laterally offset from each other by at least the width of the ladder.

(8) A spiral ladder may be considered acceptable as an alternative for inclined ladders. In this regard, the uppermost 2.5 *m* can continue to be comprised of the spiral ladder and need not change over to vertical ladders.

32.2.4 Means of Access Within Spaces

1.For oil tankers: cargo oil tanks and water ballast tanks except those specified in **-2** and **-8** are to be provided with means of access in accordance with the following **(1)** to **(4)**.

(1) For tanks of which the height is not less than 6 *m*, permanent means of access are to be provided in accordance with **(a)** to **(f)**.

(a) A continuous athwartship permanent means of access is to be arranged at each transverse bulkhead on the stiffened surface, at a minimum of 1.6 *m* to a maximum of 3 *m* below the deck head.

(b) At least one continuous longitudinal permanent means of access is to be provided at each side of the tank.

One of these accesses is to be at a minimum of 1.6 *m* to a maximum of 6 *m* below the deck head and the other is to be at a minimum of 1.6 *m* to a maximum of 3 *m* below the deck head.

(c) Access between the arrangements specified in **(a)** and **(b)** and from the main deck to either **(a)** or **(b)** is to be provided.

(d) A continuous longitudinal permanent means of access integrated into the structural members on the stiffened surface of a longitudinal bulkhead, in alignment, where possible, with horizontal girders of transverse bulkheads is to be provided for access to transverse webs from the upper deck and tank bottom unless permanent fittings are installed at the uppermost platform for use as an alternative means deemed appropriate by the Society, for inspection at intermediate heights.

(e) A transverse permanent means of access on the cross-ties providing access to the tie flaring brackets at both sides of the tank, with access from one of the longitudinal permanent means of access in **(d)** for ships having cross-ties which are not less than 6 *m* above the tank bottom.

(f) An alternative means deemed appropriate by the Society may be provided for small ships with cargo oil tanks less than 17 *m* in height as an alternative to **(d)**.

(2) For tanks less than 6 *m* in height, an alternative means deemed appropriate by the Society or portable means may be utilized in lieu of permanent means of access.

(3) Notwithstanding **(1)** and **(2)** above, tanks not containing internal structures need not to be provided with permanent means of access.

(4) Means of access deemed appropriate by the Society are to be provided for access to under deck structures, transverse webs and cross-ties outside the reach of permanent and/or portable means of access, as required in **(1)** and **(2)** above.

2. For oil tankers: water ballast wing tanks of less than 5 *m* width forming double side spaces and their bilge hopper sections are to be provided with means of access in accordance with the following **(1)** to **(3)**.

(1) For double side spaces above the upper knuckle point of the bilge hopper sections, permanent means of access are to be provided in accordance with **(a)** to **(c)**:

(a) Where the vertical distance between the uppermost horizontal stringer and the deck head is not less than 6 *m*, one continuous longitudinal permanent means of access is to be provided for the full length of the tank with a means to allow passing through transverse webs installed at a minimum of 1.6 *m* to a maximum of 3 *m* below the deck head with a vertical access

(b) A continuous longitudinal permanent means of access integrated in the structure at a vertical distance not exceeding 6 *m* apart is to be provided.

(c) Plated stringers are, as far as possible, to be in alignment with horizontal girders of transverse bulkheads.

(2) For bilge hopper sections of which the vertical distance from the tank bottom to the upper knuckle point is not less than 6 *m*, one longitudinal permanent means of access is to be provided for the full length of the tank in accordance with the following **(a)** and **(b)**. It is to be accessible by a vertical permanent means of access at each end of the tank.

(a) The longitudinal continuous permanent means of access may be installed at a minimum of 1.6 *m* to a maximum of 3 *m* from the top of the bilge hopper section. A platform extending from the longitudinal continuous permanent means of access in way of the web frame may be used to access the identified critical structural areas.

(b) Alternatively, the continuous longitudinal permanent means of access may be installed at a minimum of 1.2 *m* below the top of the clear opening of the web ring allowing the use of portable means of access to reach identified critical structural areas.

(3) Where the vertical distance referred to in **(2)** is less than 6 *m*, alternative means deemed appropriate by the Society or portable means of access may be utilized in lieu of permanent means of access. To facilitate the operation of the alternative means of access, in-line openings in horizontal stringers are to be provided. The openings are to be of an adequate diameter and are to have suitable protective railings.

3. For bulk carriers, means of access to the overhead structure of the cross deck are to be fitted in accordance with the following **(1)** to **(5)**.

(1) Permanent means of access are to be fitted to provide access to the overhead structure at both sides of the cross deck and in the vicinity of the centreline. Each means of access is to be accessible from the cargo hold access or directly from the main deck and installed at a minimum of 1.6 *m* to a maximum of 3 *m* below the deck.

(2) An athwart ship permanent means of access fitted on the transverse bulkhead at a minimum of 1.6 *m* to a maximum of 3 *m* below the cross deck head is deemed as equivalent to **(1)**.

(3) Access to the permanent means of access in **(1)** and **(2)** above may be via the upper stool.

(4) Ships having transverse bulkheads with full upper stools with access from the main deck which allows monitoring of all framing and plates from inside do not require permanent means of access of the cross deck.

(5) Alternatively, movable means of access may be utilized for access to the overhead structure of the cross deck if its vertical distance is not greater than 17 *m* above the tank top.

4. For cargo holds of bulk carriers, means of access are to be fitted in accordance with the following **(1)** to **(6)**.

(1) Permanent means of vertical access are to be provided in all cargo holds and built into the structure to allow for an inspection of a minimum of 25% of the total number of hold frames port and starboard equally distributed throughout the hold including at each end in way of transverse bulkheads. But in no circumstances is this arrangement to be less than 3 permanent means of vertical access fitted to each side (fore and aft ends of hold and mid-span). Permanent means of vertical access fitted between two adjacent hold frames is counted as access for the inspection of both hold frames. A portable means of access may be used to gain access over the sloping plating of lower hopper ballast tanks.

(2) In addition to **(1)**, portable or movable means of access are to be utilized for access to the remaining hold frames up to their upper brackets and transverse bulkheads.

(3) Portable or movable means of access may be utilized for access to hold frames up to their upper bracket in place of the permanent means required in **(1)**. These means of access are to be on board the ship and readily available for use.

(4) The width of vertical ladders for access to hold frames is to be at least 300 *mm*, measured between stringers.

(5) A single vertical ladder over 6 *m* in length is acceptable for the inspection of the hold side frames in a single skin construction.

(6) For double-side skin construction no vertical ladder for the inspection of the cargo hold surfaces is required. Inspection of this structure is to be provided from within the double hull space.

5. For topside tanks of bulk carriers, means of access are to be fitted in accordance with the following **(1)** to **(4)**.

(1) For each topside tank of not less than 6 *m* in height, one longitudinal continuous permanent means of access is to be provided along the side shell webs and installed at a minimum of 1.6 *m* to a maximum of 3 *m* below deck with a vertical access ladder in the vicinity of each access to that tank.

(2) If no access holes are provided through the transverse webs within 600 *mm* of the tank base and the web frame rings have a web height greater than 1 *m* in way of side shell and sloping plating, then step rungs/grab rails are to be provided to allow safe access over each transverse web frame ring.

(3) Three permanent means of access, fitted at the end bay and middle bay of each tank, are to be provided spanning from tank base up to the intersection of the sloping plate with the hatch side girder. The existing longitudinal structure, if fitted on the sloping plate in the space may be used as part of this means of access.

(4) For topside tanks of which the height is less than 6 *m*, alternative means deemed appropriate by the Society or portable means may be utilized in lieu of the permanent means of access.

6. For bilge hopper tanks of bulk carriers, means of access are to be fitted in accordance with the following **(1)** to **(3)**.

(1) For each bilge hopper tank of not less than 6 *m* in height, one longitudinal continuous permanent means of access is to be provided along the side shell webs and installed at a minimum of 1.2 *m* below the top of the clear opening of the web ring in accordance with **(a)** to **(c)**, with a vertical access ladder in the vicinity of each access to the tank.

(a) An access ladder between the longitudinal continuous permanent means of access and the bottom of the space are to be provided at each end of the tank.

(b) Alternatively, the longitudinal continuous permanent means of access can be located through the upper web plating above the clear opening of the web ring, at a minimum of 1.6 *m* below the top of the bilge hopper section, when this arrangement facilitates more suitable inspection of identified structurally critical areas.

An enlarged longitudinal frame can be used for the purpose of the walkway.

(c) For double-side skin bulk carriers, the longitudinal continuous permanent means of access may be installed within 6 *m* from the knuckle point of the bilge, if used in combination with alternative methods to gain access to the knuckle point.

(2) If no access holes are provided through the transverse ring webs within 600 *mm* of the tank base and the web frame rings have a web height greater than 1 *m* in way of side shell and sloping plating, then step rungs/grab rails are to be provided to allow safe access over each transverse web frame ring.

(3) For bilge hopper tanks of less than 6 *m* in height, alternative means deemed appropriate by the Society or portable means may be utilized in lieu of the permanent means of access. That such means of access can be deployed and made readily available in the areas where needed is to be demonstrated.

7. For double-side skin tanks of bulk carriers, permanent means of access are to be provided in accordance with the requirements in **-1** or **-2** above, as applicable.

8. For fore peak tanks with a depth of not less than 6 *m* at the centreline of the collision bulkhead, suitable means of access are to be provided for access to critical areas such as the underdeck structure, stringers, collision bulkhead and side shell structure in accordance with the following **(1)** and **(2)**.

(1) Stringers of less than 6 *m* in vertical distance from the deck head or a stringer immediately above are considered to provide suitable access in combination with portable means of access.

(2) Where the vertical distance between the deck head and stringers, stringers or the lowest stringer and the tank bottom is not less than 6 *m*, alternative means of access deemed appropriate by the Society is to be provided.

9. Where the Society deems that a permanent means of access may be susceptible to damage during normal cargo loading and unloading operations or is impracticable to fit a permanent means of access, alternative means of access deemed appropriate by the Society may be utilized in lieu of those specified in **-1** to **-8** above, provided that the means of attaching, rigging, suspending or supporting them forms a permanent part of the ship's structure.

32.2.5 Specifications for Means of Access and Ladders

1. Permanent means of access are, in general, to be integral to the structure of the ship, thus ensuring that they are robust. Where deemed necessary by the Society for facilitating that such means of access are of integral parts of the structure itself, reasonable deviations from the requirements of the position of means of access in **32.2.3** and/or **32.2.4** may be accepted.

2. Elevated passageways forming sections of a permanent means of access, where fitted, are to have a minimum clear width of 600 *mm*, except for going around vertical webs where the minimum clear width may be reduced to 450 *mm*, and have guard rails over the open side of their entire length.

3. Sloping parts of the access are to be of non-skid construction.

4. Elevated passageways forming sections of a permanent means of access, are to be provided with guard rails of1,000 *mm* in height and consist of a rail and an intermediate bar 500 *mm* in height and of substantial construction, with stanchions not more than 3 *m* apart, on the open side.

5. For access through horizontal openings, hatches or manholes, the dimensions are to be sufficient to allow a person wearing a self-contained air-breathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening is not to be less than 600 *mm* 600 *mm*. When access to a cargo hold is arranged through the cargo hatch, the top of the ladder is to be placed as close as possible to the hatch coaming.

Access hatch coamings having a height greater than 900 *mm* are also to have steps on the outside in conjunction with the ladder.

6. For access through vertical openings, or manholes, in swash bulkheads, floors, girders and web frames providing passage through the length and breadth of the space, the minimum opening is not to be less than 600 *mm* 800 *mm* at a height of not more than 600 *mm* from the bottom shell plating unless gratings or other foot holds are provided.

7. For oil tankers of less than 5,000 *tonnes deadweight*, smaller dimensions for the openings referred to in **-5** and **-6** may be approved by the Society in special circumstances, if the ability to traverse such openings or to remove an injured person can be proved to the satisfaction of the Society.

8. Access to permanent means of access and vertical openings from the ship's bottom is to be provided by meansof easily accessible passageways, ladders or treads. Treads are to be provided with lateral support for the foot. Where the rungs of ladders are fitted against a vertical surface, the distance from the centre of the rungs to the surface is to be at least 150 *mm*. Where vertical manholes are fitted higher than 600 *mm* above the walking level, access is to be facilitated by means of treads and hand grips with platform landings on both sides.

9. For ladders or similar facilities forming sections of a permanent means of access, their specifications are to the satisfaction of the Society.

32.2.6 Ship Structure Access Manual

1. For every ship, means of access to carry out overall and close-up inspections and thickness measurements are to be described in a Ship Structure Access Manual approved by the Society, and any change of the contents of which is to be updated and an updated copy of which is to be kept on board. The Ship Structure Access Manual is to include the following for each space.

(1) Plans showing the means of access to the space, with appropriate technical specifications and dimensions

(2) Plans showing the means of access within each space to enable an overall inspection to be carried out, with appropriate technical specifications and dimensions (the plans are to indicate from where each area in the space can be inspected)

(3) Plans showing the means of access within the space to enable close-up inspections to be carried out, with appropriate technical specifications and dimensions (the plans are to indicate the positions of critical structural areas, whether the means of access is permanent or portable and from where each area can be inspected)

(4) Instructions for inspecting and maintaining the structural strength of all means of access and means of attachment, taking into account any corrosive atmosphere that may exist within the space

(5) Safety instructions for when rafting is used for close-up inspections and thickness measurements

(6) Instructions for the rigging and use of any portable means of access in a safe manner

(7) An inventory of all portable means of access

(8) Records of periodical inspections and maintenance of the ship's means of access

2. Where alternative means of access are adapted in accordance with the provisions of **32.2.4**, a means for safe operation and rigging of such alternative means to and from and within the spaces are to be clearly described in the Ship Structure Access Manual.

Chapter 33 ICE CLASS SHIPS

33.1 General

33.1.1 Aplication

1. The requierements in this Chapter apply to hull structure, equipment and machinery, etc. of ice class ships.

2. The requierements in this Chapter are framed for the ice strengthering of ships which are intended to navigate in the Northern Baltic complying with the *Finnish-Swedish Ice Class Rules 2010* or in the Canadian Artic complying with the *Artic Shipping Pollution Prevention Regulations*.

33.1.2 Maximum and Minimum Draught

1. The maximum and minimum ice draughts at fore and aft perpendicular are to be determined in accordance with the upper and lower ice waterlines.

2. Restrictions on draughts when operating in ice are to be documented and kept on board readily available to the master.

3. If the summer load line in fresh water is anywhere located at a higher level than the *UIWL*, the ship`s side is to be provided with a warning triangle and with an ice class draught mark at the maximum permissible ice class draught amidships. (see **Fig. 33.1**)

4. Any ballast tank, situated above the *LIWL* and needed to load down the ship to this water line is to be equipped with proper devices to prevent the water from freezing.

5. The propeller is to be fully submerged, if possible entirely below the ice.

6. The minimum forward draught is not be less than that obtained from the following formula.

$(2.0 + 0.00025\Delta)h_0\ (m)$ but need not exceeed $4h_0$

Where

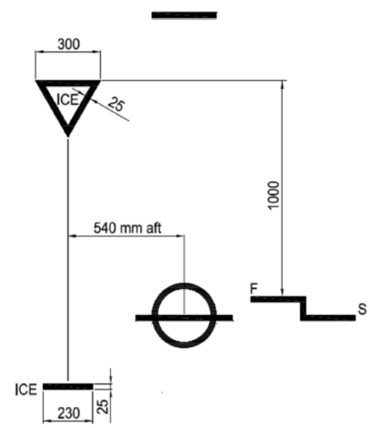
Δ: The displacement of the ship at the maximum draught amidships on the *UIWL*

h_0: Constant given in **Table 33.1** according to the respective ice class.

Table 33.1 Value of Constant h_0

Ice Class	h_0
I	1.0
II	0.8
III	0.6
IV	0.4
V	0.4

Fig. 33.1 Ice Class Draught Marking



Notes:

1 The upper edge of the warning triangle is to be located vertically above the Ice mark, 1,000*mm* higher that the Summer Load Line in fresh water but in no case higher than the deck line. The sides of the triangle are to be 300*mm* in length.

2 The ice class draught mark is to be located 540*mm* abaft the centre of the load line ring or 540*mm* abaft the vertical line of the timber load line mark, if applicable.

3 The marks and figures are to be cut out of 5*mm*-8*mm* plates and then welded to the ship`s side. The marks and figures are to be painted in a red or yellow reflecting colour in order to make the marks and figures plainly visible even in ice conditions.

4 The dimensions of all figures are to be the same as those used in the load line mark.

33.2 Design Ice Pressure

33.2.1 Design Ice Pressures

1. Design ice pressure (P) is not to be less than that obtained from the following formula:

$C_d C_p C_a p_0 (MPa)$

Where

C_d: As given by the following formula. However, C_d needs not to exceed 1.0

C_d: $\frac{ak+b}{1000}$

$$k = \frac{\sqrt{\Delta H}}{1000}$$

Δ: Displacement (t) of the ship on the maximum draught specified in **33.1.2-6**

H: Engine output *(kW)*

a and b: As given in **Table 33.2** according to the region under consideration and the value of *k*.

C_p: As given in **Table 33.3** according to the ice class and the region under consideration.

p_0: The nominal ice pressure; the value 5.6 *MPa* is to be used.

C_a: As given by the following formula. However, C_a is not to be used less than 0.35 but need not to exceed 1.0 $\sqrt{\frac{0.6}{l_a}}$

l_a: To be taken as specified in **Table 33.4** according to the structural member under consideration.

Table 33.2 Value of *a* and *b*

	Bow region		Midbody & Stern regions	
	$k \leq 12$	$k > 12$	$k \leq 12$	$k > 12$
a	30	6	8	2
b	230	518	214	286

Table 33.3 Coefficient C_p

Ice Class	Bow region	Midbody region	Stern region
I	1.00	1.00	0.75
II	1.00	0.85	0.65
III	1.00	0.70	0.45
IV	1.00	0.50	0.25
V	1.00	-	-

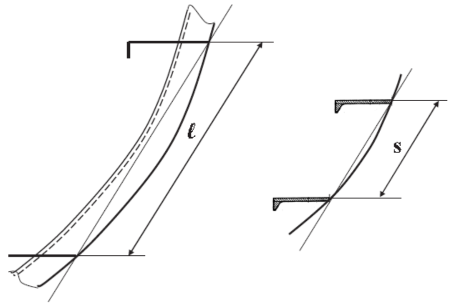
Table 33.4 Value of l_a

Structural member	Type of framing	l_a (m)
Shell	Transverse	Frame spacing
	Longitudinal	1.7-spacing of frame
Frames	Transverse	Frame spacing
	Longitudinal	Span of frame
Ice stringer	-	Span of stringer
Web frame	-	2-spacing of web frame

Note:

The frame spacing and spans are normally assumed to be measured along the plate and perpendicular to the axis of the stiffener for plates, along the flange for members with a flange, and along the free edge for flat bar stiffeners. For curved members, the span or spacing is defined as the chord length between the span or spacing points. The span points are defined by the intersection between the flange or upper edge of the member and the supporting structural element. (See **Fig. 33.2**)

Fig. 33.2 Definition of the Frame Span *l* and Frame Spacing *s* for Curved Members



2. *h* is the height of the area under the ice pressure (*P*) specified in **-1** and is to be as given in **Table 33.5** according to the ice class.

Table 33.5 Value of *h*

Ice Class	*h(m)*
I	0.35
II	0.30
III	0.25
IV	0.22
V	0.22

33.3 Hull Structures and Equipment

33.3.1 Shell Plating

1. The vertical extension of the ice belt is to be as given in **Table 33.6** according to the ice class and is to comply with the following requirements.

(1) Fore foot

For Ice Class I ships with the sell plating below the ice belt from the stern to a position five main frame spaces abaft the point where the bow profile departs from the keel line is to have at least the thickness required in the ice belt in the midbody region

(2) Upper bow ice belt

For Ice Class I and II ships with an open water service speed equal to or exceeding 18 *knots*, the shell plate from the upper limit of the ice belt to 2*m* above it and from the stern to a position at least 0.2*L* abaft the forward perpendicular, is to have at least the thickness required in the ice belt in the midbody region. A similar strengthening of the bow region is to apply to a ship with lower service speed, when it is, e.g. on the basis of the model tests, evident that the ship will have a high bow wave.

(3) Side scuttles are not to be situated in the ice belt.

(4) If the weather deck in any part of the ship is situated below the upper limit of the ice belt, the bulwark and the construction of the freeing ports are to be given at least the same strength as is required for the shell in the ice belt.

Table 33.6 Vertical Extension of the Ice Belt

Ice Class	Hull region	Above the UIWL	Below the LIWL
I	Bow	0.6 *m*	1.20*m*
	Midbody		
	Stern		1.0*m*
II	Bow	0.5*m*	0.90*m*
	Midbody		0.75*m*
	Stern		
III	Bow	0.4*m*	0.70*m*
IV	Midbody		0.60*m*
	Stern		
V	Bow	0.4*m*	0.70*m*

2. The thickness of shell plating in the ice belt is not to be less than obtained from the following formula according to the type of framing.

For the transverse framing: $667s\sqrt{\frac{f_1 p_{PL}}{\sigma_y}}+t_c \quad (mm)$

For the longitudinal framing: $667s\sqrt{\frac{p}{f_2\sigma_y}}+t_c \quad (mm)$

Where

S: Frame spacing (m)

p_{PL}: $0.75p$ (MPa)

p: As specified in **33.2.1-1**

f_1: As given in the following formula. Where, however, f_1 is greater than 1.0, f_1 is to be taken as 1.0.

$$1.3-\frac{4.2}{(h/s+1.8)^2}$$

f_2: As given in the following formula depending on the value of h/s

Where $h/s<1.0$: $0.6+\frac{0.4}{h/s}$

Where $1.0 \leq h/s<1.8$: $1.4-0.4h/s$

h: As specified in **33.2.1-2**

σ_y: Yield stress of the following values are to be used

235 N/mm^2 for normal-strength hull structural steel

315 N/mm^2 for high-strength hull structural steel

However, if steels with different yield stresses than those given above are used, the value is to be at the discretion of the Society.

τ_c: 2*mm*: If special surface coating, by experience shown capable to withstand the abrasion of ice, is applied and maintained, lower values may be approved.

33.3.2 General Requirements for Frames

1. The vertical extension of the ice strengthening of the framing is to be at least as given in **Table 33.7** according to the respective ice classes and regions. Where an upper bow ice belt is required in **33.3.1-1,** the ice strengthening part of the framing is to be extended at least to the top of the ice belt. Where the ice strengthening would go beyond a deck or a tank top by no more than 250*mm*, it can be terminated at that deck or tank top

2. Within the ice strengthening are all frames are to be effectively attached to all the supporting structures. A longitudinal frame is to be attached to all the supporting web frames and bulkheads by brackets at both ends. When a transverse frame terminates at a stringer or deck, a bracket or similar construction is to be fitted. When frame is running through the supporting structure, both sides of the web plate of the frame area to be connected to the structure by direct welding, collar plate or lug. When a bracket is installed, it is to have at least the same thickness as the web plate of the frame and the edge is to be appropriately stiffened against buckling.

3. In all regions for Ice class I ships, in the bow and midbody regions for Ice class II ships and in the bow regions for III, IV and V Ice class ships, the following are to apply in the ice strengthening area:

(1) The frames are to be attached to the shell by double continous welds. No scalloìng is allowed except when crossing shell plate butts.

(2) The web thickness of the frames is not to be less than the greatest of the following **(a)** to **(d)**

(a) $\frac{h_w\sqrt{\sigma_y}}{C}$

h_w: web height (*mm*)

C: 805 for profiles

282 for flat bars

σ_y: As specified in **5.3.1-2**

(b) 2.5% of the frame spacing for transverse frames

(c) Half of the net thickness of the shell plating t-t_c. For the purpose of calculating the web thickness of frames, the required thickness of the shell plating is to be calculated according to **33.3.1-2** using the yield strength σ_y of the frames

(d) 9*mm*

(3) Where there is a deck, tank top or bulkhead in lieu of a frame, the plate thickness of this is to be as per the preceding **(2),** to a depth corresponding to the height of adjacent frames.

(4) Frames that are not normal to the plating or the profile is unsymmetrical, and the span exceeds 4.0 *m*, are to be supported against tripping by brackets, intercostals, stringers or similar at a distance not exceeding

1.3 *m*. if the span is less than 4.0 *m*, the supports against tripping are required for unsymmetrical profiles and stiffeners for webs which are not normal to plating.

Table 33.7 Vertical Extension of the Ice Strengthening of Framing

Ice Class	Hull region	Above the UIWL	Below the *LIWL*
I	Bow	1.2*m*	Down to double bottom or below top of the floors
	Midbody		2.0 *m*
	Stern		1.6 *m*
II III IV	Bow	1.0*m*	1.6 *m*
	Midbody		1.3 *m*
	Stern		1.0 *m*
V	Bow	1.0*m*	1.6 *m*

33.3.3 Transverse Frames

1. The section modulus and the effective shear area of a main or intermediate transverse frame specified in 33.3.2-1 are to be not less than that obtained from the following formula:

Section modulus: $\frac{pshl}{m_t \sigma_y} \times 10^6 \ (cm^3)$

Effective shear area: $\frac{\sqrt{3} f_3 phs}{2\sigma_y} \times 10^4 \ (\mathrm{cm}^2)$

Where:

p: as specified in 33.2.1-1

s: Frame spacing (m) (See the note to Table 33.4)

h: As specified in 33.2.1-2

m_t: As given by the following formula

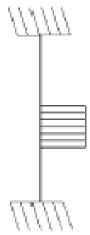
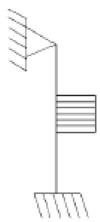
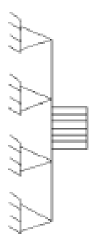
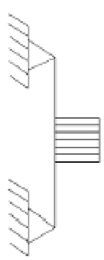
$$\frac{7m_0}{7\text{-}5h/l}$$

m_0: As specified in Table 33.8

f_3: Factor which takes into account the maximum shear force versus the load location and the shear stress distribution, taken as 1.2

σ_y: As specified in 33.3.1-2

Table 33.8 Value of m_0

Boundary condition	m_0	Example
	7.0	Frames in a bulk carrier with top side tanks
	6.0	Frames extending from the tank top to a single deck
	5.7	Continous frames between Several decks or stringers
	5.0	Frames extending between two decks only

Note:

The boundary conditions are those for the main and intermediate frames. Load is applied at mid span.

2. Notwithstanding the **-1** above, where less than 15% of the span, *l*, of the frame is situated within the ice strengthening zone for frames, ordinary frames scantling may be used.

3. The upper end of the strengthening part of a main frame and of an intermediate frame are to be attached to a deck or an ice stringer as specified in 33.3.5. Where a frame terminates above a deck or a stringer (hereinafter, referred to as the lower deck in this section) which is situated at or above the upper limit of the ice belt, the part of the frame above the lower deck is to be in accordance with the followings:

(1) The part of the main frame and the intermediate frame may have the scantling required by the ordinary frame; and

(2) The upper end of the main frame and the intermediate frame is to be connected to a deck which situated above the lower deck (hereinafter, referred to as the higher deck in this section). However, the upper end of the intermediate frame may be connected to the adjacent main frames by a horizontal stiffener having the same scantlings as the main frame.

4. The lower end of the strengthened part of a main frame and of an intermediate ice frame is to be attached to a deck, tank top or ice stringer specified in **33.3.5**. Where an intermediate frame terminates below a deck, tank top or ice stringer which is situated at or below the lower limit of the ice belt, the lower end may be connected to the adjacent main frames by a horizontal member of the same scantlings as the frames.

33.3.4 Ice Stringers

1. The section modulus and effective shear area of a stringer situated within the ice belt are not to be less than those obtained by the following formulae:

Section modulus: $\frac{f_6 f_7 p h l^2}{m\sigma_y}\left(1-\frac{h_s}{l_s}\right)\times 10^6 (cm^3)$

Effective shear area: $\frac{\sqrt{3}\, f_6 f_7 f_8 p h l}{2\sigma_y}(1\text{-}h_s/l_s)\times 10^4 (cm^2)$

f_6: Factor which takes account of the distribution of load to the transverse frames is to be taken as 0.9

f_7: Safety factor of stringers is to taken as 1.8

f_8: Factor which takes into account the maximum shear force versus load location and the shear stress distribution, taken as 1.2

p: As specified in **33.2.1-1**

h: As specified in **33.2.1-2**

However, the product of p and h is not to be taken as less than 0.15

l: Span of the stringer (m)

m: Boundary conditions factor as defined in **33.3.4-1**

σ_y: As specified in **33.3.4-2**

2. The section modulus and effective shear area of a stringer situated outside the ice belt but supporting ice strengthened frames are not to be less than those obtained by the following formulae:

Section modulus: $\frac{f_9 f_{10} p h l^2}{m\sigma_y}\left(1-\frac{h_s}{l_s}\right)\times 10^6 \quad (cm^3)$

Effective shear area: $\frac{\sqrt{3} f_9 f_{10} f_{11} p h l}{2\sigma_y}(1\text{-}h_s/l_s)\times 10^4 \quad (cm^2)$

f_9: Factor which takes account of load to the transverse frames is to be taken as 0.8

f_{10}: Safety factor of stringers is to be taken as 1.8

f_{11}: Factor which takes into account the maximum shear force versus load location and the shear stress distribution, taken as 1.2.

p: As specified in **33.2.1-1**

h: As specified in 33.2.1-2

However, the product of p and h is not to be taken as less than 0.15

l: Span (m) of the stringer

h_s: The distance to the ice belt

l_s: The distance (m) to the adjacent ice stringer (m)

m: Boundary condition factor as defined in 33.3.4-1

σ_y: As specified in 33.3.1-2

3. Narrow deck strips abreast of hatches and serving as ice stringers are to comply with the section modulus and shear area requirements in the preceding **-1** and **-2** respectively. In the case of very long hatches, the product p and h may be taken as less than 0.15 but in no case less than 0.10. Regard is to be paid to the deflection of the ship`s sides due to ice pressure in way of very long hatch openings, when designing weather deck, hatch covers and their fittings.

33.3.5 Web Frames

1. The load F transferred to a web frame an ice stringer or from longitudinal framing is not to be less than that obtained by the following formula:

$f_{12}phS$ (MN)

f_{12}: Safety factor of web frames is to be taken as 1.8

p: Ice pressure (MPa) as specified in 33.2.1-1, in calculating C_a however, l_a is to be taken as 2S

h: As specified in 33.2.1-2

However, the product of p and h is not to be taken as less than 0.15

S: Distance (m) between web frames

2. Notwithstanding the provisions specified in -1 above, in case the supported stringer is outside the ice belt, the force F may be reduced to that obtained by the following formula:

$f_{12}phS(1-h_s/l_s)$ (MN)

h_s and l_s: As specified in 33.3.5-2

3. The section modulus and effective shear area are to be calculated by the following formulae:

Effective shear area: $\frac{\sqrt{3}\alpha f_{13}Q}{\sigma_y}\times 10^4\ (cm^2)$

Section modulus: $\frac{M}{\sigma_y}\sqrt{\frac{1}{1-(\gamma A/A_a)^2}}\times 10^6\ (cm^3)$

f_{13}: Factor which takes into account the shear force distribution is to be taken as 1.1

Q: Maximum calculated shear force under the load F transferred to a web frame an ice stringer or from longitudinal framing as specified in **-1** or **-2,** as given in the following formula:

$Q=F$

M: Maximum calculated bending moment under the load F transferred to a web frame from an ice stringer or from longitudinal framings as specified in **-1** or **-2**, as given in the following formula:

$M=0.193Fl$

l: Span (m) of the web frame

α and γ: As given in **Table 33.9**. For intermediate values of A_f/A_w is to be obtained by linear interpolation.

A: Required shear area (cm^2)

A_a: Actual cross sectional area(cm^2) of the web frame, as given in the following formula:

$A_a = A_f + A_w$

A_f: Actual cross sectional area (cm^2) of free flange

A_w: Actual effective cross sectional area (cm^2) of web plate

σ_y: As required in **33.3.1-2**

Table 33.9 Value of α and γ

A_f/A_w	0.00	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00
α	1.50	1.23	1.16	1.11	1.09	1.07	0.106	1.05	1.05	1.04	1.04
γ	0.00	0.44	0.62	0.71	0.76	0.80	0.83	0.85	0.87	0.88	0.89

4. The scantlings of web frames may be calculated by direct analysis where deemed appropriate by the Society. In this case, the following are to be complied with:

(1) The pressure to be used is 1.8p (MPa) where p is determined according to **33.2.1-1**, and the load patch is to be applied at locations where the capacity of the structure under the combined effects of bending and shear are minimized.

(2) The structure is to be checked with load centred at the *UIWL*, $0.5h_0$(m) below the *LIWL*, and positioned several vertical location in between. Several horizontal locations which are the locations centred at the mid-span or spacing are to be checked. If the load length l_a cannot be determined directly from the arrangement of the structure, several values of l_a may be checked using corresponding values for C_a.

(3) Acceptance criterion for designs is that the combined stresses from bending and shear, using the von Mises yield criterion, is to be lower than the σ_y as specified in **33.3.1-2.** When the direct analysis is using beam theory, the allowable shear stress is not to be greater than 0.9 τ_y, where $\tau_y = \sigma_y/\sqrt{3}$.

33.3.6 Stem

1. A stern is recommended to be similar to the structure shown in **Fig, 33.3**

2. The plate thickness of a shaped plate stern and in the case of a blunt bow, any part of the shell where angle α and Ψ as specified in **33.3.4-1** are respectively not less than 30 *degrees* and 75 *degrees*, is to be obtained from the formula **in 33.3.1-2**

Where

S: Spacing (m) of elements supporting the plate

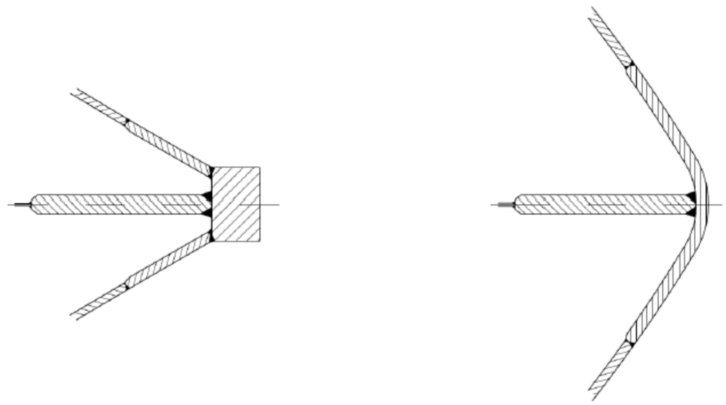
P_{pl}: Ice pressure (MPa) as specified in **33.2.1-1**

l_a: Spacing (m) of vertical supporting elements

3. The stern and the part of a blunt bow specified in the preceding **-2** is to be supported by floors or brackets spaced not more than 0.6m apart and having a thickness of at least half the plate thickness.

4. The reinforcement of the stern is to be extended from the keel to a point 0.75m above *ULWL* or, in case an upper bow ice belt is required in **33.3.1-1** to the upper limit of this.

Fig. 33.3 Example of Suitable Stems



33.3.7 Arrangements for Towing

Special consideration is to be given to the strength and installation of towing arrangements.

33.3.8 Stern

1. The clearance between the propeller blade tip and hull, including the stern frame, is not to be less than h_0 as specified in **33.1.2-6** to prevent from occurring high loads on the blade tip.

2. On twin and triple screw ships, the ice strengthening of the shell and framing are to be extended to the double bottom for 1.5 *metres* forward and aft of the side propellers.

3. On twin and triple screw ships, the shafting and stern tubes of side propellers are to be normally enclosed within plated bossing. If detached struts are used, their design, strength and attachment to the hull is to be duly considered.

4. The introduction of new propulsion arrangements with azimuthing thrusters or podded propellers, which provide an improved manoeuvrability, will result in increased ice loading of the stern region and the stern area. This fact is to be considered in the design of the aft/stern structure.

33.3.9 Bilge Keel

Special consideration is to be given to the design of bilge keels.

33.4 Fundamental Requirements of Machinery

33.4.1 Materials

1. Materials for Machinery Parts exposed to Seawater

Materials exposed to seawater, such as propeller blades, propeller hub and blade bolts are to have an elongation of not less than 15% for the *U*14*A* test specimens given in **Part 10**. Materials other than bronze and austenitic steel are to have an average impact energy value of 20 *J* at -10˚C for the U4 test specimens given in **Part 10**

33.4.2 Engine Output

1. The engine ouTput (*H*) is not to be less than the greater of two outputs determined by the following formula for the maximum draught amidships referred to as the *UIWL* and the minimum draught referred to as the *LIWL*, and in no case less than 1,000*kW* for ice class ships with, II, III, IV and V, and not less than 2,800*kW* for ice class ships with Ice class I.

$$H=K_e\frac{(R_{CH}/1000)^{3/2}}{D_p}$$

H: Engine output (kW)

K_e : Constant given in **Table 33.10**

D_p: Diameter (m) of the propeller

R_{CH}: The resistance (N) of the ship in a channel with brash ice and a consolidated layer

$$R_{CH}=C_1+C_2+C_3C_\mu(H_F+H_M)^2(B+C_\psi H_F)+C_4L_{PAR}H_F^2+C_5\left(LT/B^2\right)^3\left(A_{wf}/L\right)$$

L: Length (m) of the ship between the perpendiculars on the *UIWL*

B: Maximum breadth (m) of the ship on the *UIWL*

T: Actual ice class draughts (m) of the ship, in general being a draught amidships of length L_f corresponding to the *UIWL* and a draught amidships of the length L_f corresponding to the *LIWL*.

UIWL: Upper ice waterline defined by the maximum draughts fore, amidships and aft when sailing in ice covered waters.

LIWL: Lower ice waterline defined by the minimum draughts fore,amidships and aft when sailing in ice covered waters.*The LIWL* is to be determined with due regard to the vesel´sice going capability in ballast loading conditions (e.g propeller submergence)

In any case, $\left(LT/B^2\right)^3$ is not to be taken as less than 5 and not to be taken as more than 20.

L_{PAR}: Length (m) of the parallel midship body, measured horizontally between the fore and aft ends of the flat side on the waterline at the actual ice class draught, see **Fig. 33.4**

L_{BOW}: Length (m) of the bow, measured draught and the fore perpendicular at the *UIWL*, see **Fig. 33.4**

A_{wf}: Area (m^2) of the waterline of the bow at the actual ice class draught, see **Fig. 33.4**

Ψ: arctan(tan φ_2/ sin α) (*deg*)

φ_1, φ_2, α: The angle (deg) between the ship and the water plane at the actual ice class draught, see **Fig. 33.4**. If the ship has a bulbous bow then φ_1 is taken as 90 *degress*.

C_1 and C_2: Coefficient taken into account a consolidated upper layer of the brash ice and are to be taken as the followings.

(1) For Ice class I

$$C_1=f_1BL_{PAR}/(2T/B+1)+(1+0.021\varphi_1)(f_2B+f_3L_{BOW}+f_4BL_{BOW})$$

$$C_2=(1+0.063\varphi_1)(g_1+g_2B)+g_3(1+1.2T/B)B^2/\sqrt{L}$$

(2) For, II, III, IV and V Ice class

$$C_1=0$$

$$C_2=0$$

C_3, C_4 and C_5: Value given in **Table 33.11**

C_μ: Value given by the following formula, but in no case less than 0.45

$$C_\mu=0.15\cos\varphi_2+\sin\Psi+\sin\alpha$$

C_Ψ: Value given by the following formula, but taken as 0 where $\Psi \leq 45^\circ$

$$C_\Psi = 0.047\Psi - 2.115$$

$f_1, f_2, f_3, f_4, g_1, g_2$ and g_3: Value given in **Table 33.11**

H_M: Thickness (m) of the brash ice in a channel as given by the followings.

(1) For I and II ice class ships $H_M = 1.0$

(2) For III ice class ship $H_M = 0.8$

(3) For IV ice class ships $H_M = 0.6$

(4) For V ice class ships $H_M = 0.5$

H_F: Thickness (m) of the brash ice layer displaced by the bow as given by the following formula.

$$H_F=0.26+(H_MB)^{0.5}$$

Fig. 33.4 Dimensions

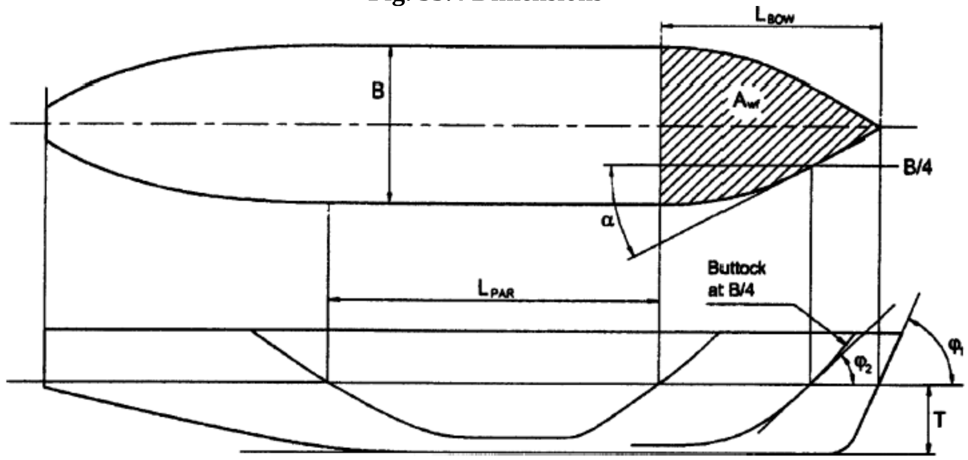


Table 33.10 **Value of Constant K_e**

Propeller type or machinery	CPP or Electric or Hydraulic propulsion machinery	FPP
1 propeller	2.03	2.26
2 propellers	1.44	1.60
3 propellers	1.18	1.31

Table 33.11 **Value of $f_1, f_2, f_3, f_4, g_1, g_2, g_3, C_3, C_4, C_5$**

f_1: 23.0 (N/m^2)	g_1: 1,530 (N)	C_3: 845(N/m^3)
f_2: 45.8 (N/m)	g_2: 170 (N/m)	C_4: 42(N/m^3)
f_3: 14.7 (N/m)	g_3: 400 $(N/m^{1.5})$	C_5: 825(N/m^3)
f_4: 29.0 (N/m^2)		

2. Special Requirements for Existing Ships

For I and II Ice class ships which are at beginning stage of construction before 1 September 2003, the engine output (H) is to comply with the requirements specified in **-1** above or equivalent requirements by 1 January in the year when 20 years have elapsed since the year the ship was delivered. When, for an existing ship, values for some of the hull form parameters required for the calculation method specified in **-1** above are difficult to obtain, the following alternative formulae may be used. The dimensions of the ship, defined below, are measured on the *UIWL*.

$$H = K_e \frac{(R_{CH}/1000)^{3/2}}{D_P}$$

H: Engine output (kW)

K_e: Constant given in Table 33.10

D_P: Diameter of the propeller (m)

R_{CH}: The resistance of the ship in a channel with brash ice and a consolidated layer (N)

$$R_{CH} = C_1 + C_2 + C_3(H_F + H_M)^2(B + 0.628H_F) + C_4 L H_F^2 + C_5 \left(\frac{LT}{B^2}\right)^3 (B/4)$$

L: Length (m) of the ship between the perpendiculars

B: Maximum breadth (m) of the ship

T: Actual ice class draught (m) of the ship

However, $(LT/B^2)^3$ is not to be taken as less than 5 and not to be taken as more than 20.

C_1 and C_2: Coefficient taken into account a consolidated upper layer of the brash ice and are be taken as the following.

(1) For I ice class ships and ice class ships with a bulbous bow

$C_1 = f_1 BL/(2T/B+1) + 2.89(f_2 B + f_3 L + f_4 BL)$

$C_2 = 6.67(g_1 + g_2 B) + g_3 (1 + 1.2T/B) B^2/\sqrt{L}$

(2) For I ice class ships and ice class ships without a bulbous bow

$C_1 = f_1 BL/(2T/B+1) + 1.84(f_2 B + f_3 L + f_4 BL)$

$C_2 = 3.52(g_1 + g_1 B) + g_3 (1 + 1.2T/B) B^2/\sqrt{L}$

(3) For II ice class ships

$C_1 = 0$ and $C_2 = 0$

$f_1, f_2, f_3, f_4, g_{1,} g_2, g_3, C_3, C_4$ and C_5:Value given in **Table 33.12**

H_M: Thickness (*m*) f the brash ice in a channel as given by the followings.

$H_M = 1.0$

H_F: Thickness (*m*) of the brash ice layer displaced by the bow as given by the following formula.

$H_F = 0.26 + (H_M B)^{0.5}$

Table 33.12 Value of f_1, f_2, f_3, f_4, $g_{1,}$ g_2, g_3, C_3, C_4, C_5

f_1: 10.3 (N/mm^2)	g_1 : 1,530(N)	C_3: 460(N/m^3)
f_2: 45.8 (N/m)	g_2: 170(N/m)	C_4: 18.7(N/m^3)
f_3: 2.94 (N/m)	g_3: 400 $(N/m^{1.5})$	C_5: 825(N/m)
f_4: 5.8 (N/m^2)		

3. For ships having features of which, there is ground to assume that they will improve the performance of the ship when navigation in ice or ships parameter values of which defined in **-1** above are beyond the range given in **Table 33.13**, an engine output less than that required in **-1** may be approved, provided that it gives a minimum speed of 5 *knots* in the following brash ice channels.

(1) For I *ice* class ships: 1.0m of the brash ice and a 0.1m thick consolidated layer of ice

(2) For II ice class ships: 1.0*m* of the brash ice

(3) For III ice class ships: 0.8*m* of the brash ice

(4) For IV ice class ships: 0.6*m* of the brash ice

(5) For V ice class ships: 0.5m of the brash ice

Table 33.13 The Range of Parameters

Parameter	Minimum	Maximum
$\alpha\ (deg)$	15	55
$\varphi_1(deg)$	25	90
$\varphi_2(deg)$	10	90
$L(m)$	65.0	250.0
$B(m)$	11.0	40.0
$T(m)$	4.0	15.0
L_{BOW}/L	0.15	0.40
L_{PAR}/L	0.25	0.75
D_p/T	0.45	0.75
$A_{wf}/(LB)$	0.09	0.27

33.4.3 Rudders and Steering Arrangements

1. The rudder scantling of rudders post, rudder stock, pintles, steering gear etc. are to comply with requirements in **Chapter 3, Part 2** and **Chapter 15 , Part 7** these calculations is not to be taken less than that given in the **Table 33.14**.

2. The local scantling of rudders are to be determined assuming that the whole rudder belongs to the ice belt. The rudder plating and frames are to be designed using the ice pressure for the plating and frames in the midbody region.

3. For I and II ice class ships, the rudder stock and the upper part of the rudder are to be protected from direct contact with intact ice by either an ice knife that extends blew the *LIWL* or by equivalent means. Special consideration is to be given to the design of the rudder and the ice knife for ship with flap-type rudders.

4. For I and II ice class ships, the rudders and steering arrangements are to be designed as follows to endure the loads that work on the rudders by the ice when backing into an ice ridge.

(1) Relief valves for hydraulic pressure are to be installed

(2) The components of the steering gear are to be dimensioned to stand the yield torque of the rudder stock.

(3) Suitable arrangements such as rudder stoppers are to be installed.

Table 33.14 Minimum Speed

Class	Speed (*kt*)
I	20
II	18
III	16
IV	14
V	14

33.5 Design Loads of Propulsion Units

33.5.1 General

1. In the design of the propeller, propulsion shafting system and power transmission system, the following are to be taken into account

(1) Maximum backward blade force

(2) Maximum forward blade force

(3) Maximum blade spindle torque

(4) Maximum propeller ice torque

(5) Maximum propeller ice thrust

(6) Design torque on propulsion shafting system

(7) Maximum thrust on propulsion shafting system

(8) Blade failure load

2. The loads specified in **-1** above are to comply with the following

(1) The ice loads cover open and ducted-type propellers situated at the stern of ships having controllable pitch or fixed pitch blades. Ice loads on bow propellers and pulling type propellers are to receive special consideration and ice loads due to ice impact on the bodies of azimuthing thrusters are not covered by this Chapter.

(2) The given loads in this chapter are expected, single occurrence, maximum values for the whole ships service life for normal operation conditions. The loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice,

(3) The loads are total loads (unless otherwise stated) during interaction and are to be applied separately (unless otherwise stated) and are intended for component strength calculations only.

3. Design Loads of Propellers

(1) The loads given are intended for component strength calculations only and are total loads including ice-induced loads and hydrodynamic loads during propeller/ice interaction

(2) The F_b and F_f specified in 33.5.2 and 33.5.3 originate from different propeller/ice interaction phenomena, and do not occur simultaneously. Hence, they are to be applied separately to one blade.

(3) If the propeller is not fully submerged when the ship is in the ballast condition, the propulsion system is to be designed according to Ice Class II for Ice Classes III and IV.

33.5.2 Maximum Backward Blade Force

1. The maximum backward blade force which bends a propeller blade backwards when a propeller mills an ice block while rotating ahead is to be given by the following formulae:

(1) For open propellers:

When $D \le D_{limit} = 0.85\ (H_{ice})^{1.4} (m)$

$$F_b = 27\left(\frac{n}{60}D\right)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} D^2\ (kN)$$

When $D > D_{limit} = 0.85\ (H_{ice})^{1.4} (m)$

$$F_b = 23(H_{ice})^{1.4}\left(\frac{n}{60}D\right)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} D\ (kN)$$

(2) For ducted propellers:

When $D \le D_{limit} = 4\ H_{ice}(m)$

$$F_b = 9.5\left(\frac{n}{60}\right)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} D^2\ (kN)$$

When $D > D_{limit} = 4\ H_{ice}(m)$

$$F_b = 66(H_{ice})^{1.4}\left(\frac{n}{60}D\right)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} D^{0.6}\ (kN)$$

Where

F_b: Maximum backward blade force for the ship`s service life (kN)
Direction of the backward blade force resultant taken perpendicular to chord line at radius $0.7R$.

H_{ice}: Ice thickness (m) specified in **Table 33.15**

D: Propeller diameter (m)

EAR: Expanded blade area ratio

d: external diameter of propeller hub (at propeller plane) (m)

Z: number of propeller blades

n: Nominal rotational propeller speed (rpm) at maximum continuous revolutions in free running condition for controllable pitch propellers and 85% of the nominal rotational propeller speed at maximum continuous revolutions in free running condition for fixed pitch propellers.

Table 33.15 The thickness of the ice block H_{ice}

	I	II	III	IV
Thickness of the design maximum ice block entering the propeller H_{ice} (m)	1.75	1.5	1.2	1.0

2. The maximum backward blade force F_b is to be applied as a uniform pressure distribution to an area of the blade for the following load cases:

(1) In the case of open propellers:

(a) The F_b specified in **-1(1)** above is to be applied to an area from 0.6R to the tip and from the blade leading edge to a value 0.2 of the chord length.

(b) A load equal to 50% of the F_b specified in **-1(1)** above is to be applied to the propeller tip area outside of 0.9R.

(c) In the case of reversible propellers, a load equal to 60% of the F_b specified in **-1(1)** above is to be applied to an area from 06R to the tip and from the blade trailing edge to a value 0.2 of the chord length.

(2) In the case of ducted propellers:

(a) The F_b specified in **-1(2)** above is to be applied to an area from 0.6R to the tip and from the blade leading edge to a value 0.2 of the length.

(b) In the case of reversible propellers, a load equal to 60% of the F_b specified in **-1(2)** above is to be applied to an area from 0.6R to the tip and from the blade trailing edge to a value 0.2 of the chord length.

33.5.3 Maximum Forward Blade Force

1. The maximum forward blade force which bends a propeller blade forwards when a propeller interacts with an ice block while rotating ahead is to be given by the following formulae:

(1) For open propellers:

When $D \le D_{limit} = \frac{2}{(1-d/D)} H_{ice}(m)$

$$F_f = 250\left(\frac{EAR}{Z}\right)D^2(kN)$$

when $D > D_{limit} = \frac{2}{(1-d/D)} H_{ice}(m)$

$$F_f = 500H_{ice}\left(\frac{EAR}{Z}\right)\left(\frac{1}{1-d/D}\right)D(kN)$$

(2) For ducted propellers:

When $D \le D_{limit} = \frac{2}{(1-d/D)} H_{ice}(m)$

$$F_f = 250\left(\frac{EAR}{Z}\right)D^2(kN)$$

When $D > D_{limit} = \frac{2}{(1\text{-}d/D)} H_{ice}(m)$

$$F_f = 500 H_{ice} \left(\frac{EAR}{Z}\right)\left(\frac{1}{1\text{-}d/D}\right) D(kN)$$

Where

F_f: The maximum forward blade force for the ship`s service life (kN)

Direction of the forward blade force resultant taken perpendicular to chord line at radius 0.7R

H_{ice}, D, EAR, d and Z: As specified in 33.5.2

2. The maximum forward blade force F_f blade force F_f is to be applied as a uniform pressure distribution to an area of the blade for the following load cases:

(1) In the case of open propellers:

(a) The F_f specified in **-1(1)** above is to be applied to an area from 0.6R to the tip and from the blade leading edge to a value 0.2 of the chord length.

(b) A load equal to 50% of the F_f specified in **-1(1)** above is to be applied to the propeller tip area outside of 0.9R.

(c) In the case of reversible propellers, a load equal to 60% of the F_f specified in **-1(1)** above is to be applied to an area from 0.6R to the tip and from the blade trailing edge to a value 0.2 of the chord length.

(2) In the case of ducted propellers:

(a) The F_f specified in **-1(2)** above is to be applied to an area from 0.6R to the tip from blade leading edge to a value 0.5 of the chord length.

(b) In the case of reversible propellers, a load equal to 60% of the F_f specified in **-1(2)** above is to be applied to an area from 0.6R to the propellers, a load equal to 60% of the F_f specified in **-1(2)** above is to be applied to an area from 0.6 to the tip and from the blade trailing edge to a value 0.2 of the chord length.

33.5.4 Maximum Blade Spindle Torque

The spindle torque around the spindle axis of the blade fitting is to be calculated both for the load cases specified in 33.5.2 and 33.5.3 for F_b and F_f. In cases where these spindle torque values are less than the default value obtained from the following formula, the default value is to be used.

$$Q_{smax} = 0.25 C_{0.7} \ (kNm)$$

Where

$C_{0.7}$: Length (m) of the blade chord at radius 0.7R

F: Either F_b determined in 33.5.2-1 or F_f. determined in 33.5.3-1, whichever has the greater absolute value (kN)

33.5.5 Frequent Distributions for Propellers Blade Loads

1. A weibull-type distribution (probability that F_{ice} exceeds $(F_{ice})_{max}$), as given in **Fig. 33.5**, is to be used for the fatigue design of blades.

$$P\left(\frac{F_{ice}}{(F_{ice})_{max}} \geq \frac{F}{(F_{ice})_{max}}\right) = e^{\left(-\left(\frac{F}{(F_{ice})_{max}}\right)^{k} In(N_{ice})\right)}$$

Where

F_{ice}: Random variable for ice loads (kN) on the blade, and meet the requirements $0 \leq F_{ice} \leq (F_{ice})_{max}$

$(F_{ice})_{max}$: Maximum ice load for the ships`s life (kN)

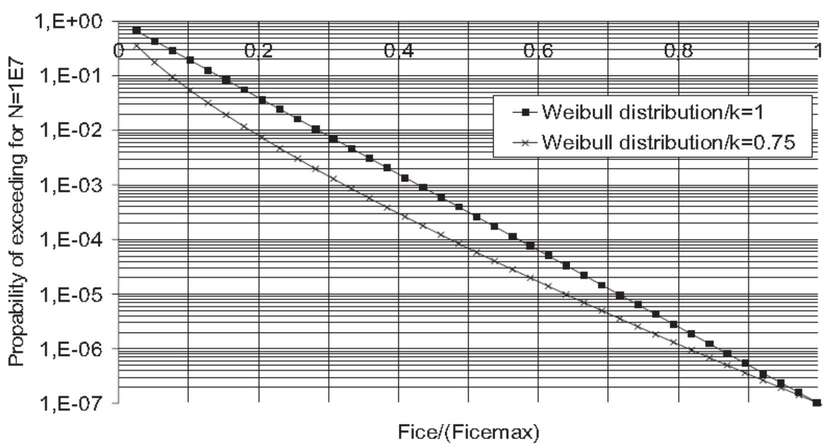
k: Shape parameter for Weibull-type distribution The following definitions apply:

Open propeller: k=0.75

Ducted propeller: k=1.0

N_{ice}: Total number of ice loads on a propeller blade for the ship`s service life

Fig. 33.5 The Weibull-type distribution (probability that F_{ice} exceeds $(F_{ice})_{max}$) that is used for fatigue designs



2. Number of ice loads

(1) The number of load cycles per propeller blade in the load spectrum shall be determined according to the formula:

$$N_{ice} = k_1 k_2 k_3 k_4 N_{class} \frac{n}{60}$$

Where

N_{class}: Reference number of loads for ice classes, as specified in **Table 33.16**

k_1: Propeller location factor, as specified in **Table 33.17**

k_2: Propeller type factor, as specified in **Table 33.18**

k_3: Propulsion type factor, as specified in **Table 33.19**

Table 33.16 Reference number of loads for ice classes N_{class}

Class	I	II	III	IV
Impacts in life/n	$9 \cdot 10^6$	$6 \cdot 10^6$	$3.4 \cdot 10^6$	$2.1 \cdot 10^6$

Table 33.17 Propeller location factor k_1

Factor	Centre propeller	Wing Propeller
k_1	1	1.35

Table 33.18 Propeller type factor k_2

Factor	open propeller	ducted Propeller
k_2	1	1.1

Table 33.19 Propeller type factor k_3

Factor	open propeller	ducted Propeller
k_3	1	1.2

k_4: The submersion factor k_4 is determined from the equation from the equation.

$$K_4 = \begin{cases} 0.8 - f & : f < 0 \\ 0.8 - 0.4f & : 0 \le f \le 1 \\ 0.6 - 0.2f & : 1 < f \le 2.5 \\ 0.1 & : f > 2.5 \end{cases}$$

Where

$$f = \frac{h_0 - H_{ice}}{D/2} - 1$$

h_0: The depth of the propeller centreline at the lower ice waterline (*LIWL)* of the ship (*m*)

H_{ice} and D: as specified in **33.5.2**

(2) In the case of components that are subject to loads resulting from propeller/ice interaction with all of the propeller blades, the number of load cycles (N_{ice}) is to be multiplied by the number of propeller blades (Z).

33.5.6 Maximum Propeller Ice Thrust

The maximum propeller ice thrust applied to a propeller is to be given by the following formulae:

(1) Maximum backward propeller ice thrust

$$T_b = 1.1F_b(kN)$$

(2) Maximum forward propeller ice thrust

$$T_f = 1.1F_f(kN)$$

Where

F_b: Maximum backward blade force for the ship`s service life, as specified in 33.5.2-1

F_f: Maximum forward blade force for the ship`s service life, as specified in 33.5.3-1

T_b: Maximum backward propeller ice thrust (kN)

T_f: Maximum forward propeller ice thrust (kN)

33.5.7 Design Thrust along Propulsion Shaft Lines

The design thrust along the propeller shaft line is to be given by the following formulae:

(1) Maximum shaft thrust forwards:

$$T_r = T + 2.2T_f\ (kN)$$

(2) Maximum shaft thrust backwards:

$$T_r = 1.5T_b\ (kN)$$

Where:

T_b and T_f: Maximum propeller ice thrust (kN) determined in 33.5.6

T: propeller bollars thrust (kN). If not known, T is to be taken as specified in Table 33.20

Table 33.20 Value of *T*

Propeller Type	T
Controllable pitch propellers (open)	$1.25T_n$
Controllable pitch propellers (ducted)	$1.1T_n$
Fixed pitch propellers driven by turbine or electric motor	T_n
Fixed pitch propellers driven by diesel engine (open)	$0.85T_n$
Fixed pitch propellers driven by diesel engine (ducted)	$0.75T_n$

Note:

T_n: Nominal propeller thrust (kN) at maximum continuous revolutions in free running open water conditions.

33.5.8 Maximum Propeller Ice Torque

The maximum propeller ice torque applied to the propeller is to be given by the following formulae:

(1) For open propellers:

When $D \le D_{limit} = 1.8H_{ice}$ (m)

$$Q_{max}=10.9\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}\left(\frac{n}{60}D\right)^{0.17}D^{3}\,(kNm)$$

When $D > D_{limit} = 1.8H_{ice}$ (m)

$$Q_{max}=20.7\,(H_{ice})^{1.1}\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}\left(\frac{n}{60}D\right)^{0.17}D^{1.9}\,(kNm)$$

(2) For ducted propellers:

When $D \le D_{limit} = 1.8H_{ice}$ (m)

$$Q_{max}=7.7\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}\left(\frac{n}{60}D\right)^{0.17}D^{3}\,(kNm)$$

When $D > D_{limit} = 1.8H_{ice}$ (m)

$$Q_{max}=14.6\,(H_{ice})^{1.1}\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}\left(\frac{n}{60}D\right)^{0.17}D^{1.9}\,(kNm)$$

Where:

H_{ice}, D and d: As specified in 33.5.2

$P_{0.7}$: Propeller pitch (m) at $0.7R$

In the case of controllable pitch propellers, $P_{0.7}$ is to correspond to maximum continuous revolutions at the bollard condition. If not know, $P_{0.7}$ is to be taken as $0.7P_{0.7n}$, where $P_{0.7n}$ is the propeller pitch at maximum continuous revolutions at a free running condition.

n: Rotation propeller speed (rpm) at the bollard condition

If not known, n is to be taken as specified in Table 33.21

Table 33.21 Rotation propeller speed *n*

Propeller type	n
Controllable pitch propellers	n_n
Fixed pitch propellers driven by turbine or electric motor	n_n
Fixed pitch propellers driven by diesel engine	$0.85n_n$

Note:

n_n: Nominal rotational speed (rpm) at maximum continuous revolutions at the free running condition

33.5.9 Design Torque on Propulsion Shafting System

1. The propeller ice excitation torque for shaft line transient torsional vibration dynamic analysis is to comply with the following requirements:

(1) The excitation torque is to described by a sequence of blade impacts which are of half sine shape and occur at the table. The total ice torque is to be obtained by summing the torques of single ice blade ice impacts

taking into account the phase shift. The single ice blade impact is given by the following formulae: **(See Fig. 33.6)**

(a) when $0 \leq \varphi \leq \alpha_i (deg)$

$Q(\varphi) = C_q Q_{max} \sin(\varphi(180/\alpha_i))$

(b) when $\alpha_i \leq \varphi \leq 360$ (deg)

$Q(\varphi) = 0$

Where

Q_{max}: Maximum torque on the propellers as specified in **33.5.8**

C_q: As specified in **Table 33.22**

a_i: Duration of propeller blade/ice interaction expressed in rotation angle as specified in **Table 33.22**

Table 33.22 Values of C_q and α_i

Torque excitation	Propeller-ice interaction	C_q	α_i
Case 1	Single ice block	0.75	90
Case 2	Single ice bloc	1.0	135
Case 3	Two ice block (phase shift 360/2/Z deg)	0.5	45

Note:

Total ice torque is obtained by summing the torque of single blades, taking into account the phase shift 360deg/Z. In addition, at the beginning and at the end of the milling sequence, a linear ramp functions for 270 degrees of rotation angle is to be used.

(2) The number of propeller revolutions and the number of impacts during the milling sequence are to be given by the following formulae. For bow propellers, the number of propeller revolutions and the number of impacts during the milling sequence are subject to special consideration.

(a) The number of propeller revolutions:

$N_Q = 2H_{ice}$

(b) The number of impacts:

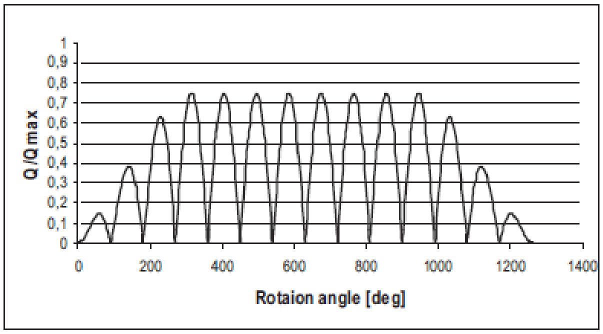
ZN_Q

Where

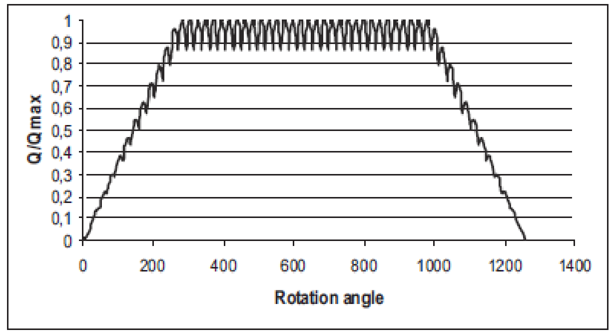
H_{ice}: As specified in **Table 33.15**

Z: Number of propeller blades

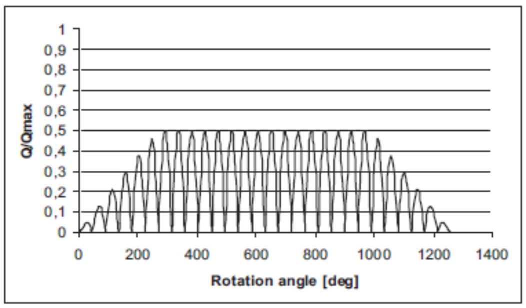
Fig. 33.6 Example of the shape of the propeller ice torque excitation (Four bladed propeller)



(a) Case 1 Single blade impact ($\alpha_i = 90°$)



(b) Case 2 Single blade impact ($\alpha_i = 135°$)



(c) Case 3 Double blade impact t ($\alpha_i = 45°$)

2. Design torque along propeller shaft line

(1) If there is not a predominant torsional resonance within the designed operating rotational speed range extended 20% above the maximum and 20% below the minimum operating speeds, the following estimation of the maximum torque can be used:

$$Q_r = Q_{emax} + Q_{max}\frac{I}{I_t}\,(kNm)$$

Q_{emax}: maximum engine torque (kNm)

If the maximum torque, Q_{emax}, is not known, it is to be taken as specified in **Table 33.23**

I: equivalent mass moment of inertia of all parts on the engine side of the component under consideration (kgm^2)

I_t: equivalent mass moment of inertia of the whole propulsion system (kgm^2)

(2) If there is a first blade order torsional resonance within the designed operating rotational speed range extended 20% above the maximum and 20% below the minimum operating speeds, the design torque (Q_r) of the shaft component is to be determined by means of torsional vibration analysis if the propulsion line.

Table 33.23 Maximum engine torque Q_{emax}

Propeller type	Q_{emax}
Propellers driven by electric motor	Q_{motor}
CP propellers not driven by electric motor	Q_n
FP propellers driven by turbine	Q_n
FP propellers driven by diesel engine	$0.75Q_n$

Notes:

Q_{motor}: Electric motor peak torque (*kNm*)

Q_n: Nominal torque at MCR in free running condition (*kNm*)

Q_r: Maximum response torque along the propeller shaft line (*kNm*)

33.5.10 Blade Failure Loads

1. The blade failure load is to be given by the following formula:

$$F_{ex}=\frac{300ct^2\sigma_{ref}}{0.8D-2r}\ (kN)$$

Where

σ_{ref}: the references stress is to be given by the following formula:

$$\sigma_{ref}=0.6\sigma_{0.2}+0.4\sigma_u (MPa)$$

Where

σ_u: Tensile stress of blade material *(MPa)*

$\sigma_{0.2}$: Yield stress or 0.2% proof strength of blade material *(MPa)*

c: Chord length of blade section *(m)*

F_{ex}: ultimate blade load resulting from blade loss through plastic bending *(kN)*

r: blade section radius *(m)*

t: *Maximum blade section thickness* (*m*)

2. The force specified in **-1.** Above is to be acting at 9.8*R* in the weakest direction of the blade and at a spindle arm of 2/3 the distance of the axis of blade rotation of the leading or trailing edge, whichever is greater.

33.6 Design of Propellers and Propulsion Shafting Systems

33.6.1 General

With respect to the design of the propeller and the propulsion shafting system, the following are to be taken into account:

(1) Propeller and propulsion shafting systems are to have sufficient strength for the loads specified in 33.5.

(2) The blade failure load given in 33.5.10 is not to damage the propulsion shafting system other than the propeller blade itself.

(3) Propeller and propulsion shafting systems are to have sufficient fatigue strength.

33.6.2 Propeller Blade Stresses

1. Propeller blade stresses are to be calculated for the design loads given in 33.5.2 and 33.5.3 using Finite Element Analysis.

In the case of a relative radius $r/R<0.5$, the blade stresses for all propellers at their root areas may be calculated by the formula given below. Root area dimensions based on this formula can be accepted even if FEM analysis shows greater stresses at the root area.

$$\sigma_{st}=C_1\frac{M_{BL}}{100ct^2}(MPa)$$

Where

$$C_1:\frac{\text{stress obtained with FEM analysis result}}{\text{stress obtained with beam equation}}$$

If the actual value is not available, C_1 should be taken as 1.6

Where

M_{BL}: Blade bending moment (kNm), in the case of a relative radius $r/R<0.5$, the following:

$$M_{BL}=\left(0.75-\frac{r}{R}\right)RF$$

F: Maximum of F_b and F_f, whichever is greater.

2. The calculated blade stress σ_{st} specified in **-1** above is to comply with the following:

$$\frac{\sigma_{ref2}}{\sigma_{st}}\geq 1.5$$

Where

σ_{st}: Maximum stress resulting from F_b or F_f

σ_u: Tensile stress of blade material (MPa)

σ_{ref2}: Reference stress (MPa), whichever is less

$\sigma_{ref2}=0.7\sigma_u$, or $\sigma_{ref2}=0.6\sigma_{0.2}+0.4\sigma_u$

3. Fatigue design or propeller blades

(1) The fatigue design of a propeller blade is based on the estimated load distribution for the service life of the ship and the S-N curve for the blade material. An equivalent stress that produces the same fatigue damage as the expected load distribution is to be calculated an the acceptability criterion for fatigue is to be fulfilled as given in this section. The equivalent stress is normalized for 100 million cycles. If the following criterion is fulfilled, the fatigue calculations specified in this section are not required.

$$\sigma_{exp}\geq B_1\sigma_{ref2}{}^{B_2}log(N_{ice})^{B_3}$$

Where

The coefficients B_1, B_2 and B_3 are as given in the **Table 33.24**

Table 33.24 The coefficients B_1, B_2 and B_3

Coefficients	Open propeller	Ducted propeller
B_1	0.00270	0.00184
B_2	1.007	1.007
B_3	2.101	2.470

(2) For the calculation of equivalent stress, two types of S-N curves are to be used.

(a) Two-slope S-N curve (slopes 4.5 and 10), see **Fig. 33.7**.

(b) One-slope S-N curve (the slope can be chosen), see **Fig. 33.8**.

(3) The type of the S-N curve shall be selected to correspond to the material properties of the blade. If the S-N curve is not know, a two-slope S-N curve is to be used.

Fig. 33.7 Two-slope S-N curve

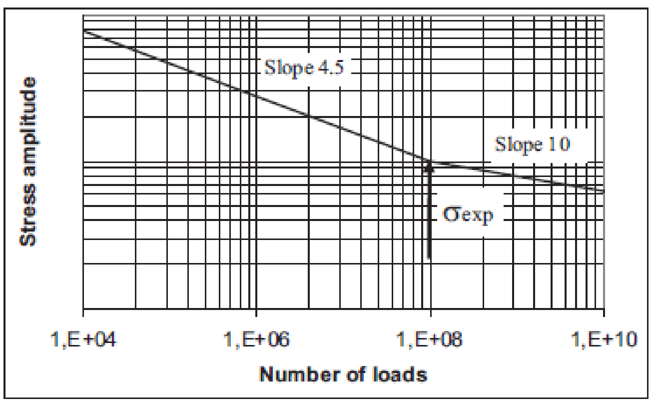
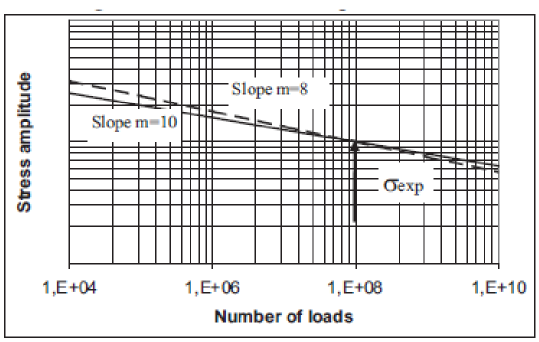


Fig. 33.8 Constant-slope S-N curve



(4) The equivalent fatigue stress for 100 million stress cycles which produces the same fatigue damage as the load distribution is:

$\sigma_{\mathrm{fat}} = \rho(\sigma_{\mathrm{ice}})_{\mathrm{max}}$

Where

ρ: Depending on the applicable S-N curve, ρ is to be given by either **(5)** or **(6).**

$(\sigma_{\mathrm{ice}})_{\mathrm{max}} = 0.5\left((\sigma_{ice})_{fmax} - (\sigma_{ice})_{bmax}\right)$

$(\sigma_{\mathrm{ice}})_{\mathrm{max}}$: The mean value of the principal stress amplitudes resulting from forward and backward blade forces at the location being studied.

$(\sigma_{\mathrm{ice}})_{\mathrm{fmax}}$: The principal stress resulting from backward load

(5) The calculation of the parameter ρ for a two-slope S-N curve is as follows:

Parameter ρ relates the maximum ice load to the distribution of ice loads according to the following regression formulae:

$\rho = C_1 (\sigma_{ice})_{max}{}^{C2} \sigma_{ft}{}^{C3} lg(N_{ice})^{C4}$

Where

$\sigma_{ft} = \gamma_{\varepsilon}\gamma_{v}\gamma_{m}\sigma_{exp}$

σ_{ft}: Characteristic fatigue strength for blade material (*MPa*)

γ_{ε}: The reduction factor for scatter and test specimen size effect

γ_{v}: The reduction factor variable amplitude loading

γ_{m}: The reduction factor for mean stress

σ_{exp}: The mean fatigue strength of the blade material at 10^8 cycles to failure in seawater (*MPa*)

The following values are to be used as reduction factors if actual values are not available:

$\gamma_{\varepsilon} = 0.67, \gamma_{v}$=0.75, $\gamma_{m} = 0.75$

The coefficients $C_1, C_2,\ C_3\ and\ C_4$ are given in **Table 33.25.**

Table 33.25 The coefficients C_1, C_2, C_3 and C_4

Coefficients	Open propeller	Ducted propeller
C_1	0.000711	0.000509
C_2	0.0645	0.0533
C_3	-0.0565	-0.0459
C_4	2.220	2.584

(6) The calculation of the parameter for a constant-slope S-N curve

In the case of materials with a constant-slope S-N curve-see **Fig. 33.8**-the ρ factor is to be calculated using the following formula:

$$\rho = \left(G\frac{N_{ice}}{N_R}\right)^{1/m}\left(1n(N_{ice})\right)^{-1/k}$$

Where

K is the shape parameter of the Weibull distribution, it is as follows:

(a) *k*=1.0 for ducted propellers

(b) *k*=0.75 for open propellers

N_R: The reference number of load cycles (=10^8)

m: Slope for S-N curve in log/log scale

G: Values for the parameter *G* are given in **Table 33.26**. Linear interpolation may be used to calculate the *G* values for m/k ratios other than those given in **Table 33.26**

Table 33.26 Value for the *G* parameter for different *m/k* ratios

m/k	*G*
3	6
3.5	11.6
4	24
4.5	52.3
5	120

m/k	*G*
5.5	287.9
6	720
6.5	1871
7	5040
7.5	14034

m/k	*G*
8	40320
8.5	119292
9	362880
9.5	1.133E6
10	3.623E6

4. Acceptability criterion for fatigue

The equivalent fatigue stress at all locations on a blade has to fulfill the following acceptability criterion:

$$\frac{\sigma_{ft}}{\sigma_{fat}} \geq 1.5$$

33.6.3 Propeller bossing and CP mechanism

1. The blade bolts, the CP mechanism, the propeller boss, and the fitting of the propeller to the propeller shaft are to be designed to withstand maximum and fatigue design loads, as defined in **33.5**. the safety factor is as follows.

(1) The safety factor against yielding is to be greater than 1.3

(2) The safety factor against fatigue is to be greater than 1.5

2. The safety factor loads resulting from loss of a propeller blade through plastic bending as defined in **33.5.10** is to be greater than 1.0 against yielding.

33.6.4 Propulsion shaft line

1. The shafts and shafting components, such as the thrust and stern tube bearing, couplings, flanges and sealings, shall be designed to withstand the propeller/ice interaction axial, bending and torsion loads. The factor is to be at least 1.3

2. The ultimate load resulting from total blade failure as defined in Section **33.5.10** is not to cause yielding in shafts and shaft components. The loading is to consist of the combined axial, bending, and torsion loads, wherever this is significant. The minimum safety factor against yielding is to be 1.0 for bindings and torsional stresses.

33.6.5 Azimuthing Main Propulsors

With respect to the design of azimuthing main propulsors, the following are to be taken into account in addition to the requirements specified in **33.6.1:**

(1) Loading cases which are extraordinary for propulsion units are to be taken into account. The estimation of loading cases is to reflect the operational realities of the ship and the thrusters.

(2) The steering mechanism, the fitting of the unit and body of the thruster are to be designed to withstand the loss of a blade without damage.

(3) The plastic bending of a blade is to be considered in the propeller blade position, which causes the maximum load on the considered component.

(4) Azimuth thrusters are to be designed for the estimated loads

(5) The thickness of an ice sheet is to be taken as the thickness of the maximum ice block entering the propeller, as defined in **Table 33.15**

33.6.6 Vibrations

The propulsion system shall be designed in such a way that the complete dynamic system is free from dominant torsional, axial, and bending resonances within the designed running speed range, extended by 20% above and below the maximum and minimum operating rotational speeds. If this condition cannot be fulfilled, a detailed vibration analysis has to be carried out in order to determine that the acceptable strength of the components can be achieved.

33.7 Alternative design

As an alternative to **33.5** and **33.6**, a comprehensive design study may be carried out.

33.8 Miscellaneous Machinery Requirements

33.8.1 Starting Arrangements

1. The capacity of air reservoirs is to be sufficient to provide, without reloading, not less than 12 consecutive starts of the propulsion engines if these have to be reserved for going astern, or 6 consecutive stars if such propulsion engines do not have to be reversed for going astern.

2. If the air reservoirs serve any other purposes than starting propulsion engines, they are to have additional capacity sufficient for such purposes.

3. The capacity of air compressors is to be sufficient for charging the air reservoirs from atmospheric to full pressure in one hour. In the case of I *Super* ice class ships that require their propulsion engines to be reversed for going astern, the compressors are to be able to charge the air reservoirs in half an hour.

33.8.2 Sea Inlet and Cooling Water Systems

1. Cooling water systems are to be designed to ensure a supply of cooling water when navigating in ice.

2. To satisfy **-1** above, at least one cooling sea water inlet chest is to be arranged as follows. However, I*D* ice class ships may not comply with the requirements given in **(2), (3)** and **(5):**

(1) Sea inlet are to be situated near the centre line of ships and well aft if possible.

(2) As guidance for design, the volume of sea chests is to be about $1m^3$ for every $750kW$ of engine output of ships including the output of auxiliary engines necessary for the ship service.

(3) Sea chests are to be sufficiently high to allow ice to accumulate above inlet pipes.

(4) Pipes for discharging cooling water, allowing full capacity discharge, are to be connected to sea chests.

(5) Areas through grating holes are not to be less than 4 *times* inlet pipe sectional areas

3. In cases where more that two sea chests are arranged, it is not necessary to satisfy the requirements given in **-2(2)** and **(3)** above.In such cases , sea chests are to be arranged for alternating the intake and discharge of cooling water as well as complying with the requirements given **-2(1), (4)** and **(5)** above.

4. Heating coils may be installed in the upper parts of sea chests.

5. Arrangements for using ballast water for cooling purposes may be useful as a reserve in the ballast condition, but cannot be accepted as a substitute for the sea inlet chests described above.