Contents

RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

Part C HULL CONSTRUCTION AND EQUIPMENT

Chapter 1 GENERAL

1.1 General

1.1.1 Application*

1 The requirements in this Part apply to ships not less than 90m 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 in **Part V**, 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 **Part V**, 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 **10.9** and **17.3.5**.

4 Reinforcement of the ship for loading containers is to be done in accordance with the provisions of **32.4.1**. Cell guide constructions, where provided, are to be in accordance with the provisions of **32.11**.

5 The hull structural members of ships intended for the carriage of cargoes having moisture contents which exceed transportable moisture limit are to be in accordance with the requirements provided in this Part. In addition, the special considerations deemed necessary by the Society are to be taken into account.

6 Among the requirements applicable to bulk carriers defined in **1.3.1(13) of Part B**, those requirements in **18.4**, **31.6** and **34.2** are to be applied to the self-unloading ships defined in **1.3.1(19) of Part B**.

1.1.4 (Deleted)

(Deleted)

1.1.5 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.

1.1.6 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.

1.1.7 Materials*

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

2 Where high tensile steel specified in **Chapter 3, Part K of the Rules** 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 **32.2.4** for ships subject to the requirements in **Chapter 32** and **15.2** for other ships. 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 (However, 0.66 may be taken where a fatigue assessment of the structure is performed to verify compliance with the requirements of the Society).

0.62: where high tensile steel *KE*47 is used (However, only applies to ships subject to **Chapter 32**).

(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 K of the Rules** 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 15**. However, the coefficient (K) is to be rounded to three decimal places and not less than 0.63.

$$K = f_T\{8.81\,(\sigma_y/1000)^2 - 7.56\,(\sigma_y/1000) + 2.29\} \text{ for } \sigma_y \leq 355 \ (N/mm^2)$$

$$K = f_T f_C(235/\sigma_y) \text{ for stainless steel with } \sigma_y > 355 \ (N/mm^2)$$

Where

f_C: Determined as follows:

$$f_C = 3.04\,(\sigma_y/1000)^2 - 1.09\,(\sigma_y/1000) + 1.09$$

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

f_T: Determined as follows:

$$f_T = 0.0025\,(T - 60) + 1.00$$

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.

(3) Notwithstanding the requirements in **(1)** above, 0.78 is to be used as the lower limit of the coefficient (K) when determining the construction and scantlings for areas of anticipated stress concentration, except where deemed appropriate by the Society.

4 Where steels for low temperature service specified in **Chapter 3, Part K of the Rules** which have minimum specified yield stress greater than 235 N/mm^2 are 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 **15.2**. Moreover, the extent of use of steels for low temperature service is to be at the discretion of the Society.

0.90: where *KL*27 are used

0.76: where *KL*33 are used

0.71: where *KL*37 are used.

(2) Details such as the thickness of plates and the section modulus of stiffeners of each structural member are to be at the discretion of the Society.

(3) The construction and scantlings where steels for low temperature service other than those mentioned in **(1)** above are used are to be at the discretion of the Society.

5 Where materials other than steels complying with **Part K 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.

6 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.

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

1.1.8 Fire-proof Construction

Fire-proof construction is to be in accordance with the requirements in **Part R**.

1.1.9 Means of Escape

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

1.1.10 (Deleted)

(Deleted)

1.1.11 Application of Steels*

1 The steels used for hull structures are to be of the grades provided in **Part K** in accordance with the requirements given in **Table C1.1** and **C1.2**. 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 $0.4L$ amidships, the widths of single strakes of sheer strakes to the strength deck, stringer plates in the strength deck, bilge strakes (excluding ships of less than $150m$ in length L_1 having double 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 $1,800mm$). The widths of single strakes on rounded gunwales are to be determined by the Society.

$$5L_1 + 800\ (mm)$$

L_1: Distance (m) measured on the waterline at the scantling draught d_S from the forward side of the stem to the centre of the rudder stock. L_1 is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught d_S. In ships without rudder stocks (e.g. ships fitted with azimuth thrusters), the Rule length L_1 is to be taken equal to 97% of the extreme length on the waterline at the scantling draught d_S.

d_S: Scantling draught (m) at which the strength requirements for the scantlings of the ship are met and represents the full load condition. d_S is to be not less than that corresponding to the assigned freeboard.

3 Where stainless clad steel specified in **Chapter 3, Part K of the Rules** is used for hull construction, the thickness of the base steel is to be used as the thickness of the plate in **Table C1.1** and **Table C1.2**.

4 The steels with thicknesses from $50mm$ up to $100mm$ 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 $50mm$ 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 C1.1** or **Table C1.2** 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 C1.1 Application of Mild Steels for Various Structural Members

Structural member	Application		Thickness of plate : t (mm)					
			$t \le 15$	$15<t\le 20$	$20<t\le 25$	$25<t\le 30$	$30<t\le 40$	$40<t\le 50$
Shell Plating								
Sheer strake at strength deck	within0.4L amidship	$L_1 \le 250$	A^{*1*4}	B	D		E	
		$L_1>250$	E					
	within 0.6L amidship excluding the above		A^{*1*4}		B	D		E
	other than those mentioned above		A^{*1*4}				B	D
Side plating	within 0.4L amidship	within 0.1D downward from the lower surface of strength deck	A^{*1*4}		B	D		E
		other than those mentioned above	A^{*1*4}				B	D
Bilge strake	within 0.4L amidship	$L_1>250$	D				E	
		ships of $150 \le L_1 \le 250$, having double bottom structures and ships having single bottom structures	A^{*1*4}	B	D		E	
	within 0.6L amidship excluding the above		A^{*1*4}		B	D		E
	other than those mentioned above		A^{*1*4}				B	D
Bottom plating including keel plate	within 0.4L amidship		A		B	D		E
Deck Plating								
Stringer plate in strength deck	within 0.4L amidship	$L_1 \le 250$	A^{*2*5}	B	D		E	
		$L_1>250$	E					
	within 0.6L amidship excluding the above		A		B	D		E
	other than those mentioned above		A				B	D
Strength deck strake adjoining to longitudinal bulkhead	within 0.4L amidship		A^{*2*5}	B	D		E	
	within 0.6L amidship excluding the above		A		B	D		E
	other than those mentioned above		A				B	D
Strength deck other than mentioned above	within 0.4L amidship		A^{*2*5}		B	D		E
Strength deck at cargo hatch corner	container carriers and other ships with similar hatch openings configuration		A^{*2}	B	D		E	
	bulk carriers, ore carriers, combination carriers and other ships with similar hatch openings configuration	within 0.6L amidship	A^{*2}	B	D		E	
		cargo region excluding the above	A		B	D		E
	other than those mentioned above within 0.4L amidship		A^{*2}		B	D		E
Deck plating exposed to weather, in general	within 0.4L amidship		A				B	D
Longitudinal bulkhead plate								
Upper strake in longitudinal bulkhead adjoining to strength deck	within 0.4L amidship		A		B	D		E
Other than those mentioned above	within 0.4L amidship		A				B	D
Longitudinals								

Structural member	Application		Thickness of plate : t (mm)					
			$t\leq15$	$15<t\leq20$	$20<t\leq25$	$25<t\leq30$	$30<t\leq40$	$40<t\leq50$
Upper strake in sloping plate of topside tank adjoining to strength deck	within 0.4L amidship		A		B	D		E
Longitudinal plating members above strength deck	corners of dome openings on trunk deck and inner deck plating above strength deck in ships with membrane tanks carrying liquefied gases in bulk	within 0.6L amidship	A^{*5}	B	D		E	
		cargo region excluding the above	A		B	D		E
	longitudinal girders including end brackets and face plates	within 0.4L amidship	A^{*3*5}		B	D		E
	longitudinal plating members other than those mentioned above	within 0.4L amidship	A^{*3*5}		B	D		E
Cargo Hatch								
Cargo hatch coaming longitudinally extended on the strength deck	longitudinal members over 0.15L (including face plate and its flange, but excluding other stiffeners. See Fig. C1.1) and end brackets and deck house transition	within 0.4L amidship	D				E	
		within 0.6L amidship excluding the above	D					E
		other than those mentioned above	D					
Hatch cover	top plates, bottom plates and primary supporting members		A				B	D
Stern								
Stern frame, rudder horn, rudder trunk, shaft bracket	—		A		B	D		E
Rudder								
Rudder plate	—		A		B	D		E
Other								
Other members than those mentioned above (including stiffeners)			A^{*1*4}					

Remarks:

1. For ships with length of L_1 exceeding 150m 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 K of the Rules**.
2. For ships with length of L_1 exceeding 150m and single strength deck, longitudinal strength members of strength deck plating within 0.4L amidship are not to be less than grade KB as defined in **Part K of the Rules**.
3. For ships with length of L_1 exceeding 150m and single strength deck, continuous longitudinal plating of strength members above strength deck within 0.4L amidship are not to be less than grade KB as defined in **Part K of the Rules**.
4. For ships with ice strengthening conforming to **Chapter 8**, **Part I of the Rules**, shell strakes in way of ice strengthening area for plates are not to be less than grade KB as defined in **Part K of the Rules**.
5. For ships with membrane tanks carrying liquefied gases in bulk with length of L_1 exceeding 150m having deck structure comprising trunk deck and inner deck (see **Fig. C1.2**), the following structural members within 0.4L amidship are not to be less

than grade *KB* as defined in **Part K of the Rules**.

(1) Strength deck

(2) Inner deck above strength deck

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

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

Notes:

1. *A*, *B*, *D*, *E* refer to the following grades of steel.
   A: *KA*, *B*: *KB*, *D*: *KD*, *E*: *KE*
2. L_1 is the distance (m) measured on the waterline at the scantling draught d_S from the forward side of the stem to the centre of the rudder stock. L_1 is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught d_S. In ships without rudder stocks (e.g. ships fitted with azimuth thrusters), the Rule length L_1 is to be taken equal to 97% of the extreme length on the waterline at the scantling draught d_S.
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 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 C rudder specified in **Chapter 3** is to be approved by the Society.
6. Continuous longitudinal plating of strength members above strength deck (including trunk deck, inner deck and longitudinal strength member plating between trunk deck and inner deck) are to be treated as longitudinal plating members above strength deck.

Fig. C1.1 Example of Cross Section in Longitudinal Hatch Coaming Area

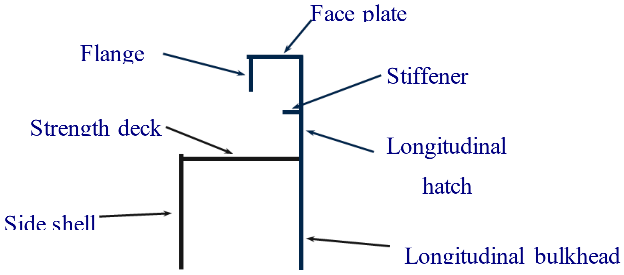


Fig. C1.2 Typical Deck Structure of Ships with Membrane Tank Carrying Liquefied Gases in Bulk

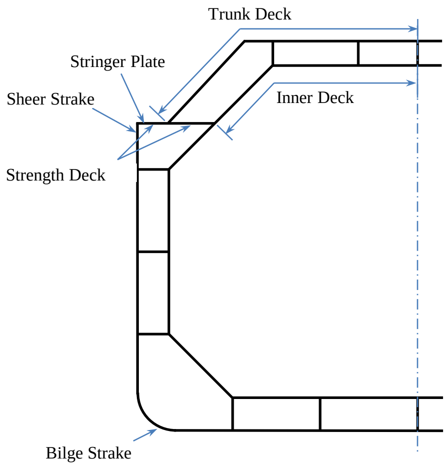


Table C1.2 Application of High Tensile Steels for Various Structural Members

<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≤15</th><th>15<t≤20</th><th>20<t≤25</th><th>25<t≤30</th><th>30<t≤40</th><th>40<t≤50</th></tr>
<tr><td colspan="9">Shell plating</td></tr>
<tr><td rowspan="4">Sheer strake at strength deck</td><td rowspan="2">within0.4L amidship</td><td>L_1≤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 0.1D 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≤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≤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="4">Strength deck at cargo hatch corner</td><td colspan="2">container carriers and other ships with similar hatch openings configuration</td><td colspan="2">AH</td><td colspan="2">DH</td><td colspan="2">EH</td></tr>
<tr><td rowspan="2">bulk carriers, ore carriers, combination carriers and other ships with similar hatch openings configuration</td><td>within 0.6L amidship</td><td colspan="2">AH</td><td colspan="2">DH</td><td colspan="2">EH</td></tr>
<tr><td>cargo region 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 within 0.4L amidship</td><td colspan="3">AH</td><td colspan="2">DH</td><td>EH</td></tr>
<tr><td>Deck plating exposed to weather, in general</td><td colspan="2">within 0.4L amidship</td><td colspan="5">AH</td><td>DH</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="3">AH</td><td colspan="2">DH</td><td>EH</td></tr>
<tr><td>Other than those mentioned above</td><td colspan="2">within 0.4L amidship</td><td colspan="5">AH</td><td>DH</td></tr>
</table>

<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≤15</th><th>15<t≤20</th><th>20<t≤25</th><th>25<t≤30</th><th>30<t≤40</th><th>40<t≤50</th></tr>
<tr><td colspan="9">Longitudinals</td></tr>
<tr><td>Upper strake in sloping plate of topside tank adjoining to strength deck</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="4">Longitudinal plating members above strength deck</td><td rowspan="2">corners of dome openings on trunk deck and inner deck plating above strength deck in ships with membrane tanks carrying liquefied gases in bulk</td><td>within 0.6L amidship</td><td colspan="2">*AH*</td><td colspan="2">*DH*</td><td colspan="2">*EH*</td></tr>
<tr><td>cargo region excluding the above</td><td colspan="3">*AH*</td><td colspan="2">*DH*</td><td>*EH*</td></tr>
<tr><td>longitudinal girders including end brackets and face plates</td><td>within 0.4L amidship</td><td colspan="3">*AH*</td><td colspan="2">*DH*</td><td>*EH*</td></tr>
<tr><td>longitudinal plating members other than those mentioned above</td><td>within 0.4L amidship</td><td colspan="3">*AH*</td><td colspan="2">*DH*</td><td>*EH*</td></tr>
<tr><td colspan="9">Cargo Hatch</td></tr>
<tr><td rowspan="3">Cargo hatch coaming longitudinally extended on the strength deck</td><td rowspan="3">longitudinal members over 0.15L (including face plate and its flange, but excluding other stiffeners) and end brackets and deck house transition</td><td>within 0.4L amidship</td><td colspan="4">*DH*</td><td colspan="2">*EH*</td></tr>
<tr><td>within 0.6L amidship excluding the above</td><td colspan="5">*DH*</td><td>*EH*</td></tr>
<tr><td>other than those mentioned above</td><td colspan="6">*DH*</td></tr>
<tr><td>Hatch cover</td><td colspan="2">top plates, bottom plates and primary supporting members</td><td colspan="5">*AH*</td><td>*DH*</td></tr>
<tr><td colspan="9">Stern</td></tr>
<tr><td>Stern frame, rudder horn, rudder trunk, shaft bracket</td><td colspan="2">—</td><td colspan="3">*AH*</td><td colspan="2">*DH*</td><td>*EH*</td></tr>
<tr><td colspan="9">Rudder</td></tr>
<tr><td>Rudder plate</td><td colspan="2">—</td><td colspan="3">*AH*</td><td colspan="2">*DH*</td><td>*EH*</td></tr>
<tr><td colspan="9">Other</td></tr>
<tr><td colspan="3">Other members than those mentioned above (including stiffeners)</td><td colspan="6">*AH*</td></tr>
</table>

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 distance (m) measured on the waterline at the scantling draught d_S from the forward side of the stem to the centre of the rudder stock. L_1 is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught d_S. In ships without rudder stocks (e.g. ships fitted with azimuth thrusters), the Rule length L_1 is to be taken equal to 97% of the extreme length on the waterline at the scantling draught d_S.
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 is as follows.
   (1) If the point where the bottom flat line stops being parallel to the centre line of the ship is within 0.6L amidships, the applicable part is to be taken as 0.6L amidships.
   (2) If the point where the bottom flat line stops being parallel to the centre line of the ship is outside 0.6L 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.

1.1.12 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 C1.1** and **Table C1.2**.

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 C1.1** and **Table C1.2**. 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.

4 For ships other than liquefied gas carriers, intended to be loaded with cold liquid cargoes, the application of steels used for cargo tank boundary plating is to be suitable for the design minimum cargo temperature, regardless of the requirements specified in **Table C1.1** and **Table C1.2**. In this case, the design minimum cargo temperature (T_C) of the cold liquid cargoes is to be determined.

1.1.13 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 **2.1.9** and **2.1.10, Part A** respectively.

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

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

Where:

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

t: Thickness (mm) of web plate

7 Scantlings of stiffeners based on requirements in this Part may be decided based on the concept of grouping designated sequentially placed stiffeners of equal scantlings. The scantling of the group is to be taken as the greater of the values obtained from the following requirements **(1)** and **(2)**. However, this requirement is not applicable to fatigue requirements as given in **1.1.23-4**.

(1) the average of the required scantling of all stiffeners within a group

(2) 90% of the maximum scantling required for any one stiffener within the group.

1.1.14 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.

1.1.15 Brackets

1 The size of brackets is to be determined by **Table C1.3** according to the length of the longer arm.

2 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.

3 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.

4 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 C1.3 Brackets (Unit: *mm*)

Length of longer arm	Thickness		Breadth flange	Length of longer arm	Thickness		Breadth of 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				

1.1.16 Modification of Span (l) for Thicker Brackets

Where brackets are not thinner than the girder plates, the value of l specified in **Chapter 8** and **Chapters 11** to **14** 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.

(5) 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.

1.1.17 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 M**.

7 Jigs used for welding and construction work are to be appropriately treated (i.e., removed, smoothened out, etc.) upon completion of concerned work in order to avoid any adverse effects on strength.

1.1.18 Docking

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

1.1.19 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.

1.1.20 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 29**.

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

1.1.21 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.

2 Where the scantlings are reduced in accordance with **-1**, the notation "*CoC*" will be entered in the Classification Register.

1.1.22 Direct Calculations*

1 Where approved by the Society, direct calculations may be used to determine the scantlings of primary members. Where the scantlings determined based upon direct calculation exceed the scantlings required in this Chapter, the former is to be adopted.

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.

3 Where direct calculations specified in **-1** above are used, the data necessary for the calculations are to be submitted to the Society.

1.1.23 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.

1.1.24 Ship Identification Number*

1 For cargo ships not less than 300 *gross tonnage* 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 **2.1.33, Part A**, 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 R**, 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 M** 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 M**. 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.

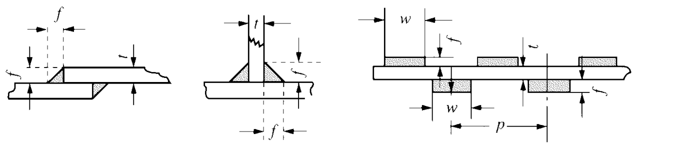
3 The kind and size of fillet welds are to be in accordance with **Table C1.4** and their application to the hull construction is to be as required by **Table C1.5**. In tankers, they are also to be in accordance with **Table C29.20**.

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 C1.4** and the spacing of the slots is to be as determined by the Society.

5 In the case of a cross-joint where high in-plane loads act upon the attached plate and are transmitted through the weld and the intermediate plate (see **Fig. C1.3**), differences in thickness are to be taken into account and special consideration is to be given to measures such as appropriately increasing the fillet weld leg length, providing a groove, etc. in order to avoid any excessive stress concentrations.

Table C1.4 Kinds and Sizes of Fillet Welds

(Unit: *mm*)

Kind of fillet weld / Thickness of members	 Lap joint, Tee joint, Measurement of weld length and pitch					
	Continuous fillet weld		Intermittent fillet weld			
	Size of fillet *f*		Size of fillet *f*	Length of fillet *w*	Pitch *p*	
	*F*1	*F*2			*F*3	*F*4
Up to 5	3	3	3	60	150	250
6	4		4	75	200	350
7	5	4	5			
8						
9	6		6			
10						
11						
12	7	5	7			
13						
14						
15	8	6	8			
16						
17						
18	9	7	9			
19						
20						
21						
22	10		10			
23						
24						
25						
From 26 to 40	11	8	11			

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 *F*1 determined according to the thickness of the thinner plate.

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

4 Generally, *F*2 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 C1.5 Application of Fillet Welds

Line No.	Item			Application		Kind of weld
1	Rudders	Rudder frames		Rudder plates		$F3$
2				Vertical frames forming main pieces		$F1$
3				Rudder frames (except above)		$F2$
4	Single bottoms	Floor plates		Shell plates	In strengthened bottom forward, after peaks and deep tanks	$F3$
5					Elsewhere	$F4$
6				Face plates of floor plates	In strengthened bottom forward and main engine room	$F3$
7					Elsewhere	$F4$
8				Through plates and rider plates of centre keelsons		$F1$
9		Centre keel-sons	Girders	Flat plate keels	In strengthened bottom forward	$F2$
10					Elsewhere	$F3$
11				Rider plates		$F3$
12				Floor plates		$F2$
13		Side keel-sons	Girders	Shell plates	In strengthened bottom forward	$F3$
14					Elsewhere	$F4$
15				Rider plates	In main engine rooms	$F3$
16					Elsewhere	$F4$
17				Floor plates		$F3$
18	Double bottoms with transverse framing	Solid floors		Shell plates	In strengthened bottom forward	$F3$
19					Elsewhere	$F4$
20				Inner bottom plates	Bed plates of main engine and thrust bearings	$F2$
21					In strengthened bottom forward and main engine room (except above)	$F3$
22					Elsewhere	$F4$
23				Girders under inner bottom below main engine seatings		$F1$
24				Centre girders	In strengthened bottom forward and main engine room (except above)	$F2$
25					Elsewhere	$F3$
26				Margin plates		$F2$
27		Oiltight or watertight floors		Boundaries		$F1$
28		Stiffeners on floor plates		Oiltight and watertight floors		$F3$
29				Elsewhere		$F4$

Line No.	Item			Application		Kind of weld
30	Double bottoms with transverse framing	Open floors	Frames	Shell plates		*F*4
31			Reverse frames	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 and solid floors are as required for side 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 inner 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 centre 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

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 beams	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	Bulkhead plates	Above the lower ends of brackets connecting stiffeners to deck girder	*F*1
78				In deep tank bulkheads	*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 engines, 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 connections 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>
<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 girder plates</td><td rowspan="2">Webs or face plates of webs</td><td rowspan="2">Elsewhere</td><td>Where face area exceeds 65 cm^2</td><td>$F2$</td></tr>
<tr><td>90</td><td>Where face area does not exceed 65 cm^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 C1.4** 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. C1.4**(a). Where the members are backed by other members at the opposite side as shown in **Fig. C1.4** (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. C1.4** (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.

6 In cases where the bulkheads of compartments intended to carry liquid cargoes are corrugated bulkheads, the welding of the corrugated bulkheads is to be in accordance with the requirements given in **14.4**. In cases where the bulkheads of compartments not intended to carry liquids cargo are corrugated bulkheads, the kind of fillet weld used for the corrugated bulkhead is to be in accordance with the requirements for bulkheads.

Fig. C1.3 Example of Cross-joint

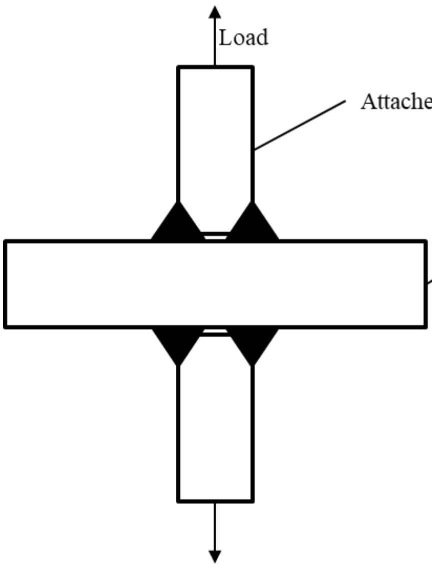
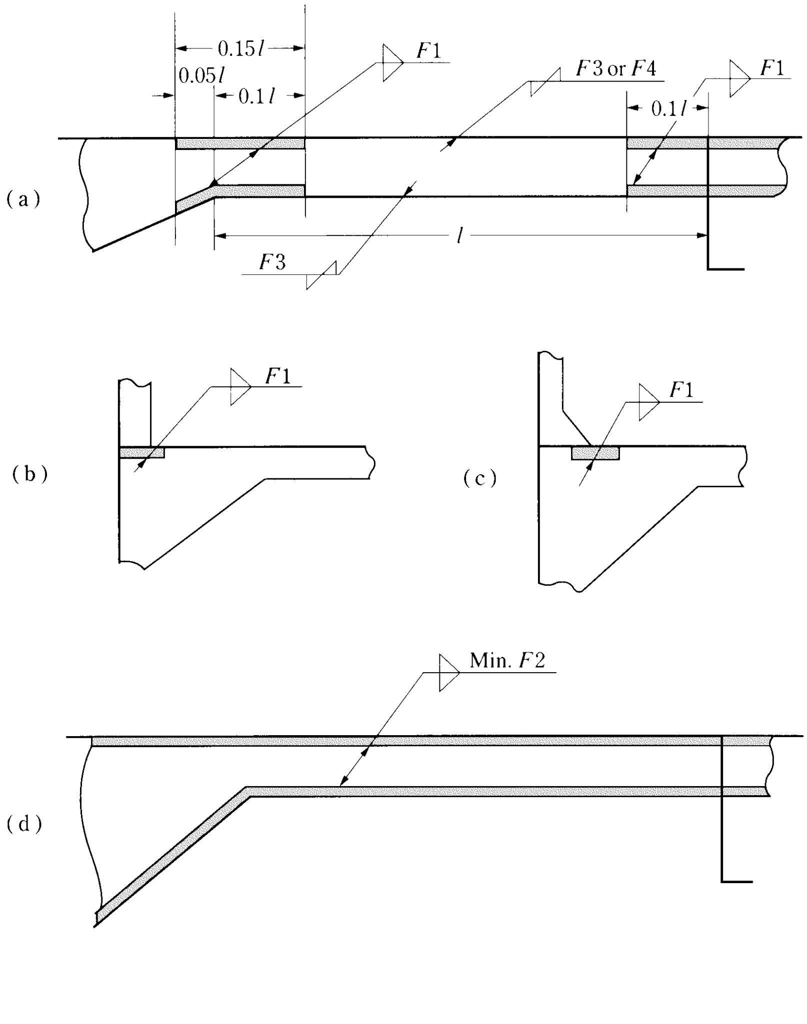


Fig. C1.4 Parts of Continuous Fillet Weld



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.

$$1.5\sqrt{L-50}+3.0 \ (mm)$$

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. C2.1**. 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.

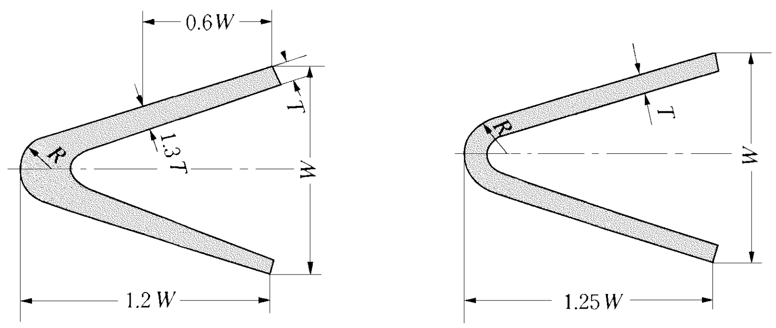
2 The thickness of the boss of the propeller post is not to be less than that obtained from the following formula:

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

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, the scantlings of various parts of propeller posts are to be suitably increased.

Fig. C2.1 Standard Dimensions of Propeller Posts



W: $2.2L+88$ (mm)
T: $0.18L+15$ (mm)
R: $0.40L+16$ (mm)

Propeller Post of
Cast Steel Stern Frame

W: $2.5L+100$ (mm)
T: $2.2\sqrt{L}+5.0$ (mm)
R: $0.40L+16$ (mm)

Propeller Post of
Steel Plate Stern Frame

2.2.3 Shoe Pieces*

1 The scantling of each cross-section of the shoe piece (*See* **Fig. C2.2**) is to be determined by the following formulae **(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.

$M = Bx \ (M_{\max} = Bl) \ (N\text{-}m)$

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. C2.2**

l: Distance (m) from the mid-point of the pintle bearing to the fixed point of the shoe piece, as specified in **Fig. C2.2**

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 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 l is the equivalent stress to exceed $115/K_{SP}$ (N/mm^2). The equivalent stress σ_e is to be obtained from the following formula:

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

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

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

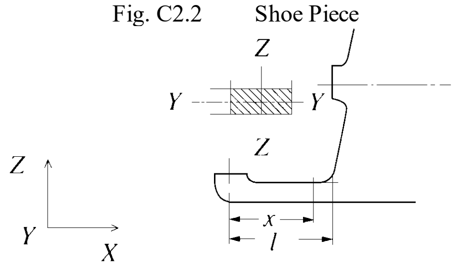
Shear stress: $\tau = \dfrac{B}{A_S} \ (N/mm^2)$

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. C2.2 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 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:

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

Where:

M: Bending moment at the section considered as deemed appropriate by the Society.

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:

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

Where:

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

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

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

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

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

The bending stress, shear stress and torsional stress acting on the rudder horn are to be at the discretion of the Society.

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.

4 The thickness of the rudder horn side plating is not to be less than:

$$2.4\sqrt{L_1 K_{rh}} \ (mm)$$

L_1: Distance (m) measured on the waterline at the scantling draught d_S from the forward side of the stem to the centre of the rudder stock. L_1 is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught d_S. In ships without rudder stocks (e.g. ships fitted with azimuth thrusters), the Rule length L_1 is to be taken equal to 97% of the extreme length on the waterline at the scantling draught d_S.

d_S: Scantling draught (m) at which the strength requirements for the scantlings of the ship are met and represents the full load condition. d_S is to be not less than that corresponding to the assigned freeboard.

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

5 Connection to hull structure

The rudder horn plating is to be effectively connected to the aft ship structure, e.g. by connecting the plating to side shell and transverse/longitudinal girders, in order to achieve a proper transmission of forces (*See* **Fig.C2.3**).

Brackets or stringer are to be fitted internally in horn, in line with outside shell plate (*See* **Fig.C2.3**) except in cases where not practicable.

Transverse webs of the rudder horn are to be led into the hull up to the next deck in a sufficient number.

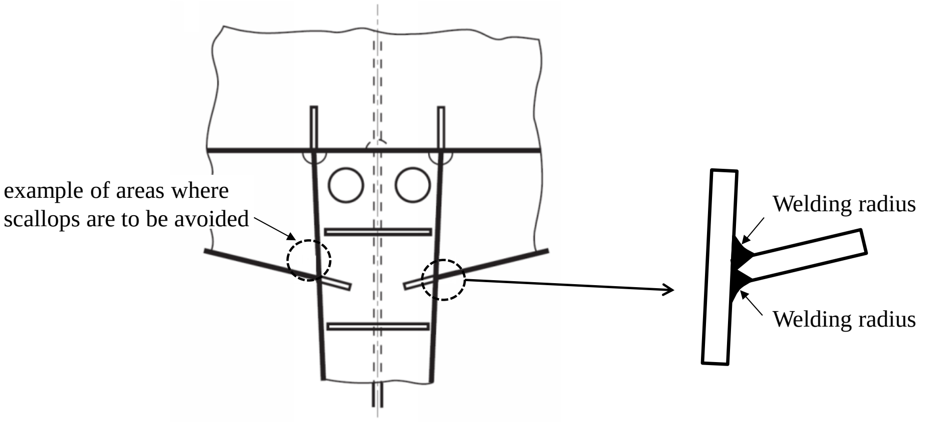
Strengthened plate floors are to be fitted in line with the transverse webs in order to achieve a sufficient connection with the hull.

The centre line bulkhead (wash-bulkhead) in the after peak is to be connected to the rudder horn.

Scallops are to be avoided in way of the connection between transverse webs and shell plating (*See* **Fig.C2.3**).

The weld at the connection between the rudder horn plating and the side shell is to be full penetration. The welding radius is to be as large as practicable and may be obtained by grinding (*See* **Fig.C2.3**).

Fig. C2.3 Connection of rudder horn to aft ship structure



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 **3.1.5**, 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)

2.2.8 Rudder trunk

1 The requirements of this paragraph apply to trunk configurations which are extended below stern frame and arranged in such a way that the trunk is stressed by forces due to rudder action.

2 Materials, welding and connection to hull

The steel used for the rudder trunk is to be of weldable quality, with a carbon content not exceeding 0.23% on ladle analysis or a carbon equivalent C_{EQ} not exceeding 0.41%.

The weld at the connection between the rudder trunk and the shell or the bottom of the skeg is to be full penetration.

For rudder trunks extending below shell or skeg, the fillet shoulder radius r (mm) (*See* **Fig. C2.4**) is to be as large as practicable and to comply with the following formulae:

$r = 0.1d_l/K_T$

without being less than:

$r = 60$ when $\sigma \geq 40 / K_T$ (N/mm^2)

$r = 30$ when $\sigma < 40 / K_T$ (N/mm^2)

Where

d_l: rudder stock diameter axis defined in **3.5.2**.

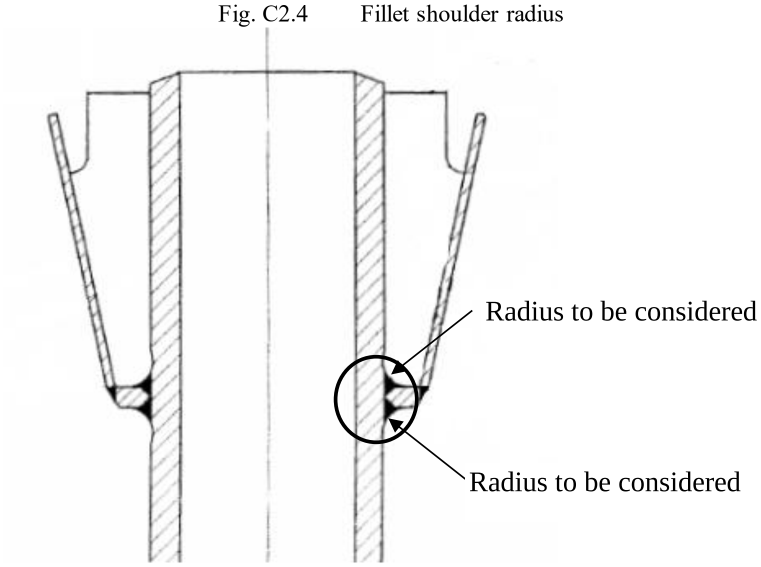
σ: bending stress in the rudder trunk (N/mm^2).

K_T: material factor for the rudder trunk as given in **3.1.2**.

The radius may be obtained by grinding. If disk grinding is carried out, score marks are to be avoided in the direction of the weld. The radius is to be checked with a template for accuracy. Four profiles at least are to be checked. A report is to be submitted to the Surveyor.

Rudder trunks comprising of materials other than steel are to be specially considered by the Society.

Fig. C2.4 Fillet shoulder radius



3 Scantlings

The scantlings of the trunk are to be such that:

- the equivalent stress due to bending and shear does not exceed $0.35\,\sigma_Y$,
- the bending stress on welded rudder trunk is to be in compliance with the following formula:

  $\sigma \leq 80 / K_T$ (N/mm^2)

  with:

  σ: As defined in **-2**.

  K_T: Material factor for the rudder trunk as given in **3.1.2**, not to be taken less than 0.7

  σ_Y: Specified minimum yield stress (N/mm^2) of the material used

For calculation of bending stress, the span to be considered is the distance between the mid-height of the lower rudder stock bearing and the point where the trunk is clamped into the shell or the bottom of the skeg.

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. C3.1** (*A*))

(2) Type *B*: Rudders with neck bearing and bottom pintle (*See* **Fig. C3.1** (*B*))

(3) Type *C*: Rudders having no bearing below the neck bearing (*See* **Fig. C3.1** (*C*))

(4) Type *D*: Mariner type rudders with neck bearing and pintle, of which lower end is fixed (*See* **Fig. C3.1** (*D*))

(5) Type *E*: Mariner type rudders with two pintles, of which lower ends are fixed (*See* **Fig. C3.1** (*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 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 K**.

2 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 **1.1.7-2(1)**.

3 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 K**.

4 For rudder stocks, pintles, coupling bolts, keys, and edge bars, the specified minimum yield stress is not to be less than $200 N/mm^2$. The requirements in this Chapter are for materials with a specified minimum yield stress of $235 N/mm^2$. If materials having a specified minimum 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: Specified minimum 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

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

3.1.3 Welding and Design Details

1 Slot welding is to be limited as far as possible. Slot welding is not to be used in areas with large in-plane stresses transversely to the slots or in way of cut-out areas of Type *A*, *D* and *E* rudders.

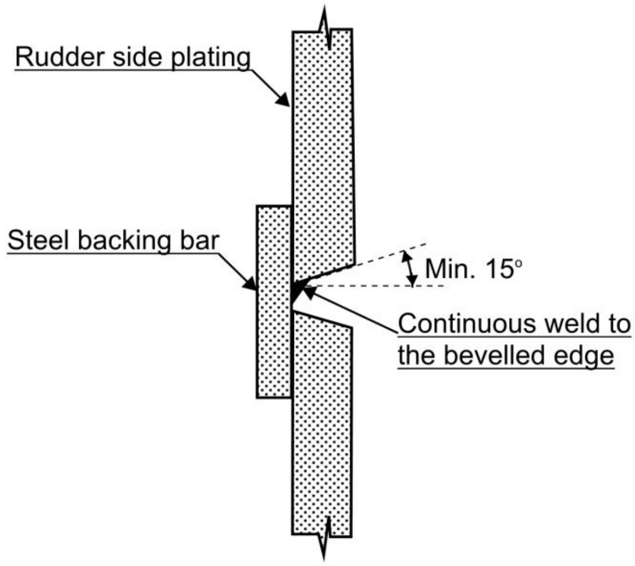
When slot welding is applied, the length of slots is to be minimum 75 *mm* with breadth of $2t$, where t is the rudder plate thickness (*mm*). The distance between ends of slots is not to be more than 125 *mm* (*See* **Fig. C3.2**). The slots are to be fillet welded around the edges and filled with a suitable compound, e.g. epoxy putty. Slots are not to be filled with weld.

Continuous slot welds may be used in lieu of slot welds. When continuous slot welding is applied, the root gap is to be between 6-10 *mm*. The bevel angle is to be at least 15° (*See* **Fig. C3.2**).

2 In way of the rudder horn recess of Type *A*, *D* and *E* rudders the radii in the rudder plating (except in way of solid part in cast steel) are not to be less than 5 *times* the plate thickness, but in no case less than 100 *mm*. Welding in side plate are to be avoided in or at the end of the radii. Edges of side plate and weld adjacent to radii are to be ground smooth.

3 Welds in the rudder side plating subjected to significant stresses from rudder bending, and welds between plates and heavy pieces (solid parts in forged or cast steel or very thick plating) are to be made as full penetration welds. In way of highly stressed areas e.g. cut-out of Type *A*, *D* and *E* rudders and upper part of Type *C* rudders, cast or welding on ribs is to be arranged. Two sided full penetration welding is normally to be arranged. Where back welding is impossible, one side welding using steel backing bars is, in principle, to be performed. In such cases, one-sided continuous welding is to be used to weld the steel backing bars to bevelled edge (*See* **Fig. C3.3**). The bevel angle is to be at least 15 *degrees* for one sided welding. Other welding procedures, however, may be approved when deemed appropriate by the Society.

Fig. C3.3 Use of Steel Backing Bar in way of Full Penetration Welding of Rudder Side Plating



4 Requirements for welding and design details of rudder trunks are described in **2.2.8**.

5 Requirements for welding and design details when the rudder stock is connected to the rudder by horizontal flange coupling are described in **3.8.1-5**.

6 Requirements for welding and design details of rudder horns are described in **2.2.5-5**.

3.1.4 Equivalence

1 The Society may accept alternatives to requirements given in this Chapter, provided they are deemed to be equivalent.

2 Direct analyses adopted to justify an alternative design are to take into consideration all relevant modes of failure, on a case by case basis. These failure modes may include, amongst others: yielding, fatigue, buckling and fracture. Possible damages caused by cavitation are also to be considered.

3 If deemed necessary by the Society, lab tests, or full scale tests may be requested to validate the alternative design approach.

3.1.5 Increase in Diameter of Rudder Stocks for Special Cases

1 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.

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

3.1.6 Sleeves and Bushes

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

Fig. C3.1

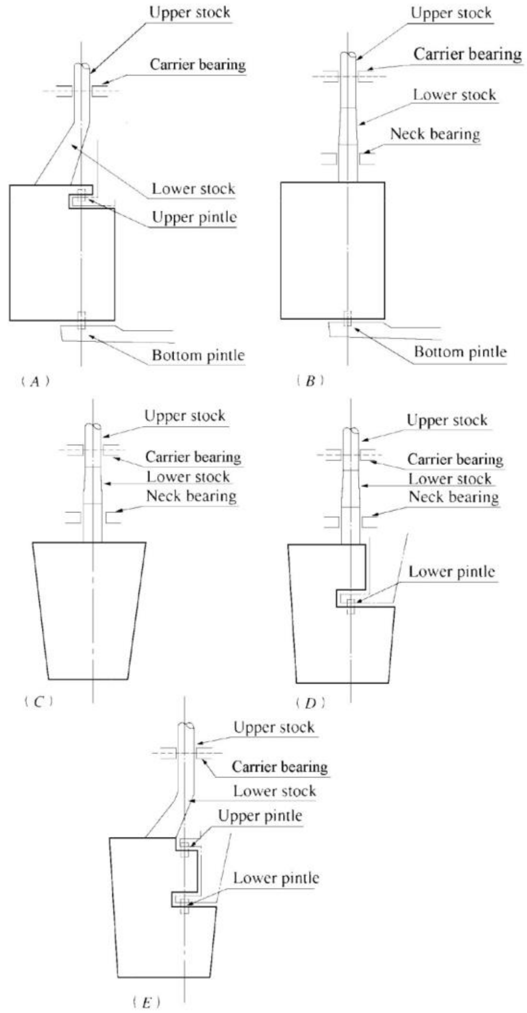
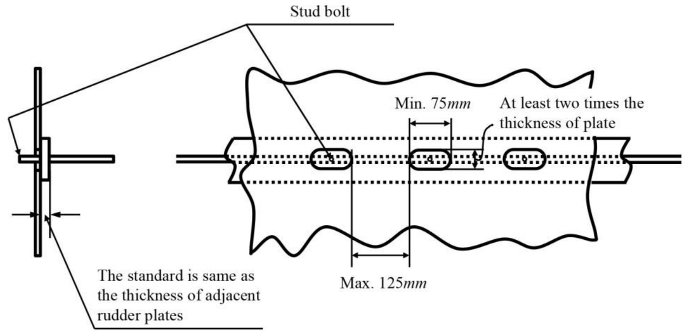
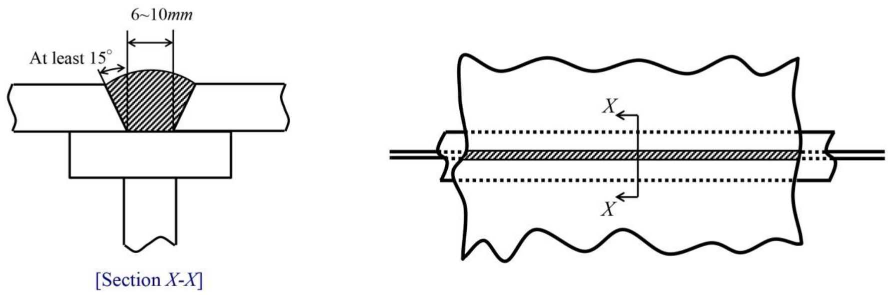


Fig. C3.2 Slot welding and Continuous Slot Welding



Note: The standard leg length of slot welding is F_1.

(a) Slot Welding



(b) Continuous Slot Welding

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.

$$F_R = 132K_1K_2K_3AV^2 \ (N)$$

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 as defined in **2.1.30, Part 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.

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

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

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

h: Mean height of rudder (m), which is determined according to the coordinate system in **Fig. C3.4**

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 C3.1**)

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. C3.4 Coordinate System of Rudders

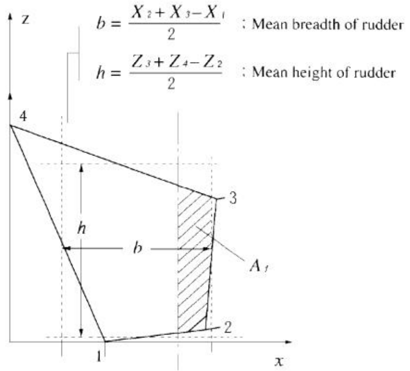
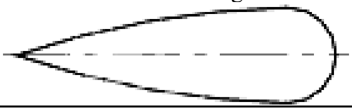
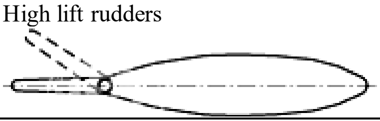
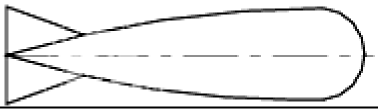


Table C3.1 Factor K_2

Profile Type	K_2	
	Ahead condition	Astern condition
NACA-00 series Göttingen 	1.10	0.80
Flat side 	1.10	0.90
Hollow 	1.35	0.90
High lift rudders 	1.70	1.30
Fish tail 	1.40	0.80
Mixed profiles (e.g. HSVA)	1.21	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.

$T_R = F_R r$ $(N\text{-}m)$

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. C3.4**

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.

$e : \dfrac{A_f}{A}$

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:

$$T_R = T_{R1} + T_{R2} \quad (N\text{-}m)$$

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

$$T_{R\min} = 0.1 F_R \frac{A_1 b_1 + A_2 b_2}{A} \quad (N\text{-}m)$$

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. C3.5. A_{1f} and A_{2f} are areas situated ahead of the centreline of the rudder stock.

b_1 and b_2: Mean breadth (m) of portions A_1 and A_2 determined by applying Fig. C3.4.

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.

$$T_{R1} = F_{R1} r_1 \quad (N\text{-}m)$$

$$T_{R2} = F_{R2} r_2 \quad (N\text{-}m)$$

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

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

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

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.

$$r_1 = b_1(\alpha - e_1) \quad (m)$$

$$r_2 = b_2(\alpha - e_2) \quad (m)$$

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

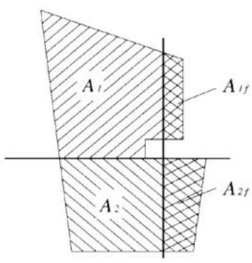
For astern condition: 0.66

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. C3.5 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 dose 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.

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

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

Bending stress: $\sigma_b = \dfrac{10.2M}{d_l^3} \times 10^3\ \ (N/mm^2)$

Torsional stress: $\tau_t = \dfrac{5.1T_R}{d_l^3} \times 10^3\ \ (N/mm^2)$

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 d_l may be determined by the following formula:

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

Where:

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

For a spade rudder with trunk extending inside the rudder, the rudder stock scantlings are to be checked against the following two cases:

(1) pressure applied on the entire rudder area; and

(2) pressure applied only on rudder area below the middle of neck bearing.

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:

$$t = 5.5S\beta\sqrt{\left(d_s + \frac{F_R \times 10^{-4}}{A}\right)K_{p1}} + 2.5 \ (mm)$$

Where:

d_s: Scantling draught (m) (*See* **15.2.1-1**)

A and 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 exceed 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

The rudder plating in way of the solid part is to be of increased thickness per **3.7.4**.

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 **3.6.1**, 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 centre 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 centreline 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.

(1) In general, except in way of rudder recess sections where **(2)** applies

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

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

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

Where:

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

(2) In way of the recess for the rudder horn pintle on Type A, D and E rudders

Bending stress: $\sigma_b = 75$ (N/mm^2)

Shear stress: $\tau = 50$ (N/mm^2)

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

Note: The stresses in **(2)** apply equally to high tensile and ordinary steels.

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

5 Maintenance openings 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 Connections of Rudder Blade Structure with Solid Parts

3.7.1 Solid Part Protrusions

Solid parts in forged or cast steel, which house the rudder stock or the pintle, are to be provided with protrusions, except where not required as indicated below.

These protrusions are not required when the web plate thickness is less than:

- 10 *mm* for web plates welded to the solid part on which the lower pintle of Type *A*, *D* and *E* rudders is housed and for vertical web plates welded to the solid part of the rudder stock coupling of Type *C* rudders.
- 20 *mm* for other web plates.

3.7.2 General

The solid parts are in general to be connected to the rudder structure by means of two horizontal web plates and two vertical web plates.

3.7.3 Minimum Section Modulus of the Connection with the Rudder Stock Housing

The section modulus of the cross-section of the structure of the rudder blade (cm^3) formed by vertical web plates and rudder plating, which is connected with the solid part where the rudder stock is housed is to be not less than:

$$c_S d_l^3 \left(\frac{H_E - H_X}{H_E}\right)^2 \frac{K_{pl}}{K_s} 10^{-4} \ (cm^3)$$

Where:

c_S : Coefficient, to be taken equal to:

$c_S = 1.0$ if there is no opening in the rudder plating or if such openings are closed by a full penetration welded plate

$c_S = 1.5$ if there is an opening in the considered cross-section of the rudder

d_l : Rudder stock diameter (mm)

H_E : Vertical distance between the lower edge of the rudder blade and the upper edge of the solid part (mm)

H_X : Vertical distance between the considered cross-section and the upper edge of the solid part (mm)

K_{pl} : Material factor for the rudder blade plating as given in **3.1.2**.

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

The actual section modulus of the cross-section of the structure of the rudder blade is to be calculated with respect to the symmetrical axis of the rudder. The breadth of the rudder plating (m) to be considered for the calculation of section modulus is to be not greater than:

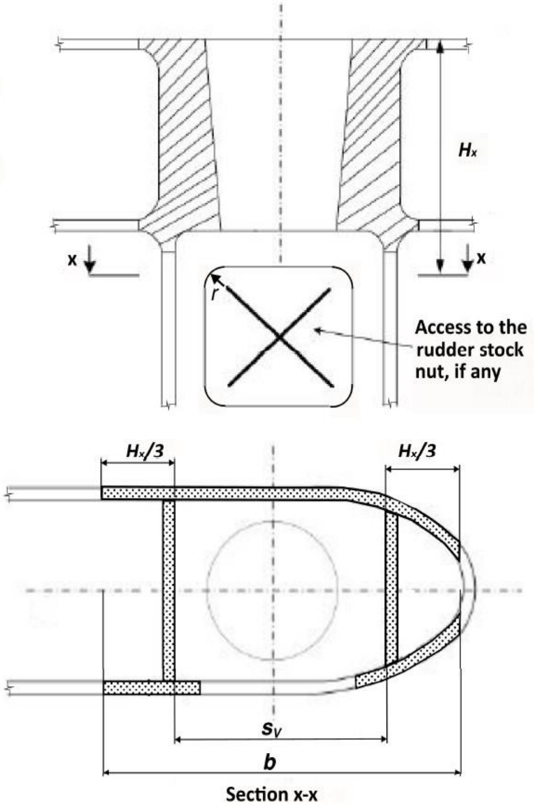
$$b = s_V + 2\frac{H_X}{3}$$

Where:

s_V : spacing between the two vertical webs (m) (*See* **Fig. C3.6**)

Where openings for access to the rudder stock nut are not closed by a full penetration welded plate, they are to be deducted (*See* **Fig. C3.6**).

Fig. C3.6 Cross-section of the Connection between rudder blade structure and rudder stock housing (in cases where there is an opening on only one side)



3.7.4 Thickness of the Horizontal Web Plates

The thickness of the horizontal web plates connected to the solid parts (mm), as well as that of the rudder blade plating between these webs, is to be not less than the greater of the following values:

$t_H = 1.2t$

$$t_H = 0.045\frac{d_S^2}{s_H}$$

Where:

t: As defined in **3.6.1**

d_S: Diameter (mm) to be taken equal to:

d_l for the solid part housing the rudder stock

d_p for the solid part housing the pintle

d_l: Rudder stock diameter (mm) defined in **3.5.2**

d_p: Pintle diameter (mm) defined in **3.9.1**

s_H: Spacing between the two horizontal web plates (mm).

The increased thickness of the horizontal webs is to extend fore and aft of the solid part at least to the next vertical web.

3.7.5 Thickness of the Vertical Web Plates

The thickness of the vertical web plates welded to the solid part where the rudder stock is housed as well as the thickness of the rudder side plating under this solid part is to be not less than the values obtained (mm) from **Table C3.2**.

The increased thickness is to extend below the solid piece at least to the next horizontal web.

Table C3.2 Thickness of Side Plating and Vertical Web Plates

Type of rudder	Thickness of vertical web plates (mm)		Thickness of rudder plating (mm)	
	Rudder blade without opening	Rudder blade with opening	Rudder blade without opening	Area with opening
Type A and B rudders	$1.2t$	$1.6t$	$1.2t$	$1.4t$
Type C, D and E rudders	$1.4t$	$2.0t$	$1.3t$	$1.6t$
t = thickness of the rudder plating, in mm, as defined in **3.6.1**				

3.8 Couplings between Rudder Stocks and Main Pieces

3.8.1 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**

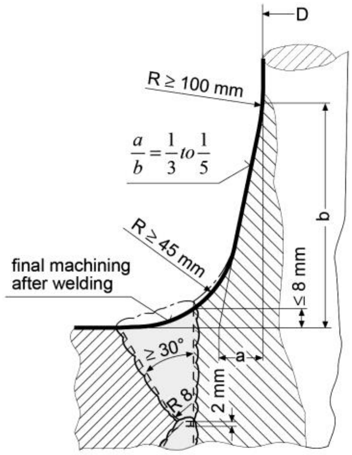
d_b: Bolt diameter (mm), determined by a number of bolts not exceeding 8

4 The width of the material between the perimeter of the bolt holes of the coupling flanges and the perimeter of the flange is not to be less than $0.67d_b$ (mm).

5 The welded joint between the rudder stock and the flange is to be made in accordance with **Fig.C3.7** or equivalent.

6 Coupling bolts are to be fitted bolts and their nuts are to be locked effectively.

Fig. C3.7 Welded Joint between Rudder Stock and Coupling Flange



3.8.2 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.

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

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: 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:

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

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

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

6 Coupling bolts are to be fitted bolts and their nuts are to be locked effectively.

3.8.3 Cone Couplings with Key*

1 Tapering and coupling length

Cone couplings that are mounted or dismounted without hydraulic arrangements (e.g. oil injection and hydraulic nut) are to have a taper c on diameter of 1:8～1:12. (*See* **Fig. C3.8** and **Fig. C3.10**)

Where:

$$c = (d_0 - d_u)/\ell_c$$

The diameters d_0 and d_u are shown in **Fig. C3.8** and the cone length ℓ_c is defined in **Fig. C3.10**.

The cone coupling is to be secured by a slugging nut. The nut is to be secured, e.g. by a securing plate.

The cone shapes are to fit exactly. The coupling length ℓ is to be, in general, not less than $1.5d_0$.

2 For couplings between stock and rudder a key is to be provided, the shear area of which is not to be less than:

$$a_s = \frac{17.55M_Y}{d_k\sigma_{Y1}}(cm2)$$

where:

M_Y : Design yield moment of rudder stock (N-m)

$$M_Y = 0.02664\frac{{d_u}^3}{K_S}$$

Where the actual diameter d_{ua} is greater than the calculated diameter d_u, the diameter d_{ua} is to be used. However, d_{ua} applied to the above formula need not be taken greater than 1.145 d_u.

d_u : Stock diameter (mm) according to 3.5.1

K_S : Material factor for stock as given in 3.1.2

d_k : Mean diameter of the conical part of the rudder stock (mm) at the key

σ_{Y1}: Specified minimum yield stress of the key material (N/mm^2)

The effective surface area (cm^2) of the key (without rounded edges) between key and rudder stock or cone coupling is not to be less than:

$$a_k = \frac{5M_Y}{d_k \sigma_{Y2}} (cm2)$$

Where:

σ_{Y2}: Specified minimum yield stress of the key, stock or coupling material (N/mm^2) whichever is less.

3 The dimensions of the slugging nut as specified in -1 are to be as follows (*See* Fig. C3.8):

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

Height: $h_n \geq 0.6 d_g$ (mm)

Outer diameter: $dn \geq 1.2 d_e$ or $1.5 d_g$ (mm), whichever is greater

4 It is to be proved that 50% of the design yield moment is solely transmitted by friction in the cone couplings. This can be done by calculating the required push-up pressure and push-up length according to 3.8.4-2 and -3 for a torsional moment $M_Y' = 0.5\,M_Y$.

5 Notwithstanding the provisions in -2 and -3 above, where a key is fitted to the coupling between stock and rudder, and it is considered that the entire rudder torque is transmitted by the key 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.

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

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

Fig. C3.8 Cone Coupling with Key

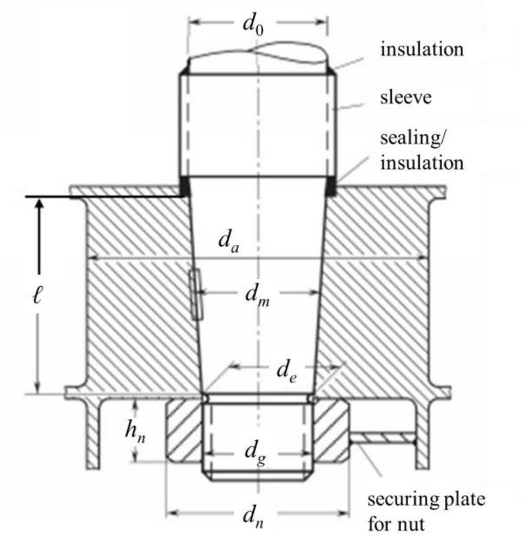


Fig. C3.9 Gudgeon Outer Diameter

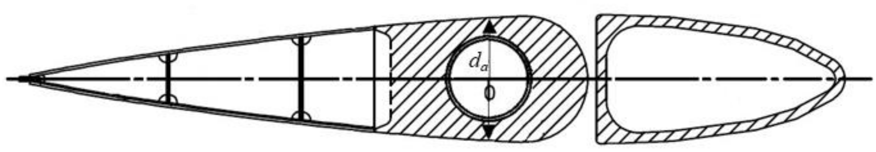


Fig. C3.10 Cone Length and Coupling Length

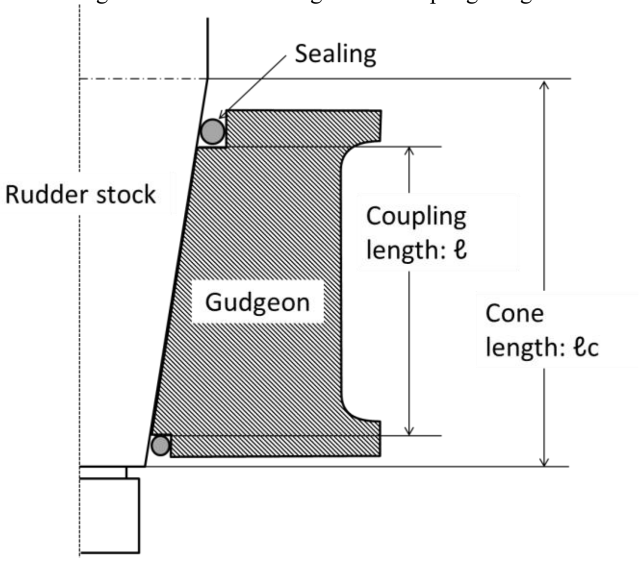
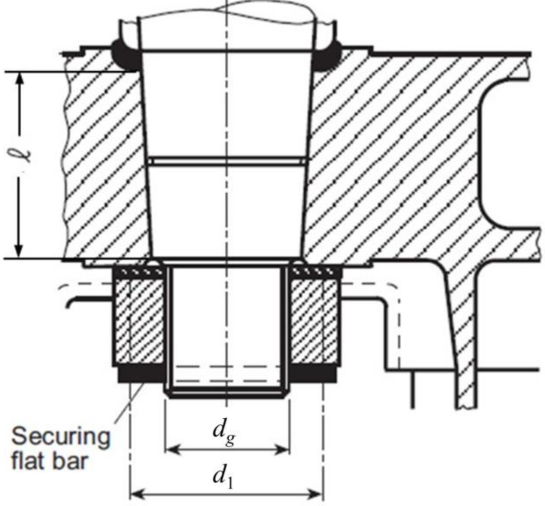


Fig. C3.11 Cone Coupling without Key



3.8.4 Cone Couplings with Special Arrangements for Mounting and Dismounting the Couplings

1 Where the stock diameter exceeds 200 *mm*, the press fit is recommended to be effected by a hydraulic pressure connection. In such cases the cone is to be more slender, c ≈1:12 to ≈1:20.

In case of hydraulic pressure connections the nut is to be effectively secured against the rudder stock or the pintle.

For the safe transmission of the torsional moment by the coupling between rudder stock and rudder body the push-up pressure and the push-up length are to be determined according to **-2** and **-3** respectively.

2 Push-up pressure

The push-up pressure is not to be less than the greater of the two following values:

$$p_{req1} = \frac{2M_Y}{d_m^2 \ell \pi \mu_0} 10^3 \qquad (N/mm2)$$

$$p_{req2} = \frac{6M_c}{\ell^2 d_m} 10^3 \qquad (N/mm2)$$

Where:

M_Y : Design yield moment of rudder stock, as defined in **3.8.3-2** (N-m)

d_m : Mean cone diameter (mm) (*See* **Fig. C3.8**)

ℓ : Coupling length (mm)

μ_0 : Frictional coefficient, equal to 0.15

M_c : Bending moment in rudder stock at the top of the cone coupling (e.g. in case of spade rudders) (N-m)

For spade rudder with trunk extending inside the rudder, the coupling is to be checked against the following two cases:

(1) pressure applied on the entire rudder area; and

(2) pressure applied only on rudder area below the middle of neck bearing.

It has to be proved by the designer that the push-up pressure does not exceed the permissible surface pressure in the cone. The permissible surface pressure is to be determined by the following formula:

$$p_{perm} = \frac{0.95\sigma_Y(1-\alpha^2)}{\sqrt{3+\alpha^4}} - p_b$$

$$p_b = \frac{3.5M_c}{d_m \ell^2} 10^3$$

Where:

σ_Y : Specified minimum yield stress (N/mm^2) of the material of the gudgeon

$$\alpha = \frac{d_m}{d_a}$$

d_m : Mean cone diameter (mm) (*See* **Fig. C3.8**)

d_a : Outer diameter of the gudgeon (*See* **Fig. C3.8** and **Fig. C3.9**. The least diameter is to be considered.) (mm)

The outer diameter of the gudgeon is not to be less than 1.25 d_0, with d_0 defined in **Fig. C3.8**.

3 Push-up length

The push-up length $\Delta\ell$ (mm) is to comply with the following formula:

$$\Delta\ell_1 \leq \Delta\ell \leq \Delta\ell_2$$

Where:

$$\Delta\ell_1 = \frac{p_{req} d_m}{E\left(\frac{1-\alpha^2}{2}\right)c} + \frac{0.8R_{tm}}{c}$$

$$\Delta\ell_2 = \frac{p_{perm} d_m}{E\left(\frac{1-\alpha^2}{2}\right)c} + \frac{0.8R_{tm}}{c}$$

R_{tm} : Mean roughness (mm) taken equal to about 0.01 mm

c : Taper on diameter according to **3.8.3-1**

E : Young's modulus (N/mm^2), to be taken as 2.06×10^5

Note: In case of hydraulic pressure connections the required push-up force P_e for the cone (N) may be determined by the following formula:

$$P_e = p_{req} d_m \pi \ell \left(\frac{c}{2} + 0.02\right)$$

The value 0.02 is a reference for the friction coefficient using oil pressure. It varies and depends on the mechanical treatment and roughness of the details to be fixed.

Where due to the fitting procedure a partial push-up effect caused by the rudder weight is given, this may be taken into account when fixing the required push-up length, subject to approval by the Society.

3.9 Pintles

3.9.1 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**

3.9.2 Construction of Pintles*

1 Tapering

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.

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

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

2 Push-up pressure for pintle

The required push-up pressure for pintle in case of dry fitting (N/mm^2) is to be determined by p_{req1} as given below. The required push-up pressure for pintle in case of oil injection fitting (N/mm^2) is to be determined by the maximum pressure of p_{req1} and p_{req2} as given below.

$$p_{req1} = 0.4\frac{Bd_0}{d_m^2 \ell}$$

$$p_{req2} = \frac{6M_{bp}}{\ell^2 d_m} \times 10^3 \ (N/mm^2)$$

Where:

B : As defined in **3.9.1**

d_m, ℓ : As defined in **3.8.4-2**

d_0 : Pintle diameter (mm) (*See* **Fig. C3.8**)

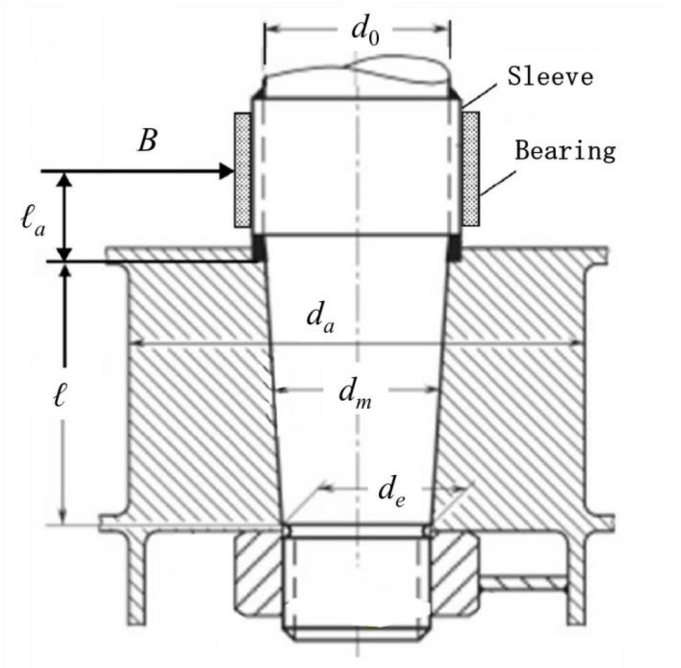
M_{bp}: bending moment in the pintle cone coupling (N-m) to be determined by:

$$M_{bp} = B\ell_a$$

ℓ_a: Length between middle of pintle-bearing and top of contact surface between cone coupling and pintle (m) (*See* **Fig. C3.12**)

The required push up length $\Delta\ell_1$ is to be calculated similarly as in **3.8.4-3**, using the required push-up pressure (as defined above) and properties for the pintle.

Fig. CS3.12 Pintle Cone Coupling Indicating ℓ_a



3 The minimum dimensions of the threads and the nuts of pintles are to be determined by applying the requirements in **3.8.3-3** correspondingly.

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

5 Pintles are to be properly protected from corrosion.

3.10 Bearings of Rudder Stocks and Pintles

3.10.1 Sleeves and Bushes

1 Rudder stock bearing

Sleeves and bushes are to be fitted in way of bearings. For rudder stocks and pintles having diameter less than 200 mm, sleeves in way of bushes may be provided optionally. The minimum thickness of sleeves and bushes is to be equal to:

- $t_{min} = 8\ mm$ for metallic materials and synthetic material
- $t_{min} = 22\ mm$ for lignum material

2 Pintle bearing

The thickness of any sleeve or bush is neither to be less than:

$$t = 0.01\sqrt{B}\ \ (mm)$$

Where:

B: As specified in **3.9.1**

nor than the minimum thickness defined in **-1**.

3.10.2 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.

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

Where:

B: As specified in **3.9.1**

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

The allowable surface pressure for the various bearing combinations is to be taken from **Table C3.3**. When verified by tests, however, values different from those in this Table may be taken.

Table C3.3 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 greater than 60 Shore D [1)]	5.5[2)]
Steel[3)], bronze and hotpressed bronze graphite materials	7.0

Notes:

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

2: Surface pressures exceeding 5.5 N/mm^2 may be accepted in accordance with bearing manufacturer's specification and tests, but in no case more than 10 N/mm^2.

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

3.10.3 Bearing Dimensions

The length/diameter ratio of the bearing surface is not to be greater than 1.2.

The bearing length L_p of the pintle is to be such that

$$d_{p0} \leq L_p \leq 1.2d_{p0}$$

Where:

d_{p0}: As specified in **2.2.7**

3.10.4 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 not to be taken as less than 1.5 mm on the bearing diameter unless a smaller clearance is supported by the manufacturer's recommendation and there is documented evidence of satisfactory service history with a reduced clearance.

3.11 Rudder Accessories

3.11.1 Rudder Carriers*

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.

3.11.2 Prevention of Jumping*

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

Chapter 4 SUBDIVISIONS

4.1 General

4.1.1 Application*

The requirements in this Chapter apply to cargo ships of not less than 500 *gross tonnage* engaged in international voyages and 80*m* in length for freeboard (L_f) and upwards. However, tankers specified in **Chapter 29** of this Part, ships to which the requirements in **Part N** or **Part S** apply and those ships specifically approved by the Society may be exempted.

4.1.2 Definitions*

For the purpose of this chapter, the following definitions apply.

(1) "Compartment" is a part of the hull formed by shells, decks and bulkheads which are to be watertight as a rule.

(2) "Group of compartments" is a part of the hull formed by two or more compartments which are adjacent with each other.

(3) "Deepest subdivision draught" (d_s) is the summer draught assigned to the ship in accordance with the requirements of **Part V**.

(4) "Light service draught" (d_l) is the service draught corresponding to the lightest anticipated loading and associated tankage, including, however, such ballast as may be necessary for stability and/or immersion. Passenger ships should include the full complement of passengers and crew on board.

(5) "Partial subdivision draught" (d_p) is the draught which corresponds to the summation of light service draught specified in **(4)** above and 60% of the difference between light service draught and the deepest subdivision draught.

(6) "Subdivision length of the ship" (L_s) is the greatest projected moulded length in metres of the ship at or below deck or decks limiting the vertical extent of flooding with the ship at the deepest subdivision draught.

(7) "Amidships" is at the middle of the length for freeboard (L_f).

(8) "Aft terminal" is the aft limit of L_s.

(9) "Forward terminal" is the forward limit of L_s.

(10) "Trim" is the difference between the draught forward and the draught aft, where the draughts are measured at the perpendiculars for the forward and aft ends of the length for freeboard (L_f), disregarding any rake of keel.

(11) "Breadth of ship" (B') is the greatest moulded breadth in metres of the ship at or below the deepest subdivision draught.

(12) "Draught" (d') is the vertical distance in metres from the keel line to the water line in question at amidships.

(13) "Permeability of a space" (μ) is the proportion of the immersed volume of that space (a compartment or group of compartments) which can be occupied by water. The value μ is shown in **Table C4.1-1** and **Table C4.1-2** according to the purpose of the space. However, in spaces intended for the carriage of liquid, the more stringent value of μ is to be taken when calculating the subdivision index in **4.2**. Where substantiated by calculations and specifically accepted by the Society, other figures for permeability specified in **Table C4.1-1** and **Table C4.1-2** may be used notwithstanding the provision above.

(14) "Internal opening" is the opening provided in decks or bulkheads forming a compartment excluding those that are completely exposed.

(15) "External opening" is the opening provided in shells, exposed decks or bulkheads forming a compartment.

(16) "Timber" means all types of wooden material covered by the *Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 2011* (*IMO* resolution *A*.1048(27)), including both round and sawn wood but excluding wood pulp and similar cargo.

(17) "Timber deck cargo" means a cargo of timber carried on an uncovered part of a freeboard or superstructure deck.

(18) "Machinery spaces" are spaces between the watertight boundaries of a space containing the main and auxiliary propulsion machinery, including boilers, generators and electric motors primarily intended for propulsion.

Table C4.1-1 Permeability of General Compartment

Space for	Locker	Accommodation	Machinery	Void	Liquid
Permeability	0.60	0.95	0.85	0.95	0 or 0.95

Table C4.1-2 Permeability of Cargo Compartment

Space for	Permeability at draught d_s	Permeability at draught d_p	Permeability at draught d_l
Dry cargo spaces	0.70	0.80	0.95
Container spaces	0.70	0.80	0.95
Ro-ro spaces	0.90	0.90	0.95
Cargo liquids	0.70	0.80	0.95

4.2 Subdivision Index

4.2.1 Subdivision Index*

1 The value of the Required Subdivision Index (R) is to be given by the following formula:

(1) In case $L_s > 100m$

$$R = 1 - \frac{128}{L_s + 152}$$

(2) In case $100m \geq L_s$

$$R = 1 - \left[1/\left(1 + \frac{L_s}{100} \cdot \frac{R_0}{1 - R_0}\right)\right]$$

R_0 : The value R as calculated in accordance with the formula in **(1)** above.

2 The Attained Subdivision Index (A) for the ship is to be not less than the Required Subdivision Index (R), calculated in accordance with **-1** above. A is obtained by the summation of the partial indices A_s, A_p and A_l, weighted as shown and calculated for the draughts d_s, d_p and d_l specified in **4.1.2(3)** to **(5)** in accordance with the following formula:

$$A = 0.4A_s + 0.4A_p + 0.2A_l$$

Each partial index is a summation of contributions from all damage cases taken in consideration, using the following formula:

$$A_x = \Sigma p_i \cdot s_i$$

Where, each partial index is not less than $0.5R$.

A_x: Each partial index correspond to draughts, d_s, d_p and d_l specified in **4.1.2(3)** to **(5)**.

p_i: Probability that a compartment or a group of compartments in question may be flooded (hereinafter referred to as "compartment flooding probability"), which is to be in accordance with the requirements in **4.2.2**.

s_i: Probability of survival after flooding a compartment or a group of compartments in question (hereinafter referred to as "survival probability"), which is to be in accordance with the requirements in **4.2.3**.

i: Indication of each compartment or group of compartments in question.

3 Partial index (A_x) is to be calculated under the following conditions:

(1) As a minimum, the calculation of A is to be carried out at level trim for the deepest subdivision draught and the partial subdivision draught. The estimated service trim may be used for the light service draught. If, in any anticipated service condition within the draught range from d_s to d_l, the trim variation in comparison with the calculated trim is greater than 0.005 L_f, one or more additional calculations of A are to be performed for the same draughts but including sufficient trims to ensure that, for all intended service conditions, the difference in trim in comparison with the reference trim used for one calculation will be not more than $0.005L_f$. Each additional calculation of A is to comply with **-2** above.

(2) All flooding in compartments and groups of compartments over the entire ship's length is to be taken into account.

(3) Assumed extent of hull damage is the following:

(a) Vertical extent is to be up to $d' + 12.5$ (m) from the baseline. However, if a lesser extent will give a more severe result, then such an extent is to be assumed.

(b) Horizontal extent of damage is measured inboard from Ship's side, at a right angle to the centreline at the level of the deepest subdivision draught and damage of the transverse extent greater than half breadth ($B'/2$) of the ship may be exempted. Where the ship has a compartment formed by longitudinal watertight bulkheads which are not on the ship's centreline, all damage which extend from the outmost compartment (hereinafter referred to as "wing compartment") to the ship's centreline are to be assumed.

(4) In the flooding calculations carried, only one breach of the hull damage need to be assumed and only one free surface need to be considered.

(5) In the case of unsymmetrical arrangements, the calculated A value is to the mean value obtained from calculations involving both sides. Alternatively, it is to be taken as that corresponding to the side which evidently gives the least favourable result.

(6) When determining the positive righting lever (GZ) of the residual stability curve in the intermediate and final equilibrium stages of flooding, the displacement for the intact loading condition is to be used. All calculations are to be done with the ship freely trimming.

4.2.2 Compartment Flooding Probability (p_i) *

1 The Compartment Flooding Probability (p_i) for a compartment or group of compartments is to be determined by the following **(1)**, **(2)** or **(3)** according to the number of damaged compartment.

(1) Where the damage involves a single zone only:

$$p_i = p(x1_j, x2_j) \cdot [r(x1_j, x2_j, b_k) - r(x1_j, x2_j, b_{k-1})]$$

Where:

$x1$: The distance (m) from the aft terminal of L_s to the aft end of the zone in question

$x2$: The distance (m) from the aft terminal of L_s to the forward end of the zone in question

b: The mean transverse distance (m) measured at right angles to the centreline at the deepest subdivision draught between the shell and an assumed vertical plane extended between the longitudinal limits used in calculating the factor p_i and which is a tangent to, or common with, all or part of the outermost portion of the longitudinal bulkhead under consideration. This vertical plane is to be so orientated that the mean transverse distance to the shell is a maximum, but not more than twice the least distance between the plane and the shell. If the upper part of a longitudinal bulkhead is below the deepest subdivision draught the vertical plane used for determination of b is assumed to extend upwards to the deepest subdivision waterline. In any case, b is not to be taken greater than $B'/2$.

j: The aftmost damage zone number involved in the damage starting with no.1 at the stern

k: The number of a particular longitudinal bulkhead as barrier for transverse penetration in a damage zone counted from shell towards the centre line. However, value of k according to side shell is to be taken as zero.

$p(x1, x2)$: It is specified in **-2**.

$r(x1, x2, b)$: It is specified in **-3**. However, $r(x1, x2, b_0)$ is to be taken as zero.

(2) Where the damage involves two adjacent zones:

$$\begin{aligned} p_i = {} & p(x1_j, x2_{j+1}) \cdot [r(x1_j, x2_{j+1}, b_k) - r(x1_j, x2_{j+1}, b_{k-1})] \\ & - p(x1_j, x2_j) \cdot [r(x1_j, x2_j, b_k) - r(x1_j, x2_j, b_{k-1})] \\ & - p(x1_{j+1}, x2_{j+1}) \cdot [r(x1_{j+1}, x2_{j+1}, b_k) - r(x1_{j+1}, x2_{j+1}, b_{k-1})] \end{aligned}$$

(3) Where the damage involves three or more adjacent zones:

$$\begin{aligned} p_i = {} & p(x1_j, x2_{j+n-1}) \cdot [r(x1_j, x2_{j+n-1}, b_k) - r(x1_j, x2_{j+n-1}, b_{k-1})] \\ & - p(x1_j, x2_{j+n-2}) \cdot [r(x1_j, x2_{j+n-2}, b_k) - r(x1_j, x2_{j+n-2}, b_{k-1})] \\ & - p(x1_{j+1}, x2_{j+n-1}) \cdot [r(x1_{j+1}, x2_{j+n-1}, b_k) - r(x1_{j+1}, x2_{j+n-1}, b_{k-1})] \\ & + p(x1_{j+1}, x2_{j+n-2}) \cdot [r(x1_{j+1}, x2_{j+n-2}, b_k) - r(x1_{j+1}, x2_{j+n-2}, b_{k-1})] \end{aligned}$$

n: The number of adjacent damage zones involved in the damage

2 The Compartment Flooding Probability (p_i) is to be determined by the following **(1)**, **(2)** or **(3)** according to longitudinal position of compartment under consideration.

(1) Where neither limits of the compartment or group of compartments under consideration coincides with the aft or forward terminals:

In case $J \leq J_k$:

$$p(x1, x2) = p_1 = \frac{1}{6} J^2 (b_{11} J + 3 b_{12})$$

In case $J > J_k$:

$$\begin{aligned} p(x1, x2) = p_2 = {} & -\frac{1}{3} b_{11} {J_k}^3 + \frac{1}{2}(b_{11} J - b_{12}) {J_k}^2 + b_{12} J J_k - \frac{1}{3} b_{21} ({J_n}^3 - {J_k}^3) \\ & + \frac{1}{2}(b_{21} J - b_{22})({J_n}^2 - {J_k}^2) + b_{22} J (J_n - J_k) \end{aligned}$$

J: Non-dimensional damage length given below:

$$J = \frac{(x2 - x1)}{L_s}$$

$x1$ and $x2$ are specified in **-1** above.

J_k: As given by the following formula:

In case $L_s \leq 260m$:

$$J_k = \frac{J_m}{2} + \frac{1 - \sqrt{1 - \frac{55}{6}J_m + \frac{121}{4}{J_m}^2}}{11}$$

$$J_m = \min\left\{\frac{10}{33}, \frac{60}{L_s}\right\}$$

In case $L_s > 260m$:

$$J_k = J_k^* \cdot \frac{260}{L_s}$$

$$J_k{}^* = \frac{J_m{}^*}{2} + \frac{1 - \sqrt{1 - \frac{55}{6}J_m{}^* + \frac{121}{4}J_m{}^{*2}}}{11}$$

Where: $J_m^* = 3/13$

$$J_m = \frac{60}{L_s}$$

b_{11}, b_{12}, b_{21} and b_{22}: Coefficient given by the following:

$$b_{11} = \frac{1}{6}\left(\frac{2}{(J_m - J_k)J_k} - \frac{11}{{J_k}^2}\right)$$

$$b_{12} = 11 \qquad \text{If } L_s \leq 260(m)$$

$$= \frac{1}{6}\left(\frac{11}{J_k} - \frac{1}{J_m - J_k}\right) \qquad \text{If } L_s > 260(m)$$

$$b_{21} = -\frac{1}{6}\frac{1}{(J_m - J_k)^2}$$

$$b_{22} = \frac{1}{6}\frac{J_m}{(J_m - J_k)^2}$$

J_n: Normalized length of a compartment or group of compartments is to be taken as the lesser of J and J_m.

(2) Where the aft limit of the compartment or group of compartments under consideration coincides with the aft terminal or the forward limit of the compartment or group of compartments under consideration coincides with the forward terminal:

In case $J \leq J_k$:

$$p(x1, x2) = \frac{1}{2}(p_1 + J)$$

In case $J > J_k$:

$$p(x1, x2) = \frac{1}{2}(p_2 + J)$$

$x1$, $x2$, p_1, p_2, J and J_k are specified in **(1)** above.

(3) Where the compartment or groups of compartments considered extends over the entire subdivision length (L_s):

$p(x1, x2) = 1$

$x1$ and $x2$ are specified in **(1)** above.

3 The factor $r(x1, x2, b)$ is to be determined by the following formulae:

$$r(x1, x2, b) = 1 - (1 - C) \cdot \left[1 - \frac{G}{p(x1, x2)}\right]$$

$x1$, $x2$ and b are specified in **-1** above.

C: Coefficient given by the following:

$$C = 12 \cdot J_b \cdot (-45 \cdot J_b + 4)$$

J_b: Coefficient given by the following:

$$J_b = \frac{b}{15 \cdot B'}$$

G: As given by the following formula:

Where the compartment or groups of compartments considered extends over the entire subdivision length (L_s):

$$G = G_1 = \frac{1}{2} b_{11} {J_b}^2 + b_{12} J_b$$

Where neither limits of the compartment or group of compartments under consideration coincides with the aft or forward terminals:

$$G = G_2 = -\frac{1}{3} b_{11} {J_0}^3 + \frac{1}{2}(b_{11}J - b_{12}){J_0}^2 + b_{12} J J_0$$

Where the aft limit of the compartment or group of compartments under consideration coincides with the aft terminal or the forward limit of the compartment or group of compartments under consideration coincides with the forward terminal:

$$G = \frac{1}{2} \cdot (G_2 + G_1 \cdot J)$$

b_{11}, b_{12} and J are specified in **-2** above.

J_0: Coefficient given by the following:

$$J_0 = \min(J, J_b)$$

4.2.3 Probability of Survival (s_i) *

1 The Probability of Survival (s_i) for any damage case at any initial loading condition is to be obtained from the formula:

$$s_i = \min\{s_{\text{intermediate,i}} \text{ or } s_{\text{final,i}}\}$$

$s_{\text{intermediate,i}}$: Probability to survive all intermediate flooding stages until the final equilibrium stage. It is calculated in accordance with **-2**.

$s_{\text{final,i}}$: Probability to survive in the final equilibrium stage of flooding. It is calculated in accordance with **-3**.

2 The factor $s_{\text{intermediate,i}}$ is to be obtained from the following formula.

(1) For cargo ships fitted with cross-flooding devices, the factor $s_{\text{intermediate,i}}$ is taken as the least of the values obtained from all flooding stages including the stage before equalization, if any, and is to be calculated as follows. Where the intermediate heel angle exceeds 30º, $s_{\text{intermediate,i}}$ is to be taken as 0.

$$s_{\text{intermediate,i}} = \left[\frac{GZ_{\max}}{0.05} \cdot \frac{Range}{7}\right]^{\frac{1}{4}}$$

$GZ_{\max}$: Maximum positive righting lever (m) up to angle θ_v. However, in calculations of $s_{\text{intermediate,i}}$, it is not to be taken as more than 0.05 m.

θ_v : Angle (°), at any stage of flooding, where the righting lever becomes negative, or the angle (°) at which an opening incapable of being closed weathertight becomes submerged.

$Range$: Range of positive righting levers (°) measured from angle θ_e. However, the positive range is to be taken up to angle θ_v and, in the calculations of $s_{\text{intermediate,i}}$, it is not to be taken as more than 7°.

θ_e : Equilibrium heel angle (°) at any stage of flooding.

(2) Where cross-flooding fittings are required, the time for equalization is not to exceed 10 min.

(3) For cargo ships not fitted with cross-flooding devices the factor $s_{\text{intermediate,i}}$ is taken as 1, except if the Administration considers that the stability in intermediate stages of flooding may be insufficient, it is to require further investigation thereof.

3 The factor $s_{\text{final,i}}$ is to be obtained from the following formula.

$$s_{\text{final,i}} = K \cdot \left[\frac{GZ_{\max}}{0.12} \cdot \frac{Range}{16}\right]^{\frac{1}{4}}$$

K: Coefficient given by the following:

$K = 1.0$ if $\theta_e \le \theta_{\min}$

$K = 0$if $\theta_e \ge \theta_{\max}$

$$K = \sqrt{\frac{\theta_{\max} - \theta_e}{\theta_{\max} - \theta_{\min}}} \quad \text{otherwise}$$

where, $\theta_{\min}$ is 25° and $\theta_{\max}$ is 30° for cargo ships.

θ_v : Angle (°), at any stage of flooding, where the righting lever becomes negative, or the angle (°) at which an opening incapable of being closed weathertight becomes submerged.

$GZ_{\max}$: As specified in -2 above. However, in the calculations of $s_{\text{final},i}$, it is not to be taken as more than 0.12 (m).

θ_e : Equilibrium heel angle (°) at any stage of flooding.

Range: As specified in -2 above. However, the positive range is to be taken up to angle θ_v and, in calculations of $s_{\text{final},i}$, it is not to be taken as more than 16°.

4 Where horizontal watertight boundaries are fitted above the waterline under consideration, the factor (s) calculated for the lower compartment or group of compartments is to be obtained by multiplying the value as determined in -1 above by the factor v_m given by following formula.

$$v_m = v(H_{j,n,m}, d') - v(H_{j,n,m-1}, d')$$

$H_{j,n,m}$: It is the least height (m) above the baseline within the longitudinal range of $x1_{(j)} \dots x2_{(j+n-1)}$ of the m-th horizontal boundary which is assumed to limit the vertical extent of flooding for the damaged compartments under consideration;

$H_{j,n,m-1}$: It is the least height (m) above the baseline within the longitudinal range of $x1_{(j)} \dots x2_{(j+n-1)}$ of the m-1-th horizontal boundary which is assumed to limit the vertical extent of flooding for the damaged compartments under consideration;

j, n, $x1$ and $x2$ are specified in 4.2.2-1.

m: It is each horizontal boundary counted upwards from the waterline under consideration;

$v(H_{j,n,m}, d')$ and $v(H_{j,n,m-1}, d')$: Coefficient given by the following:

$$v(H, d') = 0.8\frac{(H-d')}{7.8} \quad \text{if } H_m - d' \leq 7.8m$$

$$v(H, d') = 0.8 + 0.2\left[\frac{(H-d')-7.8}{4.7}\right] \quad \text{Otherwise}$$

$v(H_{j,n,m}, d')$ is to be taken as 1, if H_m coincides with the uppermost watertight boundary of the ship within the range $x1_{(j)} \dots x2_{(j+n-1)}$, and $v(H_{j,n,0}, d')$ is to be taken as 0.

v_m is to be taken as 0, if v_m determined by above formula is taken as less than 0, and v_m is to be taken as 1, if v_m determined by above formula is taken as more than 1.

5 Where the requirement in -4 above is applied, in general, each contribution dA to the Attained Subdivision Index A is obtained from the formula:

$$dA = p_i \bullet [v_1 \cdot s_{\min 1} + (v_2 - v_1) \cdot s_{\min 2} + \cdots + (1 - v_{m-1}) \cdot s_{\min m}]$$

v_m: The value calculated in accordance with -4 above;

$s_{\min}$: The least factor of s for all combinations of damages obtained when the assumed damage extends from the assumed damage height H_m downwards.

6 Probability of survival (s_i) is to be taken as 0 in cases where the final waterline (in consideration of sinkage, heel and trim) immerses the lower edge of openings through which progressive flooding may take place and such flooding is not accounted for in the calculation of the probability of survival (s_i). Such openings are to include air pipes, ventilators and openings which to be closed by means of weathertight doors or hatch covers.

7 The probability of survival (s_i) is to be taken as 0 if, taking into account sinkage, heel and trim, any of the following **(1)** to **(3)** occur in any intermediate stage or in the final stage of flooding:

(1) Immersion of any vertical escape hatch in the freeboard deck

(2) Any controls intended for the operation of watertight doors, valves on piping or on ventilation ducts intended to maintain the integrity of watertight bulkheads from above the freeboard deck become inaccessible or inoperable

(3) Immersion of piping or ventilation ducts located within the assumed extent of damage and carried through a watertight boundary if this can lead to the progressive flooding of compartments not assumed as flooded.

8 Notwithstanding the requirements given in -7 above, where compartments are assumed to be flooded due to progressive flooding in the damage stability calculations, s_i may be taken as $s_{\text{intermediate},i}$ for the flooding of those compartments under consideration.

9 Unsymmetrical flooding is to be in accordance with following **(1)** and **(2)**.

(1) Unsymmetrical flooding is to be kept to a minimum consistent with the efficient arrangements.

(2) Where it is necessary to correct large angles of heel, the means adopted is to, where practicable, be self-acting, but in any case where controls to equalization devices are provided they are to be operable from above the freeboard deck. These fittings together with their controls are to be acceptable to the Society.

10 Where the ship carries timber deck cargo, the calculation of s_i may be modified as deemed appropriate by the Society.

4.3 Openings

4.3.1 Internal Openings*

1 Internal openings below the final damage waterline or the intermediate waterline and considered to prevent progressive flooding in the calculation of the subdivision index are to be watertight.

2 The number of internal openings required to be watertight under the requirement of **-1** above is to be minimized, and their closing appliances are to comply with the following **(1)** to **(5)**. Relaxation of the requirements regarding watertight openings above the freeboard deck may be considered, where deemed by the Society that the safety of the ship is not impaired.

(1) Closing appliances are to be of ample strength and watertightness for water pressure to the equilibrium/intermediate waterplane.

(2) Closing appliances for internal openings which are used while at sea are to be sliding watertight doors complying with the following conditions.

(a) Capable of being remotely closed from the bridge

(b) Capable of being opened and closed by hand locally, from both sides of the opening with the ship listed 30 degrees to either side

(c) Provided with position indicators on the bridge and at all operating positions showing whether the doors are open or closed

(d) Provided with an audible alarm which will sound at the door position whenever such a door is remotely closed

(e) Power, control and indicators for which are to be operable in the event of main power failure
Particular attention is to be paid to minimizing the effect of control system failure.

(3) Closing appliances normally closed at sea, are to be watertight closing appliances complying with the following conditions.

(a) Capable of being opened and closed by hand locally, from both sides of the opening with the ship listed 30 degrees to either side
If hinged, it is to be of a quick acting or single action type.

(b) Provided with position indicators showing whether the doors are open or closed on the bridge and at all operating positions
Such indicators are to be operable in the event of main power failure.

(c) Provided with notices affixed to both sides of the closing devices stating “To be kept closed at sea” unless provided with means of remote closure

(d) Be in accordance with **(2)(d)** and **(e)** above, if operable remotely

(4) Watertight doors or ramps fitted to internally subdivided cargo spaces are to be permanently closed at sea, and are to comply with the following conditions.

(a) Not to be remotely controlled

(b) Provided with notices affixed to both sides of the doors stating “Not to be opened at sea”

(c) Fitted with a device which prevents unauthorized opening where accessible during the voyage

(5) Other closing appliances which are kept permanently closed at sea are to comply with **(4)(a)** and **(b)** above.

3 Bolted watertight manholes kept permanently closed at sea, need not apply to the provisions of **-2** above.

4 Closing appliances for internal openings required to be watertight are to comply with **13.3**, unless otherwise provided in **-2** above.

4.3.2 External Openings*

1 All external openings below the final damage waterline in the calculation of the subdivision index are to be watertight.

2 The closing appliances for external openings required to be watertight under -1 above are to comply with the following **(1)** to **(4)**.

(1) Closing appliances are to be of ample strength and watertightness for water pressure to the equilibrium/intermediate waterplane.

(2) Indicators showing whether the doors are open or closed are to be provided on the bridge and all operating positions. Such

indicators are to be operable in the event of main power failure. However, such indicators are not required for cargo hatch covers, fixed side scuttles and bolted manholes.

(3) Closing appliances are to be provided with a notice shown as **(a)** or **(b)** affixed at their operating positions. However, such notice is not required for cargo hatch covers, fixed side scuttles and bolted manholes.

(a) Closing appliances which are normally closed at sea are to have notices stating, “To be kept closed at sea”.

(b) Closing appliances which are to be permanently closed at sea are to have notices stating, “Not to be opened at sea”.

(4) Closing appliances for openings in the shell plating below the bulkhead deck are to be permanently closed at sea. Such closing appliances are to be fitted with a device which prevents unauthorized opening if they are accessible during voyage, except where specially approved by the Society.

3 Closing appliances for external openings above the equilibrium/intermediate waterplane but below the bulkhead deck are to be permanently closed at sea, and are to comply with the following **(1)** to **(3)**.

(1) Indicators showing whether the doors are open or closed are to be provided on the bridge and at all operating positions. Such indicators are to be operable in the event of main power failure. However, such indicators are not required for fixed side scuttles.

(2) Closing appliances are to be provided with a notice affixed at their operating positions stating “Not to be opened at sea”. However, such notices are not required for fixed side scuttles.

(3) Closing appliances for openings in the shell plating accessible during the voyage are to be fitted with a device which prevents unauthorized opening, except where specially approved by the Society.

4 Closing appliances for external openings required to be watertight are to comply with **13.3**, unless otherwise provided in **-2** and **-3** above.

Chapter 5 SINGLE BOTTOMS

5.1 General

5.1.1 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 9.2 and 9.3.

5.2 Centre Keelsons

5.2.1 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.

5.2.2 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.

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

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

5.2.3 Rider Plates

1 The thickness of rider plates specified in 5.2.1 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.

5.2.4 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 5.2.

5.3 Side Keelsons

5.3.1 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 6.8.2, the spacing of side keelsons is not to exceed 0.9 *metres*.

5.3.2 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.

5.3.3 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:

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

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.

5.3.4 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:

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

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 **5.2.2-1**.

5.3.5 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 **5.3.3** and **5.3.4**.

5.4 Floor Plates

5.4.1 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: $0.0625\,l \ (m)$

Thickness: $10d_0 + 4 \ (mm)$

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_0: 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 made.

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 plates.

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.

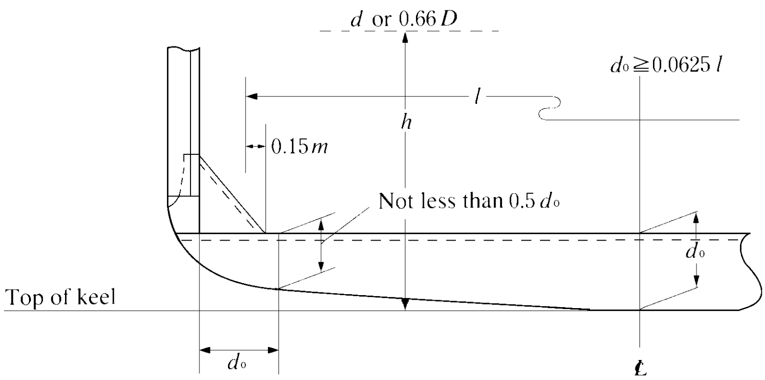
5.4.2 Depth of Floors

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_0 specified in **5.4.1-1** from the inner edge of the frames along the upper edge of floors is not to be less than $0.5d_0$ (*See* **Fig. C5.1**). 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. C5.1 Shape of Floors



5.4.3 Floors in Bottom Forward*

At the strengthened bottom forward specified in 6.8.2, the depth of floor plates is to be increased, or alternatively, the sectional area of face plates of floors required by 5.5.2 is to be doubled.

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

5.4.4 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 5.4.1.

5.4.5 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.

5.4.6 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.

5.4.7 Floor Plates Forming Part of Bulkheads

Floor plates forming part of bulkheads are to be in accordance with the requirements in **Chapters 13** and **14**.

5.5 Face Plates Fitted Up to Upper Edge of Floors

5.5.1 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.

5.5.2 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:

$$\frac{42.7}{1000}\frac{Shl^2}{d_0}-\frac{5}{3}d_0t\ \ (cm^2)$$

Where:

l: Span (m) defined in 5.4.1-1

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 $2mm$ 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 5.4.1 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.

5.5.3 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 5.5.2-2.

2 The construction and scantlings of floors of strengthened bottom forward specified in 6.8.2 are to be in accordance with the requirements in 5.4.3.

Chapter 6 DOUBLE BOTTOMS

6.1 General

6.1.1 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 **2.1.48, Part A of the Rules**.

$h = B'/20$

B' : It is specified in **4.1.2(11)**.

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

2 Part or all of double bottoms may be omitted for ships deemed by the Society to not require a double bottom for special reasons and for ships deemed appropriate by the Society which are less than 500 *gross tonnage* or which are not engaged in international voyages and less than 100 m in length.

3 For ships other than ships specified in **-2** above, double bottoms may be omitted in way of watertight tanks on the condition that 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 14**. However, the thickness of inner bottom plating need not be increased by 1.0mm as given for the top plating of deep tanks in **14.2.7**.

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 31** 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 can not 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.

6.1.2 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.

6.1.3 Drainage*

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

2 Regarding the application of **-1** above, small wells may be constructed in the double bottom in connection with drainage arrangements. Such wells are not to extend downward more than necessary.The vertical distance from the bottom of such a well to a plane coinciding with the keel line is not to be less than $0.5h$ (h is specified in **6.1.1-1**) or 500 mm, whichever is greater, or as deemed appropriate by the Society.

3 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.

6.1.4 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.

6.1.5 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.

6.1.6 Strengthening under Boilers*

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

6.1.7 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.

6.1.8 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.

6.1.9 Minimum Thickness

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

6.2 Centre Girder and Side Girders

6.2.1 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 **6.8.3**.

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

6.2.2 Depth of Centre Girder

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

6.2.3 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:

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

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 formulae

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: $\frac{3-\frac{B}{l_H}}{103}$

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

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

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

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_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 obtained from **Table C6.1** 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 C6.1 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

6.2.4 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.

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

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.

6.2.5 Thickness of Half-height Girders

The thickness of half-height girders is not to be less than that obtained from the formula in **6.2.4-2**.

6.2.6 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 **6.4.4**.

6.3 Solid Floors

6.3.1 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 **6.8.3**, between the collision bulkhead and the after end of the strengthened bottom forward specified in **6.8.2**

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

6.3.2 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: 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 C6.2** depending on $\frac{B}{l_H}$

l_H: Length defined in **6.2.3**

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

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

Where:

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

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

C_2': Coefficient given in **Table C6.3** 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:

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

Where:

ϕ: 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 C6.2 Coefficient C_2

B/l_H		C_2		
and above	below	Longitudinal Framing	Transverse framing: Where solid floors are provided at every frame	Transverse framing: Elsewhere
	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 C6.3 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

6.3.3 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.**

6.4 Longitudinals

6.4.1 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.

6.4.2 Spacing

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

$2L+550$ (mm)

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

6.4.3 Longitudinals*

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

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

Where:

C: Coefficient given below:

Where no strut specified in 6.4.4 is provided midway between floors: 1.0

Where a strut specified in 6.4.4 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 $230m$, L' is to be taken as $230m$.

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.

$$\frac{100C'Shl^2}{24-12f_B}\ (cm^3)$$

Where:

C': Coefficient obtained from the following:

Where no strut specified in 6.4.4 is provided midway between floors: 0.9

Where a strut specified in 6.4.4 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.

6.4.4 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:

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

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 6.4.3-1

h_i: 0.9 times the value of h (m) specified in 6.4.3-2

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

6.5 Inner Bottom Plating, Margin Plates and Bottom Shell Plating

6.5.1 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:

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

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

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 **6.4.3-2**

C: b_0 or αb_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 $1.2\leq\frac{B}{l_H}$

l_H: As specified in **6.2.3**

b_0 andb_1: As given in **Table C6.4** 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:

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

f_B: As specified in **6.4.3-1**

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

$0.43\frac{l}{S}+2.5$ for $1\leq\frac{l}{S}<3.5$

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 2mm above that obtained from the second formula in **-1** or that specified in **6.1.1-5**, 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 2.5mm above that specified in **-1** or in **6.1.1-5**, 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 2mm above that specified in **-1** or in 6.1.1-5, whichever is greater.

Table C6.4 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_0		4.4	3.9	3.3	2.2	1.6	-	-	-
b_1		-	-	-	2.2	2.1	1.9	1.7	1.4

6.5.2 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.

6.5.3 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.

6.5.4 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 6.2.4-2.

6.5.5 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 16.3.4 or from the first formula in 6.5.1-1, whichever is greater. However, in application of the latter formula, α is to be as given by the following formula:

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

Where:

f_B: As specified in 6.4.3-1

6.6 Tank Side Brackets

6.6.1 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 6.2.4-2.

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.

6.6.2 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.

6.7 Open Floors

6.7.1 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 6.7.

6.7.2 Scantlings of Frames and Reverse Frames

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

$CShl^2$ (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. C6.1**).

S: Spacing (m) of frames

h: $d + 0.026L'$ (m)

L': As specified in **6.4.3-1**

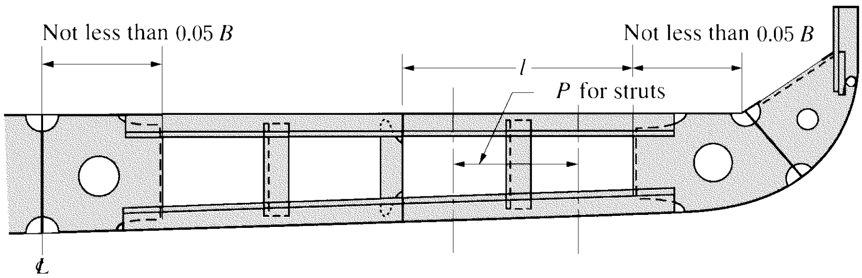
C: Coefficient given below:

Where no vertical strut specified in **6.7.3** is provided: 6.67

Where vertical struts specified in **6.7.3** 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. C6.1 Open Floors



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

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

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

h: As specified in **6.4.3-2**

C': Coefficient given below:

Where no vertical strut specified in **6.7.3** is provided: 6.0

Where vertical struts specified in **6.7.3** are provided: 3.6

6.7.3 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 **6.4.4**.

6.7.4 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 **6.2.4-2**.

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.

6.8 Construction and Strengthening of the Bottom Forward

6.8.1 Application*

1 In ships having a bow draught under $0.037L'$ 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 **6.4.3-1**.

2 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.

3 In ships having a bow draught of not less than $0.037L'$ in the ballast condition, the construction of the strengthened bottom forward may be as specified in **6.2**, **6.3** and **6.4**.

6.8.2 Strengthened Bottom Forward*

1 The part of flat bottom forward from the position specified in **Table C6.5** 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 C6.5 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 stem)		0.15L	0.175L	0.2L	0.225L	0.25L	0.275L	0.3L

6.8.3 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 0.025L 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.

6.8.4 Scantlings of Longitudinal Shell Stiffeners or Bottom Longitudinals

1 In ships having a bow draught of not more than $0.025L'$ 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:

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

Where:

l: Spacing (m) of solid floors

λ: $0.774l$

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

P: Slamming impact pressure obtained from the following formula:

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

C_1: Coefficient given in **Table C6.6**

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. C6.2**)

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

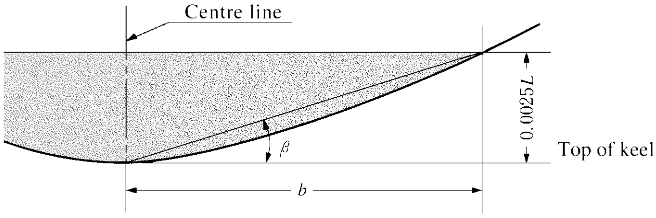
b: Horizontal distance (m) measured in the station $0.2L$ from the stem, from the centre line of ship to the intersection of the horizontal line $0.0025L$ above the top of keel with the shell plating (*See* **Fig. C6.2**)

2 In ships having a bow draught of more than $0.025L'$ but less than $0.037L'$ 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 **6.4**.

Table C6.6 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. C6.2 Measurement of b



(Hull section at the station 0.2 L from the stem)

Chapter 7 FRAMES

7.1 General

7.1.1 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 13**. 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.

7.1.2 Frames in way of Deep Tanks

The scantlings of frames in way of deep tanks are to comply with the provisions in **Chapter 14** as well as those in this Chapter.

7.1.3 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.

7.1.4 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.

7.1.5 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.

7.1.6 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.

7.1.7 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.

7.1.8 Consideration of Bow Impact Pressure*

The transverse frames, side longitudinals and web frames supporting side longitudinals that are fitted where the bow 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.

7.2 Frame Spacing

7.2.1 Transverse Frame Spacing

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

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

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.

7.2.2 Longitudinal Frame Spacing

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

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

7.2.3 Consideration for Frame Spacing Exceeding the Standard

Where the spacing of frames exceeds the standard spacing stipulated in **7.2.1** and **7.2.2** by at least 250 mm, the scantlings and structural arrangement of double bottoms and other relevant structures are to be specially considered.

7.2.4 Maximum Frame Spacing

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

7.3 Transverse Hold Frames

7.3.1 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 7.3.2 to 7.3.4 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 6.1.1-6 in the loaded hold exceeds 0.9.

7.3.2 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:

$$C_0CShl^2 \quad (cm^3)$$

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. C7.1 and Fig. C7.2 (a) and (b))

h: Vertical distance (m) from the lower end of l at the place of measurement to a point $d+0.038L'$ above the top of the keel (*See* Fig. C7.2 (a) and (b))

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

C_0: 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:

$$C_1 + C_2$$

(1) For ordinary framing systems without top side tanks

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

$$C_2 = 2.2k\alpha\frac{d}{h}$$

α: Coefficient given in **Table C7.1**
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

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

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

α: As specified in **(1)**

Where B/l exceeds 4.0, the value of C_2 is to be suitably increased.

Table C7.1 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_0CShl^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:

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

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. C7.2** (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.

7.3.3 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 8**, 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 **7.3.2-1**

l: As specified in **7.3.2-1** 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. C7.1** and **Fig C7.2** (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. C7.2** (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. C7.2** (c))

α_1 and α_2: As given in **Table C7.2**

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. C7.2** (c))

H: Vertical distance (m) from the lower end of H_0 to the freeboard deck at side (*See* **Fig. C7.2** (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 C7.2 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

7.3.4 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.

7.4 Side Longitudinals and Other Structural Members

7.4.1 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:

$100CShl^2$ (cm^3)

$2.9\sqrt{L'}Sl^2$ (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:

$$\frac{1}{24-k}$$

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 15** to the actual section modulus of the transverse section of hull at bottom

However, where f_B is less than 0.85, it 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**.

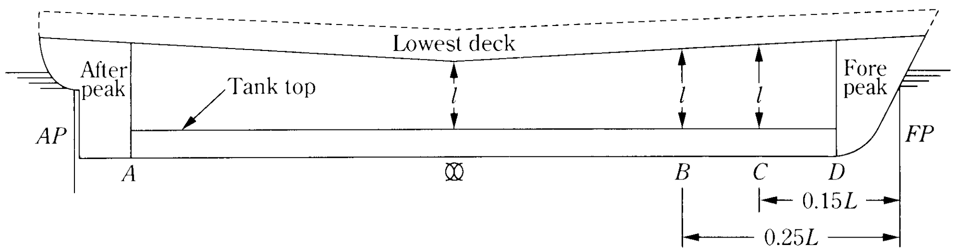
3 The depth of flat bars used for longitudinals is not to exceed 15 times the thickness of flat bars.

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.

Fig. C7.1 Measuring Points of l for Hold Frames

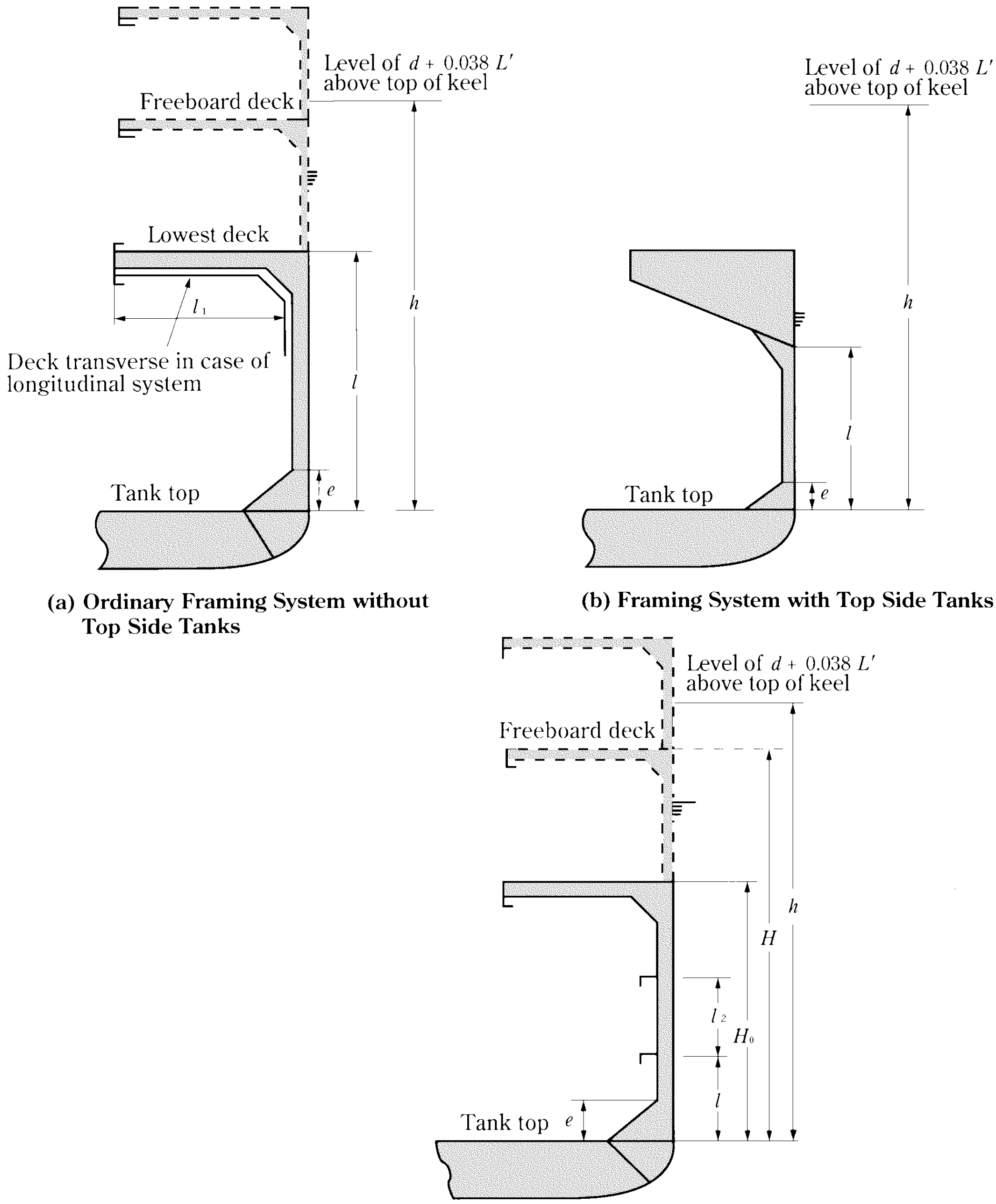


For frames between A and B, l is to be measured at ⊠

For frames between B and C, l is to be measured at B

For frames between C and D, l is to be measured at C

Fig. C7.2 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.

7.4.2 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: $0.1l$ (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

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

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

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+0.038L' above the top of keel

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

L': As specified in **7.4.1-1**

C_1 and C_2: Coefficients given in **Table C7.3**

k: Coefficient given in **Table C7.4** 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 C7.3 Coefficients C_1 and C_2

	For web frames abaft 0.15 L from the fore end	For web frames between 0.15 L 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 C7.4 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

7.5 Cantilever Beam Systems

7.5.1 Cantilever Beams

Cantilever beams are to comply with the requirements in **(1)** to **(8)**:

(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. C7.3**)

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

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 **10.2** 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 **10.2.1-2** 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 **10.2.1-2(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 20**, 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 **10.2.1-1**.

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

(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:

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

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

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.

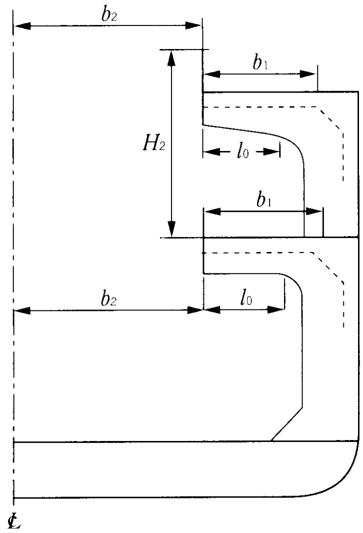
(7) Web plates adjacent to the inner edge of end brackets are to be specially reinforced.

(8) Cantilever beams supporting hatch covers on lower decks are to comply with the requirements in **(a)** and **(b)**:

(a) The leg length of the fillet welds between webs and hatch side girders is to be $F1$.

(b) Where the stiffeners are provided to prevent web plates from buckling, consideration is to be given to the arrangement of the ends of such stiffeners to ensure that there are no stress concentrations at the connections between web plates and the members supporting hatch covers on lower decks.

Fig. C7.3 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.

7.5.2 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%.

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

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 7.5.1(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:

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

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:

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

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

Where:

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

d_ω: 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_ω 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 **7.4.2** or **Chapter 8**.

(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:

$$0.6 + 9.81\frac{0.05hl^2 + 0.09h_u{l_u}^2}{1.4\left(\frac{1}{2}b_1h_1 + b_2h_2\right)l_1}$$

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:

$$0.0255\frac{Shl}{d_\omega}\ (mm)$$

S: Web frame spacing (m)

h and l: As stipulated in **(a)** above

d_ω: 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.

7.5.3 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.

7.6 Tween Deck Frames

7.6.1 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 **7.6** 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.

7.6.2 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:

$$6Shl^2 \ (cm^3)$$

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:

$$CSlL \ (cm^3)$$

Where:

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

C: Coefficient given in **Table C7.5**

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**.

$$2.4\left(1 + 0.0714n\frac{h_1}{h}\right)Shl^2 \ (cm^3)$$

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 **10.2** for the deck beam at the top of frame (kN/m^2)

Table C7.5 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

7.6.3 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.

7.6.4 Superstructure Frames

1 Superstructure frames are to be provided at every frame located below.

2 Notwithstanding the requirements in **7.6.2-2,** 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 **7.6.2** using 0.74 as the coefficient C.

3 Web frames or partial bulkheads are to be provided above the bulkheads required by **Chapter 13** or at other positions such as may be considered necessary to give effective transverse rigidity to the superstructures.

7.6.5 Frames of Cruiser Sterns

The section modulus of frames of cruiser sterns is not to be less than 0.86 times that required by **7.8.1**.

7.7 Frames below Freeboard Deck Forward of Collision Bulkhead

7.7.1 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).

7.7.2 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.

7.8 Frames below Freeboard Deck abaft of After Peak Bulkhead

7.8.1 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:

$8Shl^2$ (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 8 WEB FRAMES AND SIDE STRINGERS

8.1 General

8.1.1 Application

The requirements in this Chapter apply to side stringers supporting the transverse hold frames specified in 7.3.3 and the web frames supporting these side stringers.

8.1.2 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.

8.1.3 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.

8.1.4 Consideration of Bow Impact Pressure*

The side stringers supporting transverse hold frames that are fitted where the bow 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.

8.2 Web Frames

8.2.1 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_1Shl^2 (cm^3)

Thickness of web: t_1 or t_2 whichever is greater:

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

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

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 C8.1

k: Coefficient given in Table C8.2 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 C8.1 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 bulkhead
C_1	3.0	3.8
C_2	23	28

Table C8.2 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

8.2.2 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.

8.2.3 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.

8.2.4 Beams at the Top of Web Frames

Beams at the top of web frames are to be suitably increased in both strength and stiffness.

8.3 Hold Side Stringers

8.3.1 Scantlings of Hold Side Stringers

1 The scantlings of side stringers are not to be less than that obtained from the following formula:

Depth: 0.125l (m) plus one quarter of the depth (m) of slot for ordinary frames.

Section modulus: C_1Shl^2 (cm^3)

Thickness of web: t_1 or t_2 whichever is greater

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

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

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 **1.1.16**.

h: Vertical distance (m) from the middle of S to a point d+0.038L' above the top of keel
However, where h is less than that 0.05L (m), h is to be taken as 0.05L (m).
L': As specified in **8.2.1-1**

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 C8.3**

k: Coefficient given in **Table C8.2** 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 C8.3 Coefficients C_1 and C_2

	For side stringers abaft 0.15L from the fore end	For side stringers between 0.15L from the fore end and the collision bulkhead
C_1	5.1	6.4
C_2	42	52

8.3.2 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.

8.3.3 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.

8.3.4 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.

8.3.5 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 9 ARRANGEMENTS TO RESIST PANTING

9.1 General

9.1.1 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 **7.7** and **7.8**.

9.1.2 Swash Plates*

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.

9.1.3 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.

9.2 Arrangements to Resist Panting Forward of Collision Bulkhead

9.2.1 Arrangement and Construction

1 A 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 **7.2.1-2**, 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 **9.2.2-2** 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 and side 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.

9.2.2 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 $0.3L$ (cm^2), 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.

$$t_1 = 0.042\frac{Shl}{d_0}+2.5 \ (mm)$$

$$t_2 = 11\sqrt[3]{\frac{{d_0}^2(t_1-2.5)}{k}}+2.5 \ (mm)$$

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 $0.12L$ 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 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 C9.1** 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.

(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: $\frac{0.77Sbh}{1-0.5\frac{l}{k_0}}$ (cm^2)

Where $\frac{l}{k_0}$ is less than 0.6: $1.1Sbh$ (cm^2)

Web thickness: $16d_w\sqrt{\frac{Sbh}{A}}$ (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.

Table C9.1 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

9.2.3 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: $0.2\,l$ (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.

$$t_1 = 0.042\frac{Shl}{d_0} + 2.5 \ (mm)$$

$$t_2 = 11\sqrt[3]{\frac{{d_0}^2(t_1 - 2.5)}{k}} + 2.5 \ (mm)$$

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 C9.1** 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: $1.1Sbh$ (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: $0.45 + 0.0055L$ (m)

Section modulus: $1.2Ll^2$ (cm^3)

Web thickness: $4 + 0.6\sqrt{L}$ (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: $0.68 + 0.008L$ (m)

Web thickness: $4.5 + 0.65\sqrt{L}$ (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: $0.45 + 0.0055L$ (m)

Web thickness: $4.5 + 0.65\sqrt{L}$ (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: $0.68 + 0.008L$ (m)

Web thickness: $5 + 0.7\sqrt{L}$ (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:

$3.5 + 0.55\sqrt{L}$ (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: $\frac{0.115SbL}{1-0.5\frac{l}{k_0}}$ (cm^2)

Where $\frac{l}{k_0}$ is less than 0.6: $0.164SbL$ (cm^2)

Web thickness:

$6.2d_w\sqrt{\frac{SbL}{A}}$ (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.

9.2.4 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.

9.3 Arrangements to Resist Panting abaft of After Peak Bulkhead

9.3.1 Floors

The requirements in **9.2.2-1** apply to the scantlings and arrangement of floors in the after peak. The floors are to extend well above the stern tubes.

9.3.2 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 **9.2.2-2**.

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.

9.3.3 Cruiser Sterns

Cruiser sterns are to be strengthened by structural members such as web frames and side stringers as found necessary.

9.4 Arrangements to Resist Panting between Both Peaks

9.4.1 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.

9.4.2 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 10 BEAMS

10.1 General

10.1.1 Camber of Weather Deck

The standard camber of weather deck is $\frac{B}{50}$ at midship.

10.1.2 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.

10.1.3 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.

10.2 Deck Load

10.2.1 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 C10.1** 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. C10.1**):

Where L is less than 150 m: $\frac{L}{10}e^{-\frac{L}{300}} + \left(\frac{L}{150}\right)^2 - 1.0$

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. C10.2**).

(2) h for the deck in Line II in **Table C10.1** 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 C10.2**, 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 accommodation or navigation spaces.

Fig. C10.1 Value of f

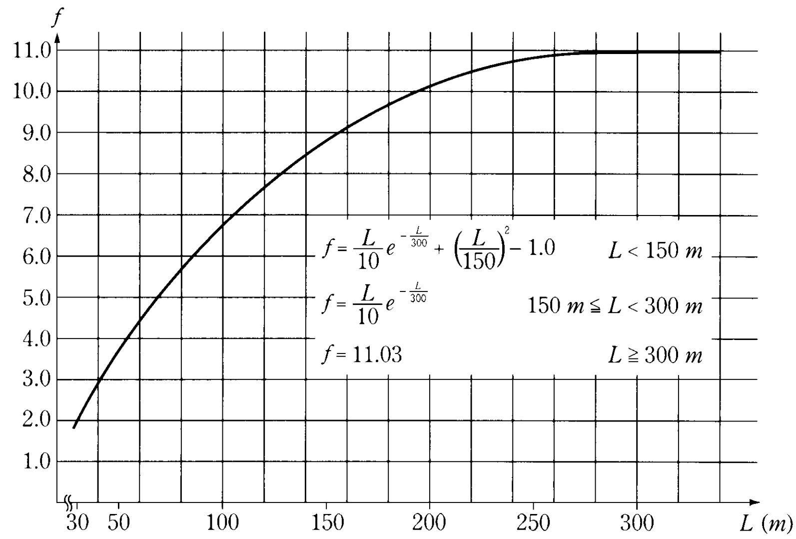


Fig. C10.2 Positions for Measuring y

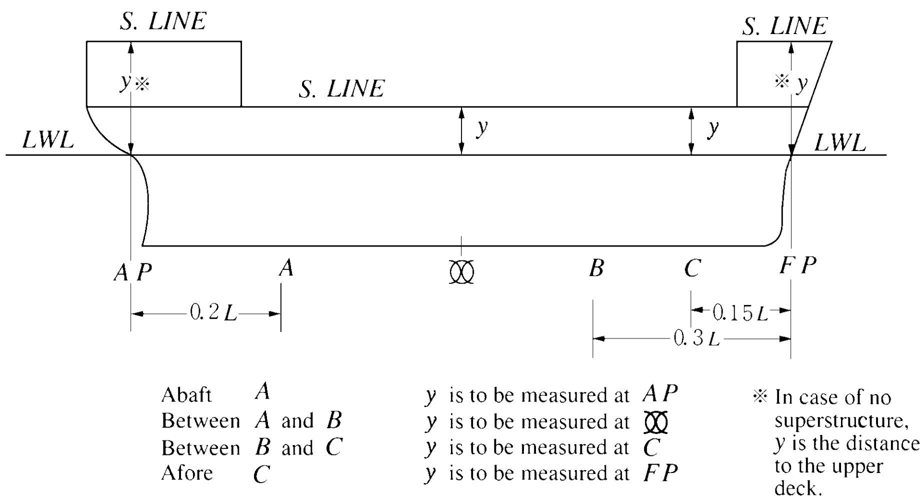


Table C10.1 Values of a and b

Line	Position of deck	a			b
		Beams,(1) Deck plating	Pillars	Deck girders	
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 C10.2 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 abaft 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:

$$0.55\left(\frac{L}{100}\right)+0.175$$

10.3 Longitudinal Beams

10.3.1 Spacing

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

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

2 It is recommended that the spacing of longitudinal beams should not exceed 1 *metre*.

10.3.2 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.

10.3.3 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:

$$1.14Shl^2 \ (cm^3)$$

Where:

S: Spacing (m) of longitudinal beams

h: Deck load (kN/m^2) specified in **10.2**

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**.

10.3.4 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.

10.4 Transverse Beams

10.4.1 Arrangement of Transverse Beams

Transverse beams are to be provided on every frame.

10.4.2 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.

10.4.3 Section Modulus of Transverse Beams

The section modulus of transverse beams is not to be less than that obtained from the following formula:

$$0.43Shl^2 \ (cm^3)$$

Where:

S: Spacing (m) of transverse beams

h: Deck load (kN/m^2) specified in **10.2**

l: Horizontal distance (m) from the inner edge of beam brackets to the longitudinal deck girder, or between the longitudinal deck girders

10.5 Beams on Bulkhead Recesses and Others

10.5.1 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 **13.2.8**.

10.6 Beams on Top of Deep Tanks

10.6.1 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 **14.2.3**, taking the top of deck beams as the lower end of h and beams as stiffeners.

10.7 Deck Beams Supporting Especially Heavy Loads

10.7.1 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.

10.8 Unusually Long Machinery Openings*

10.8.1 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.

10.9 Deck Beams Supporting Vehicles

10.9.1 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.

10.9.2 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.

10.10 Deck Beams Supporting Unusual Cargoes

10.10.1 Section Modulus of Beams

The section modulus of beams of decks carrying cargo loads which can not be treated as evenly distributed loads is to be determined by taking into account the load distribution of each particular cargo.

Chapter 11 PILLARS

11.1 General

11.1.1 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.

11.1.2 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.

11.1.3 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.

11.1.4 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.

11.2 Scantlings

11.2.1 Sectional Area of Pillars*

The sectional area of pillars is not to be less than that obtained from the following formula:

$$\frac{0.223w}{2.72-\frac{l}{k_0}} \ (cm^2)$$

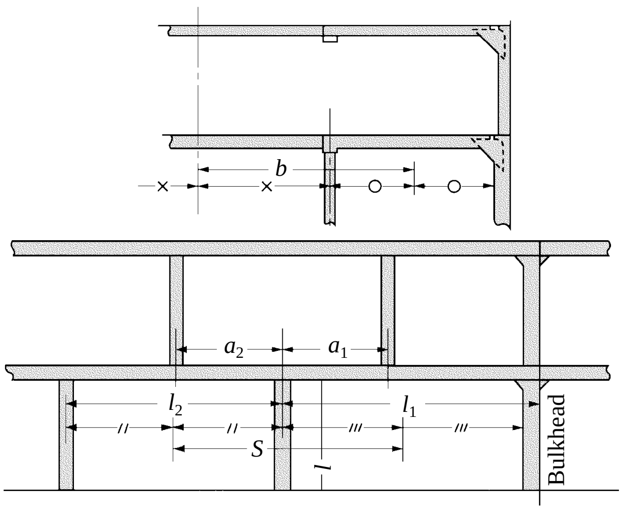
Where:

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. C11.1**)

k_0: Minimum radius of gyration (cm) of the section of pillars

w: Deck load (kN) supported by the pillar, as specified in **11.2.2**

Fig. C11.1 Measurement of S, b, l, etc.



11.2.2 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. C11.1**)

b: Mean distance (m) between the mid-points of two adjacent spans of beams supported by the pillars or the frames (*See* **Fig. C11.1**)

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. C11.1**)

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 athwartships 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).

11.2.3 Thickness of Plates

1 The plate thickness of tubular pillars is not to be less than that obtained from the following formula:

$0.022d_p + 4.6$ (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.

11.2.4 Outside Diameter of Round Pillars

The outside diameter of solid round pillars and tubular pillars is not to be less than 50 mm.

11.2.5 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 **11.2.1** or obtained from the following formula, whichever is greater:

$1.09Sbh$ (cm^2)

Where:

S and b: As specified in **11.2.2**

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

11.3 Bulkheads in lieu of Pillars

11.3.1 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.

11.4 Casings in lieu of Pillars

11.4.1 Construction

The casings provided in lieu of pillars are to be of sufficient scantlings to withstand the deck load and side pressure.

Chapter 12 DECK GIRDERS

12.1 General

12.1.1 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.

12.1.2 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.

12.1.3 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:

$$85.4\sqrt{d_0 l}\ \ (mm)$$

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.

12.1.4 End Connection*

1 End connections of deck girders are to be in accordance with the requirements in **1.1.14**.

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.

12.2 Longitudinal Deck Girders

12.2.1 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:

$$1.29l(lbh + kw)\ \ (cm^3)$$

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 **1.1.16** (*See* **Fig. C12.1**).

b: Distance (m) between the centres of two adjacent spans of beams supported by girders or frames (*See* **Fig. C12.1**)

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 **11.2.2**

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. C12.1**).

$$12\frac{a}{l}\left(1-\frac{a}{l}\right)^2$$

(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:

$$0.484l(lbh+kw) \quad (cm^3)$$

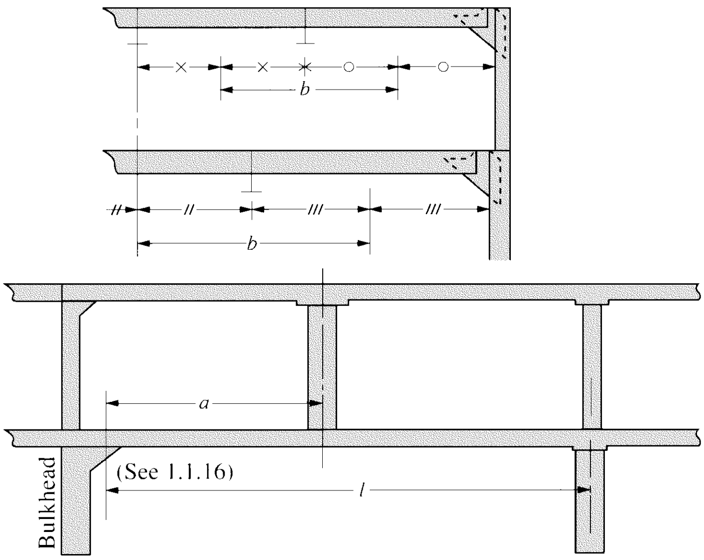
Where:

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. C12.1 Measurement of l, b, and a



12.2.2 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 (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 **12.2.1**

l: As specified in **12.2.1-1**

12.2.3 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 **12.2.1-1**

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**.

12.3 Transverse Deck Girders

12.3.1 Section Modulus of Girders

1 The section modulus of transverse deck girders is not to be less than that obtained from the following formula:

$$0.484l(lbh+kw) \quad (cm^3)$$

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 **12.2.1**

w and k: In accordance with **12.2.1**

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).

12.3.2 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 **12.3.1**

l: As specified in **12.3.1**

12.3.3 Thickness of Web Plates

The thickness of web plates is to be in accordance with the requirements in **12.2.3**.

12.4 Deck Girders in Tanks

12.4.1 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 **14.2.5-1**.

12.4.2 Moment of Inertia of Girders

The moment of inertia of girders is to be in accordance with the requirements in **14.2.5-2**.

12.4.3 Thickness of Web Plates

The thickness of web plates is to be in accordance with the requirements in **12.2.3** or **12.3.3,** and the requirements in **14.2.5-3**.

12.5 Hatch Side Girders

12.5.1 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.

12.5.2 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.

12.6 Hatch End Beams

12.6.1 Scantlings of Hatch End Beams

The scantlings of hatch end beams are to be in accordance with the requirements in **12.3**, **12.4** and **12.5**.

12.7 Movable Car Deck Girders

12.7.1 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 **12.1.3**.

12.7.2 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 **1.1.13-3**

(2) Effective width (b_{eft}) for girders crossing at right angles with the stiffening direction:

$$b_{eft} = \sum_n \left(\frac{C_{et} \cdot a}{2}\right) \ (mm)$$

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 **1.1.13-3**.

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 C12.1**.

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 C12.1 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

12.7.3 Structural Details

1 The connection of girder webs to the car deck is to use the fillet welding method in accordance with **Table C12.2**.

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.

$$\frac{d}{C} + 1.0 \ (mm)$$

d: Depth of girders (mm)

C: Coefficient as given by the following:

65 for symmetrically flanged girders

55 for asymmetrically flanged girders

Table C12.2 Fillet Weld of Girder to Movable Car Deck(*4)

	Panels on which vehicular traffic is frequent(*1)	Panels other than those specified in the left column
(1) Girders on the deck panel periphery	*F*2 (Both sides)	*F*2 (Both sides)
(2) Within 0.3 l midspan of girders other than mentioned in **(1)**(*2)		
(3) Within 0.1 l of end parts of girders other than mentioned in **(1)**(*2)		
(4) Within 0.2 l' of intersections of girders other than mentioned in **(1)**(*3)		
(5) Other areas than those mentioned above		*F*2 (One side), at least

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 0.1 l' on either side of the intersection of girders is to be welded

(*4) "*F*2" in this table is as specified in **Table C1.4**

Chapter 13 WATERTIGHT BULKHEADS

13.1 Arrangement of Watertight Bulkheads

13.1.1 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 freeboard deck. Where a collision bulkhead extends up to a deck above the freeboard deck in accordance with the requirements of **13.1.5(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 freeboard deck, the part of the ramp which is more than 2.3 m above the freeboard 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.

5 The factor s_i calculated in accordance with **4.2.3** will not be less than 1 at the deepest subdivision draught loading condition, level trim or any forward trim loading conditions, if any part of the ship forward of the collision bulkhead is flooded without vertical limits.

13.1.2 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.

13.1.3 Machinery Space Bulkheads

A watertight bulkhead is to be provided at each end of the machinery space.

13.1.4 Hold Bulkheads*

1 Cargo ships of an ordinary type are to have hold bulkheads in addition to the bulkheads specified in **13.1.1** to **13.1.3** at reasonable intervals so that the total number of watertight bulkheads may not be less than that given by **Table C13.1**.

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 C13.1 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

13.1.5 Height of Watertight Bulkheads*

The watertight bulkheads required in 13.1.1 to 13.1.4 are to extend to the freeboard deck with the following exceptions.

(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 deck next above the freeboard deck and to be made weathertight. However, where all parts of the extension, including any part of the ramp attached to it are located within the limits specified in 13.1.1 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.

13.1.6 Transverse Strength of Hull

1 Where the watertight bulkheads required in 13.1.1 to 13.1.5 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.

13.2 Construction of Watertight Bulkheads

13.2.1 Thickness of Bulkhead Plates

The thickness of bulkhead plates is not to be less than that obtained from the following formula:

$$3.2S\sqrt{h} + 2.5 \quad (mm)$$

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*.

13.2.2 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 13.2.1

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 13.2.1.

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 13.2.1.

13.2.3 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 C13.2, according to the type of end connections.

Table C13.2 Value of C

Vertical Stiffener				
Lower end	Upper end			
	Lug-connection or supported by horizontal girders	Connection		End of stiffener unattached
		Type A	Type B	
Lug-connection or supported by horizontal girders	1.00	1.00	1.15	1.35
Connected by brackets	0.80	0.80	0.90	1.00
Only the web of stiffener attached at end	1.15	1.15	1.35	1.60
End of stiffener unattached	1.35	1.35	1.60	2.00

Horizontal Stiffener		
The other end	One end	
	Lug-connection, connected by brackets or supported by vertical girders	End of stiffener unattached
Lug-connection, connected by brackets or supported by vertical girders	1.00	1.35
End of stiffener unattached	1.35	2.00

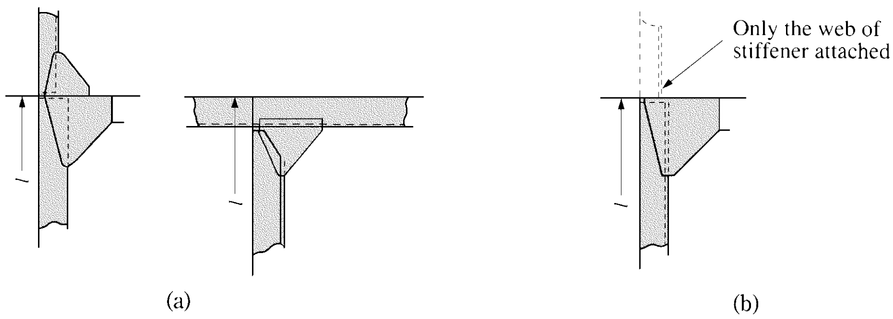
Notes:

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.C13.1** (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.C13.1** (b))

Fig. C13.1 Types of End Connections



13.2.4 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 **13.2.1**

S_1: Breadth (m) of face part or web part indicated as a or b, respectively, in **Fig. C13.2**

C: Coefficient given below:

Face part: $\dfrac{1.5}{\sqrt{1+\left(\dfrac{t_w}{t_f}\right)^2}}$

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: $3.6CShl^2$ (cm^3)

Where:

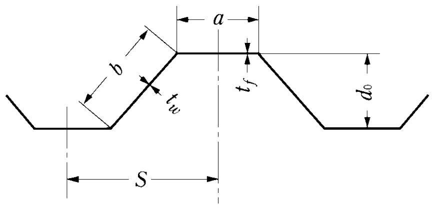
S: Half pitch length (m) of the corrugation (*See* **Fig. C13.2**)

h: As specified in **13.2.3**

l: Length (m) between the supports, as indicated in **Fig. C13.3**

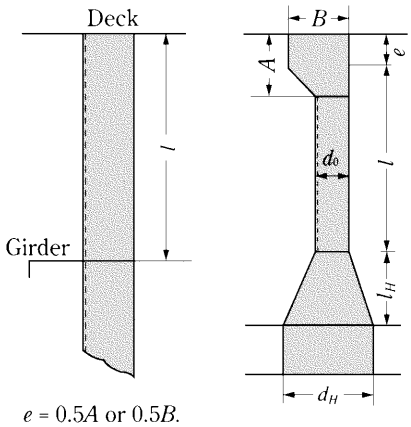
C: Coefficient given in **Table C13.3**, according to the type of end connection

Fig. C13.2 Measurement of S



$S_1 = a$ or b.
S = Half pitch length.

Fig. C13.3 Measurement of l



e = 0.5A or 0.5B.
whichever is smaller.

Table C13.3 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
(1)	Supported by horizontal or vertical girders or lower end of bulkhead welded directly to decks or inner bottoms	$\dfrac{4}{2+\dfrac{Z_1}{Z_0}+\dfrac{Z_2}{Z_0}}$	$\dfrac{4}{2.2+\dfrac{Z_2}{Z_0}}$	$\dfrac{4}{2.6+\dfrac{Z_2}{Z_0}}$
(2)	Lower end of bulkhead welded to stool efficiently supported by ship structure	$\dfrac{4.8(1+\frac{l_H}{l})^2}{2+\dfrac{Z_1}{Z_0}+\dfrac{d_H}{d_0}}$	$\dfrac{4.8(1+\frac{l_H}{l})^2}{2.2+\dfrac{d_H}{d_0}}$	$\dfrac{4.8(1+\frac{l_H}{l})^2}{2.6+\dfrac{d_H}{d_0}}$
		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 **13.2.4-5** 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:

$$0.0417\frac{CShl}{d_0}+2.5 \ \ (mm)$$

The web thickness is not to be less than that obtained from the following formula:

$$1.74\sqrt[3]{\frac{CShlb^2}{d_0}}+2.5 \ \ (mm)$$

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 C13.4**

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 C13.4 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 **13.2.2**.

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

13.2.5 Collision Bulkheads

For collision bulkheads, the plate thickness and section modulus of stiffeners are not to be less than that those specified in **13.2.1** and **13.2.3** or **13.2.4** taking h as 1.25 *times* the specified height.

13.2.6 Girders Supporting Bulkhead Stiffeners

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

$$4.75Shl^2 \ (cm^3)$$

Where:

S: Breadth (m) of the area supported by the girder

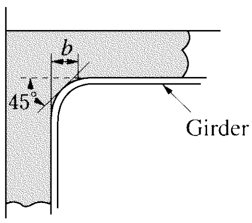
h: Vertical distance (m) measured from the mid-point of l for vertical girders, and from the mid-point of S for horizontal girders, to the top of the bulkhead deck at the centre line of the ship

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 **1.1.16**. Where brackets with curved free edges are attached, the effective arm length of the brackets is to be taken as b indicated in **Fig. C13.4**.

Fig. C13.4 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:

$$0.0417\frac{CShl}{d_0}+2.5\ \ (mm)$$

$$1.74\sqrt[3]{\frac{CShlS_1^2}{d_0}}+2.5\ \ (mm)$$

Where:

S, h and l: As specified in -1

d_0: Depth (m) of girders

S_1: As specified in -3

C: As specified in 13.2.4-4

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 1.1.13-3. Where stiffeners are provided within the effective breadth, they may be included in the calculation.

13.2.7 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.

13.2.8 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 10.4.3 and 13.2.3 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 13.2.1, 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.

13.2.9 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.

13.3 Watertight Doors

13.3.1 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 13.3.2 to 13.3.5.

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.

13.3.2 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 13.3.4-2.

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.

13.3.3 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.

13.3.4 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 **13.3.2-3** are not to be remotely controlled.

13.3.5 Indication*

Watertight doors, except watertight doors or ramps fitted to internally subdivided cargo spaces specified in **4.3.1-2(4)**, are to be provided with position indicators showing whether the doors are open or closed on the bridge and at all operating positions.

13.3.6 Alarms*

1 Failure of the normal power supply of alarms required to be installed by **13.3.6-2** and **13.3.6-3** is to be indicated by an audible and visual alarm. This alarm is to be located on the bridge.

2 Watertight doors which are capable of being remotely closed are to be provided with audible alarms which will sound at the door position whenever such doors are remotely closed.

3 All watertight doors (including sliding doors) operated by hydraulic door actuators, irrespective of whether their control positions are a central hydraulic unit or local operating position, are to be provided with either a low fluid level alarm, a low gas pressure alarm or some other means as applicable for monitoring the loss of stored energy in the hydraulic accumulators. Such alarms are to be both audible and visible and located on the bridge.

13.3.7 Source of Power*

1 The remote controls, indications and alarms required in **13.3.4** to **13.3.6** 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 **2.9.11-2, Part H**.

13.3.8 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.

13.3.9 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.

13.3.10 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.

13.4 Other Watertight Construction

13.4.1 Maintaining the Watertightness

Trunks, etc. required to maintain watertightness are to comply with this chapter.

Chapter 14 DEEP TANKS

14.1 General

14.1.1 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".

14.1.2 Application*

1 Watertight divisions (other than those specified in **14.1.3-4**), 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 13**.

2 The bulkheads of deep tanks carrying oils with a flashpoint below 60°C are to comply with the requirements in **Chapter 29**, 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 according to the provisions in **Part N** or **Part S**, 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.

14.1.3 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 13**. 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.

14.1.4 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 C14.1** in accordance with the length of ship.

Table C14.1 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

14.1.5 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 **14.2.2**, **14.2.3**, **14.2.4**, **14.2.5** and **14.2.6**, 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 **14.2.2(1)** or of **14.2.3(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.

14.2 Deep Tank Bulkheads

14.2.1 Application

The construction of bulkheads and decks forming boundaries of deep tanks is to be in accordance with the requirements in **Chapter 13**, unless otherwise specified in this Chapter.

14.2.2 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

14.2.3 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 **13.2.3**

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 C14.2**, according to the type of end connections

Table C14.2 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.C13.1** (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.C13.1** (b))

14.2.4 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 **13.2.4-1**

h: As specified in **14.2.2**

C: Coefficient given below:

For face part: $\dfrac{1.4}{\sqrt{1+(\frac{t_w}{t_f})^2}}$

For web part: 1.0

t_f and t_w: As specified in **13.2.4-1**

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 C14.1**

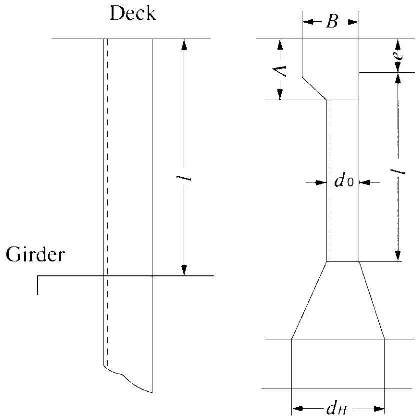
C: Coefficient given in **Table C14.3**, according to the type of end connection

h: As specified in **14.2.3**

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. C14.1**), 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. C14.1 Measurement of l



$$e = A - \frac{d_0}{2B}A$$

Table C14.3 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:

$$1.74\sqrt[3]{\frac{CShlb^2}{d_0}} + 3.5 \ (mm)$$

Thickness of the face part except the upper end part of vertically corrugated bulkheads:

$$12a + 3.5 \ (mm)$$

Where:

h: As specified in **14.2.3**

C, S, d_0, a and b: As specified in **13.2.4-4**

l: As specified in **-2**

14.2.5 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 **14.2.3**

l: Span (m) specified in **13.2.6**

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:

$$C=\left|1+\frac{1}{5}\frac{l}{h}-(2+\frac{l}{h})\frac{x}{l}+\frac{l}{h}(\frac{x}{l})^2\right|$$

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 13.2.6-6.

14.2.6 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 14.2.5 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 14.2.5

b_s: Breadth (m) of the area supported by the cross ties

3 The ends of cross ties are to be bracketed to girders.

14.2.7 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 14.2.2.

14.2.8 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 14.2.2, 14.2.4 and 14.2.5 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.

14.3 Fittings of Deep Tanks

14.3.1 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.

14.3.2 Drainage from Top of Tanks

Efficient arrangements are to be made for draining bilge water from the top of deep tanks.

14.3.3 Inspection Plugs

The inspection plugs provided on deep tank tops as required in **14.1.3** 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.

14.3.4 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.

14.4 Welding of Corrugated Bulkheads

14.4.1 General

1 The welding of corrugated bulkheads is to be in accordance with **Table C14.4**.

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.

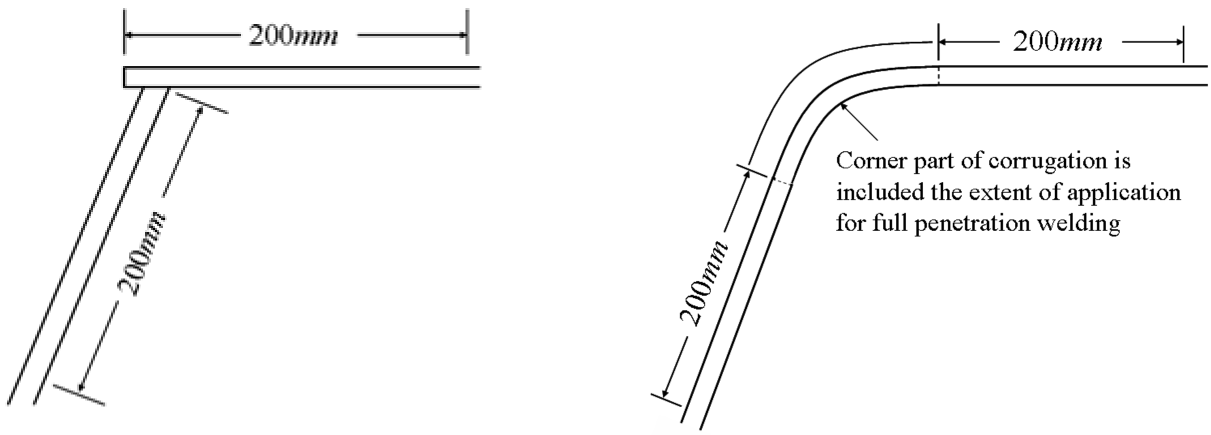
3 In cases where stools are fitted, the fillet weld leg length for the top or bottom plating of stools to the side plating of stools as well as the side plating of stools to inner bottom plating is to be suitably increased or to be bevelled and welded.

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 **31A.3.5-5(2)** and **-6(5)**.

Table C14.4 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 150m and above · Full penetration double bevel welds (2) For ships having a length, L_1, that is less than 150m · Full penetration double bevel welds for webs and flanges of the corrugated bulkhead that are within about 200mm from the corner of the corrugation (see **Fig.C14.2**) · 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 150m and above · Full penetration double bevel welds (2) For ships having a length, L_1, that is less than 150m · Full penetration double bevel welds for webs and flanges of the corrugated bulkhead that are within about 200mm from the corner of the corrugation (see **Fig.C14.2**) · 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 corrugated bulkhead		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. C14.2 Extent of about 200mm from the Corner of the Corrugation



(a) Welded type

(b) Bent type

Chapter 15 LONGITUDINAL STRENGTH

15.1 General

15.1.1 Special Cases in Application*

1 Notwithstanding the requirements in this Chapter, the longitudinal strength for ships subject to **Chapter 32** is to comply with the requirements in **Chapter 32**.

2 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.)

15.1.2 Continuity of Strength*

Longitudinal members are to be so arranged as to maintain the continuity of strength.

15.2 Bending Strength

15.2.1 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. C15.1**)

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-m*)

$M_w(-) = -0.11C_1C_2L_1^2B(C_b' + 0.7)$ (*kN-m*)

C_1:As given by the following formulae:

$$10.75 - \left(\frac{300-L_1}{100}\right)^{1.5} \quad \text{for } L_1 \leq 300m$$

$$10.75 \quad \text{for } 300m < L_1 \leq 350m$$

$$10.75 - \left(\frac{L_1-350}{150}\right)^{1.5} \quad \text{for } 350m < L_1$$

L_1: Distance (m) measured on the waterline at the scantling draught d_S from the forward side of the stem to the centre of the rudder stock. L_1 is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught d_S. In ships without rudder stocks (e.g. ships fitted with azimuth thrusters), the Rule length L_1 is to be taken equal to 97% of the extreme length on the waterline at the scantling draught d_S.

d_S: Scantling draught (m) at which the strength requirements for the scantlings of the ship are met and represents the full load condition. d_S is to be not less than that corresponding to the assigned freeboard.

C'_b: Volume of displacement corresponding to the scantling draught d_S divided by $L_1 B_S d_S$

However, the value is to be taken as 0.6, where it is less than 0.6.

B_S: Breadth (m) measured amidships at the scantling draught d_S.

C_2: Coefficient specified along the length at positions where the transverse section of the hull is under consideration, as given in **Fig. C15.2**

Fig. C15.1 Positive Value of Longitudinal Bending Moment

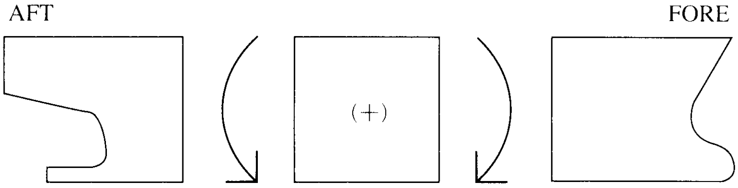
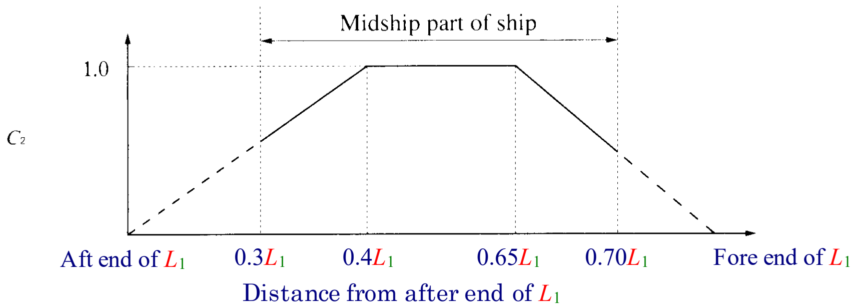


Fig. C15.2 Value of Coefficient C_2



2 Notwithstanding the requirements of **-1** above, the section modulus of the transverse section of the hull amidships is not to be less than the value of W_{min} obtained from the following formula:

$$W_{min} = C_1 L_1^2 B(C'_b + 0.7) \ \ (cm^3)$$

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 amidships 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 **15.2.3**.

$$3W_{min}L_1 \ \ (cm^4)$$

W_{min}: Section modulus of the transverse section of hull amidships 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 midship 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.

15.2.2 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 **17.2**.

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 **15.2.1-1** with necessary modifications.

15.2.3 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 $0.06(B - \Sigma b)$. Σb 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.

15.3 Shearing Strength

15.3.1 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 t_s 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.

$$t_s = 0.455|F_s + F_w(+)|\frac{m}{I}\ (mm)$$

$$t_s = 0.455|F_s + F_w(-)|\frac{m}{I}\ (mm)$$

I: Moment of inertia (cm^4) of the transverse section under consideration about its horizontal neutral axis, where the requirements in **15.2.3** 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 **15.2.3** 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. C15.3**)

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:

$F_w(+) = +0.3C_1C_3L_1B(C_b' + 0.7)\ (kN)$

$F_w(-) = -0.3C_1C_4L_1B(C_b' + 0.7)\ (kN)$

C_1, L_1 and C_b': As specified in **15.2.1-1**

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. C15.4** and **Fig C15.5**

Fig. C15.3 Positive Value of Shearing Force

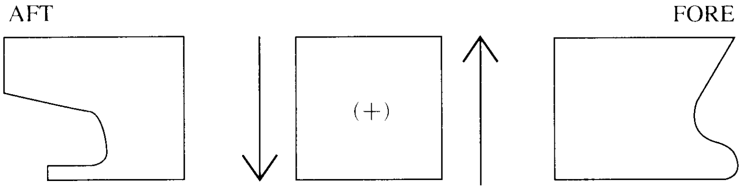


Fig. C15.4 Values of Coefficient C_3

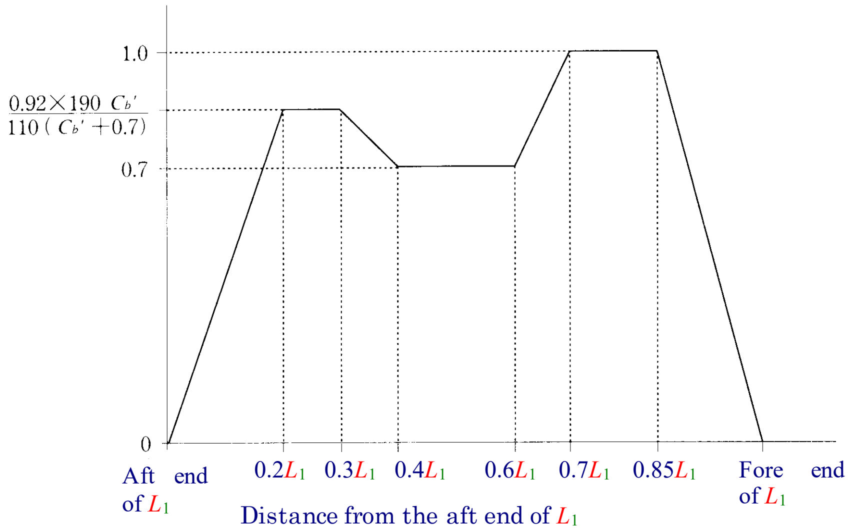
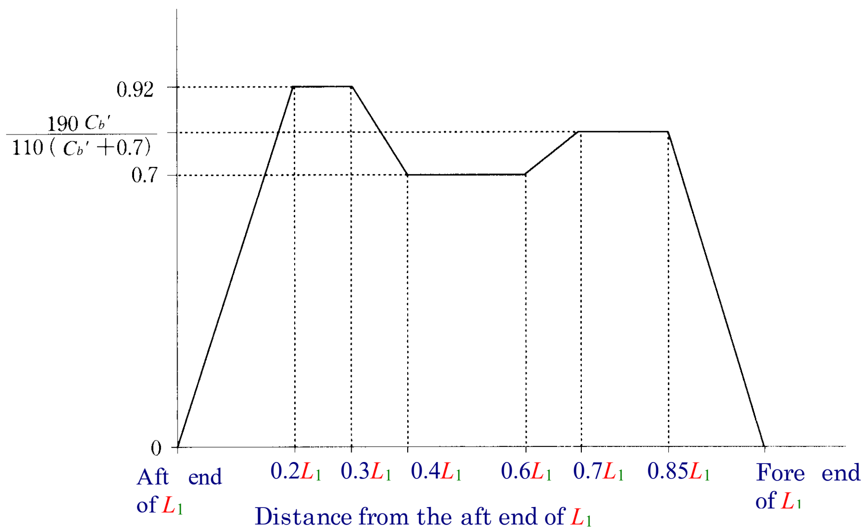


Fig. C15.5 Values of Coefficient C_4



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.

15.3.2 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. C15.6** 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.

$$t = 0.91\frac{Fm}{I}\ (mm)$$

Where:

I and m: As specified in **15.3.1-1**

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:

$F(+) = |\alpha(F_s + F_w(+)) + \Delta F|$ (kN)

$F(-) = |\alpha(F_s + F_w(-)) + \Delta F|$ (kN)

F_s, $F_w(+)$ and $F_w(-)$: As specified in **15.3.1-1**

Except when deemed otherwise by the Society, the values of α and ΔF may be based on those specified in **Table C15.1**.

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. C15.6 Types of Ships with Longitudinal Bulkheads

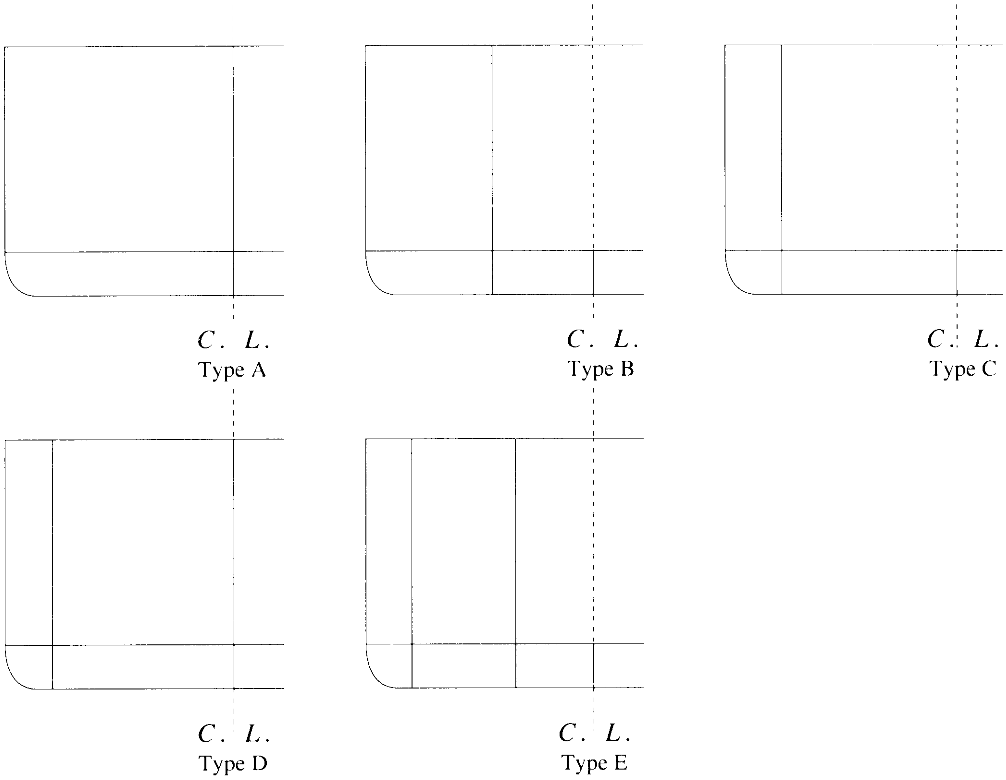


Table C15.1 Values of α and ΔF

Type	Application	$\alpha(=\alpha_1\cdot\alpha_2)$		$\Delta F(=n_i(R-\alpha f))$	
		α_1	α_2	R	f
A	Side shell	$0.5-0.575\dfrac{k_1A_L}{2A_s+A_L}$	1	$4.9W_bbS$	$19.6W_bbS$
	Longitudinal bulkhead	$\dfrac{0.575k_1A_L}{2A_s+A_L}$	2	$9.8W_bbS$	
B	Side shell	$0.5-\dfrac{0.55k_1A_L}{A_s+A_L}$	1	$4.9W_bbS$	$19.6(W_aa+W_bb)S$
	Longitudinal bulkhead	$\dfrac{0.55k_1A_L}{A_s+A_L}$		$9.8(\beta W_aa+0.5W_bb)S$	
C	Side shell	0.5	$1-\dfrac{1.06k_2A_{DL}}{A_s+A_{DL}}$	$4.9(\beta W_aa+W_cc)S$	$19.6(W_aa+W_cc)S$
	Longitudinal bulkhead		$\dfrac{1.06k_2A_{DL}}{A_s+A_{DL}}$		
D	Side shell	$0.5-\dfrac{0.675k_1A_L}{2(A_s+A_{DL})+A_L}$	$1-\dfrac{1.05k_2A_{DL}}{A_s+A_{DL}}$	$4.9(0.5W_bb+W_cc)S$	$19.6(W_bb+W_cc)S$
	Outer longitudinal bulkhead		$\dfrac{1.05k_2A_{DL}}{A_s+A_{DL}}$		
	Centre longitudinal bulkhead	$\dfrac{0.675k_1A_L}{2(A_s+A_{DL})+A_L}$	2	$9.8W_bbS$	
E	Side shell	$0.5-\dfrac{0.615k_1A_L}{A_s+A_{DL}+A_L}$	$1-\dfrac{1.04k_2A_{DL}}{A_s+A_{DL}}$	$4.9(0.5W_bb+W_cc)S$	$19.6(W_aa+W_bb+W_cc)S$
	Outer longitudinal bulkhead		$\dfrac{1.04k_2A_{DL}}{A_s+A_{DL}}$		
	Inner longitudinal bulkhead	$\dfrac{0.615k_1A_L}{A_s+A_{DL}+A_L}$	1	$9.8(\beta W_aa+0.5W_bb)S$	

15.3.3 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.

15.4 Buckling Strength

15.4.1 General*

1 The requirements in this section apply to platings and longitudinals subject to hull girder bending and shear stresses and contributing to longitudinal strength.

2 In addition to the requirements specified in -1 above, throughout the length of the ship, the buckling strength for members in regions where changes in the framing system or significant changes in the hull cross-section occur is to be in accordance with the requirement in this section.

3 Notwithstanding the requirements in -1 and -2 above, the buckling strength can be examined by other measures as deemed appropriate by the Society than that specified in this section.

4 When calculating the buckling stresses in 15.4.3 and 15.4.4, the standard thickness deductions given in Table C15.2 apply to t_b, t_w, t_f, and t_p according to the location.

5 Where deemed necessary by the Society, the buckling strength of members other than that specified in -1 and -2 above are to be examined.

Table C15.2 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- Vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line	$0.05t$	0.5	1.0
1. One side exposure to ballast and/or liquid cargo- Horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line 2. Two side exposure to ballast and/or liquid cargo- Vertical surfaces and surfaces sloped at an angle greater 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 25° to the horizontal line	$0.15t$	2.0	4.0

Notes:
't' is the thickness of structural members under consideration. (*mm*)

15.4.2 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 $30/K$.

$$\sigma_a = \frac{M_S+M_W}{I} y \times 10^5 \ (N/mm^2)$$

K: Coefficient corresponding to the kinds of steel

e.g. 1.0 for mild steel, the values specified in **1.1.7-2(1)** for high tensile steel

M_s: Longitudinal bending moment (*kN-m*) in still water as specified in **15.2.1**

M_w: Wave induced longitudinal bending moment (*kN-m*) as specified in **15.2.1**

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 **15.3.1-1**

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

$$\tau_a = \frac{0.5mF}{It} \times 10^2 \ (N/mm^2)$$

F: Shearing force as specified in **15.3.1-1.**, the value of whichever is greater,

$|F_s + F_w(+)|$ or $|F_s + F_w(-)|$ (*kN*)

m: Moment of area (cm^3) of the athwartship section considered, as specified in **15.3.1-1**

I: As specified in preceding **-1**

t: Thickness (*mm*) of the member considered

(2) Ships with longitudinal bulkhead

$$\tau_a = \frac{mF}{It} \times 10^2 \ (N/mm^2)$$

F: Shearing force (*kN*) as specified in **15.3.2**

m, I and t: As specified in preceding **(1)**

15.4.3 Elastic Buckling Stresses of Plates*

1 Compressive buckling stress σ_E of plates is given by the following formula:

$$\sigma_E = 0.9K_m E\left[\frac{t_b}{1000s}\right]^2 \ (N/mm^2)$$

E: Modulus of elasticity for material:

2.06×10^5 for steel (N/mm^2)

t_b: Thickness (mm) of plating considering standard deductions as specified in **15.4.1-3**

s: Span (m) of shorter side of plate panel

K_m: For plating with longitudinal stiffeners

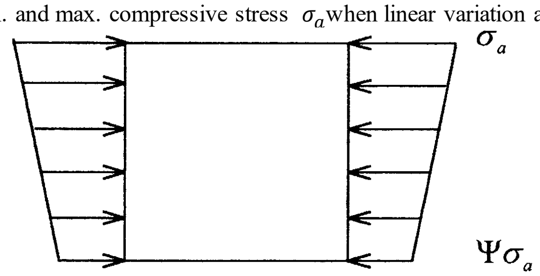
$$K_m = \frac{8.4}{\Psi+1.1} \quad (\text{for } 0 \le \Psi \le 1)$$

For plating with transverse stiffeners

$$K_m = c\left[1+\left[\frac{s}{l}\right]^2\right]^2 \cdot \frac{2.1}{\Psi+1.1} \quad (\text{for } 0 \le \Psi \le 1)$$

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:

$$\tau_E = 0.9k_t E\left[\frac{t_b}{1000s}\right]^2 \ (N/mm^2)$$

k_t: 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**

15.4.4 Elastic Buckling of Longitudinals

1 Compressive buckling stress σ_E of longitudinal frame, beam and stiffener is given by the following formula:

$$\sigma_E = 0.001E\frac{I_a}{Al^2} \ (N/mm^2)$$

E: As specified in **15.4.3-1**

I_a: Moment of inertia (cm^4) of longitudinal including plate flange and calculated with thickness as specified in **15.4.1-3**

A: Cross-sectional area (cm^2) of longitudinal including plate flange and calculated with thickness as specified in **15.4.1-3**

l: Span (m) of longitudinal

2 Torsional buckling stress σ_E of longitudinal frame, beam and stiffener is given by the following formula:

$$\sigma_E = \frac{\pi^2 E I_w}{10^4 I_P l^2}\left[m^2 + \frac{K}{m^2}\right] + 0.385E\frac{I_t}{I_P} \quad (N/mm^2)$$

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:

$\frac{h_w t_w^3}{3} \times 10^{-4}$ for flat bars (slabs)

$\frac{1}{3}\left[h_w t_w^3 + b_f t_f^3\left[1 - 0.63\frac{t_f}{b_f}\right]\right] \times 10^{-4}$ 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:

$\frac{h_w^3 t_w}{3} \times 10^{-4}$ for flat bars (slabs)

$\left[\frac{h_w^3 t_w}{3} + h_w^2 b_f t_f\right] \times 10^{-4}$ 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:

$\frac{h_w^3 t_w^3}{36} \times 10^{-6}$ for flat bars (slabs)

$\frac{t_f b_f^3 h_w^2}{12} \times 10^{-6}$ for T-sections

$\frac{b_f^3 h_w^2}{12(b_f + h_w)^2}\left[t_f(b_f^2 + 2b_f h_w + 4h_w^2) + 3t_w b_f h_w\right] \times 10^{-6}$ for angles and bulb sections

h_w: Web height (mm)

t_w: Web thickness (mm) considering standard deductions as specified in **15.4.1-3**

b_f: Flange width (mm)

t_f: Flange thickness (mm) considering standard deductions as specified in **15.4.1-3**

For bulb sections, the mean thickness of the bulb is to be used.

l: Span (m) of longitudinal

K: As given by the following:

$$K = \frac{Cl^4}{\pi^4 E I_w} \times 10^6$$

C: As given by the following:

$$C = \frac{k_P E t_P^3}{3s\left[1 + \frac{1.33 k_P h_w t_P^3}{1000 s t_w^3}\right]} \times 10^{-3}$$

s: Spacing (m) of longitudinal

t_P: Thickness (mm) of plate connected to longitudinals considering standard deductions as specified in **15.4.1-3**

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:

$$\eta_P = \frac{\sigma_a}{\sigma_{EP}}$$

σ_a: Calculated compressive stress for longitudinals as specified in **15.4.2**

σ_{EP}: Elastic buckling stress of supporting plate as calculated in **15.4.3**

E: As specified in **15.4.3-1**

m: As given by **Table C15.3**

3 Compressive buckling stress σ_E for web plate of longitudinals is given by the following formula:

$$\sigma_E = 3.8E\left[\frac{t_w}{h_w}\right]^2 \ (N/mm^2)$$

E, t_w and h_w: As specified in **-2 above**

Table C15.3 The value of m

	$0 < K < 4$	$4 \leq K < 36$	$36 \leq K < 144$	$m^2(m-1)^2 \leq K < m^2(m+1)^2$
m	1	2	3	M

15.4.5 Critical Buckling Stress

1 The critical buckling stress in compression σ_c is determined as follows:

$$\sigma_C = \sigma_E \text{ when } \sigma_E \leq \frac{\sigma_Y}{2}$$

$$\sigma_C = \sigma_Y\left[1 - \frac{\sigma_Y}{4\sigma_E}\right] \text{ when } \sigma_E > \frac{\sigma_Y}{2}$$

σ_E: The compressive buckling stress calculated according to **15.4.3** and **15.4.4**

σ_Y: Minimum yield stress (N/mm^2) of material as specified in **Part K**.

2 The critical buckling stress in shear τ_C is determined as follows:

$$\tau_C = \tau_E \text{ when } \tau_E \leq \frac{\tau_Y}{2}$$

$$\tau_C = \tau_Y\left[1 - \frac{\tau_Y}{4\tau_E}\right] \text{ when } \tau_E > \frac{\tau_Y}{2}$$

Where:

τ_E: The shearing buckling stress calculated according to **15.4.3**

τ_Y: As given by the following:

$$\tau_Y = \frac{\sigma_Y}{\sqrt{3}}$$

σ_Y: As specified in **-1 above**

15.4.6 Scantling Criteria

The buckling strength for platings (including web platings of longitudinal girders and stringers) and longitudinals is to comply with the following:

(1) $\sigma_C \geq \beta\sigma_a$ 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) $\tau_C \geq \tau_a$ for shearing buckling of plate panels

15.4.7 Other Special Requirements*

1 Flanges on angles and T-sections of longitudinals are to comply with the following formula:

$$\frac{b_f}{t_f} \leq 15$$

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 0.3L from the fore end of the ships.

Chapter 16 PLATE KEELS AND SHELL PLATING

16.1 General

16.1.1 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.

16.1.2 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 **32.2.7** for ships subject to the requirements in **Chapter 32** and **15.4** for other ships.

16.1.3 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.

16.1.4 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.

16.1.5 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.

16.1.6 Moving Parts Penetrating the Shell Plating

Moving parts penetrating the shell plating below the deepest subdivision draught specified in **4.1.2(3)**, 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 freeboard 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.

16.2 Plate Keels

16.2.1 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 **16.3.4** plus 2.0 mm. However, this thickness is not to be less than that of the adjacent bottom shell plating.

16.3 Shell Plating below the Strength Deck

16.3.1 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)

16.3.2 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 **15.3.1** and **15.3.2**.

(1) In ships with transverse framing, the thickness of side shell plating is not to be less than that obtained from the following formula:

$$C_1C_2S\sqrt{d - 0.125D + 0.05L' + h_1} + 2.5 \ (mm)$$

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:

$$\frac{91}{\sqrt{576-\alpha^2x^2}}$$

α: As given in (a) or (b), whichever is greater

(a) $15.5f_B\left(1-\frac{y}{y_B}\right)$

(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 15** 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:

$$C_1C_2S\sqrt{d-0.125D+0.05L'+h_1}+2.5\ \ (mm)$$

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)**

16.3.3 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.

16.3.4 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:

$$C_1C_2S\sqrt{d+0.035L'+h_1}+2.5\ \ (mm)$$

Where:

S: Spacing (m) of transverse frames

L': Length (m) of ship specified in **16.3.2(1)**

C_1: Coefficient specified in **16.3.2(1)**

h_1: Head specified in **16.3.2(1)**

C_2: Coefficient given below:

$$\frac{91}{\sqrt{576-(15.5f_Bx)^2}}$$

f_B and x: As specified in **16.3.2(1)**

(2) In ships with longitudinal framing, the thickness is not to be less than that obtained from the following formula:

$$C_1C_2S\sqrt{d+0.035L'+h_1}+2.5\ \ (mm)$$

Where:

S: Spacing (m) of longitudinal frames

L', C_1 and h_1: As specified in **16.3.2(1)**

C_2: Coefficient given below

Where it is less than 3.78, C_2 is to be taken as 3.78.

$$\frac{13}{\sqrt{24-15.5f_Bx}}$$

f_B and x: As specified in **16.3.2(1)**

16.3.5 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.

$$\left\{5.22(d+0.035L')\left(R+\frac{a+b}{2}\right)^{\frac{3}{2}}l\right\}^{\frac{2}{5}}+2.5\ \ (mm)$$

Where:

R: Bilge radius (m)

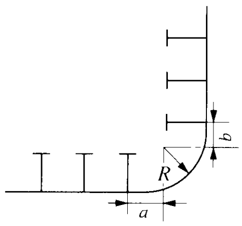
a and b: Distance (m) from the lower and upper turns of the bilge to the longitudinal frames nearest to the turns taking the distance outward from the bilge part as positive

However, where $(a+b)$ is negative, $(a+b)$ is to be taken as zero. (*See* **Fig. C16.1**)

L': As specified in **16.3.2**

l: Spacing (m) of solid floors, bottom transverses or bilge brackets

Fig. C16.1 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 **16.3.4** irrespective of the requirements in **-1**.

4 Where bilge keels are fitted, special consideration is to be given to both the material and the arrangement.

16.4 Special Requirements for Shell Plating

16.4.1 Consideration of Bow Impact Pressure*

For shell plating where the bow impact pressure is assumed to be large, sufficient consideration is to be made regarding reinforcement against forces acting on the bow such as wave impact pressure.

16.4.2 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.

16.4.3 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.

16.4.4 Shell Plating of Bottom Forward*

The thickness of shell plating at the strengthened bottom forward specified in **6.8.2** 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 **16.3.2**.

$$CS\sqrt{P} + 2.5 \quad (mm)$$

Where:

C: Coefficient given in **Table C16.1**

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 **6.8.4**

(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 **16.3.4** or obtained from the following formula, whichever is greater. Where L' is as defined in **16.3.2**.

$$1.34S\sqrt{L} + 2.5 \quad (mm)$$

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 C16.1 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

16.4.5 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)

16.5 Side Plating in way of Superstructure

16.5.1 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

16.6 Compensation at Ends of Superstructure

16.6.1 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.

16.6.2 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.

16.7 Local Compensation of Shell Plating

16.7.1 Openings in Shell*

All openings in the shell plating are to have their corners well rounded and to be compensated as necessary.

16.7.2 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)

16.7.3 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.

16.7.4 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 17 DECKS

17.1 General

17.1.1 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.

17.1.2 Watertightness of Decks*

1 Weather decks, except where hatchway and other openings specified in **Chapter 20** are provided, are to be made watertight.

2 Special consideration is to be given to maintaining watertightness where the decks are required to be watertight in compliance with the requirements of **Chapter 4**.

17.1.3 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.

17.1.4 Compensation for Openings*

1 Hatchways or other openings on strength or effective decks are to have well rounded corners, and compensation is to be suitably provided as necessary.

2 Where attachments such as slant plates or protective means are provided on hatch corners of cargo hatchways, such attachments are not to be directly welded onto strength decks.

17.1.5 Rounded Gunwales*

Rounded gunwales, where adopted, are to have a sufficient radius for the thickness of the plates.

17.2 Effective Sectional Area of Strength Deck

17.2.1 General

1 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.

2 The requirements in **32.2** are to apply to ships subject to **Chapter 32** in place of the requirements in this Chapter.

17.2.2 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 15** is to be so determined as to comply with the requirements in **Chapter 15**.

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.

17.2.3 Strength Deck beyond 0.15*L* 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.

17.2.4 Effective Sectional Area of Strength Deck within Long Poop*

Notwithstanding the requirements in **17.2.2**, the effective sectional area of the strength deck within long poop may be properly modified.

17.2.5 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.

17.3 Deck Plating

17.3.1 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 **10.2**

(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.

17.3.2 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 **14.2.7** for deep tank bulkhead plating, taking the beam spacing as the stiffener spacing.

17.3.3 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 **13.2.8-2** for watertight bulkhead plating, taking the beam spacing as the stiffener spacing.

17.3.4 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.

17.3.5 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.

17.3.6 Thickness of Decks Supporting Unusual Cargoes

The thickness of plates of decks carrying cargo loads which can not be treated as evenly distributed loads is to be determined by taking into account the load distribution of each particular cargo.

17.4 Deck Compositions

17.4.1 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 R**.

17.5 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 **Part L** 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 **12.7.2-3(1)**, using the following allowable stresses:

shear stress: $\tau = 0.34\sigma_F$ (N/mm^2)

bending stress: $\sigma = 0.50\sigma_F$ (N/mm^2)

equivalent stress: $\sigma_e = \sqrt{\sigma^2 + 3\tau^2} = 0.64\sigma_F$ (N/mm^2)

σ_F: Minimum upper yield stress (N/mm^2) or proof stress (N/mm^2) of the material

Chapter 18 SUPERSTRUCTURES

18.1 General

18.1.1 Application*

1 Ships are to be provided with forecastles. However, for ships other than those defined in **1.3.1(13)**, **Part B of the Rules**, 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.

18.2 Superstructure End Bulkheads

18.2.1 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:

$$a(bf - y) \quad (m)$$

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 that 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. C18.1**

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 C18.1**, irrespective of the provisions in **-1**:

Fig. C18.1 Value of f

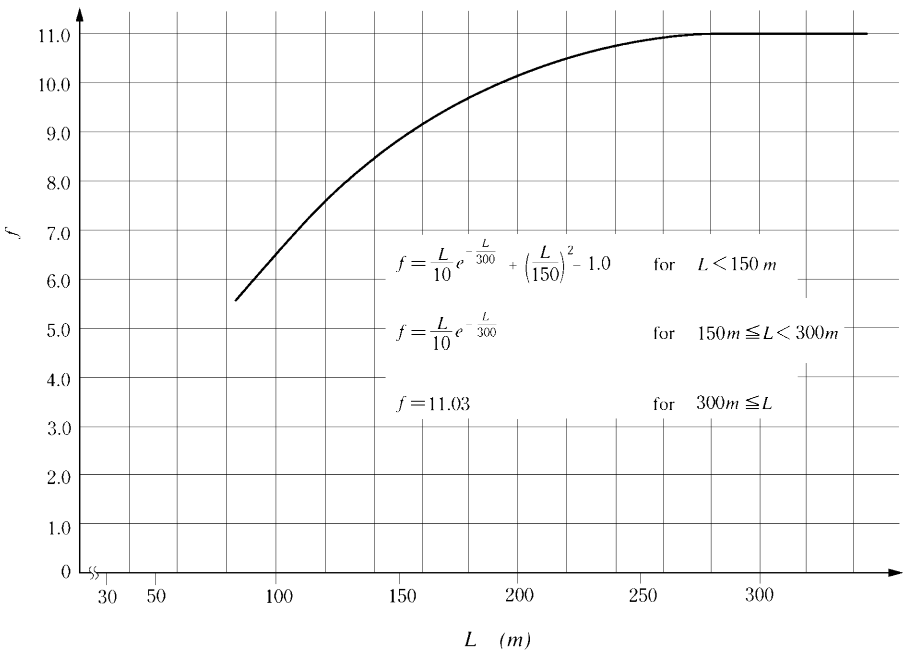


Table C18.1

	Exposed front bulkhead of the first tier superstructure	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 Bulkhead Plating

1 The thickness of superstructure end bulkhead plating is not to be less than that obtained from the following formula:

$$3S\sqrt{h} \ (mm)$$

Where:

h: Head of water (m) specified in **18.2.1**

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 **18.2.1**

18.2.3 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 **18.2.2**

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.

18.2.4 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 **18.2.2** and **18.2.3** taking this bulkhead as that of the first tier superstructure.

18.3 Closing Means for Access Openings in Superstructure End Bulkheads

18.3.1 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 **20.4.2**. However, higher sills may be required when deemed necessary by the Society.

(2) In principle, portable sills are not permitted.

18.4 Additional Requirements for Bulk Carriers, Ore Carriers and Combination Carriers, etc.*

Bulk carriers defined in **1.3.1(13)** of **Part B** and self-unloading ships defined in **1.3.1(19)** of **Part B** are to be provided with forecastles in accordance with the following requirements. However, the forecastle deck arrangements of ships for which the application of this requirement is, for some reason, difficult are 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. C18.2**)

(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 greater:

(a) $H_C + 0.5$ (m), where H_C is the height of the forward transverse hatch coaming of the foremost cargo hold.

(b) The standard height of superstructure as given in **Table C18.2**. Intermediate values of L_f are to be obtained by linear interpolation.

(4) With respect to the design loads for the hatch covers and forward transverse hatch coamings of foremost cargo holds, to reduce the load on the forward transverse hatch coaming of the foremost cargo hold and/or the pressure applying abaft on the hatch cover of the foremost cargo hold, 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 at the horizontal distance l_w (m) satisfying the following formula:

$$l_w \geq H_B / \tan 20°$$

H_B: Height of the breakwater above the forecastle.

Fig. C18.2

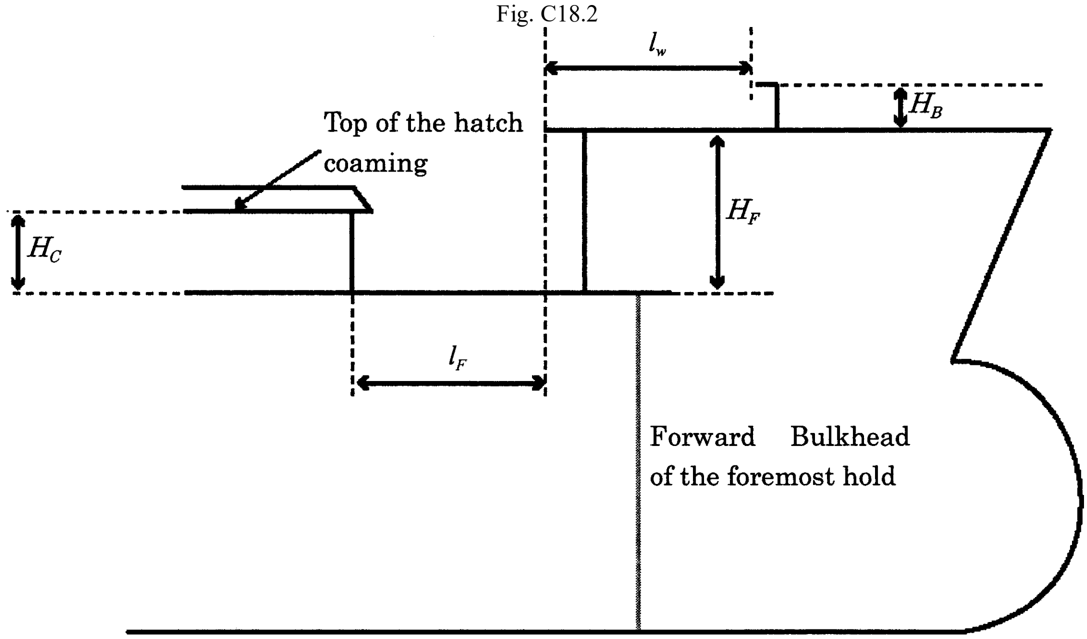


Table C18.2 Standard Height of Superstructure

Length of ship for freeboard (L_f)	Standard Height of Superstructure (m)
75 m or less	1.80
125 m or more	2.30

Chapter 19 DECKHOUSES

19.1 General

19.1.1 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.

19.2 Construction

19.2.1 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:

$$ac(bf - y) \ (m)$$

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 $0.15L$, the side wall is to be equally subdivided into spans not exceeding $0.15L$ 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. C18.1**

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 C19.1**, irrespective of the provisions in **-1**:

Table C19.1

	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)

19.2.2 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 **18.2.2** and **18.2.3**, taking the water head specified in **19.2.1** 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.

19.2.3 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 **18.3**. However, where stairways are enclosed with boundary walls fitted with closing means complying with the requirements in **18.3**, 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.

19.2.4 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.

19.2.5 Spaces below Especially Heavy Equipment

Deckhouses below especially heavy equipment such as survival craft and deck machinery are to be suitably strengthened.

19.2.6 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 20 HATCHWAYS, MACHINERY SPACE OPENINGS AND OTHER DECK OPENINGS

20.1 General

20.1.1 Relaxation from the Requirements

Relaxation from the requirements in this Chapter will be specially considered where the ship has an unusually large freeboard.

20.1.2 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 $0.25L_f$ 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 $0.25L_f$ abaft the fore end of L_f and located at least two standard heights of superstructure above the freeboard deck.

20.1.3 Definitions

The terms used in **20.2** are defined as follows.

(1) “Type 1 ship” means any ship other than “Type 2 ship”.

(2) “Type 2 ship” means ore carriers and combination carriers designed to carry either oil or solid cargoes in bulk(e.g. ore/oil carriers) defined in **1.3.1(13), Part B** (excluding those affixed with the notation “*CSR*”), and self-unloading ships defined in **1.3.1(19), Part B**.

20.2 Hatchways

20.2.1 Application

1 The construction and the means for closing of cargo and other hatchways on exposed decks are to comply with the requirements in **20.2**.

2 When the loading condition or the type of construction differs from that specified in this section, the calculation method used is to be as deemed appropriate by the Society.

3 Hatch covers and hatch coamings on non-exposed decks of ships and those of fishing vessels are to be as deemed appropriate by the Society.

20.2.2 General Requirement

1 Primary supporting members and stiffeners of hatch covers are to be continuous over the breadth and length of hatch covers. When this is impractical, appropriate arrangements are to be adopted to ensure sufficient load carrying capacity and sniped end connections are not to be allowed.

2 The spacing of primary supporting members parallel to the direction of stiffeners is not to exceed 1/3 of the span of the primary supporting members.

3 Stiffeners of hatch coamings are to be continuous as far as practical over the breadth and length of said hatch coamings.

20.2.3 Net Scantling Approach

1 Unless otherwise specified, the structural scantlings specified in this section are to be net scantlings which do not include any corrosion additions.

2 “Net scantlings” are the scantlings necessary to obtain the minimum net scantlings required by **20.2.5** and **20.2.9**.

3 Required gross scantlings are not to be less than the scantlings obtained from adding the corrosion addition t_c specified in **-4** below to the net scantlings obtained from the requirements in this section.

4 The corrosion addition t_c is to be taken as specified in **Table C20.1** according to ship type, the type of structure and structural members of steel hatchway covers, steel pontoon covers and steel weathertight covers (hereinafter referred to as “steel hatch covers”).

However, the corrosion additions for structural members that make up hatchway coamings are to be as deemed appropriate by the Society when their t_c values are not specified in **Table C20.1**.

5 Strength calculations using FEM are to be performed with net scantlings.

Table C20.1 Corrosion Additions

Type	Ship type	Framing system		t_c (mm)
Type 1 ship	Ships other than the below	Single skin hatch covers		2.0
		Double skin hatch covers	Top, side and bottom plating	1.5
			Internal structural members	1.0
		Hatch coamings, hatch coaming stays and stiffeners		1.5
	Container carrier Car carrier	Hatch covers (in general)		1.0
		Hatch coamings		1.5
Type 2 ship	Ore carrier Combination carriers which are designed to carry either oil or solid cargoes in bulk, like ore/oil carriers. Self-unloading ships (Ships specified in **1.3.1(13), Part B**(excluding those affixed with the notation "*CSR*") and **(19)**)	Single skin hatch covers		2.0
		Double skin hatch covers	Top, side and bottom plating	2.0
			Internal structural members	1.5
		Hatch coamings, hatch coaming stays and stiffeners		1.5

Notes
(1) Corrosion additions for both sides of hatch covers and hatch coamings on non-exposed decks are to be as deemed appropriate by the Society.
(2) The definitions of Type 1 ship and Type 2 ship are given **20.1.3**.

20.2.4 Design Loads*

The design loads for steel hatchway covers, steel pontoon covers, steel weathertight covers, portable beams and hatchway coamings applying the requirements in **20.2** are specified in following **(1)** to **(5)**:

(1) Design vertical wave load P_{HC} (kN/m^2) is not to be less than that obtained from **Table C20.2**. Design vertical wave loads need not to be combined with cargo loads according to **(3)** and **(4)** simultaneously.

(2) Design horizontal wave load P_A (kN/m^2) is not to be less than that obtained from the following formulae. However, P_A is not to be taken less than the minimum values given in **Table C20.3**. P_A need not be included in the direct strength calculation of the hatch cover, expect where structures supporting stoppers are assessed.

$$P_A = f_n f_c [f_b C_1 - y]$$

f_n: As given by the following:

$20 + \frac{L'}{12}$ for unprotected front coamings and hatch cover skirt plates

$10 + \frac{L'}{12}$ for unprotected front coamings and hatch cover skirt plates, where the distance from the actual freeboard deck to the summer load line exceeds the minimum non-corrected tabular freeboard according to the ILCC by at least one superstructure standard height

$5 + \frac{L'}{15}$ for side and protected front coamings and hatch cover skirt plates

$7 + \frac{L'}{100} - 8\frac{x}{L_1}$ for aft ends of coamings and aft hatch cover skirt plates abaft amidships

$5+\frac{L'}{100}-4\frac{x}{L_1}$ for aft ends of coamings and aft hatch cover skirt plates forward of amidships

L': Length of ship L_1 (m). However, where L_1 exceeds $300m$, L' is to be taken as $300m$.

L_1: Distance (m) measured on the waterline at the scantling draught d_S from the forward side of the stem to the centre of the rudder stock. L_1 is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught d_S. In ships without rudder stocks (e.g. ships fitted with azimuth thrusters), the Rule length L_1 is to be taken equal to 97% of the extreme length on the waterline at the scantling draught d_S.

d_S: Scantling draught (m) at which the strength requirements for the scantlings of the ship are met and represents the full load condition. d_S is to be not less than that corresponding to the assigned freeboard.

C_1: As given by the following formulae:

$10.75-\left(\frac{300-L_1}{100}\right)^{1.5}$ for $L_1 \leq 300m$

10.75 for $300 < L_1 \leq 350m$

$10.75-\left(\frac{L_1-350}{150}\right)^{1.5}$ for $350 < L_1$

c_L: Coefficient to be taken as 1.0

f_b: As given by the following formulae:

$1.0+\left(\frac{0.45-\frac{x}{L_1}}{C_{b1}+0.2}\right)^2$ for $\frac{x}{L_1} < 0.45$

$1.0+1.5\left(\frac{\frac{x}{L_1}-0.45}{C_{b1}+0.2}\right)^2$ for $\frac{x}{L_1} \geq 0.45$

x: Distance (m) from the hatchway coamings or hatch cover skirt plates to after perpendicular, or distance from the mid-point of the side hatchway coaming or hatch cover skirt plates to after perpendicular. However, where the length of the side hatchway coaming or hatch cover skirt plates exceeds $0.15L_1$, the side hatchway coaming or hatch cover skirt plates are to be equally subdivided into spans not exceeding $0.15L_1$ 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. When determining scantlings of the aft ends of coamings and aft hatch cover skirt plates forward of amidships, C_{b1} does not need to be taken as less than 0.8.

f_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 hatchway coamings at the position under consideration

B': Breadth (m) of ship on the exposed weather deck at the position under consideration

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 the plating when determining the thickness of plating

(3) The load on hatch covers due to cargo loaded on said covers is to be obtained from the following **(a)** and **(b)**. Load cases with partial loading are also to be considered.

(a) Distributed load due to cargo load P_L (kN/m^2) resulting from heave and pitch (i.e., ship in upright condition) is to be determined according to the following formula:

$P_L = P_{Cargo}(1+a_V)$

P_{Cargo}: Static uniform cargo load (kN/m^2)

a_V: Vertical acceleration addition given by the following formula:

$$a_V = \frac{0.11mV'}{\sqrt{L_1}}$$

m: As given by the following formulae:

$m_0 - 5(m_0 - 1)\frac{x}{L_1}$ for $0 \le \frac{x}{L_1} \le 0.2$

1.0 for $0.2 < \frac{x}{L_1} \le 0.7$

$1 + \frac{m_0+1}{0.3}\left(\frac{x}{L_1} - 0.7\right)$ for $0.7 < \frac{x}{L_1} \le 1.0$

m_0: As given by the following formula:

$$m_0 = 1.5 + \frac{0.11V'}{\sqrt{L_1}}$$

V': Speed of ship (*knots*) specified in **2.1.8, Part A**. However, where V' is less than $\sqrt{L_1}$, V' is to be taken as $\sqrt{L_1}$.

x and L_1: As specified in **(2)** above

(b) Point load P (kN) due to a single force resulting from heave and pitch (i.e., ship in upright condition) is to be determined by the following formula. However, container loads are to comply with the provisions of **(4)** below.

$$P = P_S(1 + a_V)$$

P_S: Static point load due to cargo (kN)

a_V: As specified in **(a)** above

(4) Where containers are stowed on hatch covers, cargo loads determined by following **(a)** to **(c)** are to be considered:

(a) Cargo loads (kN) acting on each corner of a container stack due to heave, pitch and roll motion of the ship (i.e., ship in heel condition) are to be determined by the following formulae (see **Fig. C20.1**). When the load case of a partially loaded container is considered, the cargo load is at the discretion of the Society.

$$A_Z = 9.81\frac{M}{2}(1 + a_V)\left(0.45 - 0.42\frac{h_m}{b}\right)$$

$$B_Z = 9.81\frac{M}{2}(1 + a_V)\left(0.45 + 0.42\frac{h_m}{b}\right)$$

$$B_Y = 2.4M$$

M: Maximum designed mass of container stack (t)

$$M = \sum W_i$$

h_m: Design height of the centre of gravity of the stack above hatch cover top plates (m) may be calculated as the weighted mean value of the stack, where the centre of gravity of each tier is assumed to be located at the centre of each container.

$$h_m = \sum \frac{(z_i W_i)}{M}$$

z_i: Distance from hatch cover top plate to the centre of ith container (m)

W_i: Weight of ith container (t)

b: Distance between midpoints of foot points (m)

A_Z and B_Z: Support forces in vertical direction at the forward and aft stack corners (kN)

B_Y: Support force in transverse direction at the forward and aft stack corners (kN)

a_V: As specified in **(3)** above

(b) Details of the application of **(a)** above are to be in accordance with the following:

i) The values of A_Z and B_Z applied for the assessment of hatch cover strength are to be shown in the drawings of the hatch covers.

ii) It is recommended that container loads, as calculated in **(a)** above, be considered as the limit for foot point loads of container stacks in cargo securing (container lashing) calculations.

(c) Stack load P_{stack} (kN), acting on each corner of a container stack, due to heave and pitch (i.e., ship in upright condition) is to be determined by the following formula.

$$P_{stack} = 9.81\frac{M}{4}(1 + a_V)$$

a_V: As specified in **(3)** above

M: As specified in **(a)** above

(5) The wave load P_{coam} to be considered in strength assessments of the hatch coaming of Type 2 ships is to be in accordance with the following **(a)** or **(b)**.

(a) Front-end hatch coaming of the foremost cargo hold: 290 (kN/m^2)

However, where a forecastle is installed in accordance with the requirements of **18.4**, this value may be 220 kN/m^2.

(b) Hatch coaming other than **(a)** above: 220 (kN/m^2)

(6) In addition to the loads specified in **(1)** to **(5)** above, when the load in the ship's transverse direction by forces due to elastic deformation of the ship's hull is acting on the hatch covers, the sum of stresses is to comply with the permissible values specified in **20.2.5-1(1)**.

(7) The designed wave load $P_{stopper}$ to be considered in strength assessments of stoppers of Type 2 ships is to be in accordance with the following **(a)** or **(b)**.

(a) Stoppers for the hatch cover to the foremost cargo hold

i) Pressure acting in the direction of the stern on the front-end of the hatch cover: 230 (kN/m^2)

However, where a forecastle is installed in accordance with the requirements of **18.4**, this value may be 175 kN/m^2.

ii) Pressure in the transverse direction of the ship: 175 kN/m^2

(b) Stoppers for hatch covers other than that specified in **(a)** above

Pressure acting in the direction of the stern on the front-end of the hatch cover and pressure in the transverse direction the ship: 175 kN/m^2

Table C20.2 Design Vertical Wave Load P_{HC} (*1) (*2) (kN/m^2)

		$L_f \leq 100m$	$L_f > 100m$
Position I	For $0.25L_f$ forward	$\frac{9.81}{76}\left\{\left(4.28L_f + 28\right)\frac{x}{L_f} - 1.71L_f + 95\right\}$ (*3)	For type B ships according to ICLL (*4) : $9.81\left\{\left(0.0296L'_f + 3.04\right)\frac{x}{L_f} - 0.0222L'_f + 1.22\right\}$ For type B-60 and B-100 ships according to ICLL (*4) : $9.81\left\{\left(0.1452L'_f - 8.52\right)\frac{x}{L_f} - 0.1089L'_f + 9.89\right\}$
	Elsewhere	$\frac{9.81}{76}(1.5L_f + 116)$	9.81×3.5
Position II		$\frac{9.81}{76}(1.1L_f + 87.6)$	9.81×2.6 (*5)

Notes:

(*1) L_f: Length of ship for freeboard defined in **2.1.3, Part A of the Rules** (m)

L'_f : L_f (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 aft end of L_f (m)

(*2) For exposed hatchways in positions other than Position I or II, the value of each design wave load will be specially considered.

(*3) Where a Position I hatchway is located at least one superstructure standard height higher than the freeboard deck, P_{HC} may be taken as $\frac{9.81}{76}(1.5L_f + 116)$ (kN/m^2).

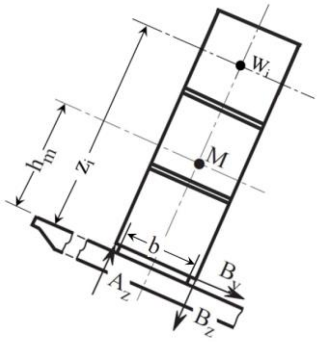
(*4) Where a Position I hatchway is located at least one superstructure standard height higher than the freeboard deck, P_{HC} may be taken as 9.81×3.5 (kN/m^2).

(*5) Where a Position I hatchway is located at least one superstructure standard height higher than the Position II deck, P_{HC} may be taken as 9.81×2.1 (kN/m^2).

Table C20.3 Minimum Value of P_A (kN/m^2)

	Unprotected front coamings and hatch cover skirt plates	others
$L_1 < 250$	$25 + \frac{L_1}{10}$	$12.5 + \frac{L_1}{20}$
$L_1 \geq 250$	50	25

Fig C20.1 Forces due to Container Loads



20.2.5 Strength Criteria of Steel Hatch Covers and Hatch Beams

1 Permissible stresses and deflections

(1) All hatch cover structural members are to comply with the following formulae:

$\sigma_{vm} \leq \sigma_a$ for shell elements in general.

$\sigma_{axial} \leq \sigma_a$ for rod or beam elements in general.

Where:

σ_a: Allowable stress as defined in **Table C20.4**

σ_{vm} : Von Mises stress (N/mm^2) to be taken as follows:

$$\sigma_{vm} = \sqrt{{\sigma_x}^2 - \sigma_x\sigma_y + {\sigma_y}^2 + 3\tau_{xy}^2}$$

σ_{axial}: Axial stress (N/mm^2) in rod or beam elements

σ_x: Normal stress (N/mm^2) in the x-direction

σ_y: Normal stress (N/mm^2) in the y-direction

τ_{xy}: Shear stress (N/mm^2) in the x-y plane

x, y: Coordinates of a two dimensional Cartesian system in the plane of the considered structural element

σ_Y: Specified minimum yield stress (N/mm^2) of the material. However, when material with σ_Y of more than 355 N/mm^2 is used, the value for σ_Y is to be as deemed appropriate by the Society.

(2) The equivalent stress σ_{vm} (N/mm^2) in steel pontoon covers and hatch beams is not to be greater than $0.68\sigma_Y$, where σ_Y is as specified in **(1)** above.

(3) For FEM calculations, equivalent stress σ_{vm} (N/mm^2) in girders with unsymmetrical flanges of steel hatchway covers and steel weathertight covers is to be determined according to the following **(a)** or **(b)**:

(a) FEM calculations using the stress obtained for fine mesh elements; or

(b) FEM calculations using the stress at the edge of the element or the stress at the centre of the element, whichever is greater.

(4) Deflection is to comply with following **(a)** and **(b)**:

(a) When the design vertical wave load specified in **20.2.4(1)** is acting on steel hatchway covers, steel pontoon covers, steel weathertight covers and portable beams, the vertical deflection of primary supporting members is not to be taken as more than that given by the following:

$0.0056l$ for steel hatchway covers and steel weathertight covers

$0.0044l$ for steel pontoon covers and hatch beams

l: Span of primary supporting members (m)

(b) Where steel hatch covers are arranged for carrying containers and mixed stowage is allowed, i.e., a 40-foot container is stowed on top of two 20-foot containers, particular attention is to be paid to the deflections of hatch covers. In addition the possible contact of deflected hatch covers with in hold cargo has to be observed.

Table C20.4 Allowable Stresses

Members of	Subject to	σ_a (N/mm^2)
Hatch cover structure	External pressure, as defined in **20.2.4(1)**	$0.80\sigma_Y$
	Other loads, as defined in **20.2.4(2)** to **20.2.4(6)**	$0.90\sigma_Y$ for static+dynamic load case $0.72\sigma_Y$ for static load case

2 Local net plate thickness of steel hatch covers

(1) The local net thickness t_{net} (mm) of steel hatch cover top plating is not to be less than that obtained from the following formula, and it is not to be less than 1% of the spacing of the stiffeners or 6 mm, whichever is greater:

$$t_{net} = 0.0158F_p s\sqrt{\frac{P}{0.95\sigma_Y}} \quad (mm)$$

F_p: Coefficient given by the following formula:

$1.9\ \sigma/\sigma_a$ (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: Maximum normal stress (N/mm^2) of the attached plate flange of primary supporting members (see **Fig. C20.2**).

σ_a: Permissible stress (N/mm^2) specified in **Table C20.4**

s: Stiffener spacing (mm)

P: Design load (kN/m^2) specified in **20.2.4(1)** and **20.2.4(3)(a)**

σ_F: Minimum yield stress (N/mm^2) of the material

(2) The net thickness of double skin hatch covers and box girders is to be obtained in accordance with **-5** below taking into consideration of the permissible stresses specified in **20.2.5-1(1)**

(3) When the lower plating of double skin hatch covers is taken into account as a strength member of the hatch cover, the net thickness t_{net} (mm) of the lower plating is not to be less than 5 mm.

(4) When lower plating is not considered to be a strength member of the hatch cover, the thickness of the lower plating is to be determined as deemed appropriate by the Society.

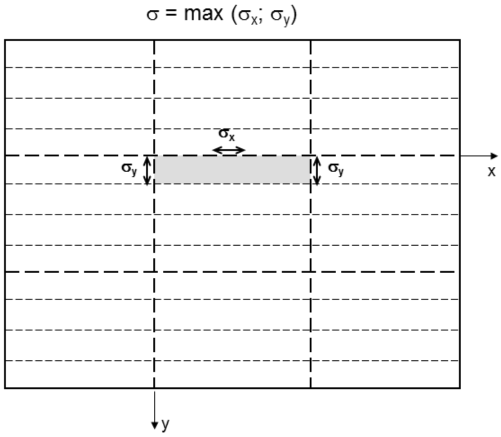
(5) When cargo likely to cause shear buckling is intended to be carried on a hatch cover, the net thickness t_{net} (mm) is not to be less than that obtained from the following formulae. In such cases, "cargo likely to cause shear buckling" refers particularly to large or bulky cargo lashed to the hatch cover, such as parts of cranes or wind power stations, turbines, etc. Cargo that is considered to be uniformly distributed over the hatch cover (e.g., timber, pipes or steel coils) does not need to be considered.

$t_{net} = 6.5s \times 10^{-3}$

$t_{net} = 5$

s: As specified in **(1)** above

Fig. C20.2 Determination of the Normal Stress of Hatch Cover Plating



3 Net scantling of stiffeners

(1) The net section modulus Z_{net} (cm^3) of the stiffeners of hatch cover top plates, based on stiffener net member thickness, is not to be less than that obtained from the following formula. The net section modulus of the stiffeners is to be determined based on an attached plate width that is assumed to be equal to the stiffener spacing.

$$Z_{net} = \frac{Ps\ell^2}{f_{bc}\sigma_a} \quad (cm^3)$$

ℓ: 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 stiffener spans, the 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 (mm)

P: Design load (kN/m^2) as specified in **-2(1)** above

σ_a : Permissible stress (N/mm^2) specified in **Table C20.4**

f_{bc}: Boundary coefficient of stiffener, taken equal to:

f_{bc} = 12, in the case of stiffener clamped at both ends.

f_{bc} = 8, in the case of stiffener simply supported at both ends or simply supported at one end and clamped at the other end

(2) The net shear sectional area A_{net} (cm^2) of the stiffener webs of hatch cover top plates is not to be less than that obtained from the following formula:

$$A_{net} = \frac{8.7Ps\ell}{\sigma_a} 10^{-3} \quad (cm^2)$$

ℓ, s and P: As specified in **(1)** above

(3) Stiffeners parallel to primary supporting members are to be continuous at crossing primary supporting member and may be regarded for calculating the cross sectional properties of primary supporting members.

(4) The combined stress of those stiffeners induced by the bending of primary supporting members and lateral pressures is not to exceed the permissible stresses according to **20.2.5-1(1)**.

(5) For hatch cover stiffeners under compression, sufficient safety against lateral and torsional buckling according to **20.2.5-6** is to be verified.

(6) For stiffeners of the lower plating of double skin hatch covers, the requirements in **(1)** and **(2)** above do not need to be applied due to the absence of lateral loads and the requirements in this **-3** do not need to be applied to stiffeners in cases where the lower plating is not considered to be a strength member.

(7) The net thickness (mm) of a stiffener (except for U-type stiffeners) web is not to be taken as less than 4 mm.

4 Primary supporting members of steel hatch covers

(1) Scantlings of the primary supporting members of steel hatch covers and hatch beams are to be determined according to **-5** below taking into consideration the permissible stresses specified in **20.2.5-1(1)**.

(2) In addition to **(1)** above, the scantlings of the primary supporting members of steel hatch covers are to comply with the requirements specified in **-6**.

(3) In addition to **(1)** and **(2)** above, net thickness t_{net} (mm) of the webs of primary supporting members is not to be less than that obtained from the following formulae, whichever is greater:

$$t_{net} = 6.5s \times 10^{-3}$$

$$t_{net} = 5$$

s: Stiffener spacing (mm)

(4) In addition to **(1)** to **(3)** above, the net thickness t_{net} (mm) of edge girders exposed to sea wash is not to be less than that obtained from the following formulae, whichever is greater:

$$t_{net} = 0.0158s\sqrt{\frac{P_A}{0.95\sigma_Y}}$$

$$t_{net} = 8.5s \times 10^{-3}$$

P_A: Design horizontal wave load (kN/m^2) as specified in **20.2.4(2)**

s: Stiffener spacing (mm)

σ_Y : Minimum yield stress (N/mm^2) of the material

5 Strength calculation

Strength calculation for hatch covers is to be carried out by using the following finite element method. Those not specified in this paragraph are to comply with the requirements in **Annex C1.1.22-1 "GUIDANCE FOR DIRECT CALCULATIONS"**.

(1) Loads

(a) The loads acting on steel hatch covers are to be according to **20.2.4** based on the type of load and loading condition. Except as deemed necessary by the Society, no loads are to be assumed to act jointly.

(b) No dynamic loads due to ship motion are to be assumed as the wheel loads from wheeled vehicles only used for loading/unloading while in port.

(2) Modelling of Structures

(a) The structural model is to be able to reproduce the behaviour of the structure with the highest possible fidelity. Stiffeners and primary supporting members subject to pressure loads are to be included in the modelling. However, buckling stiffeners may be disregarded for stress calculation.

(b) Net scantlings which exclude corrosion additions are to be used for modeling.

(c) In no case is element width to be larger than stiffener spacing. The ratio of element length to width is not to exceed 3.

(d) The element height of the webs of primary supporting members is not to exceed one-third of the web height.

(e) Stiffeners may be modelled using shell elements, plane stress elements or beam elements.

(f) Hatch covers fitted with U-type stiffeners as shown in **Fig. C20.3** are to be assessed by means of FE analysis.

(g) The geometry of the U-type stiffeners is to be accurately modelled using shell/plate elements.

(h) Nodal points are to be properly placed on the intersections between the webs of a U-type stiffener and the hatch cover plate, and between the webs and flange of the U-type stiffener.

(3) Boundary Conditions

Wherever applicable the following boundary conditions are to be applied to the FE model:

(a) Boundary nodes in way of a bearing pad on the hatch coamings are to be fixed against displacement in the direction perpendicular to the pad.

(b) Lifting stoppers are to be fixed against displacements in the direction determined by the stoppers.

(c) For a folding type hatch cover, the FE nodes connected through a hinge are to have the same translational displacement in the direction perpendicular to the hatch cover top plating.

(4) Permissible value

When the loads specified in **(1)** act on the structural model specified in **(2)**, the net scantlings are to be determined so that the stress and deflection generated in each structural member satisfy the allowable values specified in **20.2.5-1**.

(5) Miscellaneous

(a) The thickness of the top plating of steel hatch covers is to comply with the requirements in **20.2.5-2**.

(b) The scantlings of the secondary stiffeners of steel hatch covers are to comply with the requirements in **20.2.5-3**.

(c) The buckling strength for the structural members forming steel hatch covers is to comply with the requirements in 20.2.5-6.

(6) Additional requirements for steel hatch covers carrying cargoes

In addition to **(1)** to **(5)**, the details for steel hatch covers carrying cargoes are to comply with the following **(a)** to **(f)**:

(a) To prevent damage to hatch covers and the ship structure, the location of stoppers is to be compatible with the relative movements between hatch covers and the ship structure.

(b) Hatch covers and supporting structures are to be adequately stiffened to accommodate the load from hatch covers.

(c) At the cross-joints of multi-panel covers, vertical guides (male/female) are to be fitted to prevent excessive relative vertical deflections between loaded/unloaded panels.

(d) The construction and scantlings of hatchways on exposed parts or on the lower deck are to comply with the following requirements in addition to those of 20.2.

i) The loading arrangement is to be clearly shown in drawings submitted for approval. In the case of freight containers, the type and location are to be additionally described.

ii) Girders or stiffeners are to be provided for reinforcement beneath the corner fittings of freight containers.

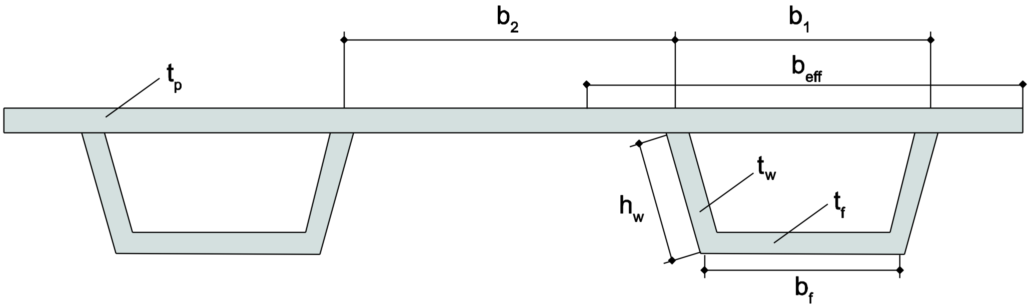
(e) The scantlings of sub structures subject to concentrated loads acting on steel hatch covers are to be determined taking into consideration the design cargo loads and permissible stresses specified in 20.2.

(f) The top plates of hatch covers, upon which wheeled vehicles are loaded, are to comply with the following:

i) The thickness of hatch cover top plating may be determined by direct calculation or in accordance with 17.3.5.

ii) The scantlings of the stiffeners of hatch covers may be determined by direct calculation or in accordance with 10.9.1.

Fig. C20.3 Example of Hatch Cover Fitted with U-type Stiffeners



6 Buckling strength of steel hatch covers

(1) Buckling assessments for hatch cover structural members are to be performed in compliance with **Annex C20.2 "Buckling Strength Assessment of Ship Structural Elements"** for the conditions specified in 20.2.5-6. For symbols not defined in 20.2.5-6, refer to **Annex C20.2**.

(2) Slenderness requirements are as follows:

(a) The slenderness requirements are to be in accordance with **2, Annex C20.2**.

(b) Slenderness requirements need not be applied to the lower boundary of double skin hatch covers unless the cargo hold is designed for carriage of ballast or liquid cargo.

(c) The breadth of the primary supporting member flange is to be not less than 40% of their depth for laterally unsupported spans greater than 3.0 m. However, tripping brackets attached to the flange may be considered as a lateral support for primary supporting members.

(3) Buckling assessments are to be performed for the following structural elements of hatch cover structures subjected to compressive stresses, shear stresses and lateral pressures:

- Stiffened and unstiffened panels, including curved panels and panels stiffened with U-type stiffeners.
- Web panels of primary supporting members in way of openings.

Procedures and detailed requirements for buckling assessment are given in **4, Annex C20.2**, including idealisation of irregular plate panels, definitions of reference stresses and buckling criteria.

(4) Panel types and assessment methods are to be accordance with the following requirements:

(a) Plate panels of hatch cover structures are to be modelled as stiffened panels (*SP*) or unstiffened panels (*UP*) as defined in **4.2, Annex C20.2**. In addition, Method A (-A) and Method B (-B) as defined in **1.3, Annex C20.2** are to be used in accordance with **Table C20.5**, **Fig. C20.4** and **Fig. C20.5**, while the procedures for openings are to be used for buckling assessments of web panels with openings.

(b) Hatch covers fitted with U-type stiffeners are also to be in accordance with the additional buckling assessment requirements specific for panels with U-type stiffeners in **5.2.5, Annex C20.2**.

(5) Buckling assessments of hatch covers are based on lateral pressure as defined in **20.2.4-1(1)**, **20.2.4-1(2)** and **20.2.4-1(5)**, and stresses obtained from FE analyses (*See* **20.2.5-5)**.

(6) The safety factor for hatch cover structural members is to be taken as S=1.0 for the plating and stiffener buckling capacity formulae defined in **5.2.2** and **5.2.3**, **Annex C20.2** respectively.

(7) The buckling strength of structural members is to be in accordance with the following formula:

$\eta_{act} \leq \eta_{all}$

Where:

η_{act}: Buckling utilisation factor based on applied stress, as defined in **1.3.2.2** and **4, Annex C20.2**, and calculated per **5, Annex C20.2.**

η_{act}: Allowable buckling utilisation factor, as given in **Table C20.6**

Table C20.5 Structural Members and Assessment Methods

Structural elements	Assessment method[(1)(2)]	Normal panel definition
Hatch cover top/bottom plating structures, see **Fig. C20.4**		
Hatch cover top/bottom plating	SP-A	Length: between transverse girders Width: between longitudinal girders
Irregularly stiffened panels	UP-B	Plate between local stiffeners/PSM
Hatch cover web panels of primary supporting members, see **Fig. C20.5**		
Web of transverse/longitudinal girder (single skin type)	UP-B	Plate between local stiffeners/face plate/PSM
Web of transverse/longitudinal girder (double skin type)	SP-B[(3)]	Length: between PSM Width: full web depth
Web panel with opening	Procedure for opening	Plate between local stiffeners/face plate/PSM
Irregularly stiffened panels	UP-B	Plate between local stiffeners/face plate/PSM

Note 1: SP and UP stand for stiffened and unstiffened panel respectively.
Note 2: A and B stand for Method A and Method B respectively.
Note 3: In case that the buckling carlings/brackets are irregularly arranged in the web of transverse/longitudinal girder, UP-B method may be used.

Fig. C20.4 Hatch Cover Top/Bottom Plating Structures

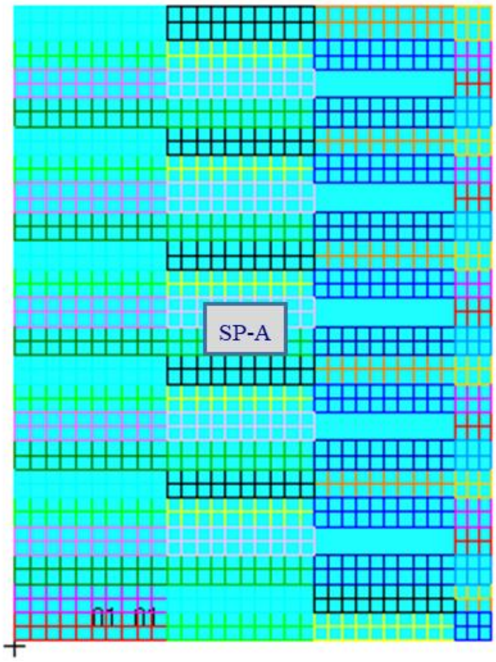


Fig. C20.5 Hatch Cover Webs of Primary Supporting Members

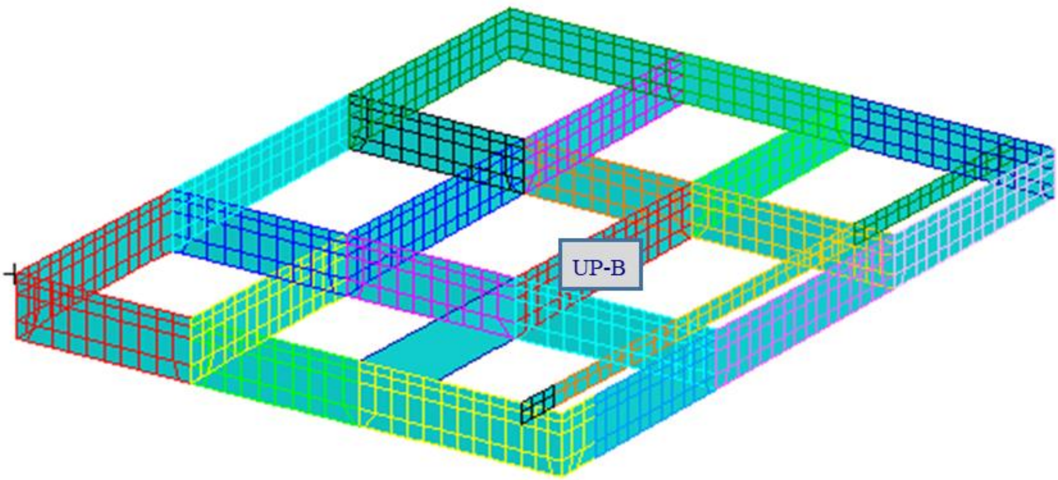


Table C20.6 Allowable Buckling Utilisation Factors

Structural component	Subject to	η_{all}, Allowable buckling utilisation factor
Plates and stiffeners Web of PSM	External pressure, as defined in **20.2.4-1(1)**	0.80
	Other loads, as defined in **20.2.4-1(2)** to **20.2.4-1(6)**	0.90 for static+dynamic load case 0.72 for static load case

20.2.6 Additional Requirements for Steel Hatch Covers Carrying Cargoes*

20.2.7 Portable Beams, Hatchway Covers, Steel Pontoon Covers and Steel Weathertight Covers

1 Portable beams are to comply with the following **(1)** to **(8)**:

(1) The 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 the 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 by

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 the lateral stability of the beams. The depth of beams at their ends is not to be less than 0.40 *times* the depth at their mid-point or 150 *mm*, whichever is greater.

(5) The upper face plates of portable beams are to extend to the ends of the beams. The web plates are to be increased in thickness to at least twice that at the mid-point for at least 180 *mm* from each end or to be reinforced with doubling plates.

(6) Portable beams are to be provided with suitable gear for releasing them from slings without the need for personnel to get on the beam.

(7) Portable beams are to be clearly marked to indicate the deck, hatchway and position to which they belong.

(8) Scantling of hatch beam with variable cross-sections is to be not less than that obtained from the following formulae.

The net section modulus (cm^3) of hatch beams at the mid-point

$$Z_{net} = Z_{net_{cs}}$$

$$Z_{net} = k_1 Z_{net_{cs}}$$

The net moment of inertia (cm^4) of hatch beams at the mid-point

$$I_{net} = I_{net_{cs}}$$

$$I_{net} = k_2 I_{net_{cs}}$$

$Z_{net_{cs}}$: Net section modulus (cm^3) complying with requirement **20.2.5-4(1)**

$I_{net_{cs}}$: Net moment of inertia (cm^4) complying with requirement **20.2.5-4(1)**

S : Spacing (m) of portable beams

ℓ : Unsupported span (m) of portable beams

b : Width (m) of steel hatch covers

k_1 and k_2 : Coefficients obtained from the formulae given in **Table C20.7**

Table C20.7 Coefficient k_1 and k_2

k_1	$1+\dfrac{3.2\alpha-\gamma-0.8}{7\gamma+0.4}$	k_1 is not to be taken as less than 1.0 $\alpha=\dfrac{\ell_1}{\ell}$, $\beta=\dfrac{I_1}{I_0}$, $\gamma=\dfrac{Z_1}{Z_0}$
k_2	$1+8\alpha^3\dfrac{1-\beta}{0.2+3\sqrt{\beta}}$	

ℓ : Overall length of hatch beam (m)

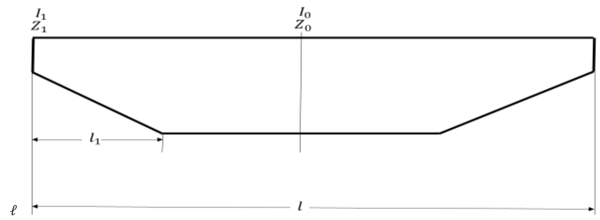
ℓ_1 : Distance from the end of parallel part to the end of portable beam (m)

I_0 : Moment of inertia 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)



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 such grips are unnecessary due to the cover's 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 the mid-point or 150 *mm*, whichever is greater.

(2) The width of the bearing surfaces 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) The depth of steel weathertight covers at the supports is not to be less than one-third the depth at the mid-point or 150 *mm*, whichever is greater.

20.2.8 Tarpaulins and Securing Arrangements for Hatchways Closed by Portable Covers

1 At least two layers of tarpaulins of Grade A complying with the requirements in **Chapter 6, Part L** 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 1/6 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 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 cover 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 suitable fittings for lashing are to be provided.

20.2.9 Hatch Coaming Strength Criteria

1 Height of coamings is to comply with following **(1)** to **(3)**:

(1) 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.

2 Scantlings of hatch coamings are to be in accordance with the followings.

(1) The local net plate thickness (*mm*) of the hatch coaming plating $t_{coam,net}$ is not to be less than that obtained from following formula in **(a)** or **(b)**:

(a) For Type 1 ships

$$t_{coam,net} = 0.0142s\sqrt{\frac{P_A}{0.95\sigma_Y}}\ (mm),\quad \text{but not to be less than } 6 + \frac{L'}{100}\ (mm)$$

s: Stiffener spacing (*mm*)

P_A: As specified in **20.2.4(2)**

σ_Y : Minimum yield stress (N/mm^2) of the material

L': Length of ship L_1 (*m*)

(b) For Type 2 ships

$$t_{coam,net} = 0.016s\sqrt{\frac{P_{coam}}{0.95\sigma_Y}}\ (\mathrm{mm}),\quad \text{but not to be less than } 9.5\ (mm)$$

P_{coam} : As specified in **20.2.4(5)**

s and σ_Y : As specified in **(a)** above

(2) For Type 1 ships, where the hatch coaming stiffener is snipped at both ends, the gross thickness $t_{coam,gross}$ (*mm*) of the coaming plate at the sniped stiffener end is not to be less than that obtained from the following formula:

$$t_{coam,gross} = 19.6\sqrt{\frac{P_A s(\ell - 0.0005s)}{1000\sigma_Y}}\ (\mathrm{mm})$$

ℓ: Stiffener span (m) to be taken as the spacing of coaming stays

s, P_A and σ_Y: As specified in **(1)** above

(3) The net section modulus Z_{net} (cm^3) and net shear area (cm^2) of hatch coaming stiffeners are not to be less than that obtained from the following formula.

(a) For Type 1 ships

$$Z_{net} = \frac{P_A s l^2}{f_{bc}\sigma_Y} \quad (\mathrm{cm}^3)$$

$$A_{net} = \frac{P_A s \ell}{\sigma_Y} 10^{-2} \quad (\mathrm{cm}^2)$$

s, ℓ, P_A and σ_Y: As specified in **(2)** above

f_{bc} : Coefficient according to the type of end connection of stiffeners given by the following formula:

f_{bc} = 12 with both ends constant

= 8 for the end spans of stiffeners sniped at the coaming corners

For sniped stiffeners of coaming at hatch corners shear area obtained from the above formula has to be increased by 35%.

(b) For Type 2 ships

$$Z_{net} = 1.21\frac{P_{coam} s \ell^2}{f_{bc} c_p \sigma_Y} \quad (cm^3)$$

f_{bc} : Coefficient according to the type of end connection of stiffeners given by the following formula:

f_{bc} = 16 with both ends constant

= 12 for the end spans of stiffeners sniped at the coaming corners

c_p = Ratio of the plastic section modulus to the elastic section modulus of the stiffeners with an attached plate breadth (mm) equal to $40t_{coam,net}$, where $t_{coam,net}$ is the plate net thickness

= 1.16 in the absence of more precise evaluation

s, ℓ, and σ_Y : As specified in **(2)** above

P_{coam} : As specified in **20.2.4(5)**

(4) Buckling strength assessment of hatch coaming is to be carried out by the method as deemed appropriate by the Society.

(5) The net scantlings of hatch coaming stays are to be in accordance with following **(a)** to **(c)** and coaming stays are to be designed for the loads transmitted through them and permissible stresses according to **20.2.5-1**.

(a) For hatch coaming stays considered to be simple beams (see **Examples 1 and 2 of Fig. C20.6**), the net section modulus Z_{net} (cm^3) of such stays at their deck connections and the net scantling $t_{w,net}$ (mm) of their webs are not to be less than that obtained from following formulae:

$$Z_{net} = \frac{{H_C}^2 s_C P}{1.9\sigma_Y} \quad (\mathrm{cm}^3)$$

$$t_{w,net} = \frac{2H_C s_C P}{\sigma_Y h} \quad (\mathrm{mm})$$

H_C: Hatch coaming stay height (m)

h: Hatch coaming stay depth (mm)

s_C: Hatch coaming stay spacing (mm)

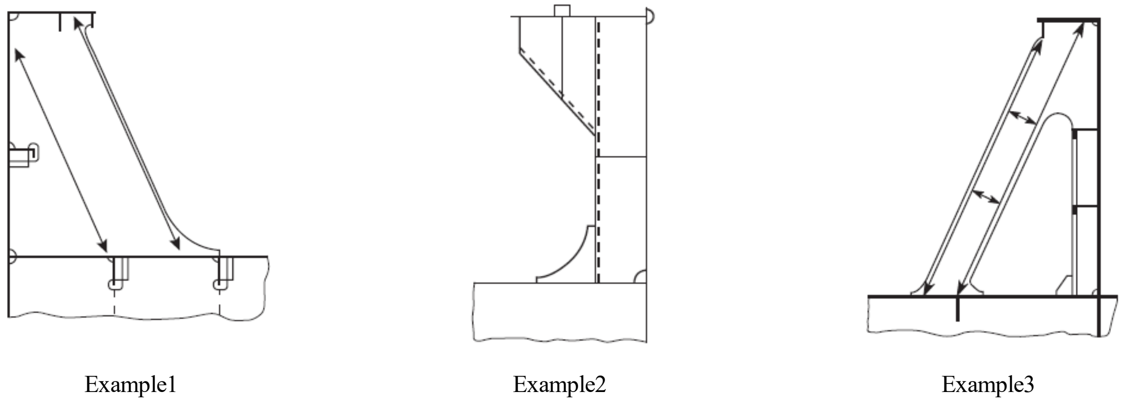
σ_Y: As specified in **(1)** above

P : Pressure (kN/m^2) on coaming taken as P_A defined in **20.2.4(2)** for Type 1 ships and as P_{Coam} defined in **20.2.4(5)** for Type 2 ships.

(b) For coaming stays other than those in **(a)** above (see **Example 3 of Fig. C20.6**), stresses are generally to be determined through FEM, and the calculated stresses are to satisfy the permissible stress criteria of **20.2.5-1**.

(c) For calculating the net section modulus of coaming stays, the area of their face plates is to be taken into account only when it is welded with full penetration welds to the deck plating and an adequate underdeck structure is fitted to support the stresses transmitted by them.

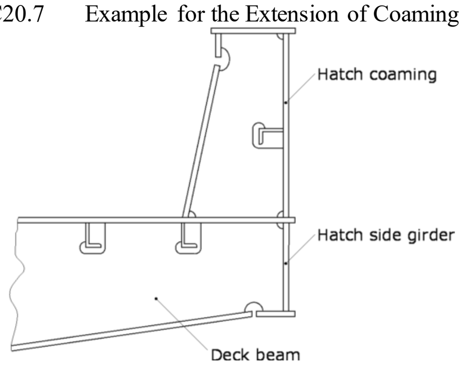
Fig. C20.6 Examples of coaming stays



3 Coamings are to be additionally supported by efficient brackets or stays provided from the horizontal stiffeners to the deck at intervals of approximately 3 metres.

4 Coaming plates are to extend to the lower edge of the deck beams or hatch side girders are to be fitted that extend to the lower edge of the deck beams (see **Fig. C20.7**). Extended coaming plates and hatch side girders are to be flanged or fitted with face bars or half-round bars, except where specially approved by the Society.

Fig. C20.7 Example for the Extension of Coaming Plates



5 Hatch coamings and hatch coaming stays are to comply with the following requirements:

(1) The local details of the structures are to be designed so as to transfer 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.

(2) Underdeck structures are to be checked against the load transmitted by the stays.

(3) 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 $0.44t_{w,gross}$, where $t_{w,gross}$ is the gross thickness of the stay web.

(4) The toes of stay webs are to be connected to deck plating with deep penetration double bevel welds extending over a distance not less than 15% of the stay width.

(5) On ships carrying cargoes such as timber, coal or coke on deck, stays are to be spaced not more than 1.5 *m* apart.

(6) Hatch coaming stays are to be supported by appropriate substructures.

(7) For hatch coamings that transfer friction forces at hatch cover supports, special consideration is to be given to fatigue strength.

(8) Longitudinal hatch coamings with a length exceeding $0.1L_1$ are to be provided with tapered brackets or equivalent transitions and a corresponding substructure at both ends. At the end of the brackets, they are to be connected to the deck by full penetration welds of minimum 300 *mm* in length.

(9) Hatch coamings and horizontal stiffeners on hatch coamings may be considered as a part of the longitudinal hull structure when designed according to the requirements for longitudinal strength and verified in cases deemed appropriate by the Society.

(10) Unless otherwise specified, the material and welding requirements for hatch coamings are to comply with the provisions of other Parts of the Rules.

20.2.10 Closing Arrangements*

1 Securing devices

(1) Securing devices between covers and coamings and at cross-joints are to ensure weathertightness.

(2) The means for securing and maintaining weathertightness by using gaskets and securing devices are to comply with the following **(a)** to **(f)**. The means for securing and maintaining weathertightness of weathertight covers are to be to the satisfaction of the Society. Arrangements are to ensure that weathertightness can be maintained in any sea condition.

(a) The weight of covers and any cargo stowed thereon are to be transmitted to the ship structure.

(b) Gaskets and compression flat bars or angles which are arranged between covers and the ship structure and cross-joint elements are to be in compliance with the following **i)** to **iv)**:

i) Compression bars or angles are to be well rounded where in contact with the gaskets and are to be made of corrosion-resistant materials.

ii) The gaskets are to be of relatively soft elastic materials. The material is to be of a quality suitable for all environmental conditions likely to be experienced by the ship, and is to be compatible with the cargoes carried.

iii) A continuous gasket is to be effectively secured to the cover. The material and form of gasket selected are to be considered in conjunction with the type of cover, the securing arrangement and the expected relative movement between the cover and ship structure.

iv) The specification or grade of the packing material is to be indicated on the drawings.

(c) Securing devices attached to hatchway coamings, decks or covers are to be in compliance with the following **i)** to **vi)**:

i) Arrangement and spacing of securing devices are to be determined with due attention to the effectiveness for weathertightness, depending upon the type and the size of hatch cover as well as to the stiffness of the cover edges between the securing devices.

ii) The moment of inertia (cm^4) of the edge elements of hatch covers is not to be less than that obtained from the following formula:

$I = 6pa^4$ (cm^4)

a : Spacing (m) between securing devices, not to be taken less than 2 m

p : Packing line pressure (N/mm), minimum 5 N/mm

iii) The gross sectional area (cm^2) of each securing device is not to be less than that obtained from the following formula. However, rods or bolts are to have a net diameter not less than 19 mm for hatchways exceeding 5 m^2 in area.

$A = 0.28ap/f$

f: As obtained from the following formula:

$f = (\sigma_Y/235)^e$

σ_Y : Minimum yield stress (N/mm^2) of the steel used for fabrication, but not to be taken greater than 70% of the ultimate tensile strength

e: A coefficient determined according to the value of σ_Y, as follows:

1.0 for $\sigma_Y \leq 235$ N/mm^2

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

a and p: As specified in **(ii)** above

iv) Individual securing devices on each cover are to have approximately the same stiffness characteristics.

v) Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

vi) Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

(d) A drainage arrangement equivalent to the standards specified in the following is to be provided.

i) Drainage is to be arranged inside the line of gaskets by means of a gutter bar or vertical extension of the hatch side and end coaming. If an application is made by the owner of a container carrier and the Society deems it to be appropriate, special consideration will be given to this requirement.

ii) Drain openings are to be arranged at the ends of drain channels and are to be provided with effective means such as non-return valves or the equivalent for preventing the ingress of water from outside. It is unacceptable to connect fire hoses to the drain openings for this purpose.

iii) Cross-joints of multi-panel covers are to be arranged with a drainage channel for water from space above the gasket and a drainage channel below the gasket.

iv) If a continuous outer steel contact between cover and ship structure is arranged, drainage from the space between the steel contact and the gasket is also to be provided for.

v) Drain openings in hatch coamings are to be arranged with sufficient distance to areas of stress concentration (e.g. hatch corners, transitions to crane posts).

(e) It is recommended that ships with steel weathertight covers are supplied with an operation and maintenance manual which includes the following **i)** to **v)**:

i) Opening and closing instructions

ii) Maintenance requirements for packing, securing devices and operating items

iii) Cleaning instructions for drainage systems

iv) Corrosion prevention instructions

v) List of spare parts

(f) Securing devices of special design in which significant bending or shear stresses occur may be designed as anti-lifting devices according to **-2** below. The packing line pressure q is to be specified, and as load, q multiplied by the spacing between securing devices a (m) is to be applied.

2 The securing devices of hatch covers, on which cargo is to be lashed, are to be designed for a lifting force resulting from the loads according to **20.2.4(4)** (see **Fig. C20.8**). Unsymmetrical loading, which may occur in practice, is to be considered. Under such loading, the equivalent stress (N/mm^2) in securing devices is not to be greater than that obtained from the following formula. Anti-lifting devices may be dispensed with at the discretion of the Society.

$$\sigma_E = \frac{150}{k_l}$$

k_l : As obtained from the following formula:

$$k_l = \left(\frac{235}{\sigma_F}\right)^e$$

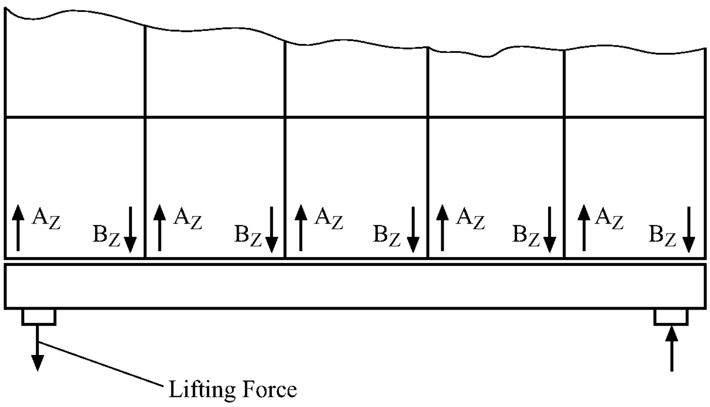
σ_Y : Minimum yield stress (N/mm^2) of the material

e: As given below

0.75 for $\sigma_Y > 235$

1.00 for $\sigma_Y \leq 235$

Fig. C20.8 Lifting Forces at a Hatch Cover



20.2.11 Hatch Cover Supports, Stoppers and Supporting Structures

1 Hatch cover supports, stoppers and supporting structures subject to the provisions of **20.2** are to comply with the following **(1)** to **(3)**:

(1) For the design of the securing devices for the prevention of shifting, the horizontal mass forces F obtained from the following formula are to be considered. Acceleration in the longitudinal direction, a_X, and in the transverse direction, a_Y, does not need

to be considered as acting simultaneously.

$F = ma$

m : Sum of mass of cargo lashed on the hatch cover and mass of hatch cover

a : Acceleration obtained from the following formula:

$a_X = 0.2g$ for longitudinal direction

$a_Y = 0.5g$ for transverse direction

(2) The design load for determining the scantlings of stoppers is not to be less than that obtained from **20.2.4(2)** and **(1)**, whichever is greater. Stress in the stoppers is to comply with the criteria specified in **20.2.5-1(1)**.

(3) The details of hatch cover supporting structures are to be in accordance with the following **(a)** to **(g)**:

(a) The nominal surface pressure (N/mm^2) of a hatch cover supports is not to be greater than that obtained from the following formula:

$P_{n\,max} = dP_n$ in general

$P_{n\,max} = 3P_n$ for metallic supporting surface not subjected to relative displacements

d: As given by the following formula. Where d exceeds 3, d is to be taken as 3.

$d = 3.75 - 0.015L_1$

$d_{\min} = 1.0$ in general

$d_{\min} = 2.0$ for partial loading conditions

L_1: Distance (m) measured on the waterline at the scantling draught d_S from the forward side of the stem to the centre of the rudder stock. L_1 is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught d_S. In ships without rudder stocks (e.g. ships fitted with azimuth thrusters), the Rule length L_1 is to be taken equal to 97% of the extreme length on the waterline at the scantling draught d_S.

d_S: Scantling draught (m) at which the strength requirements for the scantlings of the ship are met and represents the full load condition; it is to be not less than that corresponding to the assigned freeboard.

P_n: As obtained from **Table C20.8**

(b) Where large relative displacements of the supporting surfaces are to be expected, the use of material having low wear and frictional properties is recommended.

(c) Drawings of the supports are to be submitted. In these drawings, the permitted maximum pressure given by the material manufacturer is to be specified.

(d) When the manufacturer of the vertical hatch cover support material can provide proof that the material is sufficient for the increased surface pressure, not only statically but under dynamic conditions, the permissible nominal surface pressure $P_{n\,max}$, as specified in **(a)** above, may be relaxed at the discretion of the Society. However, realistic long term distributions of spectra for vertical loads and relative horizontal motion between hatch covers and hatch cover stoppers are to be as deemed appropriate by the Society.

(e) Irrespective of the arrangement of stoppers, the supports are to be able to transmit the following force P_h in the longitudinal and transverse direction.

$$P_h = \mu \frac{P_V}{\sqrt{d}}$$

P_V: Vertical supporting force

μ: Friction coefficient generally to be taken as 0.5. For non-metallic or low-friction materials, the friction coefficient may be reduced as appropriate by the Society. However, in no case μ is to be less than 0.35.

(f) Stresses in supporting structures are to comply with the criteria specified in **20.2.5-1(1)**.

(g) For substructures and adjacent constructions of supports subjected to horizontal forces P_h, special consideration is to be given to fatigue strength.

Table C20.8 Permissible Nominal Surface Pressure P_n

Material	P_n when loaded by	
	Vertical force	Horizontal force
Hull structure steel	25	40
Hardened steel	35	50
Lower friction materials	50	-

2 For steel weathertight hatch covers of Type 2 ships, effective means for stoppers complying with the requirements in **Table C20.9** against the horizontal green sea forces acting on them are to be provided.

Table C20.9 Strength Requirements for Stoppers

Design pressure	As specified in **20.2.4(7)**.
Allowable equivalent stress	In stoppers, their supporting structures and the stopper welds (calculated at the throat of welds), the equivalent stress is not to exceed the allowable value of 0.8 times the yield stress of the material.

20.2.12 Steel Hatchway Covers for Container Carriers*

1 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.

2 Treatment of towage and segregation of containers containing dangerous goods is to be at the discretion of the Society.

20.2.13 Additional Requirement for Small Hatches Fitted on Exposed Fore Deck*

Small hatches located on exposed decks 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 the distance (m) measured on the waterline at the scantling draught d_S from the forward side of the stem to the centre of the rudder stock. L_1 is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught d_S.

In ships without rudder stocks (e.g. ships fitted with azimuth thrusters), the Rule length L_1 is to be taken equal to 97% of the extreme length on the waterline at the scantling draught d_S.

d_S is the scantling draught (m) at which the strength requirements for the scantlings of the ship are met and represents the full load condition; it is to be not less than that corresponding to the assigned freeboard.

20.2.14 Steel Hatchway of Ballast Holds*

Special consideration is to be given to steel hatchway covers and similar covers as well as hatch coamings provided on exposed upper decks in way of cargo holds used as deep water ballast tanks for ships in order to ensure they are of sufficient strength to resist loads due to water ballast.

20.3 Machinery Space Openings

20.3.1 Protection of Machinery Space Openings

Machinery space openings are to be enclosed by steel casings.

20.3.2 Exposed Machinery Space Casings

1 Exposed machinery space casings are to have scantlings not less than that those required in **19.2.1** and **19.2.2**, 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)

20.3.3 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)

20.3.4 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 **18.3.1-1**.

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.

20.3.5 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.

20.3.6 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.

20.4 Companionways and Other Deck Openings

20.4.1 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.

20.4.2 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 **18.3.1-1**.

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 **18.3.1-1**, the openings to spaces below the freeboard deck are to be considered exposed.

20.4.3 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 21 MACHINERY SPACES AND BOILER ROOMS

21.1 General

21.1.1 Application

The construction of machinery spaces is to be in accordance with the requirements in the relevant Chapters, in addition to this Chapter.

21.1.2 Construction

Machinery spaces are to be sufficiently strengthened by means of web frames, strong beams and pillars or other arrangements.

21.1.3 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.

21.1.4 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.

21.2 Main Engine Foundations

21.2.1 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.

21.2.2 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.

21.3 Construction of Boiler Rooms

21.3.1 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.

21.3.2 Boiler Location

Boilers are to be so placed as to ensure accessibility and proper ventilation.

21.3.3 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.

21.4 Thrust Blocks and Foundations

21.4.1 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.

21.4.2 Construction under Thrust Foundation

Additional girders are to be provided in way of the foundations, as necessary.

21.5 Plummer Blocks and Auxiliary Machinery Seats

21.5.1 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 22 TUNNELS AND TUNNEL RECESSES

22.1 General

22.1.1 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 **13.3**.

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.

22.1.2 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:

$$2.9S\sqrt{h} + 2.5 \quad (mm)$$

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

22.1.3 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 **22.1.2**, 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.

22.1.4 Curved Top or Side Plating

The thickness of curved top or side plating is to be determined by the requirements in **22.1.2** using a stiffener spacing reduced by 150 mm from the actual spacing.

22.1.5 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.

22.1.6 Wood Sheathings

The wood sheathing mentioned in **22.1.5** 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.

22.1.7 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:

$$4.0Shl^2 \quad (cm^3)$$

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.

22.1.8 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.

22.1.9 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.

22.1.10 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.

22.1.11 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.

22.1.12 Watertight Tunnels

Where watertight tunnels similar to shaft tunnels are provided, they are to be of similar construction to that of the shaft tunnels.

22.1.13 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:

$$9.1 + 0.134 d_t h \quad (mm)$$

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 23 BULWARKS, GUARDRAILS, FREEING ARRANGEMENTS, CARGO PORTS AND OTHER SIMILAR OPENINGS, SIDE SCUTTLES, RECTANGULAR WINDOWS, VENTILATORS AND GANGWAYS

23.1 Bulwarks and Guardrails

23.1.1 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.

23.1.2 Dimensions*

1 The height of bulwarks or guardrails specified in **23.1.1** 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.

23.1.3 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.

4 A bracket type is recommended for the lower connections of bulwark stays (*See* **Fig. C23.1**). In cases where a gusset type is applied for the lower connections of bulwark stays (*See* **Fig. C23.2**), special consideration is to be given.

5 In cases where a bracket type is applied for the lower connections of bulwark stays, the bulwark stays are to be properly stiffened for the prevention of local buckling.

6 Expansion joints are to be provided at appropriate intervals in bulwarks.

Fig. C23.1 Example of Bracket Type

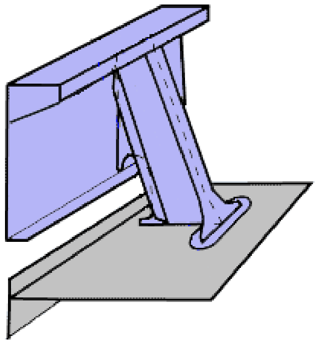
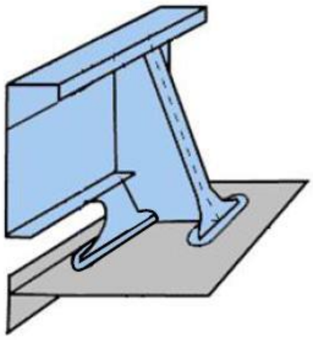


Fig. C23.2 Example of Gusset Type



23.1.4 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.

23.2 Freeing Arrangements

23.2.1 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.

23.2.2 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 $20m$:

$$0.7 + 0.035l + a \ (m^2)$$

Where l is more than $20m$:

$$0.07l + a \ (m^2)$$

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 $1.2m$:

$$0.04l(h - 1.2) \ (m^2)$$

Where h is not more than $1.2m$, but not less than $0.9m$:

$$0 \ (m^2)$$

Where h is less than $0.9m$:

$$-0.04l(0.9 - l) \ (m^2)$$

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 Part V

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 C23.1.

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 C23.1 Area of Freeing Ports

Breadth of hatchway or trunk	Area of freeing ports in relation to the total area of bulwark
0.41 B_f or less	0.2
0.75 B_f or more	0.1

Note:
The area of freeing ports at intermediate breadth is to be obtained by linear interpolation.

23.2.3 Arrangement of Freeing Ports*

1 Two-thirds of the freeing port area required by 23.2.2 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.

23.2.4 Construction of Freeing Ports

1 Where both the length and the height of freeing ports exceed $230mm$ respectively, freeing ports are to be protected by rails spaced approximately $230mm$ 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.

23.3 Bow Doors and Inner Doors

23.3.1 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.

23.3.2 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 13.1.1.

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 13.1.1. 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, inner doors and ramps are to be arranged so as to preclude the possibility of the door or ramp causing structural damage to the inner door or to the bulkhead when damage to or detachment of the door or ramp occurs. If this is not possible, a separate inner weathertight door is to be installed, as indicated in 13.1.1.

7 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in the stowed position.

23.3.3 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 $\tau = \dfrac{80}{K}$ (N/mm^2)

Bending stress $\sigma = \dfrac{120}{K}$ (N/mm^2)

Equivalent stress $\sigma_e = \sqrt{\sigma^2 + 3\tau^2} = \dfrac{150}{K}$ (N/mm^2)

K: Coefficient corresponding to the kind of steel

e.g. 1.0 for mild steel, the values specified in 1.1.7-2(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:

$\dfrac{125}{K}$ (N/mm^2)

K: Coefficient corresponding to the material, as specified in -1

23.3.4 Design Loads*

1 Doors

(1) The design external pressure P_e, 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:

$$P_e = 2.75(0.22 + 0.15 tan\,\alpha)(0.4 V sin\beta + 0.6\sqrt{L'})^2 \quad (kN/m^2)$$

V : Speed of ship, in *knots*, as specified in 2.1.8, Part A

L' : Length of ship, in m, as specified in 2.1.2, Part A, but need not to be greater than $200m$

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 α and β defined as follows:

α : Flare angle measured at a location on the shell $h_1/2$ 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 $h_1/2$ 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 $h_1/2$ above the bottom of the door

w : Breadth, in m, of the door at a height $h_1/2$ 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 M_y under external loads is to be taken as:

$M_y = F_x a + 10Wc - F_z b$ (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. C23.3**

b : Horizontal distance, in m, from the visor pivot to the centroid of the projected area of the visor door, as shown in **Fig. C23.3**

c : Horizontal distance, in m, from the visor pivot to the centre of gravity of visor mass, as shown in **Fig. C23.3**

(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)

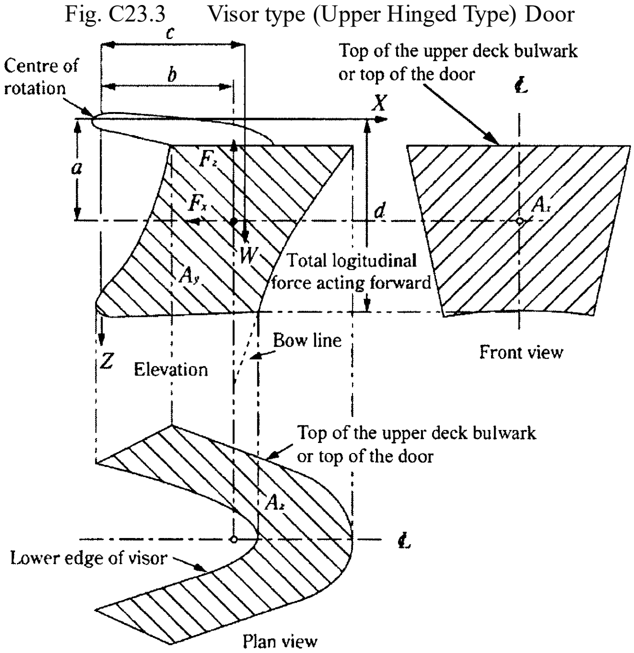
hydrostatic pressure $P_h = 10h_2$ (kN/m^2)

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. C23.3 Visor type (Upper Hinged Type) Door



23.3.5 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 **23.3.4-1(1)**

K: Coefficient corresponding to the materials as given in **23.3.3-1**

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 23.3.4-1(1) and permissible stresses given in 23.3.3-1. 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.

23.3.6 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 23.3.4-2(1) and permissible stresses in 23.3.3-1. 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.

23.3.7 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 $3mm$.

(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 $2.5m$ 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 23.3.4-1(3) is to be not less than M_{y0}:

$$M_{y0} = 10Wc + 0.1\sqrt{a^2+b^2}\sqrt{F_x^2+F_z^2} \quad (kN\text{-}m)$$

W, a, b, c, F_x and F_z: As specified in 23.3.4-1

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 23.3.3-1.

(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 23.3.4-1(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 F_x, F_y and F_z are determined as indicated in 23.3.4-1(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/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 23.3.3-1.

(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 23.3.3-1. 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 23.3.4-1(3)

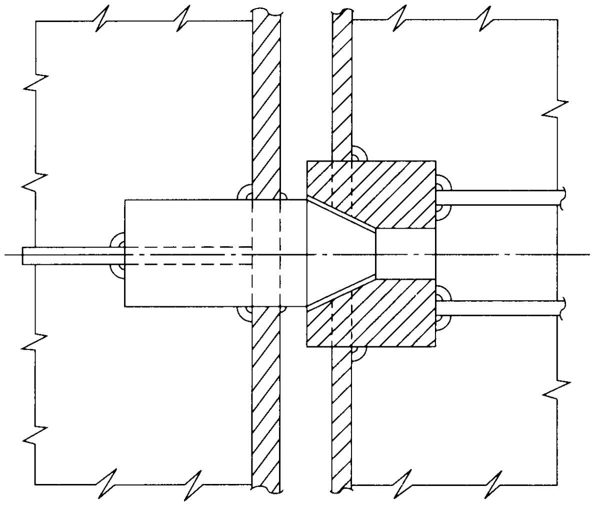
(8) For visor doors, the securing and supporting devices excluding the hinges should be capable of resisting the vertical design forces ($F_z - 10W$) within the permissible stresses given in 23.3.3-1.

(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.C23.4). 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. C23.4 Example of Thrust Bearing



23.3.8 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 $0.5m$ or the high water level alarm, whichever is lesser.

23.3.9 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.

23.3.10 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

(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 acceptable 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.

23.4 Side Shell Doors and Stern Doors

23.4.1 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.

23.4.2 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 so designed as to ensure the same watertightness and structural integrity as the surrounding shell plating.

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 230mm above the upper edge of the uppermost load line, unless additional measures for ensuring watertightness such as the following **(1)** to **(4)** are implemented. However, notwithstanding the additional measures in **(1)** to **(4)**, in no case are such doors to be fitted so as to have their lowest point below the deepest subdivision draught specified in **4.1.2(3)**.

(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.

23.4.3 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 **23.4.4**, 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 **1.1.7-2(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 $0.8\sigma_Y$, 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 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**

23.4.4 Design Loads*

The design loads for primary members and securing and supporting devices are not to be less than the values given by **Table C23.2** respectively.

Table C23.2 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 C23.3** (kN/m^2).

Table C23.3 External Design Pressure P_e

	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:

$$P_e = 0.6\ (0.8 + 0.6\sqrt{L'})^2$$

T: Deepest subdivision draught defined in **4.1.2(3)**, in m.

ZG: Height of the centre of area of the door, in m, above the baseline.

L': Length of ship, in m, as specified in **2.1.2, Part A**, but does not need to be greater than $200m$.

23.4.5 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 **23.4.4** and permissible stresses given in **23.4.3-1**. 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

F_p: See Notes for Table **C23.2**

(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.

23.4.6 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 **23.4.3-1**.

(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 **23.4.3-1**.

(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.

23.4.7 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 deck:

 (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.

23.4.8 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.

23.4.9 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

(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 acceptable 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.

23.5 Side Scuttles and Rectangular Windows

23.5.1 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

23.5.2 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') specified in **4.1.2(11)** or 500 mm, whichever is greater, above the deepest subdivision draught specified in **4.1.2(3)**. 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 length for freeboard 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') specified in **4.1.2(11)** above the deepest subdivision draught specified in **4.1.2(3)**.

(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.

23.5.3 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 7**, **Part L** 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 **23.5.5**)

3 Side scuttles to spaces below the freeboard deck and those provided to sunken poops are to be class A side scuttles, 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.

23.5.4 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.

23.5.5 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 C23.4**) determined by their nominal diameters and grades. The design pressure P is to be determined using the following equation.

$P = 10ac(bf - y)$ (kPa)

a, b, c and f: As specified in **19.2.1-1**

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 C23.5**.

Table C23.4 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 C23.5 Minimum Design pressure

	L is 250 *m* and under	*L* exceeds 250 *m*
Exposed front bulkhead of the first tier superstructure	25 + *L*/10 (*kPa*)	50 (*kPa*)
Other places	12.5 + *L*/20 (*kPa*)	25 (*kPa*)

23.5.6 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.

23.5.7 Application of Rectangular Windows*

1 Rectangular windows inboard are to be class *E* rectangular windows and class *F* rectangular windows complying with the requirements in **Chapter 8**, **Part L** or equivalent thereto.

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 **23.5.8**)

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.

23.5.8 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 C23.6**) determined by their nominal sizes and grades. The design pressure *P* is to be determined using the following equation.

$P = 10ac(bf - y)$ (*kPa*)

a, b, c and f: As specified in **19.2.1-1**

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 C23.5**.

23.6 Ventilators

23.6.1 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 **20.1.2.** 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.

23.6.2 Thickness of Ventilator Coamings

1 The thickness of ventilator coamings in Positions I and II specified in **20.1.2** leading to spaces below the freeboard deck or within enclosed superstructures is not to be less than that given by Line 1 in **Table C23.7**. Where the height of the coamings is reduced by the provisions in **23.6.1**, 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 C23.7**.

23.6.3 Connection

Ventilator coamings are to be efficiently connected to the deck and where their height exceeds 900 *mm* are to be specially supported.

23.6.4 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.

Table C23.6 Maximum Allowable Pressure of Rectangular Windows

Class	Nominal size Width (*mm*)×height (*mm*)	Glass thickness (*mm*)	Maximum allowable pressure (*kPa*)
E	300×425	10	99
	355×500	10	71
	400×560	12	80
	450×630	12	63
	500×710	15	80
	560×800	15	64
	900×630	19	81
	1000×710	19	64
F	300×425	8	63
	355×500	8	45
	400×560	8	36
	450×630	8	28
	500×710	10	36
	560×800	10	28
	900×630	12	32
	1000×710	12	25
	1100×800	15	31

Table C23.7 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.

23.6.5 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. Furthermore, these ventilators are to be provided with an indicator that enables confirmation whether the shutoff is open or closed from outside of the ventilator as well as suitable means of inspection for closing appliances.

2 All ventilator openings in exposed positions on the freeboard and superstructure decks are to be provided with efficient weathertight 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 **20.1.2**, 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.

23.6.6 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.

23.6.7 Ventilators for Emergency Generator Room*

The coamings of ventilators supplying the emergency generator room is to extend to more than 4.5m above the surface of the deck in Position I, and more than 2.3m above the surface of the deck in Position II specified in **20.1.2**. The ventilator openings are not to be fitted with weathertight closing appliances, except for those complying with **1.3.5-2, Part D**. 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.

23.6.8 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 22m above the designed maximum load line, whichever is smaller. The length L_1 is the distance (m) measured on the waterline at the scantling draught d_S from the forward side of the stem to the centre of the rudder stock. L_1 is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught d_S. In ships without rudder stocks (e.g. ships fitted with azimuth thrusters), the Rule length L_1 is to be taken equal to 97% of the extreme length on the waterline at the scantling draught d_S. d_S is the scantling draught (m) at which the strength requirements for the scantlings of the ship are met and represents the full load condition; it is to be not less than that corresponding to the assigned freeboard.

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.

23.7 Gangways

23.7.1 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.

23.7.2 Tankers*

1 The requirements in 23.7.2 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.

23.8 Means of Embarkation and Disembarkation

23.8.1 General*

Ships are to be provided with appropriate means of embarkation on and disembarkation from ships for use in port and in port related operations, unless specially approved by the Society.

Chapter 24 CEILINGS AND SPARRINGS

24.1 Ceilings

24.1.1 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.

24.1.2 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 **6.5.1-3** and **31.2.4-2** 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 **25.1.4**.

4 The thickness of ceilings referred to in **-1** and **-2** is to be as required in **24.1.1-2**.

24.2 Sparrings

24.2.1 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 above 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 25 CEMENTING AND PAINTING

25.1 Cementing

25.1.1 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.

25.1.2 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.

25.1.3 Thickness of Cement

The thickness of cement is not to be less than 20 *mm* at the edges.

25.1.4 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.

25.2 Painting

25.2.1 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.

25.2.2 Protective Coatings in Dedicated Seawater Ballast Tanks and Double-side Skin Spaces*

1 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 **31A.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 for Seawater Ballast Tanks, etc. / IMO* resolution *MSC*.215(82) as may be amended).

2 Protective Coatings in dedicated seawater ballast tanks other than those specified in **-1** above are to be as deemed appropriate by the Society.

25.2.3 Corrosion Protection for Cargo Oil Tanks*

Corrosion protection in accordance with the following **(1)** or **(2)** is to be applied to the cargo oil tanks of crude oil tankers of not less than 5,000 *tonnes* deadweight engaged on international voyages:

(1) Coatings in accordance with the *"PERFORMANCE STANDARD FOR PROTECTIVE COATINGS FOR CARGO OIL TANKS OF CRUDE OIL TANKERS"* (*IMO Performance Standard for Protective Coatings for Cargo Oil Tanks / IMO* resolution *MSC*.288(87) as may be amended); or

(2) Alternative means in accordance with the *"PERFORMANCE STANDARD FOR ALTERNATIVE MEANS OF CORROSION PROTECTION FOR CARGO OIL TANKS OF CRUDE OIL TANKERS"* (*IMO Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks / IMO* resolution *MSC*.289(87) as may be amended).

Chapter 26 MASTS AND DERRICK POSTS

26.1 General

26.1.1 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'):

$2.5H$ (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 C26.1** 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 C26.1 Diameter of Steel Wire Riggings

Height of masts 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 4, Part L**.

26.1.2 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 27 EQUIPMENT

27.1 Anchors and Chain Cables

27.1.1 General*

1 All ships are to be provided with anchors and chain cables specified in this chapter. All ships are to be provided with suitable appliances for handling anchors and lines.

2 Anchors and chain cables for ships having equipment numbers more than 16,000 are to be as determined by the Society.

3 The anchoring equipment subject to the requirements specified in this chapter is based on the following conditions of intended use. The Society, however, may require special consideration be given to anchoring equipment intended for use in deep and unsheltered waters.

(1) The anchoring equipment required herewith is intended for temporary mooring of a ship within a harbour or sheltered area when the ship is awaiting berth, tide, etc. The equipment is, therefore, not designed to hold a ship off fully exposed coasts in rough weather or to stop a ship which is moving or drifting.

(2) The anchoring equipment required herewith is designed to hold a ship in good holding ground conditions so as to avoid dragging of the anchor. In poor holding ground conditions, the holding power of the anchors is significantly reduced.

(3) Anchoring equipment is used under the environmental condition that an assumed maximum current speed of 2.5 *m/s*, a maximum wind speed of 25 *m/s* and a minimum scope of chain cable of 6, the scope being the ratio between the paid-out length of the chain and water depth. However, for ships with a ship length L_2 (as defined in **27.1.2-1**) greater than 135 *m*, the required anchoring equipment may alternatively be considered applicable to a maximum current speed of 1.54 *m/s*, a maximum wind speed of 11 *m/s* and waves with maximum significant height of 2 *m*.

(4) It is assumed that under normal circumstances a ship uses only one bow anchor and chain cable at a time.

4 Sheltered waters are generally calm stretches of water (e.g. harbours, estuaries, roadsteads, bays, lagoons) where the wind force does not exceed 6 on the Beaufort scale.

27.1.2 Equipment Numbers*

1 The equipment number (EN) is the value obtained from the following formula:

$$W^{\frac{2}{3}} + 2.0\left(hB + S_{fun}\right) + 0.1A$$

W: Full load displacement (t)

B: Breadth of ship (m) (See **2.1.4, Part A of the Rules**)

h: Effective height (m) defined as follows:

$$h = a + \sum h_i$$

a: Vertical distance (m), at the midship, from the designed maximum load line to the top of the uppermost continuous deck beam at side

h_i: Height (m) at the centreline of each tier of deckhouses having a breadth greater than $B/4$; for the lowest tier h_1 is to be measured at the centreline from the upper deck or from the notional deck line where there is local discontinuity in the upper deck (See **Fig. C27.1**)

S_{fun}: Effective front projected area of the funnel (m^2) defined as follows:

$$S_{fun} = A_{FS} - S_{shield}$$

A_{FS}: Front projected area of the funnel (m^2) calculated between the upper deck at the centreline (or the notional deck line where there is local discontinuity in the upper deck) and the effective height h_F. The value for A_{FS} is to be taken as zero if the funnel breadth is $B/4$ or less at all elevations along the funnel's height.

h_F: Effective height of the funnel (m) measured from the upper deck at the centreline (or the notional deck line where there is local discontinuity in the upper deck) and the top of the funnel. The top of the funnel may be taken at the level where the funnel breadth reaches $B/4$.

S_{shield}: Section of the front projected area A_{FS} (m^2) which is shielded by all deckhouses having breadth greater_than $B/4$. To determine S_{shield}, the deckhouse breadth is assumed B for all deckhouses having breadth greater than $B/4$ (See **Fig.**

C27.2)

A: Side projected area (m^2) of the hull, superstructures, deckhouses and funnels above the designed maximum load line which are within the length of the ship L_2 and also have a breadth greater than $B/4$. The side projected area of the funnel is to be considered in A when A_{FS} is greater than zero. In such cases, the side projected area of the funnel is to be calculated between the upper deck at the centreline (or the notional deck line where there is local discontinuity in the upper deck) and the effective height h_F.

L_2: Length (m) of ship specified in 2.1.2, Part A of the Rules or 0.97 *times* the length of ship on the designed maximum load line, whichever is smaller. The fore end of L_2 is the perpendicular to the designed maximum load draught at the forward side of the stem, and the aft end of L_2 is the perpendicular to the designed maximum load draught at a distance L_2 aft of the fore end of L_2.

Fig. C27.1 Effective Height

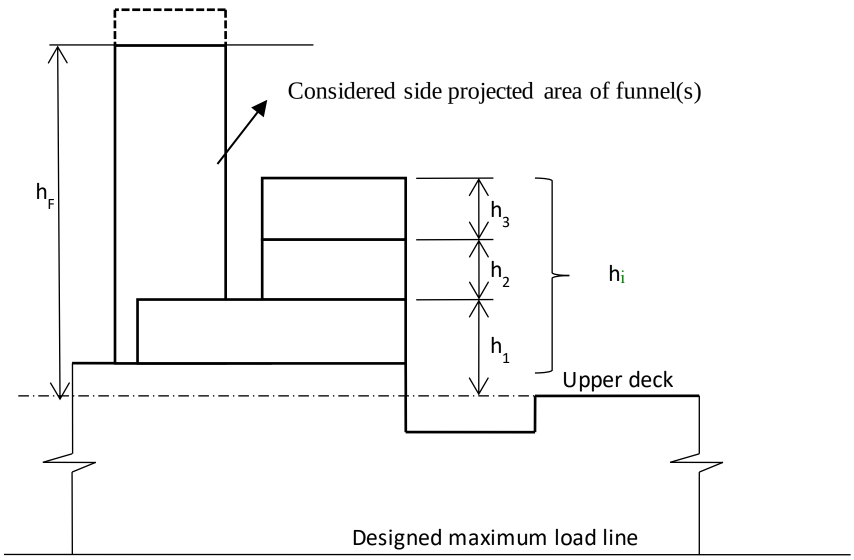
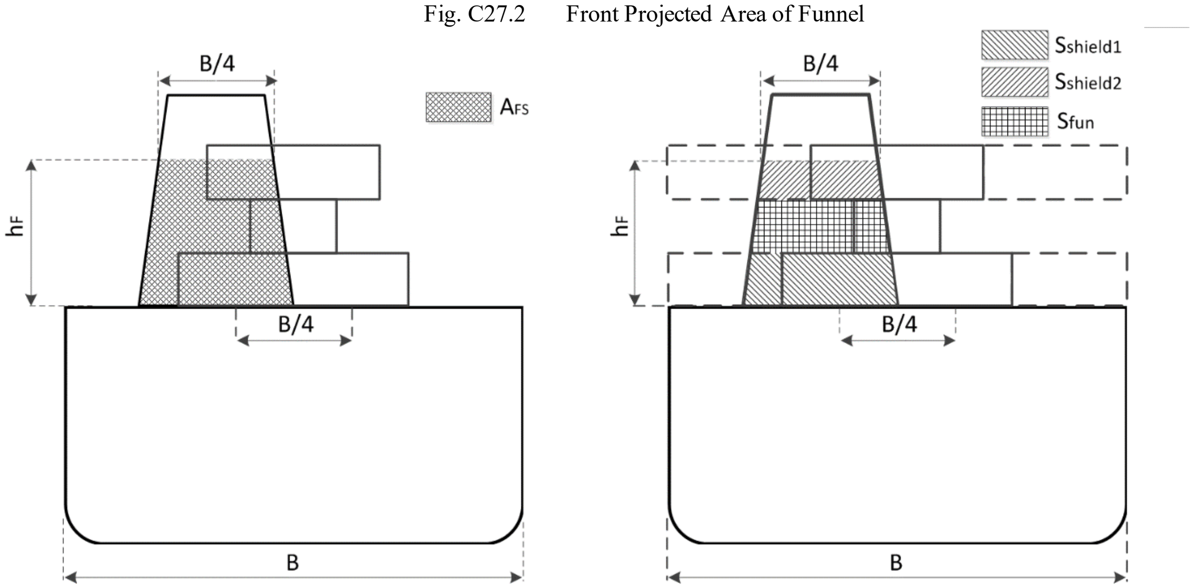
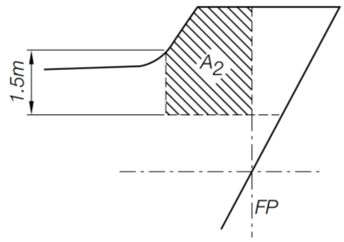


Fig. C27.2 Front Projected Area of Funnel



2 Screens or bulwarks 1.5 m or more in height are to be regarded as parts of deckhouses when determining h and A. The height of the hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining h and A. With regard to determining A, when a bulwark is more than 1.5 m high, the area shown in Fig. C27.3 as A_2 is to be included in A.

Fig. C27.3 Effective Areas for Screens, Bulwarks, etc.



3 When several funnels are fitted on the ship, the above parameters are to be taken as follows:

h_F: Effective height of the funnel (m) measured from the upper deck at the centreline (or the notional deck line where there is local discontinuity in the upper deck) and the top of the highest funnel. The top of the highest funnel may be taken at the level where the sum of each funnel breadth reaches $B/4$.

A_{FS}: Sum of the front projected area of each funnel (m^2), calculated between the upper deck at the centreline (or the notional deck line where there is local discontinuity in the upper deck) and the effective height h_F. The value for A_{FS} is to be taken as zero if the sum of each funnel breadth is $B/4$ or less at all elevations along the funnel's height.

A: Side projected area (m^2) of the hull, superstructures, deckhouses and funnels above the designed maximum load line which are within the length of the ship L_2. The total side projected area of the funnel is to be considered in the side projected area of the ship (A) when A_{FS} is greater than zero. The shielding effect of funnels in transverse direction may be considered in the total side projected area (i.e. when the side projected areas of two or more funnels fully or partially overlap), the overlapped area needs only to be counted once.

4 Notwithstanding **-1**, for tugs, the equipment number is to be obtained from the following formula:

$$W^{\frac{2}{3}} + 2.0(aB + \sum h_i b_i) + 0.1A$$

W, a, h_i and A: As specified in **-1** above

b_i: Breadth (m) of the widest superstructure or deckhouse of each tier having a breadth greater than $B/4$

27.1.3 Anchors

1 All ships are to be provided with the anchors which are not less than that given in **Table C27.1** according to their equipment number.

2 Two of the anchors given in **Table C27.1** are to be connected to their cables and be positioned on board ready for use.

3 Anchors are to comply with the requirements in **Chapter 2, Part L of the Rules**.

4 The mass of individual anchors may vary by ±7 % of the mass given in **Table C27.1**, provided that the total mass of anchors is not less than that obtained from multiplying the mass per anchor given in the table by the number installed on board. However, where approval by the Society is obtained, anchors which are increased in mass by more than 7 % may be used.

5 Where stocked anchors are used, the mass, excluding the stock, is not to be less than 0.80 *times* the mass shown in the table for ordinary stockless anchors.

6 Where high holding power anchors are used, the mass of each anchor may be 0.75 *times* the mass shown in the table for ordinary stockless anchors.

7 Where super high holding power anchors are used, the mass of each anchor may be 0.5 *times* the mass required for ordinary stockless anchors. However, super high holding power anchor mass is not to exceed 1,500 *kg*.

27.1.4 Chain Cables*

1 All ships are to be provided with chain cables which are not less than that given in **Table C27.1** according to their equipment number.

2 Chain cables for anchors are to be stud link chains of Grade 1, 2 or 3 as specified in **3.1** of **Chapter 3**, **Part L of the Rules**. However, Grade 1 chains made of Class 1 chain bars (*KSBC*31) are not to be used in association with high holding power anchors.

27.1.5 Chain Lockers*

1 Chain lockers are to be of capacities and depths adequate to provide an easy direct lead of the cables through the chain pipes and a self-stowing of the cables.

2 Chain lockers including spurling pipes are to be watertight up to the weather deck and to be provided with a means for drainage.

3 Chain lockers are to be subdivided by centre line screen walls.

4 Where a means of access is provided, it is to be closed by a substantial cover and secured by closely spaced bolts.

5 Where a means of access to spurling pipes or cable lockers is located below the weather deck, the access cover and its securing arrangements are to be to the satisfaction of the Society. Butterfly nuts and/or hinged bolts are prohibited as the securing mechanism for the access cover.

6 Spurling pipes through which anchor cables are led are to be provided with permanently attached closing appliances to minimize water ingress.

7 The inboard ends of the chain cables are to be secured to the structures by fasteners able to withstand a force not less than 15% and not more than 30% breaking load of the chain cable.

8 Fasteners are to be provided with a means suitable to permit, in case of emergency, an easy slipping of chain cables to the sea, operable from an accessible position outside the chain locker.

27.1.6 Supporting Hull Structures of Anchor Windlasses and Chain Stoppers

1 The supporting hull structures of anchor windlasses and chain stoppers are to be sufficient to accommodate operating loads and sea loads

(1) Operating loads are to be taken as not less than the following:

(a) For chain stoppers, 80 % of the chain cable breaking load

(b) For windlasses, where no chain stopper is fitted or a chain stopper is attached to the windlass, 80 % of the chain cable breaking load

(c) For windlasses, where chain stoppers are fitted but not attached to the windlass, 45 % of the chain cable breaking load

(2) Sea loads are to be taken according to **2.1.6, Section 4, Chapter 11, Part 1 of Part CSR-B&T of the Rules**

2 The permissible stresses for supporting hull structures of windlasses and chain stoppers are not to be greater than the following permissible values:

(1) For strength assessment by means of beam theory or grillage analysis:

(a) Normal stress: 1.00 R_{eH}

(b) Shear stress: 0.60 R_{eH}

R_{eH}: The specified minimum yield stress of the material

(2) For strength assessment by means of finite element analysis:

(a) Von Mises stress: 1.00 R_{eH}

(3) Normal stress referred to in **(1)** above is the sum of bending stress and axial stress with the corresponding shearing stress acting perpendicular to the normal stress. No stress concentration factors being are to be considered.

3 For strength assessments of supporting hull structures, beam theory or finite element analysis using net scantlings is to be applied as appropriate. Where finite element analysis is used, the provisions of **27.2.3-5** are to be applied. In addition, the total corrosion addition is to be in accordance with the provisions of **27.2.7**.

27.2 Towing and Mooring Arrangement

27.2.1 General*

1 The requirements in **27.2** apply to shipboard fittings used for towing and mooring operations associated with the normal operation of the ship as well as their supporting hull structures.

2 Ships are to be adequately provided with shipboard fittings which are selected from industry standards deemed appropriate by the Society. The “shipboard fittings” referred to in **27.2** are bollards, bitts, fairleads, stand rollers, chocks used for normal mooring of the ship and other similar components used for normal or other towing of the ship. Other components such as capstans, winches, etc. are not included. Any welds, bolts or equivalent devices connecting shipboard fittings to their supporting structures are considered to be part of the shipboard fitting if selected in accordance with industry standards deemed appropriate by the Society.

3 The definitions of terms which appear in this section are as follows.

(1) Maximum towing load

“Maximum towing load” is the largest load that can be assumed or intended in normal towing such as static bollard pull

(2) Safe Towing Load (*TOW*)
"Safe Towing Load" (*TOW*) is the safe load limit of shipboard fittings used for towing purpose. However, it does not represent the actual strength of shipboard fittings and their supporting hull structures

(3) Safe Working Load (*SWL*)
"Safe Working Load" (*SWL*) is the safe load limit of shipboard fittings used for mooring purpose. However, it does not represent the actual strength of shipboard fittings and their supporting hull structures

(4) Line Design Break Force (*LDBF*)
"Line Design Break Force" (*LDBF*) is the minimum force that a new, dry, spliced, mooring line will break at. This is for all synthetic cordage materials.

(5) Ship Design Minimum Breaking Load (MBL_{sd})
"Ship Design Minimum Breaking Load" (MBL_{sd}) is the minimum breaking load of new, dry mooring lines or tow lines for which shipboard fittings and supporting hull structures are designed in order to meet mooring restraint requirements or the towing requirements of other towing services.

(6) Ships intended to be regularly moored to jetty-type piers
Ships intended to be regularly moored to jetty-type piers are oil tankers, chemical tankers or gas carriers which are assumed to be moored to jetty-type piers.

(7) Breast lines, head lines, stern lines and spring lines are defined as follows. (See **Fig. C27.4**)
   (a) Breast line: A mooring line that is deployed perpendicular to the ship, restraining the ship in the off-berth direction.
   (b) Spring line: A mooring line that is deployed almost parallel to the ship, restraining the ship in either the fore or aft direction.
   (c) Head/Stern line: A mooring line that is oriented between the longitudinal and transverse directions, restraining the ship in the off-berth direction as well as in either the fore or aft direction. The amount of restraint in these directions depends on their relative line angles.

(8) Maximum wind speed v_w and acceptable wind speed v_w^*
Wind speed is considered representative of a 30 *second* mean speed from any direction and at a height of 10 *m* above the ground

(9) Current speed for maximum current speed
The current speed is considered representative of the maximum current speed acting on bow or stern ($\pm 10°$) and at a depth of one-half of the mean draft. Furthermore, it is considered that ships are moored to solid piers that provide shielding against cross currents.

(10) Ship nominal capacity condition
"Ship nominal capacity condition" is the theoretical condition in which the maximum possible amount of deck cargoes (in their respective positions) is included in the ship arrangement. For container ships, the nominal capacity condition represents the theoretical condition in which the maximum possible number of containers (in their respective positions) is included in the ship arrangement.

(11) Supporting hull structure
Supporting hull structures are the parts of the ship structure on or in which shipboard fittings are attached and which are directly subjected to the forces acting on such fittings.

(12) Sheltered waters
Sheltered waters are generally calm stretches of water (e.g. harbours, estuaries, roadsteads, bays, lagoons) where the wind force does not exceed 6 on the Beaufort scale.

(13) Towing
For the application of this section, towing means the towing operations specified in the following **(a)** and **(b)** but not including **(c)**.
   (a) Normal towing means towing operations necessary for manoeuvring in ports and sheltered waters associated with the normal operation of the ships.
   (b) Other towing means towing by another ship or a tug (e.g. such as to assist the ship in cases of emergency) but does not include the towing specified in **27.3**.
   (c) Towing services not covered by this section are as follows.
      i) Escort towing: A towing service for laden oil tankers or LNG carriers, particularly as required in specific estuaries.

Its main purpose is to control the ship in cases of propulsion or steering system failure.

ii) Canal transit towing: A towing service for ships transiting canals (e.g. the Panama Canal).

iii) Emergency towing for tankers: A towing service to assist tankers in cases of emergency as specified in **27.3.**

(14) Mooring area

"Mooring area" refers to the dedicated area on a ship where mooring equipment is installed and line-handling takes place. It also includes areas where there is a risk of personnel injury in event of snap-back or other failure of mooring equipment.

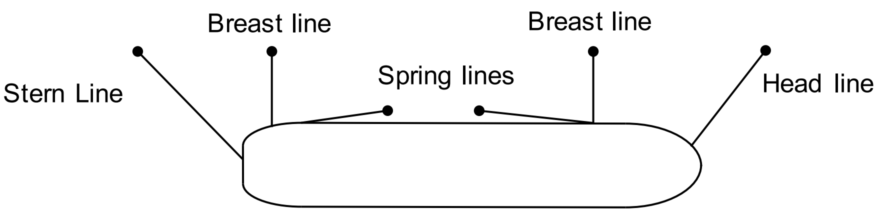
(15) Working Load Limit (*WLL*)

"Working Load Limit (*WLL*)" means the maximum load that a mooring line should be subjected to in operational service, calculated from the relevant environmental mooring restraint requirement.

(16) Bend radius (*D*/*d* ratio)

"Bend radius (*D*/*d* ratio)" means the diameter (*D*) of a mooring fitting divided by the diameter (*d*) of a mooring line that is led around or through the fitting.

Fig. C27.4 Sample Arrangement of Mooring Lines



27.2.2 Tow Lines

Where ships are provided with tow lines, wire ropes and fibre ropes used as tow lines are to comply the requirements in **Chapter 4** and **Chapter 5, Part L of the Rules**, respectively. The specifications of tow lines (e.g. breaking load, length) and the number of tow lines are to be in accordance with **Table C27.1** according to ship equipment number. However, when calculating the equipment number, the effect of deck cargoes at the ship nominal capacity condition is to be considered with respect to the side-projected area *A*.

27.2.3 Towing Fittings*

1 Strength

The strength of shipboard fittings used for towing operations at the bow, sides and stern as well as their supporting hull structures are to comply with the requirements of **27.2.3**. For fittings intended to be used for both towing and mooring, the requirements of **27.2.6** are to be applied.

2 Arrangement

(1) Towing fittings are to be located on stiffeners, girders, or both which are parts of the deck construction so as to facilitate efficient distribution of the towing load. Other arrangements may be accepted (for chocks in bulwarks, etc.) provided the strength is confirmed adequate for the intended service.

(2) When towing fittings cannot be located as specified in **(1)**, appropriate reinforced members are to be provided directly underneath the towing fittings.

3 Selection

(1) Towing fittings are to be selected from industry standards deemed appropriate by the Society, and are to be at least based on the following loads. However, the increase of the line design break force for synthetic ropes (according to **27.2.2(2)**) need not be considered for the loads applied to shipboard fittings and their supporting hull structures.

(a) For normal towing operations, the intended maximum towing load.

(b) For other towing services, the minimum breaking load of the tow line specified in **Table C27.1** according to equipment number.

(c) For fittings intended to be used for both normal and other towing operations, the greater of the loads specified in **(a)** and **(b).**

(2) When towing fittings are not selected from industry standards deemed appropriate by the Society, the strength of the fitting and of its attachment to the ship are to be in accordance with **-4** and **-5**. For strength assessments, beam theory or finite element

analysis using net scantlings is to be applied as appropriate. At the discretion of the Society, load tests may be accepted as alternatives to strength assessments by calculations.

(3) Towing bitts (double bollards) are to be of sufficient strength to withstand the loads caused by tow lines attached with eye splices.

4 Supporting Hull Structures

(1) Design load for the supporting hull structures of towing fittings are to be as specified in **(a)** to **(c)** below:

(a) For normal towing operations, 1.25 *times* the intended maximum towing load.

(b) For other towing services, the breaking load of the tow lines specified in **Table C27.1**.

(c) For fittings intended to be used for both normal and other towing operations, the greater of the design loads specifies in **(1)** and **(2)**.

(2) The reinforced members beneath shipboard fittings are to be effectively arranged for any variation of direction (horizontally and vertically) of the towing forces acting upon the shipboard fittings, and the proper alignment of the fittings and their supporting hull structures is to be ensured. (See **Fig. C27.5** for a sample arrangement.)

(3) The acting point of the towing force on shipboard fittings is to be taken at the attachment point of a tow line or at a change in its direction. For bollards and bitts, the attachment point of the tow line is to be taken as not less than 4/5 of the tube height above the base (see **Fig. C27.6**).

(4) The design load is to be applied to fittings in all directions that may occur in consideration of the arrangements shown in the towing and mooring arrangements plan specified in **27.2.9**.

(5) Where the tow line is a paid-out through a fitting, the design load is to be equal to the resultant force of the design loads acting on the line, but need not exceed twice the design load on the line. The design load acting on the line is to be the minimum design load specified in **(1)** and **(2)** (see **Fig. C27.7**).

(6) The strength of supporting hull structures is to be evaluated based on net scantling calculation.

Fig. C27.5 Sample Arrangement of Shipboard Fittings and Supporting Hull Structures

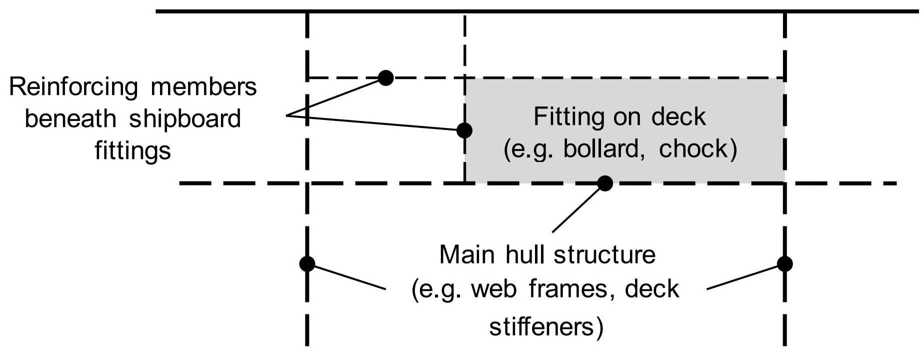


Fig. C27.6 Acting point of the towing force

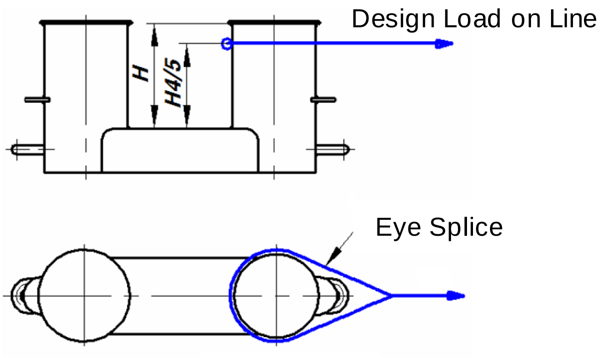
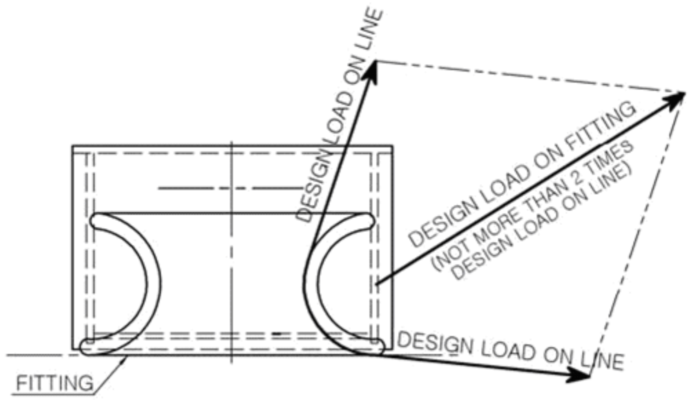


Fig. C27.7 Design Load



5 Allowable Stresses

Allowable stresses of supporting hull structures are not to be more than the following:

(1) For strength assessments using beam theory or grillage analysis:

(a) Normal stress: 100 % of the specified minimum yield stress of the material

(b) Shearing stress: 60 % of the specified minimum yield stress of the material

(2) For strength assessments using finite element analysis:

(a) Von Mises stress: 100 % of the specified minimum yield stress of the material

(3) The normal stress referred to in **(1)** above is the sum of bending stress and axial stress with the corresponding shearing stress acting perpendicular to the normal stress. No stress concentration factors are to be considered.

(4) The followings are recommended to be followed for the strength assessment by means of finite element analysis referred to in **(2)** above.

(a) The geometry is to be idealized as realistically as possible.

(b) The ratio of element length to width is not to exceed 3.

(c) Girders are to be modelled using shell or plane stress elements.

(d) Symmetric girder flanges may be modelled by beam or truss elements.

(e) The element height of girder webs is not to exceed one-third of the web height.

(f) In way of small openings in girder webs the web thickness is to be reduced to a mean thickness over the web height.

(g) Large openings are to be modelled

(h) Stiffeners may be modelled by using shell, plane stress, or beam elements.

(i) Stresses are to be read from the centre of the individual element.

(j) For shell elements the stresses are to be evaluated at the mid-plane of the element.

6 Safe Towing Load (*TOW*)

(1) For towing fittings used for the normal towing operations, *TOW* is not to exceed 80 % of the minimum design load specified in **-4(1)(a)**.

(2) For towing fittings used for the other towing operations, *TOW* is not to exceed 80 % of the minimum design load specified in **-4(1)(b)**.

(3) For towing fittings used for both normal and other towing operations, *TOW* is to be the greater of *TOW* according to **(1)** and **(2)**.

(4) The *TOW* (in tonnes) of each fitting is to be marked by weld beads and paint, or the equivalent, on the fitting.

(5) The towing and mooring arrangements plan specified in **27.2.9** is to define the method of use of tow lines.

27.2.4 Ship Design Minimum Breaking load (MBL_{sd})

1 MBL_{sd} is the design load for the selection of mooring lines, mooring fittings and for the design of supporting hull structures.

2 MBL_{sd} is to be at least not less than minimum breaking load (*MBL*) specified in **27.2.5**. Where the minimum breaking load (*MBL*) is adjusted based on the acceptable wind speed, the number of mooring lines, etc., MBL_{sd} is to be not less than the value *MBL** or *MBL***. MBL_{sd} may be determined in accordance with the method deemed appropriate by the Society.

3 Where the MBL_{sd} is determined by the widely recognized industry standards or the owner's standard, MBL_{sd} is to be not less than the minimum breaking load (*MBL*) specified in this section.

27.2.5 Mooring Lines

1 General

(1) Ships are to be provided with mooring lines of which *LDBF* is more than MBL_{sd}.

(2) Wire ropes or synthetic ropes used as mooring lines are to comply with the requirements in **Chapter 4 and Chapter 5, Part L of the Rules,** respectively.

(3) For mooring lines connected with powered winches where the rope is stored on the drum, steel cord wire ropes of suitable flexible construction may be used instead of fibre cord wire ropes subject to the approval by the Society.

(4) The length of individual mooring lines may be reduced by up to 7 % of the lengths required in this section, provided that the actual total length of the stipulated number of mooring lines is not less than the required total length.

2 The minimum breaking load (*MBL*), the number, the length of mooring lines for ships with equipment numbers of 2,000 or less (EN ≤ 2,000) are to be in accordance with the following **(1)** and **(2)**.

(1) The minimum breaking load (*MBL*), the number and the length of mooring lines are to be in accordance with **Table C27.2** according to the equipment number. However, when calculating the equipment number, the effect of deck cargoes at the ship nominal capacity condition is to be considered with respect to the side-projected area *A*.

(2) For ships having the ratio *A to EN* greater than 0.9 ($A/EN > 0.9$), the following number of ropes is to be added to the number required by **Table C27.2** for mooring lines.

Where *A/EN* is greater than 0.9 but 1.1 or less: 1

Where *A/EN* is greater than 1.1 but 1.2 or less: 2

Where *A/EN* is greater than 1.2: 3

3 The minimum breaking load and the number of mooring lines for ships with an equipment number greater than 2,000 (EN > 2,000) are to be based on the side-projected area A_1. The side-projected area A_1 is to be calculated similar to the side-projected area *A* according to **27.1.2** but in consideration of the following conditions:

(1) The lightest ballast draft is to be considered for the calculation of the side-projected area A_1. For ship types having small variation in the draft (e.g. passenger ships, RO-RO ships), the side-projected area A_1 may be calculated using the designed maximum load line.

(2) Wind shielding of the pier can be considered for the calculation of the side-projected area A_1 unless the ship is intended to be regularly moored to jetty-type piers. A height of the pier surface of 3 *m* over waterline may be assumed; in other words, the lower part of the side-projected area with a height of 3 *m* above the waterline for the considered loading condition may be disregarded for the calculation of the side-projected area A_1

(3) For ships that in which cargoes are loaded on deck, the side-projected are A_1 is to be the following **(a)** or **(b)**, whichever is the greater.

(a) Side-projected area at the lightest ballast condition.

(b) Side-projected area at the ship nominal capacity condition with cargoes loaded on deck. In such cases, the_draft is to be the designed maximum load line.

4 The mooring lines for ships with an equipment number greater than 2,000 (EN > 2,000) are based on the following environmental conditions:

(1) Maximum current speed: 1.0 m/s

(2) Maximum wind speed v_w (m/s) as follows.

(a) $v_w = 25.0 - 0.002(A_1 - 2000)$ (m/s) for passenger ships, ferries, and car carriers with 2,000 $m^2 < A_1 \leq 4{,}000\ m^2$

(b) $v_w = 21.0$ (m/s) for passenger ships, ferries, and car carriers with 4,000 $m^2 > A_1$

(c) $v_w = 25.0$ (m/s) for other ships

5 Minimum breaking load (MBL) for ships with an equipment number greater than 2,000 (EN > 2,000) is to be in accordance with the following **(1)** to **(4)**.

(1) Minimum breaking load (MBL) is to be taken as follows:

$MBL = 0.1A_1 + 350\ (kN)$

A_1: Ship side-projected area specified in **3**.

(2) Where the minimum breaking load (MBL) exceeds 1,275 kN, the maximum wind speed v_w may be decreased in conjunction with an adjustment to the strength of the lines as the acceptable wind speed v_w^* using the following formula but is not to be less than 21 m/s:

$$v_w^* = v_w \sqrt{\frac{MBL^*}{MBL}}$$

MBL^*: The adjusted minimum breaking load of mooring lines (kN)

(3) In case that the maximum wind speed is raised up considering the ship's navigation area, the maximum wind speed may be increased in conjunction with an adjustment to the strength of lines (MBL). For the calculation of the acceptable wind speed, the formula specified in **(2)** above may be used.

(4) Head lines, stern lines, breast lines or spring lines in the same service are to be of the same characteristics in terms of strength and elasticity. The strength of spring lines is to be the same as that of the head, stern and breast lines.

6 The number of mooring lines for ships with an equipment number greater than 2,000 (EN > 2,000) is to be in accordance with the following **(1)** to **(4)**.

(1) The total number of head, stern and breast lines is to be obtained from the following formula and rounded to the nearest whole number:

(a) for oil tankers, chemical tankers, bulk carriers and ore carriers

$n = 8.3 \times 10^{-4} A_1 + 4$

(b) for others

$n = 8.3 \times 10^{-4} A_1 + 6$

(2) Notwithstanding the requirement in **(1)**, the number of head, stern and breast lines may be increased or decreased in conjunction with an adjustment to the strength of the lines. The adjusted strength, MBL^{**}, is to be taken as follows:

$MBL^{**} = 1.2MBL \cdot n/n^{**} \leq MBL$($kN$) for an increased number of lines

$MBL^{**} = MBL \cdot n/n^{**}$($kN$) for a reduced number of lines

n^{**}: The increased or decreased total number of head, stern and breast lines

n: The number of lines for the considered ship type as calculated by the formulae specified in **(1)** without rounding.

MBL : MBL specified in **5(1)** or MBL^* specified in **5(2)**

(3) The total number of spring lines is to be taken as not less than the following:

Two lines when the equipment number is less than 5,000 (EN < 5,000)

Four lines when the equipment number is 5,000 or greater (EN ≥ 5,000)

(4) Where the number of head, stern and breast lines may be increased or decreased in conjunction with an adjustment to the strength of the lines, the number of spring lines is to be taken as follows but rounded up to the nearest even number.

$n_s^* = MBL / MBL^{**} \cdot n_s$

n_s: The number of lines specified in **(3)**

n_s^*: The increased or decreased total number of head, stern and breast lines.

MBL : MBL specified in **5(1)** or MBL^* specified in **5(2)**

7 The strength of head, stern and breast lines may be increased in conjunction with an adjustment to the number of lines using the formula specified in **6(2)**.

8 The length of mooring lines for ships with an equipment number greater than 2,000 (EN > 2,000) is to be taken as not less than 200 *m*.

27.2.6 Mooring Fittings*

1 Strength

The strength of shipboard fittings used for towing operations at the bow, sides and stern as well as their supporting hull structures are to comply with the requirements of **27.2.6**. For fittings intended to be used for both towing and mooring, the requirements of **27.2.3** are to be applied.

2 Arrangement

(1) Mooring fittings, mooring winches and capstans are to be located on stiffeners, girders, or both which are parts of the deck construction so as to facilitate efficient distribution of the mooring load.

(2) When mooring fittings, mooring winches and capstans cannot be located as specified in **(1)**, appropriate reinforced members are to be provided directly underneath the towing fittings.

3 Selection

(1) Mooring fittings are to be selected from industry standards deemed appropriate by the Society and are to be at least based on MBL_{sd}.

(2) When mooring fittings are not selected from industry standards deemed appropriate by the Society, the strength of the fitting and of its attachment to the ship are to be in accordance with **-4** and **-5** For strength assessments, beam theory or finite element analysis using net scantlings is to be applied as appropriate. At the discretion of the Society, load tests may be accepted as alternatives to strength assessments by calculations.

(3) Mooring bitts (double bollards) are to be chosen for the mooring line attached in a figure-of-eight fashion if the industry standard distinguishes between different methods to attach the line, i.e. figure-of-eight or eye splice.

4 Supporting Hull Structure

(1) Design load for supporting hull structures are to be as specified in **(a)** to **(c)** below:

(a) For supporting hull structures of mooring fittings, the minimum design load is to be 1.15 *times* MBL_{sd}.

(b) For supporting hull structures of mooring winches, the minimum design load is to be 1.25 *times* the intended maximum brake holding load, where the maximum brake holding load is to be assumed to be not less than 80 % of MBL_{sd}.

(c) For supporting hull structures of capstans, the minimum design load is to be 1.25 *times* the maximum hauling-in force.

(2) The design load is to be applied to fittings in all directions that may occur in consideration of the arrangements shown in the towing and mooring arrangements plan specified in **27.2.9**.

(3) The point where the mooring force acts on mooring fittings is to be taken as the attachment point of the mooring line. For bollards and bitts, the attachment point of the mooring line is to be taken as not less than 4/5 of the tube height above the base (See **Fig. C27.8(a)**). If fins are fitted to the bollard tubes to keep mooring lines as low as possible, the attachment point of the mooring line may be taken as the location of the fins. (See **Fig. C27.8(b)**)

(4) Where the mooring line is paid-out through a fitting, the design load is to be equal to the resultant force of design load acting on the line, but need not exceed twice the design load acting on the line. The design load acting on the line is to be the minimum design load specified in **(1)**.

(5) The reinforced members beneath shipboard fittings are to be effectively arranged for any variation of direction (horizontally and vertically) of the towing forces acting upon the shipboard fittings, and the proper alignment of the fittings and their supporting hull structures is to be ensured. (See **Fig. C27.5** for a sample arrangement.)

5 Allowable Stresses

Allowable stresses of supporting hull structures are to be in accordance with **27.2.3-5**.

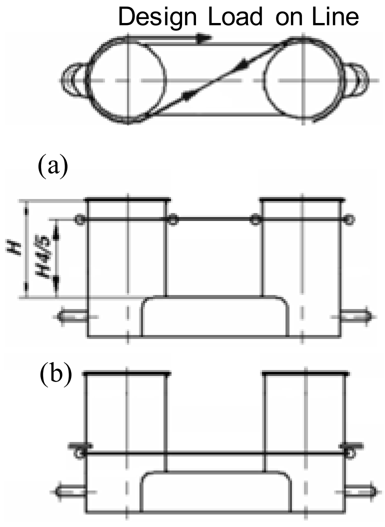
6 Safe Working Load (*SWL*)

(1) *SWL* is not to exceed MBL_{sd}.

(2) The *SWL* (in *tonnes*) of each fitting, excluding mooring winches and capstan, is to be marked by weld beads and paint, or the equivalent, on the fitting. For fittings intended to be used for both towing and mooring, the *TOW* according to **27.2.3** is to be marked in addition to *SWL*.

(3) The towing and mooring arrangements plan specified in **27.2.9** is to define the method of use for mooring lines.

Fig. C27.8 Acting Point of Mooring Force



27.2.7 Corrosion Additions

Corrosion additions are to be added to the scantlings of the supporting hull structures and shipboard fittings as following **(1)** to **(3)**. However, if the shipboard fittings are selected from industry standards deemed appropriate by the Society and the corrosion additions are considered in the standard, following **(1)** to **(3)** may not be applied.

(1) Supporting hull structures: total of 2.0 *mm*. (For container carriers, the corrosion additions specified in **32.1.3** may be applied to the supporting hull structures for which scantlings are determined by the net scantling method.) For ships which are subject to **Part CSR-B&T**, the corrosion additions specified in **Section 3, Chapter 3, Part 1, Part CSR-B&T** are to be applied.

(2) Pedestals and foundations fitted on decks which are not shipboard fittings selected from industry standards deemed appropriate by the Society: total of 2.0 *mm*

(3) Shipboard fittings not selected from industry standards deemed appropriate by the Society: total of 2.0 *mm*

27.2.8 Wear Allowances

In addition to the corrosion additions referred to in **27.2.7**, the wear allowances for shipboard fittings not selected from industry standards deemed appropriate by the Society are not to be less than 1.0 *mm*, added to surfaces which are intended to regularly contact the line.

27.2.9 Towing and Mooring Arrangements Plan*

1 The *SWL* and *TOW* for the intended use for each shipboard fitting is to be noted in the towing and mooring arrangements plan available on board for the Master. If not otherwise chosen, *TOW* is to be the load limit for a tow line attached with an eye splice.

2 Information provided on the plan is to include the following.

(1) Industry standard and referenced number of each towing and mooring fittings.

(2) For each towing and mooring fitting, the location on the ship, the purpose (mooring, normal towing, other towing, etc.), the *SWL* and/or *TOW* as well as the manner of applying towing or mooring line loads including limiting fleet angles.

(3) An arrangement of mooring lines showing the number of lines. (See **Fig. C27.4**)

(4) The Ship Design Breaking Load (MBL_{sd}).

(5) The acceptable environmental conditions for ships with equipment numbers greater than 2,000 (EN > 2,000);

  (a) Maximum wind speed or acceptable wind speed,

  (b) Maximum current speed.

(6) Condition of use for additional mooring equipment not covered by this chapter.

(7) Winch brake holding capacities

(8) For ships of 3,000 gross tonnage and above, documentation confirming that *MSC.1/Circ.*1619 has been considered.

(9) The length of each mooring line

(10) Other information or notes related to the design of shipboard fittings or lines.

27.2.10 Arrangement and selection of mooring line, mooring equipment, capstan, and winch

1 Application

(1) The requirements in this 27.2.10 apply to ships of 3,000 gross tonnage and above.

(2) Ships of less than 3,000 gross tonnage are to comply with the requirements in this 27.2.10 as far as reasonably practicable, or are to comply with applicable the national standards of their respective Administration.

2 Arrangement of mooring line, mooring equipment, capstan, and winch

(1) The arrangement of mooring lines, mooring equipment, capstans and winches is to be in accordance with the following **(a)** through **(k)**.

(a) To minimise the need for complex mooring line configurations during the normal operation of the ship, mooring winches and fairleads are to be positioned to allow the use of direct, unobstructed leads from mooring winches to the fairleads for each mooring line described in the towing and mooring arrangements plan.

(b) Where the arrangement in **(a)** above is not possible, the following **i)** to **iii)** measures are to be considered.

i) The deviation from straight leads are to be by means of pedestal fairleads, rolling fairleads or similar means that will reduce the friction between line/fitting and will reduce bend losses. Steel fittings such as horns or bollards without chafe protection are to be avoided.

ii) Lines are to traverse mooring areas from winches to fairleads by the shortest route.

iii) Changes of direction of mooring line are to be minimised to prevent reductions in mooring line strength due to bend loss and introduction of complex snap-back areas.

(c) To provide for the oversight and supervision of mooring operations, mooring areas are to be designed to give supervising personnel unobstructed views of installed mooring lines, mooring equipment, capstans and winches. This is to also include the provision of platform or other appropriate means by which supervising personnel can obtain unobstructed views of mooring areas and the berth arrangements planned to be used from positions clear of hazards.

(d) Mooring arrangements are to be designed to provide unobstructed views between shipboard personnel and the lines being worked within mooring areas.

(e) Winch operators are to be provided with mooring winch controls that are positioned so as to allow operators direct views of the lines being worked in mooring areas worked without needing to step away from the winch controls. Winch controls are to be positioned clear of hazards.

(f) Deck illumination is to provide clear views of mooring areas as well as the equipment and lines being worked during hours of darkness or in conditions of limited visibility.

(g) Designs of mooring arrangements and mooring areas are to consider the following **i)** to **iii)** constraints.

i) Anticipated variations in shore-based mooring arrangements and the need to preserve flexibility in mooring line configurations to achieve an appropriate restraining capacity.

ii) Ship structural element (including accommodation, ventilation exhausts, cargo equipment or similar obstacles) impact on access.

iii) Special requirements for the location and selection of mooring lines, mooring equipment, capstans and winches; for example, special requirements for canal transits.

(h) Unless not permitted by ship size or special features, mooring lines, mooring equipment, capstans and winches in mooring areas are to be positioned so as to provide shipboard personnel with unobstructed access to the following during mooring operations.

i) Mooring winches and winch controls.

ii) Mooring fittings.

iii) Mooring lines and mooring line stowage.

iv) Spaces between shipside fairleads and winches to permit mooring personnel to safely apply stoppers to mooring lines when necessary.

(i) Mooring arrangements are to be designed to avoid exposing shipboard personnel to lines under tension through snap-back or sudden movements of mooring lines. In this respect, the following measures are to be considered.

i) Winches are to be located close to shipside fairleads. The position of winches is to not result in inappropriate mooring line orientations that block or otherwise interfere with the use of shipside fairleads for additional mooring lines, the connecting up of tugs for towage during mooring operations or the ability to safely moor the ship.

ii) Enclosing mooring lines behind barriers provided that such enclosures do not adversely affect mooring system performance and do not prevent the effective inspection and maintenance of equipment, fittings and mooring lines.

iii) Alternative designs where ship personnel do not need to work close to or have to pass mooring lines that are under tension or are potentially under tension.

iv) Use of appropriate, alternative means to moor the ship, including but not limited to automated mooring systems.

v) Permanently fix mooring lines to mooring winches.

(j) Mooring areas should be considered as potential snap-back zones and signage should be provided to indicate that this is the case.

(k) To minimise the need for manual handling of towing and mooring lines, the following **i)** to **vi)** measures are to be considered.

i) Equipment and fitting arrangements should minimise the distance over which mooring lines may need to be handled.

ii) The use of fixed or dedicated mooring lines, considering the need to avoid inappropriate mooring line orientations that block or otherwise interfere with the use of shipside fairleads for additional mooring lines, the connecting up of tugs for towage during mooring operations or the ability to safely moor the ship.

iii) Layouts are to be designed to prevent manual intervention in transfers of mooring lines from storage drums to mooring winch drums and vice versa.

iv) Use of spooling equipment.

v) Additional mooring lines are to be available for immediate use, provided that their stowage does not interfere with the safe operation of the mooring equipment.

vi) A sufficient number of mooring winches so that manual use of warping ends, stoppers, capstans and bitts is minimized, as far as possible, during mooring operations.

(2) Being unable to comply with **(1)(b)**, **(d)**, **(e)**, **(h)**, **(i)** and **(k)** above is to be recorded as supplementary information in towing and mooring fitting arrangements plan. The reasons for not being able to fulfill the requirements and appropriate safety measures taken instead are to also be included in this supplementary information.

(3) Compliance with items **(1)(b)**, **(d)**, **(e)**, **(h)**, **(i)** and **(k)** above is to be indicated on towing and mooring fitting arrangements plan.

3 Selection of mooring line, mooring equipment, capstan, and winch

(1) Selection of mooring winches is to be in accordance with the following **(a)** to **(e)**.

(a) Consideration is to be given to the availability of winches with alternative drum arrangements, including split drum arrangements, which can reduce the need for manual handling of mooring lines during mooring operations.

(b) Consideration is to be given to the positioning of winch controls, including the availability of remote controls for winches, to improve the lines of sight and reduce operator exposure to snap-backs.

(c) Consideration is to be given to the availability of constant tension winches and their appropriateness for normal ship operations.

(d) Consideration is to be given to limiting noise levels to ensure proper communication during mooring operations.

(e) To avoid overloads on mooring winches, mooring winch brake holding capacities are to be less than 100 % of the Ship Design Minimum Breaking Load (MBL_{sd}). Alternatively, winches are to be fitted with brakes that allow for reliable settings of brake rendering loads.

(2) Selections of mooring equipment and capstans are to be in accordance with the following **(a)** to **(c)**.

(a) Consideration is to be given to the diameter (D) of surfaces of mooring fittings that are in contact with mooring lines in relation to mooring line diameter (d) (i.e. the D/d ratio) to reduce or mitigate bend loss of strength.

(b) Consideration is to be given to use mooring equipment and capstans with load-bearing surfaces to minimize damage from chafing and abrasion.

(c) Mooring equipment and capstans are to be compatible in design, diameter, strength, suitability, etc. and maintained with the original purpose and concept of the mooring arrangement.

(3) The selection of mooring line is to be in accordance with the following **(a)** to **(g)**.

(a) Consideration is to be given to the diameter (D) of surfaces of mooring fittings that are in contact with mooring lines in relation to mooring line diameter (d) (i.e. the D/d ratio) to reduce or mitigate bend loss of strength.

(b) Consideration is to be given to the compatibility of the MBL_{sd} of mooring lines and the brake capacities of mooring winches installed on board.

(c) Line Design Break Force ($LDBF$) is to be 100 % to 105 % of the MBL_{sd}. When lines made of nylon are used as mooring lines, the $LDBF$ of the lines is to be the tested under wet and spliced conditions.

(d) Consideration is to be given to the characteristics and limitations of mooring lines (including the material properties and environmental operating conditions anticipated during normal ship operations).

(e) Consideration is to be given to the anticipated behaviours of mooring lines in the event of failure.

(f) Consideration is to be given to the influence on stored energy and the potential for snap-back of high stiffness mooring lines caused by the use of tails.

(g) As far as possible, but at least for lines in the same service (e.g. headlines, breast lines or springs), Mooring lines of the same diameter and type (i.e. material) are to be used.

4 Technical specification documents for mooring lines

The technical specification documents of the mooring lines provided on board are to include the manufacturer recommended minimum diameters (D) for fittings in contact with mooring lines and the Line Design Break Forces ($LDBF$) for mooring lines. The properties of mooring lines related to $LDBF$ and bend radius (i.e. the D/d ratio) are to also be included for confirmation of appropriate mooring line selection.

5 Working Load Limit (WLL)

The WLL of mooring lines is to be used as user operating limiting values and is not to be exceeded. WLL is expressed as a percentage of MBL_{sd} and is to be used as a limiting value in operational mooring analyses. Steel wires have a WLL of 55 % of MBL_{sd} and all other cordage (synthetic) have a WLL of 50 % of the MBL_{sd}.

27.2.11 Inspection and Maintenance of Mooring Equipment Including Mooring Lines

Ships of not less than 500 gross tonnage are to have management plans for inspection and maintenance of mooring equipment including mooring lines deemed appropriate by the Society.

27.3 Emergency Towing Arrangements

27.3.1 Application

The requirements in 27.3 apply to tankers, ships carrying liquefied gases in bulk and ships carrying dangerous chemicals in bulk of not less than 20,000 deadweight tonnage(DWT) (hereinafter referred to as ‘ships’).

27.3.2 General*

1 Emergency towing arrangements approved by the Society are classified into two types: the 1,000kN type and the 2,000kN type.

2 Emergency towing arrangements are to be capable of rapid deployment and easy connection to a towing vessel at all times even in the absence of main power on the ship.

3 An appropriate type of emergency towing arrangement selected from below, corresponding to the DWT of the ship is to be fitted at both ends on board the ship.

(1) 20,000 $tons \leq DWT < 50{,}000\ tons$: 1,000$kN$ type emergency towing arrangement

(2) 50,000 $tons \leq DWT$: 2,000kN type emergency towing arrangement

4 At least one of the emergency towing arrangements specified in -3, is to be pre-rigged ready for rapid deployment.

27.4 Emergency Towing Procedures

27.4.1 General

1 Ships are to be provided with an emergency towing procedure that describes the towing procedure to be used in emergency situations.

2 The procedure specified in -1 above is to be based on existing arrangements and equipment available on board the ship and is to include the following:

(1) drawings of fore and aft deck showing possible emergency towing arrangements;

(2) inventory of equipment on board that can be used for emergency towing;

(3) means and methods of communication; and

(4) sample procedures to facilitate the preparation for and conducting of emergency towing operations.

Table C27.1 Anchors, Chain Cables and Ropes

Equipment Letter	Equipment number		Anchor		Chain cable for anchor (Stud anchor for chain)				Tow line	
			Number	Mass per anchor (stock-less anchor)	Total length	Diameter			Length	Breaking load
						Grade 1	Grade 2	Grade 3		
	Over	Up to		kg	m	mm	mm	mm	m	kN
A1	50	70	2	180	220	14	12.5		180	98
A2	70	90	2	240	220	16	14		180	98
A3	90	110	2	300	247.5	17.5	16		180	98
A4	110	130	2	360	247.5	19	17.5		180	98
A5	130	150	2	420	275	20.5	17.5		180	98
B1	150	175	2	480	275	22	19		180	98
B2	175	205	2	570	302.5	24	20.5		180	112
B3	205	240	2	660	302.5	26	22	20.5	180	129
B4	240	280	2	780	330	28	24	22	180	150
B5	280	320	2	900	357.5	30	26	24	180	174
C1	320	360	2	1020	357.5	32	28	24	180	207
C2	360	400	2	1140	385	34	30	26	180	224
C3	400	450	2	1290	385	36	32	28	180	250
C4	450	500	2	1440	412.5	38	34	30	180	277
C5	500	550	2	1590	412.5	40	34	30	190	306
D1	550	600	2	1740	440	42	36	32	190	338
D2	600	660	2	1920	440	44	38	34	190	370
D3	660	720	2	2100	440	46	40	36	190	406
D4	720	780	2	2280	467.5	48	42	36	190	441
D5	780	840	2	2460	467.5	50	44	38	190	479
E1	840	910	2	2640	467.5	52	46	40	190	518
E2	910	980	2	2850	495	54	48	42	190	559
E3	980	1060	2	3060	495	56	50	44	200	603
E4	1060	1140	2	3300	495	58	50	46	200	647
E5	1140	1220	2	3540	522.5	60	52	46	200	691
F1	1220	1300	2	3780	522.5	62	54	48	200	738
F2	1300	1390	2	4050	522.5	64	56	50	200	786
F3	1390	1480	2	4320	550	66	58	50	200	836
F4	1480	1570	2	4590	550	68	60	52	220	888
F5	1570	1670	2	4890	550	70	62	54	220	941
G1	1670	1790	2	5250	577.5	73	64	56	220	1024
G2	1790	1930	2	5610	577.5	76	66	58	220	1109
G3	1930	2080	2	6000	577.5	78	68	60	220	1168
G4	2080	2230	2	6450	605	81	70	62	240	1259

Equipment Letter	Equipment number		Anchor		Chain cable for anchor (Stud anchor for chain)				Tow line	
			Number	Mass per anchor (stock-less anchor)	Total length	Diameter			Length	Breaking load
						Grade 1	Grade 2	Grade 3		
	Over	Up to		*kg*	*m*	*mm*	*mm*	*mm*	*m*	*kN*
*G*5	2230	2380	2	6900	605	84	73	64	240	1356
*H*1	2380	2530	2	7350	605	87	76	66	240	1453
*H*2	2530	2700	2	7800	632.5	90	78	68	260	1471
*H*3	2700	2870	2	8300	632.5	92	81	70	260	1471
*H*4	2870	3040	2	8700	632.5	95	84	73	260	1471
*H*5	3040	3210	2	9300	660	97	84	76	280	1471
*J*1	3210	3400	2	9900	660	100	87	78	280	1471
*J*2	3400	3600	2	10500	660	102	90	78	280	1471
*J*3	3600	3800	2	11100	687.5	105	92	81	300	1471
*J*4	3800	4000	2	11700	687.5	107	95	84	300	1471
*J*5	4000	4200	2	12300	687.5	111	97	87	300	1471
*K*1	4200	4400	2	12900	715	114	100	87	300	1471
*K*2	4400	4600	2	13500	715	117	102	90	300	1471
*K*3	4600	4800	2	14100	715	120	105	92	300	1471
*K*4	4800	5000	2	14700	742.5	122	107	95	300	1471
*K*5	5000	5200	2	15400	742.5	124	111	97	300	1471
*L*1	5200	5500	2	16100	742.5	127	111	97	300	1471
*L*2	5500	5800	2	16900	742.5	130	114	100	300	1471
*L*3	5800	6100	2	17800	742.5	132	117	102	300	1471
*L*4	6100	6500	2	18800	742.5		120	107	300	1471
*L*5	6500	6900	2	20000	770		124	111	300	1471
*M*1	6900	7400	2	21500	770		127	114	300	1471
*M*2	7400	7900	2	23000	770		132	117	300	1471
*M*3	7900	8400	2	24500	770		137	122	300	1471
*M*4	8400	8900	2	26000	770		142	127	300	1471
*M*5	8900	9400	2	27500	770		147	132	300	1471
*N*1	9400	10000	2	29000	770		152	132	300	1471
*N*2	10000	10700	2	31000	770			137	300	1471
*N*3	10700	11500	2	33000	770			142	300	1471
*N*4	11500	12400	2	35500	770			147	300	1471
*N*5	12400	13400	2	38500	770			152	300	1471
*O*1	13400	14600	2	42000	770			157	300	1471
*O*2	14600	16000	2	46000	770			162	300	1471

Notes:

1 Length of chain cables may include shackles for connection.

2 Tow line is not a condition of Classification, but is listed in this table only for guidance. (ref. 27.2.2)

Table C27.2 Mooring Lines for Ships with Equipment Number ≦ 2,000

Equipment Letter	Equipment number		Mooring line		
			Number	Length of each line	Breaking load
	Over	Up to		*m*	*kN*
*A*1	50	70	3	80	37
*A*2	70	90	3	100	40
*A*3	90	110	3	110	42
*A*4	110	130	3	110	48
*A*5	130	150	3	120	53
*B*1	150	175	3	120	59
*B*2	175	205	3	120	64
*B*3	205	240	4	120	69
*B*4	240	280	4	120	75
*B*5	280	320	4	140	80
*C*1	320	360	4	140	85
*C*2	360	400	4	140	96
*C*3	400	450	4	140	107
*C*4	450	500	4	140	117
*C*5	500	550	4	160	134
*D*1	550	600	4	160	143
*D*2	600	660	4	160	160
*D*3	660	720	4	160	171
*D*4	720	780	4	170	187
*D*5	780	840	4	170	202
*E*1	840	910	4	170	218
*E*2	910	980	4	170	235
*E*3	980	1060	4	180	250
*E*4	1060	1140	4	180	272
*E*5	1140	1220	4	180	293
*F*1	1220	1300	4	180	309
*F*2	1300	1390	4	180	336
*F*3	1390	1480	4	180	352
*F*4	1480	1570	5	190	352
*F*5	1570	1670	5	190	362
*G*1	1670	1790	5	190	384
*G*2	1790	1930	5	190	411
*G*3	1930	2000	5	190	437

Chapter 28 (Deleted)

(Deleted)

Chapter 29 TANKERS

29.1 General

29.1.1 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 D**, **Chapter 4 in Part H**, and **Part R** as applicable according to ship size, navigating area and cargoes carried are to be applied to ships specified in **-1**.

29.1.2 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:

$$1.2\sqrt{L}\ (m)$$

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, Part H** 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.

29.2 Minimum Thickness

29.2.1 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 C29.1** 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 C29.1 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

29.3 (Deleted)

(Deleted)

29.4 Bulkhead Plating

29.4.1 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

$$t = C_1C_2S\sqrt{h} + 3.5 \ (mm)$$

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:

$$h_2 = 0.85(h_1 + \varDelta h)$$

Where:

$\varDelta h$: Additional water head given by the following formula:

$$\varDelta h = \frac{16}{L}(l_t - 10) + 0.25(b_t - 10) \ (m)$$

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 h_2 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 **1.1.7-2** for high tensile steel, and the values specified in **1.1.7-3** 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 $y \leq y_B$

$$\alpha_2 = 15.5 f_B \left(1 - \frac{y}{y_B}\right)$$

$$\alpha_3 = \beta\left(1 - \frac{2b}{B}\right)$$

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 15 in Part C** 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 **15.2.3(5)(a)** or **(b)**, **Part C**

β: Coefficient given by the following formulae

For intermediate values of L, β is to be obtained by linear interpolation.

$\beta = \dfrac{6}{a}$ where L is not more than 230 *m*

$\beta = \dfrac{10.5}{a}$ 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**.

29.4.2 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 **29.4.1-1**

S: Spacing of stiffeners (m)

3 In determining the thickness of swash bulkhead plating, sufficient consideration is to be given for buckling.

29.4.3 Trunks

The thicknesses of trunk top and side plating are to be determined applying the requirements of **29.4.1** in addition to the requirements in **Chapter 17**.

29.5 Longitudinals and Stiffeners

29.5.1 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 **29.4.1-1**

C_2: Coefficient given by the following formula:

$$C_2 = \frac{K}{24 - 15.5 f_B K}$$

f_B and K: As specified in **29.4.1-1**

2 The section modulus Z of side longitudinals including bilge longitudinals is not to be less than the value obtained from the following formula:

$$Z = 100C_1C_2Shl^2 \quad (cm^3)$$

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 **29.4.1-1**

C_2: Coefficient given by the following formula:

$$C_2 = \frac{K}{24 - \alpha K}$$

Where:

K: As specified in 29.4.1-1

α: α_1 or α_2 as given below, whichever is greater

$$\alpha_1 = 15.5 f_B \left(1 - \frac{y}{y_B}\right)$$

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

f_B and y_B: As specified in 29.4.1-1

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.

29.5.2 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:

$$Z = 125 C_1 C_2 C_3 S h l^2 \ (cm^3)$$

Where:

S: Spacing of stiffeners (m)

h: As specified in 29.4.1-1

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 29.4.1-1

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 29.4.1-1

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 C29.2 according to the fixity condition of stiffener ends:

Table C29.2 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.C13.1** (a) of the Rules).
2. Soft fixity by bracket means the fixity in the connection between beams, frames, etc., which are crossing members, and brackets (*see* **Fig.C13.1** (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 $K/18$.

29.5.3 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 longitudinals 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 **29.4.1-1**

29.5.4 Other Precautions

The section modulus of longitudinal beams is not to be less than that obtained by applying the requirements of **10.3.3**. 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 **29.5.2**.

29.6 Girders

29.6.1 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 **29.6.3** through **29.6.8** 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. C15.6**, 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. C15.6**, 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. C15.6**, 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 **29.6.5** to **29.6.8**.

29.6.2 Direct Strength Calculations for Girders*

The structural models, loads, allowable stress levels, etc. for determining the arrangement of girders and scantlings based upon direct strength calculations are to be as deemed appropriate by the Society.

29.6.3 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, openings 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 $0.25l_T$, x is to be taken as $0.25l_T$.

l_T: Length (m) of the cargo oil tank under consideration

C_1: Coefficient obtained from **Table C29.3** 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 **29.4.1-1**

(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 $0.25l_T$, x is to be taken as $0.25l_T$.

C_1: Coefficient obtained from **Table C29.4** 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 **29.4.1-1**

(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 $0.25l_T$, x is to be taken as $0.25l_T$.

C_1: Coefficient obtained from **Table C29.5** 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 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* **29.4.1-1**

(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:

$$t_2 = 8.6\sqrt[3]{\frac{H^2 a^2}{C_1' K}(t_1 - 2.5)} + 2.5 \ (mm)$$

$$t_3 = \frac{C_1'' a}{\sqrt{K}} + 2.5 \ (mm)$$

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 C29.6** 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:

$$1 + 0.5\frac{\phi}{\alpha}$$

Where:

ϕ: 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 C29.7** 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 **29.4.1-1**

Table C29.3 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

Table C29.4 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

Table C29.5 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

Table C29.6 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 C29.7 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:

$$t_1 = C_2 K \frac{Sbh_B}{d_0 - d_1}\left(1 - \frac{4}{3}\frac{y}{b'}\right) + 2.5 \ (mm)$$

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 $0.3b'$, y is to be taken as $0.3b'$.

C_2: Coefficient obtained from **Table C29.8** 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 **29.4.1-1**

(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 C29.9** 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 **29.4.1-1**

(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 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 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 $0.25b'$.

C_2: Coefficient obtained from **Table C29.10** 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 $d_0$are to be in accordance with the requirements of **(a)**.

l_T: As specified in **-1(1)(a)**

b: As specified in **-1(1)(c)**

K: As specified in **29.4.1-1**

(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:

$$t_2 = 8.6 \sqrt[3]{\frac{H^2 a^2}{C'_2 K}(t_1 - 2.5)} + 2.5 \ (mm)$$

$$t_3 = \frac{8.5 S_2}{\sqrt{K}} + 2.5 \ (mm)$$

Where:

a: Depth (m) of 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 C29.11** 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:

$$1 + 0.5\frac{\phi}{\alpha}$$

Where:

ϕ: 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 **29.4.1-1**

Table C29.8 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

Table C29.9 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	0.028	0.026	0.024	0.022	0.021	0.019

Table C29.10 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

Table C29.11 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

29.6.4 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) Not to be less than either of the 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 $0.25l_T$, x is to be taken as $0.25l_T$.

l_T: Length (m) of the cargo oil tank under consideration

C_3: Coefficient obtained from **Table C29.12** 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 **29.4.1-1**

(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 $0.25l_T$, x is to be taken as $0.25l_T$.

C_3: Coefficient obtained from **Table C29.13** 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 **29.4.1-1**

(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 C29.14** 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:

$$1 + 0.5\frac{\phi}{\alpha}$$

Where:

ϕ: 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 **29.4.1-1**

Table C29.12 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

Table C29.13 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

Table C29.14 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 C29.15** 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 **29.4.1-1**

(b) Tape 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 C29.16** 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 **29.4.1-1**

(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 C29.17** 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:

$$1 + 0.5\frac{\phi}{\alpha}$$

Where:

ϕ: 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 **29.4.1-1**

Table C29.15 Coefficient C_4

$\frac{D'}{l_T}$	0.5 and under	0.6	0.7	0.8	0.9	1.0	11	1.2	1.3 and over
C_4	0.052	0.051	0.049	0.046	0.043	0.041	0.038	0.036	0.034

Table C29.16 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

Table C29.17 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

29.6.5 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 **29.4.1-1**

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_0" 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 **29.4.1-1**

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:

$$t_1 = 0.0417\frac{C_1C_2KShl_0}{d_1} + 3.5 \quad (mm)$$

$$t_2 = 1.74\sqrt[3]{\frac{C_1C_2Shl_0S_1^2}{d_1}} + 3.5 \quad (mm)$$

$$t_3 = \frac{C_3}{\sqrt{K}} d_0 + 3.5 \ \ (mm)$$

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, C_3 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:

$$\text{Where } \frac{S'}{d_0} \geq 1.0: C_3 = 11.0$$

$$\text{Where } \frac{S'}{d_0} < 1.0: C_3 = 11.0\sqrt{\frac{S'}{d_0}}$$

(2) For webs of girders and transverses other than those specified in **(1)**, C_3 is given in **Table C29.18** 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 C29.18** 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 by the 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:

$$1 + 0.5\frac{\phi}{a}$$

Where:

a: Length (m) at the longer side of the panel surrounded by web stiffeners

ϕ: Diameter of openings (m)

Where openings are oblong, ϕ is to be the length (m) of the longer diameter.

Table C29.18 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 **1.1.13-3**. 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 **29.5.1-1**

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

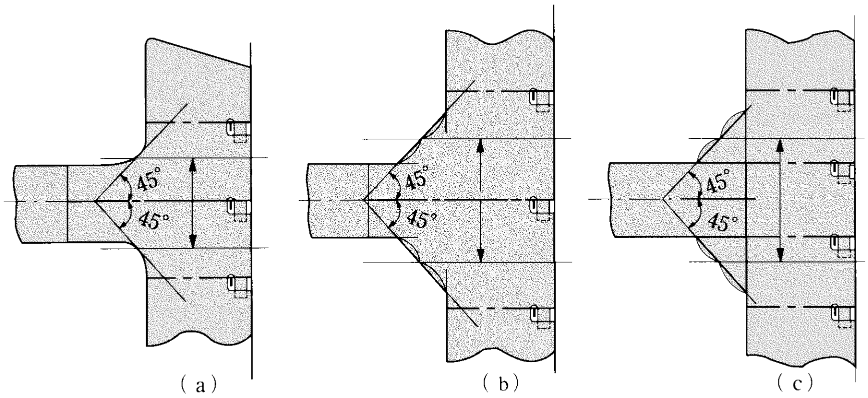
A: Sectional area (cm^2) effective to support the axial force from cross ties, which is to be taken as follows:

(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. C29.1** (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. C29.1** (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. C29.1** (c)).

Fig. C29.1 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.

29.6.6 Girders of Ships without Double Side Hull

1 In addition to the requirements in **29.6.5**, 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:

$d = 0.15l\ (m)$

$Z = 8.7KShl_0^2\ (cm^3)$

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 **29.6.5-1**

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 **29.5.1-1**

K: As specified in **29.4.1-1**

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:

$Z = 3KS\sqrt{L}l_0^2\ (cm^3)$

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.

29.6.7 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.

$t = 0.5\sqrt{L} + 3.5 \ (mm)$

29.6.8 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 29.6.8.

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:

$A = C_1 C_2 K S b_S h \ (cm^2)$

Where:

S, b_S, C_1: As specified in 29.6.5-5

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 29.4.1-1

C_2: Coefficient obtained from the following formula:

Where $l/k > 0.6$;

$$C_2 = \frac{0.77}{1 - 0.5\frac{l}{k\sqrt{K}}}$$

Where $l/k < 0.6$;

$C_2 = 1.1$

l: Length (m) of cross ties measured between the inner edges of the vertical webs on longitudinal bulkheads

k: As given below:

$$k = \sqrt{\frac{I}{A}} \ (cm)$$

I: The least moment of inertia (cm^4) of cross ties

A: Sectional area (cm^2) of cross ties

29.7 Structural Details

29.7.1 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.

29.7.2 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.

29.7.3 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.

29.7.4 Supporting Structures of Independent Prismatic Tanks*

The arrangement and scantlings of the supporting structures of the independent prismatic tanks are to be at the discretion of the Society.

29.8 Special Requirements for Corrosion

29.8.1 Thickness of Shell Plating

1 In application of the requirements in **Chapter 16,** 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 **16.3.2**.

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 **29.4.1**.

29.8.2 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 **29.4.1**.

2 In application of the requirements in **Chapter 17,** 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 **17.3**.

29.8.3 Thickness of Tank Top Plating

1 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 **29.4.1**. However, such an addition is not required for the thickness of the inner bottom plating.

29.8.4 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 **10.3.3**.

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 **29.5.1** and **29.5.2**.

29.8.5 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 **29.2**.

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**.

29.8.6 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 **29.2**.

29.8.7 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 **29.4.1-1** for the appropriate area of application.

29.9 Special Requirements for Tankers with Mid-decks

29.9.1 Application

The structural members of tankers having mid-decks penetrating longitudinally through cargo areas are to comply with the requirements in **29.1** through **29.8** in addition to the requirements in **29.9**.

29.9.2 Loads

Values of h_1, h_2 and h_3 are to be as specified in **Table C29.19** where the scantlings of structural members in cargo oil tanks below the mid-deck are obtained from the formulae specified in **29.4.1**, **29.5.2** and **29.6.5**.

Table C29.19 Loads

Loads	Provisions 29.4.1	Provisions 29.5.2	Provisions 29.6.5
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 29.4.1-1.	$0.85(h_1+\Delta h)$ (m) Δh is to be as specified in 29.4.1-1.	$0.85(h_1+\Delta h)$ (m) Δh is to be as specified in 29.4.1-1.
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

29.9.3 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 29.4.1 using the loads specified in 29.9.2.

29.10 Special Requirements for Forward Wing Tanks

29.10.1 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 $0.15L$ from the bow to the collision bulkhead are to comply with the requirements in 29.1 through 29.9 in addition to the requirements in 29.10.

29.10.2 Side Longitudinals

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

$$Z = 9C_1KShl^2 \quad (cm^3)$$

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 29.4.1-1

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:

$$C = \frac{b_1 + b_2 - 0.3}{l}$$

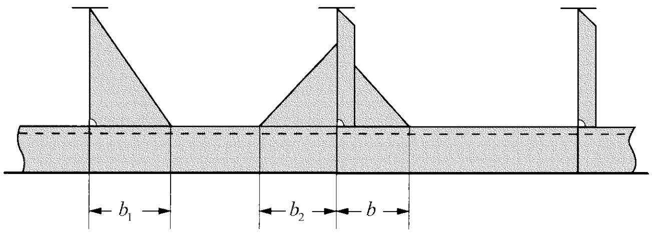
Where a bracket is provided at one end:

$$C = \frac{b - 0.15}{l}$$

b_1, b_2, b : Length (m) of bracket arms along longitudinals

Where the value of C is negative, $C = 0$. (See Fig. C29.2)

Fig. C29.2 Measurement of b, b_1 and b_2



29.11 Construction and Strengthening of the Forward Bottom

Strengthening of the forward bottom is to comply with the requirements in 6.8 and 16.4.4.

29.12 Special Requirements for Hatchways and Freeing Arrangements

29.12.1 Ships Having Unusually Large Freeboards

Ships considered to have an unusually large freeboard may be given special consideration in regards to the requirements in 29.12.

29.12.2 Hatchways to Cargo Oil Tanks*

1 The 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.

29.12.3 Hatchways to Spaces other than Cargo Oil Tanks

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 20.2.4 and 20.2.5.

29.12.4 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 or to 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 **23.2**. 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.

29.13 Welding

29.13.1 Application

The welding in tankers is to be in accordance with the requirements given in **Table C1.5** unless specified otherwise in **29.13**.

29.13.2 Fillet Welding*

1 The application of fillet welding to structural members within the cargo areas is to be as given in **Table C29.20**.

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 C29.20 Application of Fillet Welding

Column	Item		Application	kind of weld
1	Girders and Transverses	Web plates	Shell, deck, longitudinal bulkhead or inner bottom plating	*F*1
2			Web plates	*F*1
3			Face plates	*F*2
4		Slots in web plates	Web plates of longitudinal frames, beams and horizontal stiffeners on longitudinal bulkheads	*F*2
5		Tripping brackets and stiffeners provided on web plates	Web plates	*F*3
6			Longitudinal frames, beams and horizontal stiffeners on longitudinal bulkheads	*F*1
7	Longitudinal frames, beams and horizontal stiffeners on longitudinal bulkheads		Shell, deck or longitudinal bulkhead plating	*F*3
8	Cross ties		Members forming cross ties (web plates to face plates)	*F*3
9			Face plates of transverses or girders	*F*1

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 30 ORE CARRIERS

30.1 General

30.1.1 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 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** above and the requirements in this chapter are considered to be not applicable, matters are to be determined as deemed appropriate by the Society.

5 The ships specified in **-1** above are to be in accordance with the relevant requirements in **Chapter 31A**.

30.1.2 Direct Calculations*

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, the former is to be adopted.

30.2 Double Bottoms

30.2.1 General

1 The specific gravity γ of cargoes described in this Chapter is as defined by the following formula:

$$\gamma = \frac{W}{V}$$

W: Mass (t) of cargoes for the hold

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

2 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. However, the height is not to be less than h (m) as specified in **6.1.1-1**.

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 double bottoms are intended to be deep tanks, the scantlings of members in double bottoms are to be in accordance with the relevant requirements in **30.3**, in addition to those of this Section. Bottom shell plating is to be in accordance with **30.3.1**, **30.3.2-1** and **-5**. Inner bottom plating is to be in accordance with **30.3.1** and **30.3.2-1**. Bottom longitudinals are to be in accordance with **30.3.3-1**, **-3**, **-4**, **-6** and **-8**. Inner bottom longitudinals are to be in accordance with **30.3.3-4**, **-6** and **-8**. Girders are to be in accordance with **30.3.1**. However, when obtaining the value of coefficient C_2 in **30.3.2-1**, "longitudinal bulkhead plating" is to be construed as "bottom shell plating" or "inner bottom plating".

30.2.2 Inner Bottom Plating

1 The thickness t of inner bottom plating is not to be less than the greater of the values obtained from the following formulae:

$$t = \frac{CK}{1000} \cdot \frac{B^2 d}{d_0} + 2.5 \ (mm)$$

$$t = C' S \sqrt{Kh} + 2.5 \ (mm)$$

K: Coefficient corresponding to the kind of steel

e.g. 1.0 for mild steel, the values specified in **1.1.7-2(1)** for high tensile steel

d_0: Height (m) of double bottoms at the centreline

S: Spacing (m) of inner bottom longitudinals

h: Vertical distance (m) from the top of the inner bottom plating to the upper deck at the centreline

C: Coefficient given by the following formula:

$C = ab$

a: As given by the following formulae according to the value of $\frac{h\gamma}{d}$:

When $\frac{h\gamma}{d} < 1 - \frac{d_{\min}}{d}$: $1 + 0.026\frac{L'}{d} - \frac{h\gamma}{d}$

When $1 - \frac{d_{\min}}{d} \le \frac{h\gamma}{d} \le 1 + \frac{d_{\min}}{d}$: $\frac{d_{\min} + 0.026L'}{d}$

When $1 + \frac{d_{\min}}{d} < \frac{h\gamma}{d}$: $\frac{h\gamma}{d} - 1 + 0.026\frac{L'}{d}$

γ: As specified in **30.2.1-1**

d_{min}: Minimum draft amidship (m) under all operating conditions, including conditions covering ballast water exchanges of the ship

L': Length (m) of ship

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

b: b_0 or αb_1 given below according to the value of $\frac{B}{l_H}$:

When $\frac{B}{l_H} < 0.8$: b_0

When $0.8 \le \frac{B}{l_H} < 1.2$: b_0 or αb_1, whichever is greater

When $1.2 \le \frac{B}{l_H}$: αb_1

b_0 and b_1: As given in **Table C30.1** according to the value of $\frac{B}{l_H}$

l_H: Length (m) of hold

Where stools are provided at transverse bulkheads, l_H may be taken as the distance between the toes.

α: As given by the following formula:

$$\alpha = \frac{13.8}{24 - 11 f_B K}$$

f_B: Ratio of the section modulus of the transverse section of the hull on the basis of mild steel in accordance with the requirements in **Chapter 15** to the actual section modulus of the transverse section of the hull at the bottom

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

When $1 \le \frac{l}{S} < 3.5$: $(0.46\frac{l}{S} + 2.64)\sqrt{\gamma}$

When $3.5 \le \frac{l}{S}$: $4.25\sqrt{\gamma}$

l: Distance (m) between floors

Table C30.1 Coefficients b_0 and b_1

B/l_H	and over		0.6	0.8		1.0		1.2	1.4	2.0	2.2
	less than	0.6	0.8	1.0		1.2		1.4	2.0	2.2	
b_0 or b_1		b_0	b_0	b_0	b_1	b_0	b_1	b_1	b_1	b_1	b_1
		2.0	1.9	1.5	1.4	1.3	1.3	1.3	1.2	1.1	1.0

2 In ships whose cargoes are regularly handled by grabs or similar mechanical appliances, the thickness of inner bottom plating is not to be less than the value obtained from the requirements in **-1** above plus 2.5 mm. In addition, where double bottom are intended to be deep tanks, the thickness of inner bottom plating is not to be less than the greater of the values obtained from the requirements in **-1** above or **30.2.1-4** plus 2.5 mm.

30.2.3 Longitudinals*

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

$$Z = 100C_1C_2Shl^2 \quad (cm^3)$$

S: Spacing (m) of bottom longitudinals

l: Distance (m) between floors

h: Distance (m) from the longitudinals under consideration to the following point above the top of the keel

$h = d + 0.026L'$

L': As specified in **30.2.2-1**

C_1: Coefficient given below according to the value of L:

When L is 230 m and below: $C_1 = 1.0$

When L is 400 m and over: $C_1 = 1.07$

For intermediate values of L, C_1 is to be obtained by linear interpolation.

C_2: Coefficient given by the following formula:

$$C_2 = \frac{K}{24 - 15.5f_BK}$$

K and f_B: As specified in **30.2.2-1**

2 The section modulus Z of inner bottom longitudinals is not to be less than the value 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.

$$Z = 100C_1C_2Shl^2 \quad (cm^3)$$

S: Spacing (m) of inner bottom longitudinals

l: Distance (m) between floors

h: As specified in **30.2.2-1**

C_1: Value of γ specified in **30.2.1-1**

However values of C_1 are not to be less than 0.9.

C_2: Coefficient given by the following formula:

$$C_2 = \frac{K}{24 - 12f_BK}$$

K and f_B: As specified in **30.2.2-1**

3 Buckling strength of longitudinals is to be in accordance with the following **(1)** and **(2)**. The Society may request detailed assessments if deemed necessary according to the materials, scantlings, geometries and arrangement of these structural members.

(1) As for flat bars used for longitudinals, the ratio of depth to thickness is not to exceed 15.

(2) The full width b of face plates of longitudinals is not to be less than the value obtained from the following formula:

$$b = 69.6\sqrt{d_0l} \quad (mm)$$

d_0: Depth (m) of web of longitudinal

l: Spacing (m) of girders

30.2.4 Girders

The arrangements and the scantlings of girders in double bottoms are to be determined by direct calculations.

30.3 Wing Tanks or Void Spaces

30.3.1 Minimum Thickness

1 The thickness of structural members in 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 C30.2** according to the length of ship.

2 The thickness of structural members in deep tanks is not to be less than 7.0 mm.

Table C30.2 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

30.3.2 Bulkhead Plating*

1 The thickness t of bulkhead plating in deep tanks 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. However, the thickness of plating with only one side in contact with sea water may be 0.5 mm less than the greatest of the values obtained from the following formula:

$$t = C_1 C_2 S\sqrt{h} + 3.5 \ \ (mm)$$

S: Spacing (m) of stiffeners

h: h_1, h_2 and h_3 (m) as specified below:

h_1: Vertical distance from the lower edge of the bulkhead plating under consideration to the mid-point between a 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, including conditions covering ballast water exchanges 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 is to be 0, and the value at an intermediate point is to be obtained by linear interpolation.

h_2: As given by 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: Value obtained from multiplying 0.7 by the vertical distance from the lower edge of the bulkhead plating under consideration to a point 2.0 m above the top of overflow pipe

C_1: As specified in **30.2.3-1**

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 determining the thickness of longitudinal bulkhead plating, coefficient C_2 for h_1 may be gradually reduced for parts forward and afterward of the midship part, and it may be taken as $3.6\sqrt{K}$ in calculations at the end parts of the ship.

In the case of longitudinal bulkhead plating of a 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 bulkhead plating of a transverse system: $C_2 = 100\sqrt{\frac{K}{767-\alpha^2 K^2}}$

In the case of transverse bulkhead plating: $C_2 = 3.6\sqrt{K}$

Where

K: As specified in **30.2.2-1**

α: Either α_1 or α_2 according to the value of z

However, values of α are not to be less than α_3

When $z > z_B$: $\alpha_1 = 15.5 f_D \frac{z - z_B}{z_0}$

When $z \le z_B$: $\alpha_2 = 15.5 f_B \left(1 - \frac{z}{z_B}\right)$

$$\alpha_3 = \beta\left(1 - \frac{2b}{B}\right)$$

f_D: Ratio of the section modulus of the transverse section of the hull on the basis of mild steel in accordance with the requirements in **Chapter 15** to the actual section modulus of the transverse section of the hull at the strength deck

f_B: As specified in **30.2.2-1**

z: Vertical distance (m) from the top of the keel to the lower edge of the bulkhead plating under consideration

z_B: Vertical distance (m) from top of the keel amidship to the horizontal neutral axis of the transverse section of the hull

z_0: Greater of the values specified in **15.2.3(5)(a)** or **(b)**

β: Coefficient given by the following formulae:

When L is 230 m and below: $\beta = \frac{6}{a}$

When L is 400 m and over: $\beta = \frac{10.5}{a}$

For intermediate values of L, β is to be obtained by linear interpolation.

a: $\sqrt{K}$ when high tensile steels are used for not less than 80% of the side shell plating at the transverse section amidships, and 1.0 for other cases

b: Horizontal distance (m) from the side shell plating to the outer end of the bulkhead plating under consideration

2 The thickness t of longitudinal bulkhead plating is to be in accordance with the requirements in **Chapter 13**, and is not to be less than the value obtained from the following formula. The thickness of longitudinal bulkhead plating forming deep tanks is also to be in accordance with the requirements in **-1** above.

$$t = CS\sqrt{Kh} + 2.5 \ (mm)$$

S: Length (m) of the shorter side of the panel enclosed by stiffeners, etc.

h: Vertical distance (m) from the lower end of the panel under consideration to the upper deck at center line

K: As specified in **30.2.2-1**

C: Coefficient given by the following formula:

However, it is not to be less than 3.2.

$C = 4.25ab\sqrt{\gamma}$

a: As given by the following formulae:

When $1 \le \frac{l}{S} < 3.5$: $0.615 + 0.11\frac{l}{S}$

When $3.5 \le \frac{l}{S}$: 1.0

l: Length (m) of the longer side of the panel enclosed by stiffeners, etc.

b: As given by the following formulae:

When $\beta \le 40°$: 1.0

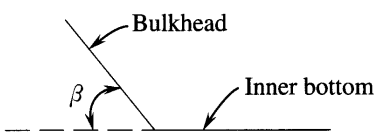
When $40° < \beta \le 80°$: $1.4 - 0.01\beta$

When $80° \le \beta$: 0.6

β: Angle of inclination (degrees) of the bulkhead plating under consideration to the horizontal plane (*See* **Fig. C30.1**)

γ: As specified in **30.2.1-1**

Fig. C30.1



3 In ships whose cargoes are regularly handled by grabs or similar mechanical appliances, the thickness of the longitudinal bulkhead plating is not to be less than the value obtained from the requirements in -2 above plus the following values. The extent of application of this requirement is to be as deemed appropriate by the Society.

Longitudinal bulkhead plating under hatchway: 2.5 mm

Longitudinal bulkhead plating other than the above: 1.0 mm

4 The thickness of longitudinal bulkhead plating is to be in accordance with the requirements in 15.3.2 and 15.3.3 as well as 15.4.

5 The thickness of shell and deck plating forming deep tanks, which are taken as bulkhead plating in deep tanks, is to be in accordance with the requirements in Chapter 16 and Chapter 17 respectively, and is not to be less than the value obtained from the requirements in -1 above, which may be reduced by 0.5 mm.

6 The thickness of tank top plating in deep tanks is not to be less than the value obtained from the requirements in -1 above plus 1.0 mm.

30.3.3 Longitudinals and Stiffeners*

1 The section modulus Z of bottom longitudinals is not to be less than the value obtained from the requirements in 30.2.3-1.

2 The section modulus Z of side longitudinals including bilge longitudinals is not to be less than the value obtained from the following formula:

$$Z = 100C_1C_2Shl^2 \ (cm^3)$$

S: Spacing (m) of side longitudinals

l: Spacing (m) of girders

h: Distance (m) from the longitudinal under consideration to the following point above the top of the keel

$$h = d + 0.038L'$$

L': As specified in 30.2.2-1

C_1: As specified in 30.2.3-1

C_2: Coefficient given by the following formula:

$$C_2 = \frac{K}{24 - \alpha K}$$

K: As specified in 30.2.2-1

α: α_1 or α_2 as given below, whichever is greater

$$\alpha_1 = 15.5f_B\left(1 - \frac{z}{z_B}\right)$$

f_B: As specified in 30.2.2-1

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

z_B: As specified in 30.3.2-1

α_2: Coefficient given by the following formulae according to the value of L:

When L is 230 m and below: $\alpha_2 = \frac{6}{a}$

When L is 400 m and over: $\alpha_2 = \frac{10.5}{a}$

For intermediate values of L, α_2 is to be obtained by linear interpolation.

a: $\sqrt{K}$ when high tensile steels are used for not less than 80% of the side shell plating at the transverse section amidships, and 1.0 for other cases

However, the section modulus Z does not need to exceed that of bottom longitudinals specified in -1 above, 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, bottom longitudinals and longitudinal stiffeners attached to longitudinal bulkheads in deep tanks, sufficient consideration is to be taken against fatigue strength.

4 For parts forward and afterward of the midship part, the scantlings of bottom longitudinals and side longitudinals may be gradually reduced and at the end parts they may be reduced by 15% of the values obtained from the requirements in -1 and -2 above respectively. However, the scantlings of bottom longitudinals and side longitudinals are not to be less than those required in -1 and -2 above respectively under any circumstances for parts between the point 0.15L from the fore end and the collision bulkhead.

5 The section modulus Z of stiffeners attached to longitudinal bulkheads is to be in accordance with the requirements in **Chapter 13**, and is to be as specified in the following **(1)** and **(2)**:

(1) The section modulus Z of longitudinal stiffeners is not to be less than the value obtained from the following formula:

$Z = C_1 C_2 Shl^2$ (cm^3)

S: Spacing (m) of longitudinal stiffeners

h: Vertical distance (m) from the stiffener under consideration to the upper deck at the centreline

l: Length (m) of longitudinal stiffener between transverse webs

C_1: Coefficient given in **Table C30.3** according to the values of β specified in **30.3.2-2** and γ specified in **30.2.1-1**

C_2: Coefficient given by the following formula:

$$C_2 = \frac{K}{24 - \alpha K}$$

K: As specified in **30.2.2-1**

α: Either α_1 or α_2 according to the value of z

When $z > z_B$: $\alpha_1 = 15.5 f_D \frac{z - z_B}{z_0}$

When $z \leq z_B$: $\alpha_2 = 15.5 f_B \left(1 - \frac{z}{z_B}\right)$

f_B: As specified in **30.2.2-1**

z: As specified in **30.3.3-2**

z_B, z_0 and f_D: As specified in **30.3.2-1**

(2) The section modulus Z of transverse stiffeners is not to be less than the value obtained from the following formula:

$Z = CKShl^2$ (cm^3)

S: Spacing (m) of transverse stiffeners

h: Vertical distance (m) from the mid-point of l to the upper deck at the centreline

l: Distance (m) between the supports of stiffeners

K: As specified in **30.2.2-1**

C: Coefficient given in **Table C30.4** according to the values of β specified in **30.3.2-2** and γ specified in **30.2.1-1**

Table C30.3 Coefficient C_1

Angle β	C_1
$\beta \leq 40°$	130γ
$40 < \beta < 80°$	$(214 - 2.1\beta)\gamma$
$\beta \geq 80°$	46γ

Table C30.4 Coefficient C

Angle β	C
$\beta \leq 40°$	7.8γ
$40 < \beta < 80°$	$(12.8 - 0.125\beta)\gamma$
$\beta \geq 80°$	2.8γ

6 The section modulus Z of stiffeners attached to bulkhead plating in deep tanks is not to be less than the value obtained from the following formula:

$Z = 125 C_1 C_2 C_3 Shl^2$ (cm^3)

S: Spacing (m) of stiffeners

h: As specified in **30.3.2-1**

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 "shell plating" is to be construed as "stiffener attached to shell plating".

l: Spacing (m) of girders

C_1: As specified in **30.2.3-1**

C_2: $\frac{K}{18}$

However, C_2 for h_1 is to be in accordance with the following:

The values of C_2 for h_1 are to be as obtained from the following formula according to the stiffening system. In determining the section modulus of stiffeners attached to bulkhead plating, coefficient C_2 for h_1 may be gradually reduced for parts forward and afterward of the midship part, and it may be taken as $\frac{K}{18}$ in calculations at the end parts of the ship.

In the case of a longitudinal system: $C_2 = \frac{K}{24-\alpha K}$

However, the value of C_2 is not to be less than $\frac{K}{18}$.

In the case of a transverse system or transverse bulkheads: $C_2 = \frac{K}{18}$

K: As specified in **30.2.2-1**

α: As specified in **30.3.2-1**

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 z and b.

C_3: As given in **Table C30.5** according to the fixity condition of the stiffener ends

Table C30.5 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. C13.1(a)**).
2. "Soft fixity by bracket" means the fixity in the connection between beams, frames, etc., which are crossing members, and brackets (*See* **Fig. C13.1(b)**).

7 Buckling strength of longitudinal frames, beams and stiffeners is to be in accordance with the following requirements **(1)** to **(3)**. 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 b of face plates of longitudinal beams, frames and stiffeners is not to be less than the value obtained from the following formula:

$b = 69.6\sqrt{d_0 l}$ (mm)

d_0: Depth (m) of web of longitudinal beam, frame or stiffener

l: Spacing (m) of girders

8 Where assembled members, special shape steels or flanged plates are used as frames, beams or stiffeners in deep tanks whose scantlings are specified only in terms of the section modulus, the thickness t of the web is not to be less than the value obtained from the following formula. However, where the stiffeners have the sufficient strength for buckling or 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.

$$t = 15K_0 d_0 + 3.5 \ (mm)$$

d_0: Depth (m) of web

K_0: As given by the following formulae:

$K_0 = \sqrt{\frac{1}{4}\left(3f_B + \frac{1}{K}\right)}$ for bottom longitudinals located not more than $0.25D$ above the top of the keel

$K_0 = \sqrt{\frac{1}{4}\left(3f_D + \frac{1}{K}\right)}$ for deck longitudinals located not more than $0.25D$ below deck

$K_0 = \sqrt{\frac{1}{4}\left(3 + \frac{1}{K}\right)}$ for other structural members

K and f_B: As specified in **30.2.2-1**

f_D: As specified in **30.3.2-1**

9 The section modulus of longitudinal beams is not to be less than the value obtained from the requirements in **10.3.3**. The section modulus of bottom longitudinals, side longitudinals and longitudinal beams in deep tanks is not to be less than the value obtained from the requirements in **-6** above.

30.3.4 Girders*

1 The arrangements and scantlings of girders in wing tanks or void spaces are to be determined by direct calculations.

2 Notwithstanding the requirements in **-1** above, the scantlings of girders in wing tanks or void spaces may be determined in accordance with the requirements in the following **-3** to **-10** for ships with L less than 230 m.

3 The construction and scantlings of transverses, girders, webs and cross ties are to be in accordance with the requirements in the following **(1)** to **(5)**. The construction and scantlings of transverses, girders, webs and cross ties in deep tanks are also to be in accordance with the requirements in **Chapter 14**.

(1) The thickness of transverses, girders, webs and cross ties are not to be less than the value given in **Table C30.2** 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 b is not to be less than the value obtained from the following formula:

$$b = 85.4\sqrt{d_0 l}$$

d_0: Depth (m) of girder

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 the following **(a)** to **(c)**:

(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 **1.1.14-3**.

(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 side transverses and transverses on longitudinal bulkheads and web plates in the vicinity of the edge of the brackets are to be provided with closely-spaced stiffeners.

4 The scantlings of side transverses are to be in accordance with the requirements in the following **(1)** to **(5)**:

(1) The following definitions are used in this **-4**.

$Q = Shl_0$

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. C30.2**)

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: As specified in **30.2.2-1**

k: Correction factor for brackets as given by 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 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 baseline, and the extension of the line of the inner edge of the side transverse. (*See* **Fig. C30.2**)

b_s: Width (m) of the area supported by cross ties (*See* **Fig. C30.2**)

d'_0: Depth (m) of side transverses at the inner edge of the lowest bracket (*See* **Fig. C30.2**)

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 the following **(a)** to **(c)**:

(a) 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 degrees to the axial direction of the cross tie (*See* **Fig. C30.3(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 degrees 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. C30.3(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 degrees 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. C30.3(c)**).

C_0, C_1 and C_2: Coefficients given in **Table C30.6** according to the number of cross ties respectively

(2) The depth (m) of side transverses is not to be less than C_0l_0 at the mid-point of l_0. Where 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.

(3) The web thickness t of side transverses at the inner edge of brackets at the lower ends is not to be less than the value obtained

from the following formula:

$$t = \frac{C_1 - 148\frac{b}{l_0}}{1000} \cdot \frac{QK}{d'_0 - a} + 3.5 \ (mm)$$

(4) The web thickness t of side transverses at the portion where cross ties are connected is not to be less than the value 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.

$$t = 16S_1\sqrt{\frac{Sb_sh_s}{A}} \ (mm)$$

(5) The section modulus Z of side transverses at the span is not to be less than the value obtained from the following formula:

$$Z = C_2k^2KQl_0 \ (cm^3)$$

5 The scantlings of transverses on longitudinal bulkheads are not to be less than the values obtained from the requirements in **-4(2)** to **(5)** 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.

6 The scantlings of bottom transverses are to be in accordance with the requirements in the following **(1)** to **(3)**:

(1) The rigidity of bottom transverses is to be well balanced with that of side transverses.

(2) The section modulus Z of bottom transverses at the span is not to be less than the value obtained from the following formula:

$$Z = 9.3k^2KSh_1l_1^2 \ (cm^3)$$

k and S: As specified in **-4(1)** above

However, l_0 is to be construed as l_1 in applying the value of k.

K: As specified in **30.2.2-1**

h_1: As given by the following formula:

$$h_1 = d + 0.026L$$

l_1: 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.

(3) The section modulus Z of bottom transverses at the bilge and at the lower end of longitudinal bulkheads is not to be less than the value 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. C30.2**) of the transverse.

$$Z = C'_2KQl_0 \ (cm^3)$$

Q and l_0: As specified in **-4(1)** above

K: As specified in **30.2.2-1**

C'_2: Coefficient given in **Table C30.6** according to the number of cross ties

7 The scantlings of deck transverses are to be in accordance with the requirements in the following **(1)** and **(2)**:

(1) The rigidity of deck transverses is to be well balanced with that of side transverses.

(2) The section modulus Z of deck transverses at the span is not to be less than the value obtained from the following formula:

$$Z = 3k^2KS\sqrt{L}l_2^2 \ (cm^3)$$

k and S: As specified in **-4(1)** above

However, l_0 is to be construed as l_2 in applying the value of k.

K: As specified in **30.2.2-1**

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

Table C30.6 Coefficients C_0, C_1, C_2 and C'_2

Number of cross tie	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

Fig. C30.2 Measurement of l_0, d'_0, b and b_s, etc.

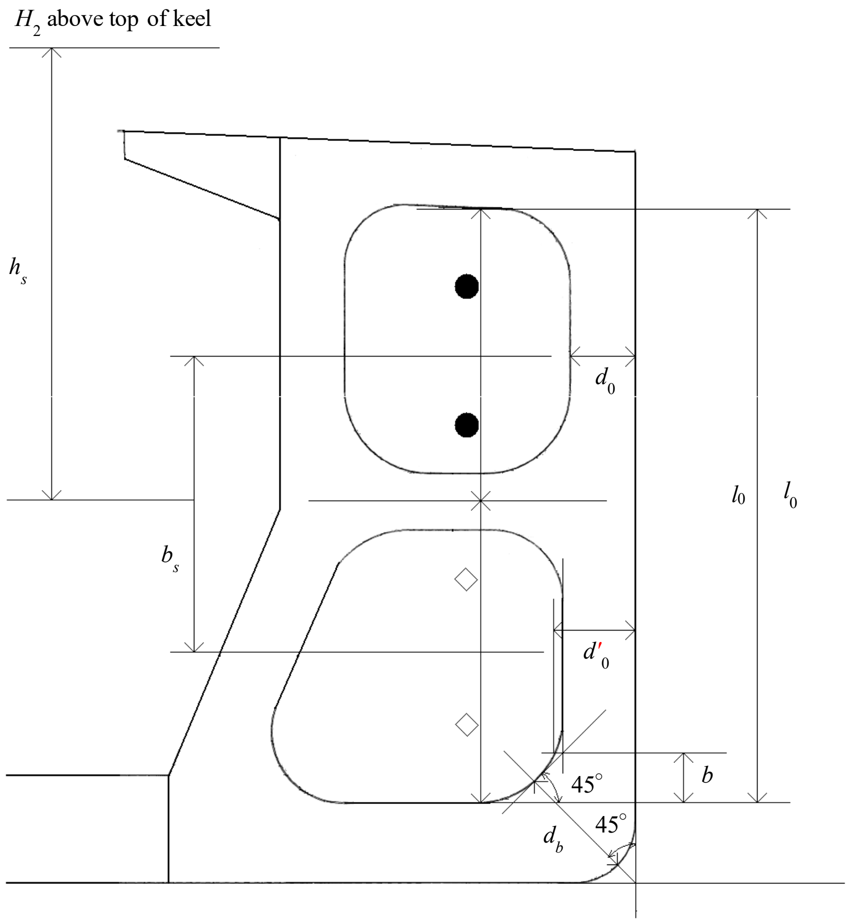
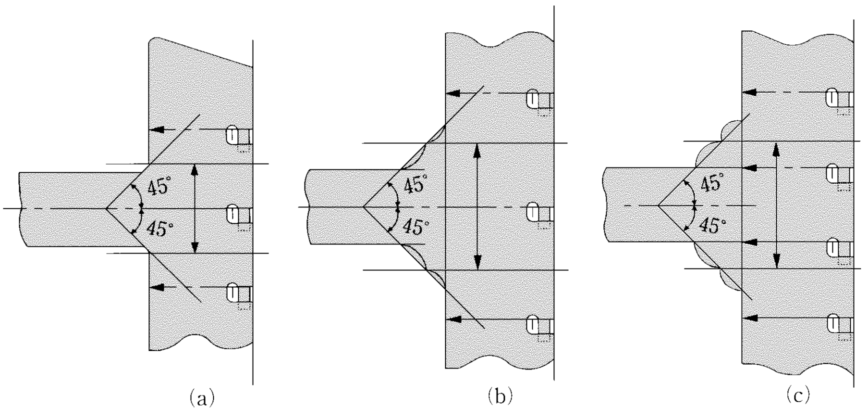


Fig. C30.3 Extent for Total Sectional Area



8 The web thickness t of transverses is not to be less than the value obtained from the following formula:

$$t = \frac{C}{\sqrt{K}} d_0 + 3.5$$

K: As specified in **30.2.2-1**

d_0: Depth (m) of web plate (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: As given in **Table C30.7** according to the ratio of S' (the spacing of stiffeners on web plates provided in a depthwise direction) to d_0. For intermediate values of S'/d_0, C 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 may be as given in **Table C30.7** multiplied by 0.85, subject to the requirements in the following **(a)** and **(b)**:

(1) 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 the value obtained by applying the requirements in **(a)**

(2) 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

(a) Where slots are provided on webs with no reinforcement, α_1, α_2 and α_3 are to be multiplied by the following factor:

$$\sqrt{4.0\frac{d_1}{S'} - 1.0}$$

d_1: Depth (m) of slots

Where d_1/S' is 0.5 or less, the multiplier is to be taken as 1.0.

(b) Where openings are provided on webs with no reinforcement, α_1, α_2 and α_3 are to be multiplied by the following factor:

$$1 + 0.5\frac{\phi}{a}$$

a: Length (m) at the longer side of the panel surrounded by web stiffeners

ϕ: Diameter (m) of openings

Where openings are oblong, ϕ is to be the length (m) of the longer diameter.

Table C30.7 α_1, α_2 and α_3

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

9 Where side transverses and transverses on longitudinal bulkheads in wing tanks are connected with cross ties, the construction of cross ties are to be as required in the following **(1)** and **(2)**:

(1) Brackets are to be provided at the ends of cross ties to connect cross ties with transverses.

(2) 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.

10 Where side transverses and transverses on longitudinal bulkheads in wing tanks are connected with cross ties, the sectional area A of cross ties is not to be less than the value obtained from the following formula:

$$A = CKSb_sh_s \ (cm^2)$$

S, b_s and h_s: As specified in **-4(1)** above

K: As specified in **30.2.2-1**

C: Coefficient given by the following formulae:

When $\frac{l}{k} > 0.6$: $C = \frac{0.77}{1-0.5\frac{l}{k\sqrt{K}}}$

When $\frac{l}{k} < 0.6$: $C = 1.1$

l: Length (m) of cross ties measured between the inner edges of the side transverses and the vertical webs on longitudinal bulkheads

k: As given by the following formula:

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

I: The least moment of inertia (cm^4) of cross ties

A: Sectional area (cm^2) of cross ties

30.4 Transverse Bulkheads and Stools in Ore Holds

30.4.1 Transverse Bulkheads in Ore Holds*

1 The scantlings of structural members of transverse bulkheads are to be in accordance with the requirements in **14.2**. In application of these requirements, h in the formulae is to be substituted by $0.36\gamma h'$, where γ is as specified in **30.2.1-1**. However, where γ is less than 1.5, γ is to be taken as 1.5. h' is to be in accordance with the following **(1)** to **(3)**:

(1) For bulkhead plating, the vertical distance (m) from the lower edge of the bulkhead plate to the upper deck at the centreline 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 centreline of the ship

For horizontal stiffeners on the bulkhead, the vertical distance (m) from the mid-point of the stiffeners to the upper deck at the centreline of the ship

l: As specified in **14.2.3**

(3) For vertical webs supporting stiffeners, the vertical distance (m) from the mid-point of l to the upper deck at the centreline of the ship

For horizontal girders supporting stiffeners the vertical distance (m) from the mid-point of S to the upper deck at the centreline of the ship

l and S: As specified in **14.2.5**

2 The scantlings of structural members of transverse bulkheads are not to be less than the values obtained from the requirements in **Chapter 13**. In addition, the thickness of the transverse bulkhead plating is not to be less than 7.0 mm.

3 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.

30.4.2 Lower and Upper Stools at Transverse Bulkheads in Ore Holds*

1 The thickness of the side plating of the lower stool of the transverse bulkhead is not to be less than the value obtained from the formula in **30.3.2-2** using the value of coefficient C reduced by 10%.

2 In ships whose cargoes are regularly handled by grabs or similar mechanical appliances, the thickness of the side plating of the lower stool of the transverse bulkhead is not to be less than the value obtained from **-1** above plus 1.0 mm. The extent of application of this requirement is to be as deemed appropriate by the Society.

3 The section modulus of horizontal stiffeners provided on the side plating of the lower stool is not to be less than the value obtained from the formula in **30.3.3-5(1)**, where the coefficient, C_2, is to be reduced by 10%. Where vertical stiffeners are provided, the section modulus is not to be less than the value obtained from the formula in **30.3.3-5(2)**.

4 Partial girders, etc. are partially to be arranged beneath the girders in the lower stool of the transverse bulkhead.

5 The scantlings of structural members of the upper and lower stools of the transverse bulkhead are not to be less than the values obtained from the requirements in **Chapter 13**.

30.5 Relative Deformation of Wing Tanks

30.5.1 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, except where the scantlings of members are determined by direct calculations.

$$\frac{2h - 0.65d}{n_b K_b + n_s \eta_s K_s + n_t \eta_t K_t} \cdot \frac{a}{b} l$$

h: Vertical distance (m) between the top of the inner bottom plating and the upper deck at the centreline of the ship

l: Length (m) of one ore hold

a: Half-breadth (m) of cargo hold

b: Breadth (m) of wing tank

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 C30.8 in accordance with the opening ratio of swash bulkheads or transverse rings

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 given by 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 given by the following formulae, 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, α is to be 1.0

Table C30.8 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

30.6 Decks and Miscellaneous

30.6.1 Decks, etc. *

For deck plating inside the line of openings, special consideration is to be taken against buckling.

30.6.2 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 m, 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 cover plates from direct contact with the 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 D, substituting the mean breadth of the ore hold for B.

30.7 Ore/Oil Carriers

30.7.1 General*

1 Ore carriers that are intended to carry oils in the cargo spaces (hereinafter referred to as “ore/oil carriers”) are to comply with the relevant requirements for tankers, in addition to those in this Chapter.

2 In addition to the requirements in this Chapter, special requirements for ore/oil carriers may be specified as deemed necessary by the Society.

30.7.2 Slop Tanks

1 Cofferdams are to be provided around slop tanks in accordance with the requirements in **29.1.2-2**. In addition, cofferdams are to be provided between slop tanks and ore holds, except where the slop tanks are cleaned and gas-freed at any time prior to loading ore cargoes.

2 The cofferdams specified in **-1** above 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 devices are 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 31 BULK CARRIERS

31.1 General

31.1.1 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.

31.1.2 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 distance (m) measured on the waterline at the scantling draught d_S from the forward side of the stem to the centre of the rudder stock. L_1 is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught d_S. In ships without rudder stocks (e.g. ships fitted with azimuth thrusters), the Rule length L_1 is to be taken equal to 97% of the extreme length on the waterline at the scantling draught d_S. d_S is the scantling draught (m) at which the strength requirements for the scantlings of the ship are met and represents the full load condition; it is to be not less than that corresponding to the assigned freeboard.

(1) BC-A: Bulk carriers designed to carry bulk cargoes with a bulk cargo density (defined in **31A.1.2(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.

31.1.3 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 **6.8** and **16.4.4**, longitudinal strength specified in **Chapter 15** and intact stability specified in **Part U**.

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 15**.

31.1.4 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 **31.1.5**, the data necessary for the calculation is to be submitted.

31.1.5 Direct Strength Calculations*

When determining the scantlings of structural members by direct strength calculation according to the provisions of **1.1.22**, the subject members, load conditions, scope of calculations, and allowable stress are to be as deemed appropriate by the Society.

31.1.6 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 C31.1** according to the length of the ship.

Table C31.1 Minimum Thickness of Structural Members in Tanks

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: Distance (m) measured on the waterline at the scantling draught d_S from the forward side of the stem to the centre of the rudder stock. L_0 is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught d_S.

However, where the value exceeds 200 m, L_0 is to be taken as 200 m.

d_S: Scantling draught (m) at which the strength requirements for the scantlings of the ship are met and represents the full load condition. d_S is to be not less than that corresponding to the assigned freeboard.

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_1: Distance (m) measured on the waterline at the scantling draught d_S from the forward side of the stem to the centre of the rudder stock. L_1 is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught d_S.

d_S: Scantling draught (m) at which the strength requirements for the scantlings of the ship are met and represents the full load condition. d_S is to be not less than that corresponding to the assigned freeboard.

31.2 Double Bottoms

31.2.1 General*

1 Except where required in **31.2**, the requirements in **Chapter 6** 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 14**.

However, the thickness of inner bottom plating need not be increased by 1 mm as given in **14.2.7** 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 formulae:

$$\gamma_D = \frac{M_D}{V}$$

$$\gamma_{Full} = \frac{M_{Full}}{V}$$

$$\gamma_H = \frac{M_H}{V}$$

$$\gamma_{HD} = \frac{M_{HD} + 0.1M_H}{V}$$

$$\gamma_B = \frac{M_B}{V}$$

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 **31.2** 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. C31.1**)

$$2.1\frac{l\,l_H}{e^2\left(1+\frac{d_1}{d_0}\right)^2}$$

l_H: Length of hold (*m*)

Where stools are provided at transverse bulkheads, l_H may be taken as the distance between the toes.

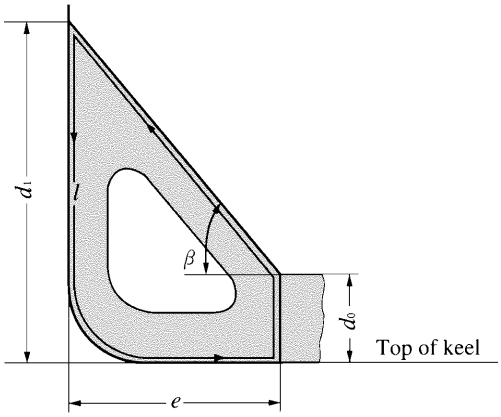
l: Total girth length (*m*) of hopper plate, side girder and shell plating composing the bilge hopper

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. C31.1 Measurement of *l*, *e*, d_0, d_1 and β



31.2.2 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 **31.2.1-3**.

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 $B/20$.

$$15\sqrt{\frac{L_H B D}{m}}\ (mm)$$

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 **31.2.1-4**

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 C31.2**

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 C31.2**, these coefficients are to be deemed as appropriate by the Society.

b: Value given in **Table C31.3** depending on k and $\frac{B}{l_H}$ specified in **31.2.1-4**

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 C31.4** 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 C31.2 Coefficient of "n" and "a"

		n	a
1	Homogeneously loaded condition	$\frac{1}{3}\left(7-2\frac{B}{l_H}\right)$	$\frac{h\gamma_{Full}}{d}-1+\frac{0.026L'}{d}$
2	Condition with slacked hold	$\frac{1}{3}\left(\alpha\left(2-\frac{B}{l_H}\right)+5-\frac{B}{l_H}\right)$	$1+\frac{0.026L'}{d}-\frac{0.5h\gamma_H}{d}$
3	Ballast condition	$\frac{1}{3}\left(7-2\frac{B}{l_H}\right)$	$\frac{d_{act}+0.026L'^{*4}}{d}$
4*1	Condition loaded/unloaded in multiple ports	$\frac{1}{3}\left(\alpha\left(2-\frac{B}{l_H}\right)+5-\frac{B}{l_H}\right)$	
	Loaded hold at assumed draught of 67% of d		$\frac{h\gamma_{Full}}{d}-0.67+\frac{0.026L'}{d}$
	Empty hold at assumed draught of 83% of d		$0.83+\frac{0.026L'}{d}$
5*2	Alternately loaded condition	1.0	
	Loaded hold		$\frac{h\gamma_{HD}}{d}-1+\frac{0.026L'}{d}$
	Empty hold		$1+\frac{0.026L'}{d}$
6*3	Hold ballast condition	$\frac{1}{3}\left(\alpha\left(2-\frac{B}{l_H}\right)+5-\frac{B}{l_H}\right)$	
	Cargo hold adapted for the carriage of water ballast		$\frac{h\gamma_B}{d}-\frac{d_{act}-0.026L'}{d}$
	Other cargo holds		$\frac{d_{act}+0.026L'}{d}$
7	Loading/unloading condition (Assumed draught is 67% of d)	$\frac{1}{3}\left(\alpha\left(2-\frac{B}{l_H}\right)+5-\frac{B}{l_H}\right)$	$\frac{h\gamma_D}{d}-0.67$

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 **31.2.1-3**

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 C31.2** (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 C31.3 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 C31.4 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.

31.2.3 Floor Plates*

1 Solid floors are to be provided with spacing not more than that obtained from the following formulae. 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 **31.2.1-3**

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 **31.2.1-4**

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 **31.2.2-3**

b: Value given in **Table C31.5** according to k and B/l_H, which are defined in **31.2.1-4**

For intermediate values of k, the value of b is to be determined by linear interpolation.

(2) The thickness obtained from the following formula according to the location in the hold:

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

t_1: Thickness given by the requirements in **(1)**

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

C_2': Coefficient given in **Table C31.6** 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:

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

ϕ: 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 C31.5 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

Table C31.6 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.

31.2.4 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 **31.2.2-3**

b: b_0 or αb_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 $0.8 \le \frac{B}{l_H} < 1.2$

αb_1: for $1.2 \le \frac{B}{l_H}$

b_0 and b_1: As given in **Table C31.7** 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 **31.2.1-4** 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 15** 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 $1 \le \frac{l}{S} < 3.5$

$4.25\sqrt{\gamma}$: for $3.5 \le \frac{l}{S}$

l: Distance between floors (m)

γ: γ_D, γ_{Full}, or γ_B as specified in **31.2.1-3** applicable to the cargo hold, whichever is greatest

Table C31.7 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	2.0	2.2	
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	1.4	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 **31.2.1-2**, 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 **31.2.1-2**, whichever is greater, except where a ceiling is provided.

31.2.5 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 **31.2.4-1**

C: Coefficient given below:

a) Where the struts specified in **31.2.6** are not provided midway between floors: 1.0

b) Where the struts specified in **31.2.6** 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 **31.2.1-3** 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 **31.2.4-1**

C: Coefficient given below:

a) Where the struts specified in **31.2.6** are not provided midway between floors: γ

C is not to be less than 0.9.

b) Where the struts specified in **31.2.6** are provided midway between floors: 0.6γ

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 **31.2.1-3** applicable to the cargo hold, whichever is greatest

h: As specified in **31.2.4-1**

l: Spacing (m) of solid floors

S: Spacing (m) of inner bottom longitudinals

31.2.6 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 not to be less than d.

L': As specified in **31.2.5-1**

h_i: γ times the value of h specified in **31.2.4-1** (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 **31.2.1-3** 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

31.2.7 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.

31.3 Bilge Hopper Tanks

31.3.1 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 **31.3** and those in **Chapter 14**.

31.3.2 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 $1 \leq l/S < 3.5$: $0.615 + 0.11\, l/S$

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 $\beta \leq 40°$: 1.0

Where $40° < \beta < 80°$: $1.4 - 0.01\beta$

Where $80° \leq \beta$: 0.6

β: Angle of hopper plate to the horizontal as specified in **31.2.1-4**

γ: γ_D, γ_{Full}, or γ_B as specified in **31.2.1-3** 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 **31.3.1-3** 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.

31.3.3 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 C31.8** according to β, the acute angle between the hopper plate and the horizontal plate in terms of γ specified in **31.2.1-3**

f_B: Ratio of the section modulus of the transverse section of the hull required in **Chapter 15** 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 C31.8 Coefficient α

Angle β	α
$\beta \leq 40°$	130γ
$40° < \beta < 80°$	$(214 - 2.1\beta)\gamma$
$\beta \geq 80°$	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 C31.9** according to β, the acute angle between the hopper plate and the horizontal plate in terms of γ specified in **31.3.2-1**

Table C31.9 Coefficient C

Angle β	C
$\beta \leq 40°$	7.8γ
$40° < \beta < 80°$	$(12.8 - 0.125\beta)\gamma$
$\beta \geq 80°$	2.8γ

3 Bottom longitudinals in bilge hopper tanks are to be in accordance with the requirements in **6.4.3.** Side longitudinals are to be in accordance with the requirements in **7.4.1-1**, 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.

31.3.4 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 C31.10** according to β, the acute angle between the hopper plate and the horizontal plane in terms of γ specified in **31.3.2-1**

Table C31.10 Coefficient C

Angle β	C
$\beta \leq 40°$	41.7γ
$40° < \beta < 80°$	$(68.5-0.67\beta)\gamma$
$\beta \geq 80°$	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 C31.11** according to β, the acute angle between the hopper plate and the horizontal plate, in terms of γ specified in **31.3.2-1**

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 C31.11 Coefficient C

Angle β	C
$\beta \leq 40°$	7.1γ
$40° < \beta < 80°$	$(11.5 - 0.11\beta)\gamma$
$\beta \geq 80°$	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.

31.4 Topside Tanks

31.4.1 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 **31.4** and those in **Chapter 14**. However, in application of the requirements in **Chapter 14**, 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.

31.4.2 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.

31.4.3 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:

$$\frac{100}{24-15.5f_D\frac{y}{y_D}}$$

f_D: Ratio of the section modulus of the transverse section of the hull required in **Chapter 15** 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.

31.4.4 Longitudinal Beams

The section modulus of longitudinal beams in topside tanks is not to be less than that obtained according to the requirements in **10.3.3**, where h is the deck load (kN/m^2) specified in **10.2** or one-half of the breadth of the topside tank at the midship part multiplied by 9.81, whichever is greater.

31.4.5 Side Frames

1 The section modulus of side longitudinals in topside tanks is not to be less than that obtained from the formula in **7.4.1-1**, taking l and h as follows:

l: Distance (m) between transverse webs

h: As specified in **7.4.1-1**, 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.

31.4.6 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.

31.4.7 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 **31.1.4** or that obtained from the following formula, whichever is greater:

$$19.8S\sqrt{\frac{y}{D}} + 2.5 \ (mm)$$

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 $0.06l$, 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**.

31.5 Transverse Bulkheads and Stools

31.5.1 Transverse Bulkheads*

1 The scantlings of structural members of transverse bulkheads are to be in accordance with the requirements in **14.2**. In application of these requirements, h in the formulae is to be substituted by $0.36\gamma h'$, where γ is as specified in **31.3.2-1**. However, where γ is less than 1.5, γ is to be taken as 1.5. h' 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 **14.2.3.**

(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 **14.2.5**.

2 Notwithstanding the requirements in **-1**, the scantlings of structural members of transverse bulkheads are not to be less than that specified in **Chapter 13**.

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.

31.5.2 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 **31.3.2-1** 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 **31.3.3-1**, 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 **31.3.3-2**.

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 **31.3.4**.

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 diaphragms.

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 13**.

31.6 Hold Frames

31.6.1 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. C31.2**)

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. C31.2**)

α: Coefficient given in **Table C31.12**

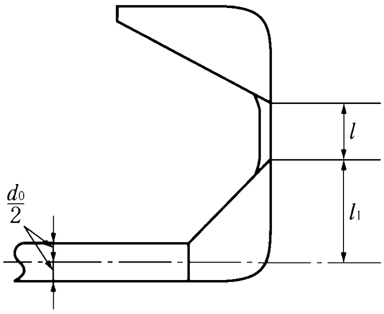
For intermediate values of B/l_H, the value of a is to be determined by linear interpolation. For the holds which are empty in fully loaded condition, the value of a is to be 1.8 *times* the value determined from the Table.

l_H: As specified in 31.2.1-4

Table C31.12 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. C31.2 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 L_1, mild steel hold frames may be asymmetric. L_1 is the distance (m) measured on the waterline at the scantling draught d_S from the forward side of the stem to the centre of the rudder stock. L_1 is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught d_S. In ships without rudder stocks (e.g. ships fitted with azimuth thrusters), the Rule length L_1 is to be taken equal to 97% of the extreme length on the waterline at the scantling draught d_S. d_S is the scantling draught (m) at which the strength requirements for the scantlings of the ship are met and represents the full load condition; it is to be not less than that corresponding to the assigned freeboard.

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.

31.6.2 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 31.3.3-1, 31.3.3-3, 31.4.3-1 and 31.4.5-1. 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 L_1, hold frames are to be fabricated with integral upper and lower brackets. L_1 is the distance (m) measured on the waterline at the scantling draught d_S from the forward side of the stem to the centre of the rudder stock. L_1 is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught d_S. In ships without rudder stocks (e.g. ships fitted with azimuth thrusters), the Rule length L_1 is to be taken equal to 97% of the extreme length on the waterline at the scantling draught d_S. d_S is the scantling draught (m) at which the strength requirements for the scantlings of the ship are met and represents the full load condition; it is to be not less than that corresponding to the assigned freeboard.

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. C31.3** is not to be less than twice the section modulus required by **31.6.1-1** 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. C31.4**)

$0.125l$ (m)

l: As specified in **31.6.1-1**

(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. C31.4**)

$1.5d_{WEB}$ (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 C31.3**):

$$\frac{0.4b_f^2}{t_f} \ (mm)$$

b_f: The flange width (mm) of the bracket

t_f: The flange thickness (mm) of the bracket

31.6.3 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. C31.3**):

$0.44t$ (mm)

(2) For the parts within $0.5l$ amidspan of l (*See* "*zone B*" in **Fig. C31.3**):

$0.4t$ (mm)

l: As specified in **31.6.1-1**

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. C31.3 Hold Frames and Upper and Lower Brackets

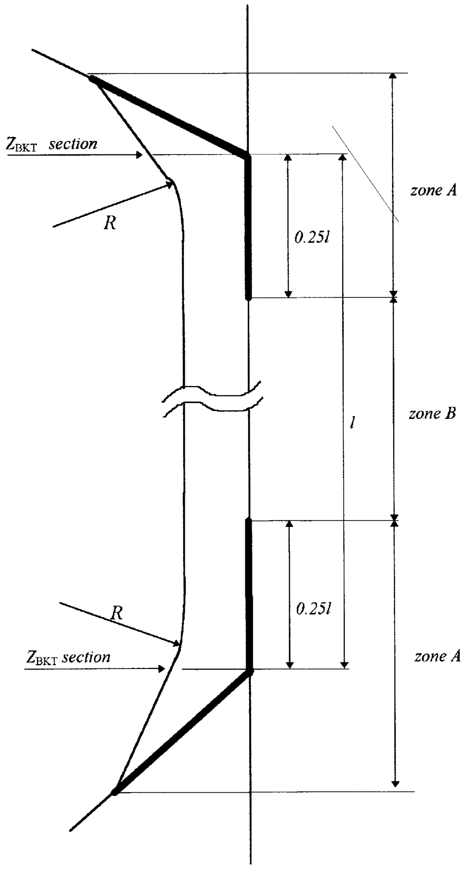
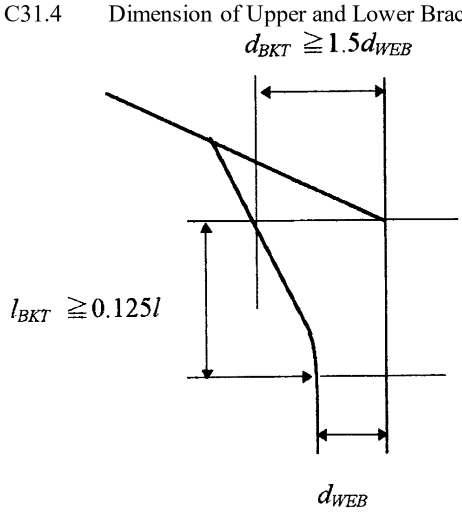


Fig C31.4 Dimension of Upper and Lower Brackets



31.7 Decks, Shell Plating and Miscellaneous

31.7.1 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.

31.7.2 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.

31.7.3 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 **16.3.4** or from the first formula in **31.2.4-1**, whichever is greater. However, in application of the latter formula, α is to be as given by the following formula:

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

f_B: As specified in **31.2.4-1**

31.7.4 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 D**.

31.7.5 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.

31.8 Supplementary Provisions for Carriage of Liquid in Holds

31.8.1 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 **31.8** 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 **14.1.5** is applied.

31.8.2 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 31A ADDITIONAL REQUIREMENTS FOR NEW BULK CARRIERS

31A.1 General

31A.1.1 Application*

1 This Chapter applies to bulk carriers defined in **31A.1.2(1)**.

2 Except where required otherwise in this chapter, the requirements of **Chapter 30** and **Chapter 31** and the general requirements for construction and equipment of steel ships, as applicable, are to be applied.

31A.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 **31.2.1-3**.

(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 C31A.1.1** may be used as standard according to the kind of cargo. For cargoes other than those given in **Table C31A.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 C31A.1.2** may be used as standard according to the kind of cargo. For cargoes other than those given in **Table C31A.1.2**, the angles of repose are to be at the Society's discretion.

Table C31A.1.1 Permeability

Cargo and etc.	Permeability
Iron Ore	0.3
Cement	0.3
Coal	0.3
Empty Space	0.95

Table C31A.1.2 Angle of Repose

Cargo	Angle of repose
Iron ore	35°
Cement	25°
Coal	35°

31A.2 Damage Stability

31A.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 **Part V of the Rules** are to be treated as complying with **-1** and **-2** above.

31A.3 Transverse Watertight Bulkheads in Cargo Holds

31A.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"), t_{net}, is to be used for examining the scantlings of the bulkhead. The actual scantlings of the bulkhead are to be at least t_{net} 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 distance (m) measured on the waterline at the scantling draught d_S from the forward side of the stem to the centre of the rudder stock. L_1 is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught d_S. In ships without rudder stocks (e.g. ships fitted with azimuth thrusters), the Rule length L_1 is to be taken equal to 97% of the extreme length on the waterline at the scantling draught d_S. d_S is the scantling draught (m) at which the strength requirements for the scantlings of the ship are met and represents the full load condition; it is to be not less than that corresponding to the assigned freeboard.

8 Notwithstanding the requirements in this section, for self-unloading ships with unloading systems that do not maintain watertightness, the combination loads acting on the bulkheads in the flooded conditions are to be considered using the extent to which the flooding may occur.

31A.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. C31A.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

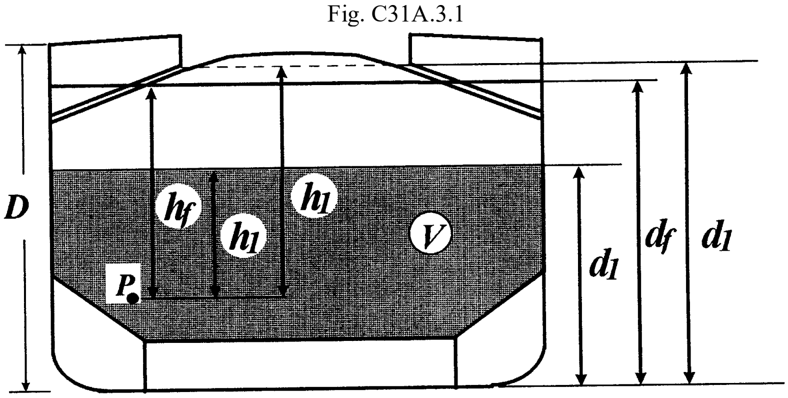
(b) $0.85D$ (m) for the other bulkheads

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. C31A.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. C31A.3.1**)

γ: $45° - \frac{\phi}{2}$

ϕ: Angle of repose defined in **31A.1.2(8)**

(2) The force F_c acting on the corrugation is given by the following:

$$F_c = \rho_c g s_1 \frac{(d_1 - h_{DB} - h_{LS})^2}{2} \tan^2\gamma \quad (kN)$$

Where:

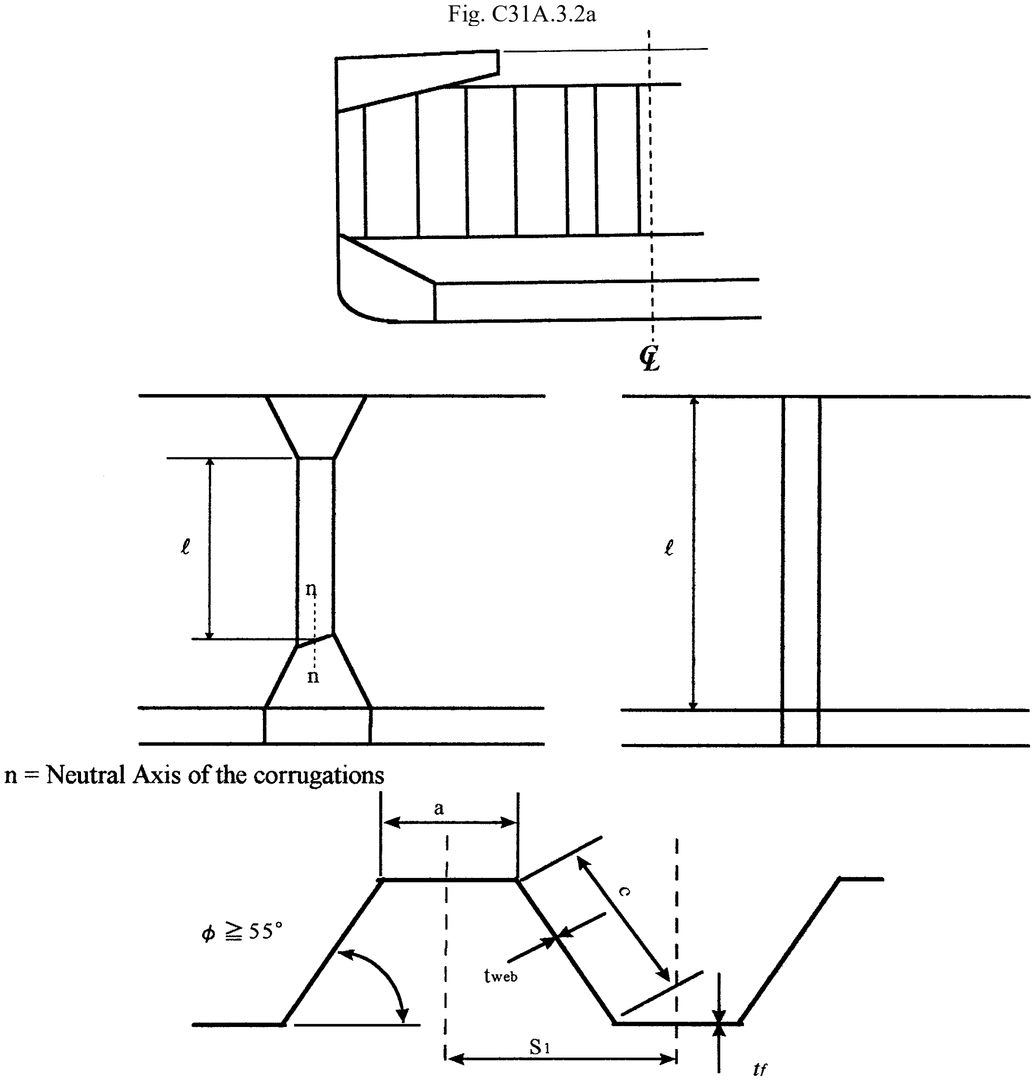
ρ_c, g, d_1 and γ: As specified in **(1)** above

s_1: Spacing (m) of corrugation (see **Fig. C31A.3.2a**)

h_{DB}: Height (m) of the double bottom

h_{LS}: Height (m) of the lower stool from the inner bottom

Fig. C31A.3.2a



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. C31A.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:

$$p_{c,f} = \rho g h_f + [\rho_c - \rho(1 - perm)]\, g h_1 \tan^2\gamma \ (kN/m^2)$$

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 **31A.1.2(7)**

(c) The force $F_{c,f}$ acting on the corrugation is given by the following:

$$F_{c,f} = s_1 \left[\rho g \frac{\left(d_f - d_1\right)^2}{2} + \frac{\rho g \left(d_f - d_1\right) + \left(p_{c,f}\right)_{le}}{2} (d_1 - h_{DB} - h_{LS}) \right] (kN)$$

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 d_1 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 : As specified in **-2** above

(b) At each point of the bulkhead located at a distance lower than d_f from the baseline, the pressure $p_{c,f}$ is given by the following:

$$p_{c,f} = \rho g h_f + [\rho_c h_1 - \rho(1 - perm)\, h_f]\, g \tan^2\gamma \ (kN/m^2)$$

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:

$$F_{c,f} = s_1 \left[\rho_c g \frac{\left(d_1 - d_f\right)^2}{2} \tan^2\gamma + \frac{\rho_c g \left(d_1 - d_f\right) \tan^2\gamma + \left(p_{c,f}\right)_{le}}{2} (d_f - h_{DB} - h_{LS}) \right] (kN)$$

Where:

$s_1, \rho_c, g, d_1, h_{DB}$ and h_{LS}: As specified in **-2** above

d_f: As specified in **-1** above

$(p_{c,f})_{le}$: 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:

$$F_f = s_1 \rho g \frac{(d_f - h_{DB} - h_{LS})^2}{2} \ (kN)$$

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

$$p = p_{c,f} \ (kN/m^2)$$

$$F = F_{c,f} \ (kN)$$

31A.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 **31A.3.2-5**

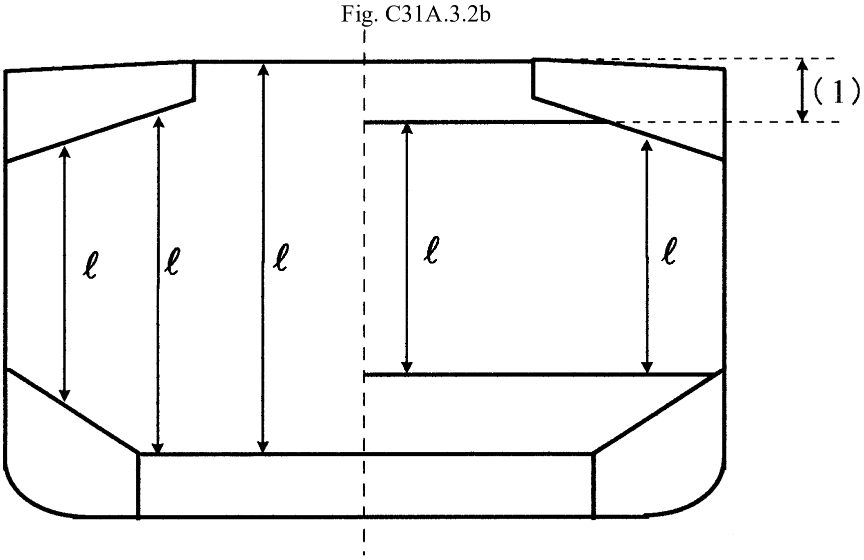
l: Span (m) of the corrugation as shown in **Fig. C31A.3.2a** and **Fig. C31A.3.2b**

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 **31A.3.2-5**

Fig. C31A.3.2b



ℓ : Span of the corrugation
Where the upper stool is 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 corrugations, in general
(b) 2 times the depth of corrugations, for rectangular stool

31A.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.

$$b_{ef} = C_e a \quad (m)$$

C_e: $\frac{2.25}{\beta} - \frac{1.25}{\beta^2}$ For $\beta > 1.25$

1.0 For $\beta \leq 1.25$

Where:

β: $10^3 \frac{a}{t_f} \sqrt{\frac{\sigma_F}{E}}$

t_f: Net flange thickness (mm)

a: Width (m) of corrugation flange (See **Fig. C31A.3.2a**)

σ_F: Yield stress (N/mm^2) of the material

E: Modulus of elasticity, 2.06×10^5 (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 **31A.3.5-5** are fitted (see **Fig. C31A.3.3a** and **Fig. C31A.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. C31A.3.3a** and **Fig. C31A.3.3b**), but it is not to be greater than $2.5at_f$.

$$2.5a\sqrt{t_f t_{sh}} \quad (cm^2)$$

Where:

a: Width (m) of corrugation flange (See **Fig. C31A.3.2a**)

t_{sh}: Net shedder plate thickness (mm)

t_f: Net corrugation flange thickness (mm)

(4) Provided that effective gusset plates as defined in **31A.3.5-6** are fitted (see **Fig. C31A.3.4a** and **Fig. C31A.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. C31A.3.4a and Fig. C31A.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. C31A.3.4a and Fig. C31A.3.4b)

S_{gu}: Width (m) of gusset plate

t_f: Net flange thickness (mm)

(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. C31A.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.

Fig. C31A.3.3a

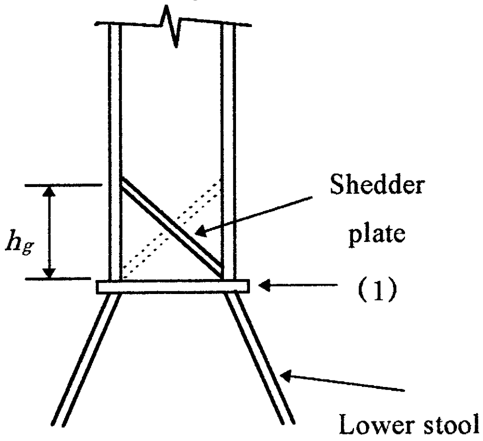


Fig. C31A.3.3b

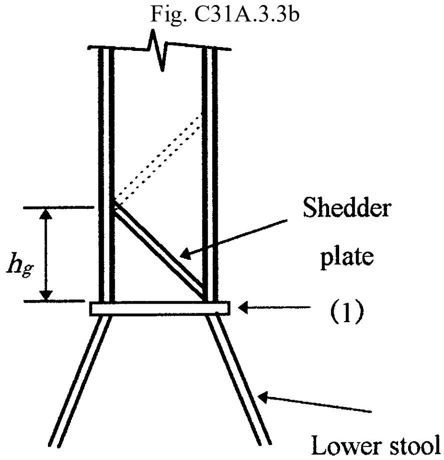


Fig. C31A.3.4a

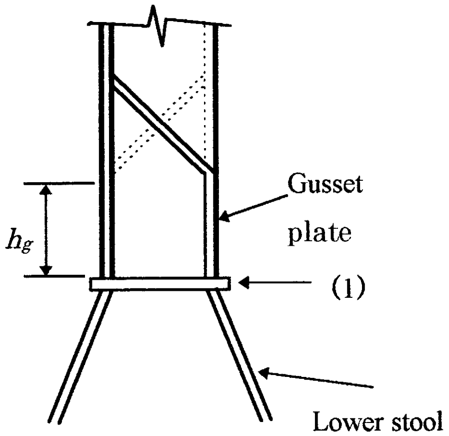
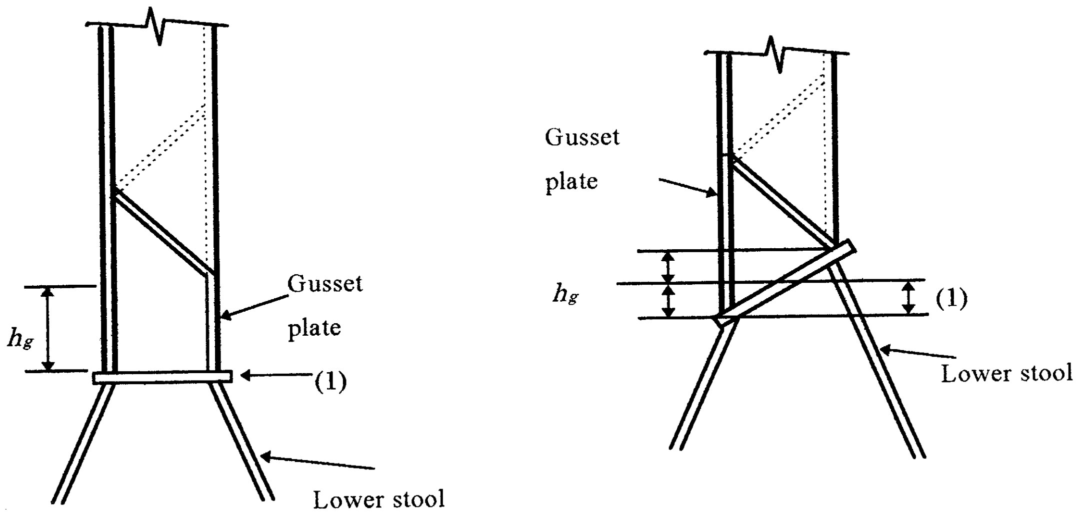


Fig. C31A.3.4b



2 Provided that effective gusset plates or shedder plates as defined in **31A.3.5-5,** and **31A.3.5-6** are fitted (see **Fig. C31A.3.4a** and **Fig. C31A.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:

$$Z'_{le} = Z_g + 10^3 \times \frac{Qh_g - 0.5h_g^2 s_1 p_g}{\sigma_a} \ (cm^3)$$

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 **31A.3.3-2**

h_g: Height (m) of shedder plates or gusset plates (See **Fig. C31A.3.3a**, **Fig. C31A.3.3b**, **Fig. C31A.3.4a** and **Fig. C31A.3.4b**)

s_1: As given in **31A.3.2-2**

p_g: Resultant pressure (kN/m^2) as defined in **31A.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 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:

$$10^3 \times \frac{M}{0.5Z_{le}\sigma_{a,le} + Z_m\sigma_{a,m}} \leq 0.95$$

Where:

M: Bending moment ($kN \cdot m$) as given in **31A.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. C31A.3.2a**)

$$\tau_a \geq \frac{Q \times 10^3}{A_W \sin\phi} \ (N/mm^2)$$

τ_a: $0.5\sigma_F$ (N/mm^2)

σ_F: Yield stress of material (N/mm^2)

Q: Shear force (kN) as given in **31A.3.3-2**

A_W: Sectional area (mm^2) of corrugation web at the lower end

ϕ: 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 τ for the web plates at the ends do not exceed the critical value τ_c.

$$\tau_c = \tau_E \text{ when } \tau_E \leq \frac{\tau_F}{2} \ (N/mm^2)$$

$$\tau_c = \tau_F\left(1 - \frac{\tau_F}{4\tau_E}\right) \text{ when } \tau_E > \frac{\tau_F}{2} \ (N/mm^2)$$

Where:

τ_F: $\frac{\sigma_F}{\sqrt{3}}$ (N/mm^2)

σ_F: Yield stress of material (N/mm^2)

τ_E: $0.9k_t E\left(\frac{t}{1000c}\right)^2$ (N/mm^2)

k_t: Coefficient as 6.34

E: Modulus of elasticity of material as 2.06×10^5 (N/mm^2)

t: Net thickness (mm) of corrugation web

c: Width (m) of corrugation web (See **Fig. C31A.3.2a**)

7 The corrugation local net plate thickness t is to comply with the following:

$$t = 14.9S_w\sqrt{\frac{1.05p}{\sigma_F}} \ (mm)$$

S_w: Plate width (m) to be taken equal to the width of the corrugation flange or web, whichever is the greater (see **Fig. C31A.3.2a**)

p: Resultant pressure (kN/m^2) at the bottom of each strake of bulkhead plating calculated in **31A.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:

$$t_n = 14.9S_n\sqrt{\frac{1.05p}{\sigma_F}} \ (mm)$$

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:

$$t_{w1} = 14.9S_w\sqrt{\frac{1.05p}{\sigma_F}} \ (mm)$$

$$t_{w2} = \sqrt{\frac{440 S_w^2 \cdot 1.05p}{\sigma_F} - t_{np}^2} \ \ (mm)$$

t_{np}: The value (mm) not greater than the net thickness of the narrower plating and t_{w1}

31A.3.5 Structural Details

1 The corrugation angle ϕ shown in **Fig. C31A.3.2a** is not to be less than 55°

2 The thickness of the lower part of the corrugations calculated in **31A.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 **31A.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. C31A.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 **31A.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 **31A.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. C31A.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 penetration welds. 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. C31A.3.6**). The supporting floors are to be connected to the inner bottom by either full penetration or deep penetration welds (see **Fig. C31A.3.6**).

Fig. C31A.3.5

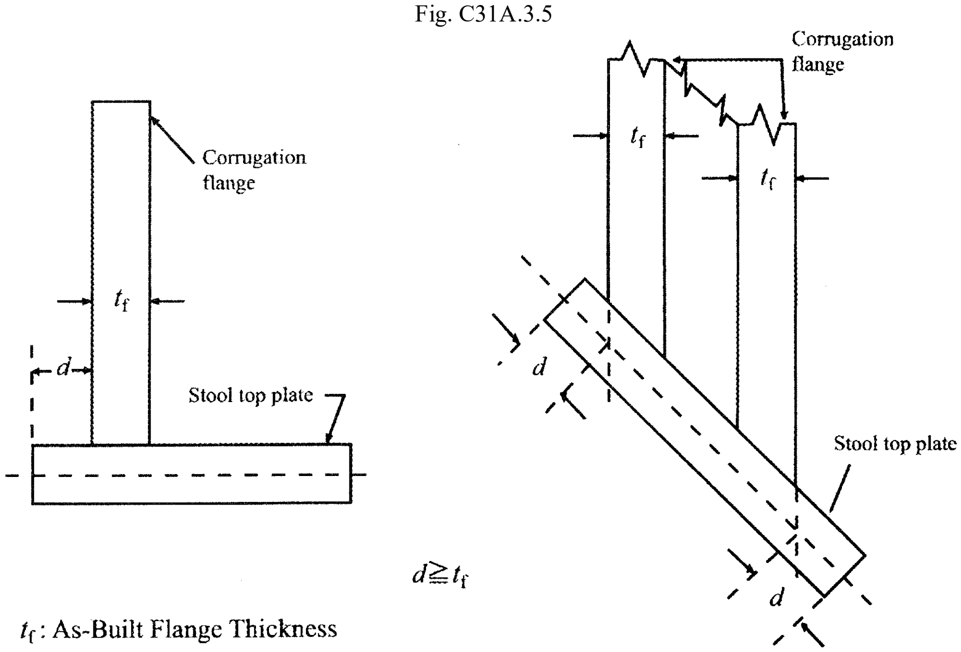
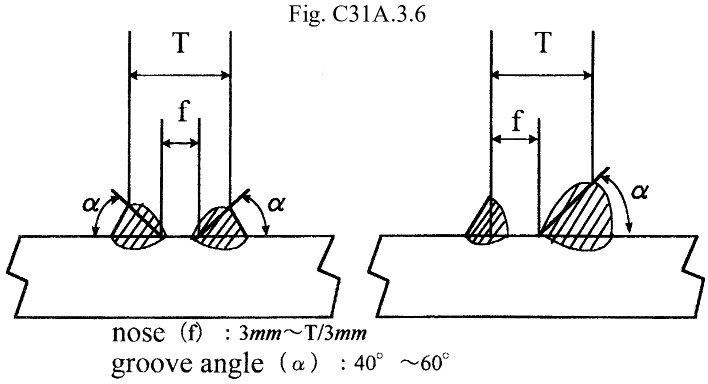


Fig. C31A.3.6



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. C31A.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.

31A.3.6 Renewal Thickness for Ship in Operation

Structural drawings of corrugated bulkheads complying with the requirements of 31A.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.

$$t_{renewal} = t_{as\text{-}built} - 3.0\ (mm)$$

31A.4 Allowable Hold Loading on Double Bottom

31A.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 31A.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

31A.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. C31A.4.1)

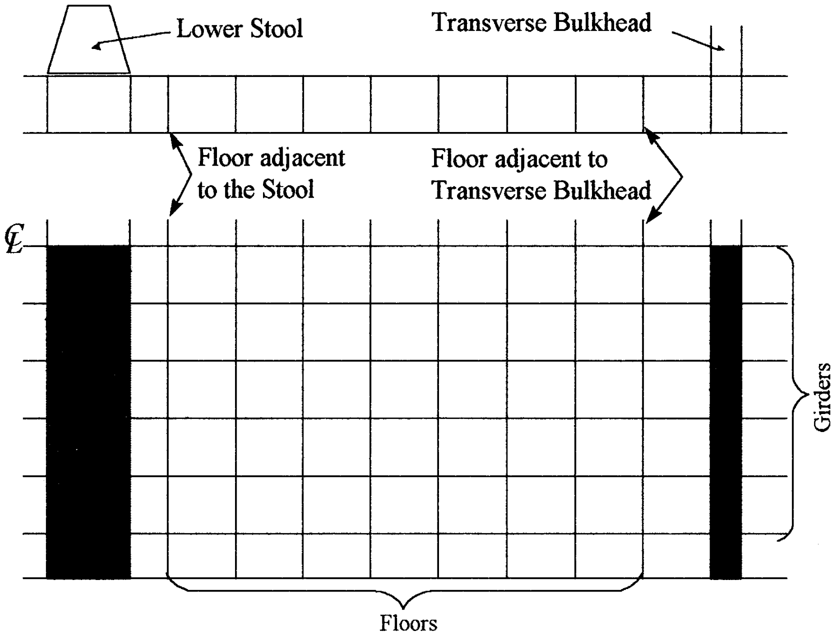
(2) All double bottom girders adjacent to stools or transverse bulkheads if no stool is fitted

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. C31A.4.1 Floors and Girders to be Calculated



31A.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:

$$C_h = \sum \min(S_{f1}, S_{f2}) + \sum \min(S_{g1}, S_{g2}) \ (kN)$$

$$C_e = \sum S_{f1} + \sum \min(S_{g1}, S_{g2}) \ (kN)$$

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 may be taken as $\frac{\sigma_F}{\sqrt{3}}$ for floors adjacent to stools or transverse bulkheads):

$$\frac{162 \cdot \sigma_F^{0.6}}{\left(\frac{S}{t_{net}}\right)^{0.8}} \text{ or } \frac{\sigma_F}{\sqrt{3}} \ (N/mm^2)$$

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. C31A.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. C31A.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)

g: Acceleration due to gravity; 9.81 (m/s^2)

$perm$: Permeability of cargo as specified in **31A.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:

$$A_{DB,h} = \sum_{i=1}^{n} S_i \cdot B_{DB,i} \ (m^2)$$

$$A_{DB,e} = \sum_{i=1}^{n} S_i \cdot (B_{DB} - S_l) \ (m^2)$$

Where:

n : Numbers of floors between stools (or transverse bulkheads, if no stool fitted)

S_i : 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.

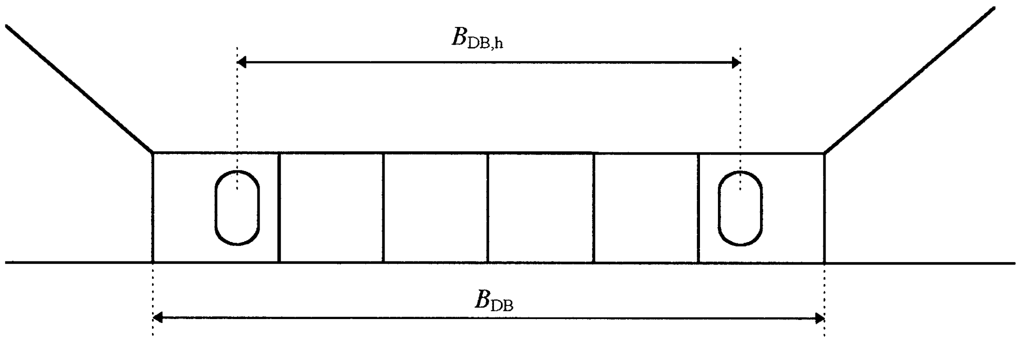
$B_{DB,i}$: $B_{DB,h}$ (m), for floors whose shear strength is calculated by S_{f2} in -2 above.

B_{DB} : Breadth (m) of double bottom between hoppers (See Fig. C31A.4.2)

$B_{DB,h}$: Distance (m) between the two considered openings (See Fig. C31A.4.2)

S_l : Spacing (m) of double bottom longitudinals adjacent to hoppers

Fig. C31A.4.2 B_{DB} and $B_{DB,h}$



31A.5 Longitudinal Strength in Flooded Condition

31A.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 **31A.5.2** and the evaluation of longitudinal strength is to be in accordance with **31A.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

3 Notwithstanding the requirements in this section, for self-unloading ships with unloading systems that do not maintain watertightness, the longitudinal strength in the flooded conditions are to be considered using the extent to which the flooding may occur.

31A.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 **31A.1.2(7)**. For steel mill products such as steel coil, permeability is to be taken as 0.

31A.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 15.2.1-1

Z_f: Actual section modulus (cm^3) for the section under consideration as calculated in 15.2.3

2 At sections other than the midship part, the section moduli may be required to fulfil requirements deemed necessary by the Society.

3 The thickness t of side shell plating for bulk carriers of single-side skin construction 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 15.3.1-1.

I and m: As specified in 15.3.1-1

4 The thicknesses of side shell plating and longitudinal bulkhead plating for bulk carriers of double-side skin construction under consideration is to be in accordance with 15.3.2 in order to have sufficient strength after flooding in all specific loading and ballast conditions. In this case, the still water shear force F_s (kN), and the wave induced shear forces $F_w(+)$ and $F_w(-)$ (kN) specified in 15.3.2 are to be in accordance with the following **(1)** and **(2)**.

(1) The still water shear force F_{sf} (kN) in the flooded condition given in -3 above is to be substituted for the still water shear force F_s (kN).

(2) The wave induced shear forces $F_w(+)$ and $F_w(-)$ (kN) given in 15.3.2 multiplied by 0.8 are to be substituted for the wave induced shear forces $F_w(+)$ and $F_w(-)$ (kN).

5 When calculating bending and shearing strength after flooding, the damaged structure is assumed to remain fully effective in resisting the applied load.

6 Axial stress buckling stress is to be assessed in accordance with **15.4.1.**

31A.6 Double-side Skin Construction and Cargo Hold Construction

31A.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 35.

(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

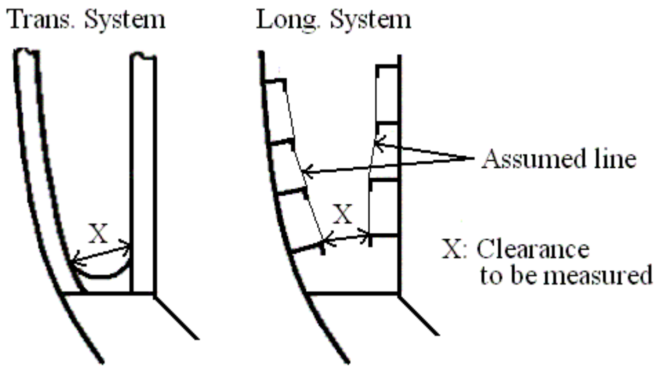
the structural configuration, but is not to be less than 600 *mm*.

(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. C31A.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. C31A.6.1 Clearance inside Double-side Skin Construction



31A.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 panels.

Chapter 31B ADDITIONAL REQUIREMENTS FOR EXISTING BULK CARRIERS

31B.1 General

31B.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 B** with single side skin construction, which fulfil all the following conditions, are to be in accordance with the provisions of **31B.1.2**, **31B.1.3**, **31B.2**, **31B.3** and **31B.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 B** with single side skin construction, which have been contracted for construction prior to 1 July 1998, are to comply with the provisions of **31B.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 **31B.6**.

5 Bulk carriers defined in **1.3.1(13), Part 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 **31B.7** when operating with any hold empty.

6 Except where especially required in this chapter, the general requirements for construction and equipment in **Chapter 31** and of steel ships are to be applied.

31B.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 **31.2.1-3**.

(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 C31B.1.1** may be used as standard according to the kind of cargo. For cargoes other than those given in **Table C31B.1.1**, the values of permeability are to be at the Society’s discretion.

Table C31B.1.1 Permeability

Cargo and etc.	Permeability
Iron Ore	0.3
Cement	0.3
Coal	0.3
Empty Space	0.95

“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 C31B.1.2** may be used as standard according to the kind of cargo. For cargoes other than those given in **Table C31B.1.2**, the angles of repose are to be at the Society’s discretion.

Table C31B.1.2 Angle of Repose

Cargo	Angle of repose
Iron ore	35°
Cement	25°
Coal	35°

31B.1.3 Implementation Schedule

1 Ships are to comply with the requirements of **31B.2**, **31B.3** and **31B.4** by the date required in **Table C31B.1.3** according to the ship's age on 1 July 1998.

Table C31B.1.3 Implementation Time Table for Existing Ships

Ship's Age on 1 July 1998: A	Implementation Scheme
20 *years* ≤ 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* ≤ 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* ≤ 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* ≤ 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 the 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.

31B.2 Damage Stability

31B.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 **31A.2.1-2.**

2 Ships not capable of complying with the requirements in **31B.2.1-1** are to take measures deemed appropriate by the Society. The requirements specified in **31B.3** and **31B.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 **Part V of the Rules**, are to be treated as complying with the preceding **-1** and **-2**.

31B.3 Transverse Watertight Corrugated Bulkhead

31B.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.

31B.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. C31A.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. C31A.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 $p_{c,f}$ is given by the following:

$$p_{c,f} = \rho g h_f \quad (kN/m^2)$$

(b) At each point of the bulkhead located at a distance less than d_1 from the baseline, the pressure $p_{c,f}$ is given by the following:

$$p_{c,f} = \rho g h_f + [\rho_c - \rho(1 - perm)] g h_1 \tan^2\gamma \quad (kN/m^2)$$

(c) The force $F_{c,f}$ acting on the corrugation is given by the following:

$$F_{c,f} = s_1 \left[\rho g \frac{(d_f - d_1)^2}{2} + \frac{\rho g (d_f - d_1) + (p_{c,f})_{le}}{2} (d_1 - h_{DB} - h_{LS}) \right] \quad (kN)$$

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 **31B.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: $45° - \frac{\phi}{2}$

ϕ: Angle of repose defined in 31B.1.2-1(3)

s_1: Spacing (m) of corrugation in 1/2 pitch (see Fig. C31A.3.2a)

$(p_{c,f})_{le}$: 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 $p_{c,f}$ is given by the following:

$$p_{c,f} = \rho_c g h_1 \tan^2\gamma \ (kN/m^2)$$

(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:

$$p_{c,f} = \rho g h_f + [\rho_c h_1 - \rho(1 - perm)h_f] g \tan^2\gamma \ (kN/m^2)$$

(c) The force $F_{c,f}$ acting on the corrugation is given by the following:

$$F_{c,f} = s_1 \left[\rho_c g \frac{(d_1 - d_f)^2}{2} \tan^2\gamma + \frac{\rho_c g (d_1 - d_f)\tan^2\gamma + (p_{c,f})_{le}}{2} (d_f - h_{DB} - h_{LS}) \right] \ (kN)$$

Where:

d_f: As specified in -1 above

d_1 and h_{DB}: As specified in -2 above

$\rho_c, g, h_1, \gamma, \rho, h_f, perm, s_1, (p_{c,f})_{le}$ 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:

$$F_f = s_1 \rho g \frac{(d_f - h_{DB} - h_{LS})^2}{2} \ (kN)$$

Where:

$s_1, \rho, g, d_f, h_{DB}$ 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:

$\rho_c, g, s_1, d_1, h_{LS}, h_{DB}$ 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)

31B.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 **31B.3.2-6**.

l: Span (m) of the corrugation to be taken as in **Fig. C31A.3.2a** and **Fig. C31A.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 **31B.3.2-6**.

31B.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:

β: $10^3 \frac{a}{t_f}\sqrt{\frac{\sigma_F}{E}}$

t_f: Net flange thickness (mm)

a: Width (m) of corrugation flange (See **Fig. C31A.3.2a**)

σ_F: Yield stress (N/mm^2) of the material

E: Modulus of elasticity, 2.06×10^5 (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 **31B.3.5-4** are fitted (see **Fig. C31A.3.3a** and **C31A.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. C31A.3.3a** and **C31A.3.3b**), but it is not be greater than $2.5at_f$.

$$2.5a\sqrt{t_f t_{sh}}\sqrt{\frac{\sigma_{Fsh}}{\sigma_{Ffl}}} \ (cm^2)$$

Where:

a: Width (m) of corrugation flange (See **Fig. C31A.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 **31B.3.5-5** are fitted (see **Fig. C31A.3.4a** and **C31A.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. C31A.3.4a** and **C31A.3.4b**).

$7h_g t_{gu}$ (cm^2)

Where:

h_g: Height (m) of gusset plate, but not to be greater than $10S_{gu}/7$ (See **Fig. C31A.3.4a** and **C31A.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. C31A.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 **31B.3.5-4**, and **31B.3.5-5** are fitted (see **Fig. C31A.3.4a** and **Fig. C31A.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:

$$Z'_{le} = Z_g + 10^3 \times \frac{Qh_g - 0.5h_g^2 s_1 p_g}{\sigma_a} \quad (cm^3)$$

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 **31B.3.3-2**

h_g: Height (m) of shedder plates or gusset plates (See **Fig. C31A.3.3a**, **Fig. C31A.3.3b**, **Fig. C31A.3.4a** and **Fig. C31A.3.4b**)

s_1: As given in **31B.3.2-3**

p_g: Resultant pressure (kN/m^2) as defined in **31B.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:

$$10^3 \times \frac{M}{0.5Z_{le}\sigma_{a,le} + Z_m\sigma_{a,m}} \leq 1.0$$

Where:

M: Bending moment (kN-m) as given in **31B.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. C31A.3.2a**)

$$\tau_a \geq \frac{Q}{A_W \sin\phi \times 10^3} \quad (N/mm^2)$$

$\tau_a = 0.5\sigma_F$ (N/mm^2)

σ_F: Yield stress of material (N/mm^2)

Q: Shear force as given in **31A.3.3-2.** (kN)

A_W: Sectional area (mm^2) of corrugation web at the lower end

ϕ: 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.

$$\tau_c = \tau_E \text{ when } \tau_E \leq \frac{\tau_F}{2} \ (N/mm^2)$$

$$\tau_c = \tau_F\left(1 - \frac{\tau_F}{4\tau_E}\right) \text{ when } \tau_E > \frac{\tau_F}{2} \ (N/mm^2)$$

Where:

$$\tau_F = \frac{\sigma_F}{\sqrt{3}} \ (N/mm^2)$$

σ_F: Yield stress of material (N/mm^2)

$$\tau_E = 0.9k_t E\left(\frac{t}{1000c}\right)^2 \ (N/mm^2)$$

k_t: Coefficient as 6.34

E: Modulus of elasticity of material as 2.06×10^5 (N/mm^2)

t: Net thickness (mm) of corrugation web

c: Width (m) of corrugation web (See **Fig. C31A.3.2a**)

7 The corrugation local net plate thickness t is to comply with the following:

$$t = 14.9S_w\sqrt{\frac{p}{\sigma_F}} \ (mm)$$

S_w: Plate width (m) to be taken equal to the width of the corrugation flange or web, whichever is the greater (See **Fig. C31A.3.2a**)

p: Resultant pressure (kN/m^2) at the bottom of each strake of bulkhead plating as calculated in **31B.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:

$$t_n = 14.9S_n\sqrt{\frac{p}{\sigma_F}} \ (mm)$$

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:

$$t_{w1} = 14.9S_w\sqrt{\frac{p}{\sigma_F}} \ (mm)$$

$$t_{w2} = \sqrt{\frac{440S_w^2 p}{\sigma_F} - t_{np}^2} \ (mm)$$

t_{np}: The value (mm) not greater than the net thickness of the narrower plating and t_{w1}

31B.3.5 Structural Details

1 Where the corrugation angle ϕ shown in **Fig. C31A.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 **31B.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 **31B.3.4-3**, **-4** and **-5** are to be maintained in 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 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.

31B.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.

31B.4 Allowable Hold Loading on Double Bottom

31B.4.1 General

1 The load in the foremost cargo hold is not to exceed the allowable hold load in flooded condition calculated in **31B.4.4**, using the flooding head given in **31B.4.2** and the shear capacity of the double bottom given in **31B.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.

31B.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. C31A.3.1**):

D (m) in general

$0.95D$ (m) for ships less than 50,000 *tonnes* deadweight with type B freeboard

31B.4.3 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. C31A.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:

$$t_{net} = t - t_c \ (mm)$$

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:

$$C_h = \sum \min(S_{f1}, S_{f2}) + \sum \min(S_{g1}, S_{g2}) \ (kN)$$

$$C_e = \sum S_{f1} + \sum \min(S_{g1}, S_{g2}) \ (kN)$$

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:

$$S_{f1} = 10^{-3} A_f \frac{\tau_a}{\eta_{f1}} \ (kN)$$

$$S_{f2} = 10^{-3} A_{f,h} \frac{\tau_a}{\eta_{f2}} \ (kN)$$

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)

$\eta_{f1} = 1.10$

$\eta_{f2} = 1.20$; 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. that bay which is closest to stool, or transverse bulkheads, if no stool fitted) are given by the followings:

$$S_{g1} = 10^{-3} A_g \frac{\tau_a}{\eta_{g1}} \ (kN)$$

$$S_{g2} = 10^{-3} A_{g,h} \frac{\tau_a}{\eta_{g2}} \ (kN)$$

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. that bay which is closest to stool, or transverse bulkheads, if no stool fitted)

$\eta_{g1} = 1.10$

$\eta_{g2} = 1.15$; may be reduced to 1.10, where appropriate reinforcements are fitted to the Society's satisfaction

31B.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:

$$W = \rho_c V \frac{1}{F} \ (t)$$

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

$$h_1 = \frac{X}{\rho_c g} \ (m)$$

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:

$$X_1 = \frac{Z + \rho g (E - h_f)}{1 + \frac{\rho}{\rho_C}(perm - 1)} \ (kN/m^2)$$

$$X_2 = Z + \rho g (E - h_f perm) \ (kN/m^2)$$

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 **31B.4.2**
h_f: As specified in **31B.4.2**
$perm$: Permeability of cargo as specified in **31A.1.2(7)** is to be taken as 0 for steel mill products.
Z: The lesser of Z_1 and Z_2 given by the following:

$$Z_1 = \frac{C_h}{A_{DB,h}} \ (kN/m^2)$$

$$Z_2 = \frac{C_e}{A_{DB,e}} \ (kN/m^2)$$

C_h, C_e: As specified in **31B.4.3**
$A_{DB,h}, A_{DB,e}$: As given by the following:

$$A_{DB,h} = \sum_{i=1}^{n} S_i \cdot B_{DB,i} \ (m^2)$$

$$A_{DB,e} = \sum_{i=1}^{n} S_i \cdot (B_{DB} - S_l) \ (m^2)$$

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_{f1} in **31B.4.3-5.**
$B_{DB,i}$: $B_{DB,h}$ (m), for floors whose shear strength is calculated by S_{f2} in **31B.4.3-5.**
B_{DB}: Breadth (m) of double bottom between hoppers (See **Fig. C31A.4.2**)
$B_{DB,h}$: Distance (m) between the two considered openings (See **Fig. C31A.4.2**)
S_l: Spacing (m) of double bottom longitudinals adjacent to hoppers

31B.5 Hold Frames

31B.5.1 Implementation Schedule

Bulk Carriers which have been contracted for construction prior to 1 July 1998, are to comply with the requirements of **31B.5.2** and **31B.5.3** by the date required in **Table C31B.5.1** corresponding to the ship's age on 1 January 2004.

Table C31B.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 reaches 15 *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.

31B.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}: $0.75t_{S12}$ (mm)

t_C: The value (mm) specified in **Table C31B.5.2**

t_{S12}: Web of hold frame and web of bracket thickness (mm) required according to **31.1.6-2** and **31.6.2-5**

(2) $t_{REN} = 0.75t_{AB}$

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. C31B.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. C31B.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. C31B.5.2**)

Below $87\sqrt{K}$ for 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 **1.1.7-2(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. C31B.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 **31B.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 $t_M \le t_{COAT}$ in the lower part of side frames as defined in **Fig. C31B.5.1**)

$t_{REN,S}$: As specified in **31B.5.3-4**

When the lower bracket length or depth does not comply with the requirements of **31.6.2-7**, a strength check in accordance with **31B.5.3-5** is to be carried out and renewals or reinforcements effected as required therein.

Table C31B.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
$\le$ 100	2.0	2.5	2.0	3.0
150	2.0	3.0	3.0	3.5
$\ge$ 200	2.0	3.0	3.0	4.0

Notes:

1: L_1 is the distance (m) measured on the waterline at the scantling draught d_S from the forward side of the stem to the centre of the rudder stock. L_1 is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught d_S. In ships without rudder stocks (e.g. ships fitted with azimuth thrusters), the Rule length L_1 is to be taken equal to 97% of the extreme length on the waterline at the scantling draught d_S. d_S is the scantling draught (m) at which the strength requirements for the scantlings of the ship are met and represents the full load condition; it is to be not less than that corresponding to the assigned freeboard.

2: For intermediate ship lengths, t_C is obtained by linear interpolation between the above values.

Fig. C31B.5.1 Lower Part and Zones of Side Frame

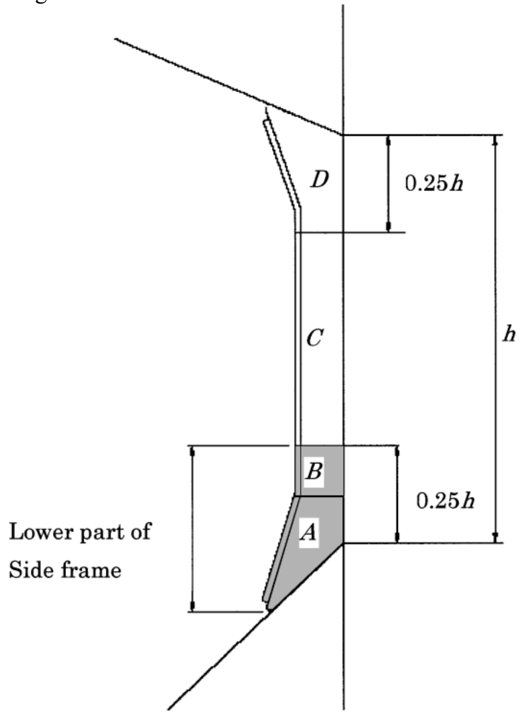
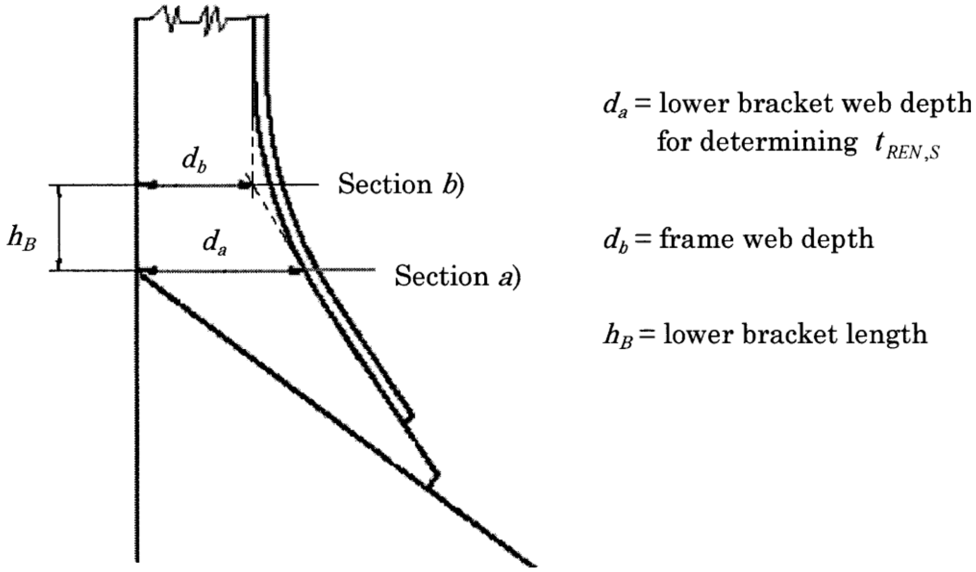


Fig. C31B.5.2 Sections *a*) and *b*)



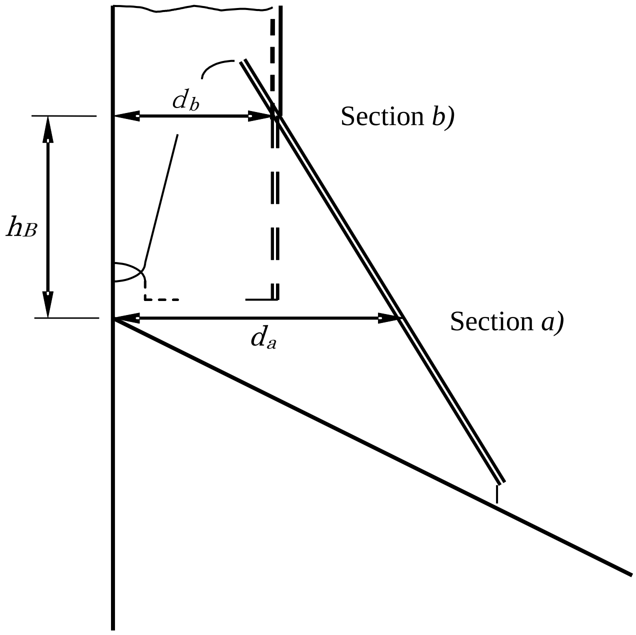
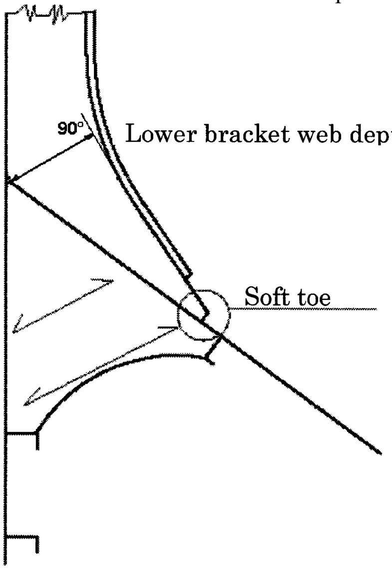


Fig. C31B.5.3 Definition of the Lower Bracket Web Depth for Determining $t_{REN,d/t}$



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 **31.6.3**.

4 When $t_{REN} < t_M \le t_{COAT}$, 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 $t_{REN} < t_M \le t_{COAT}$ 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. C31B.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. C31B.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 **25.2.1**, 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 **31.6.1-7**.

6 Reinforcing measures

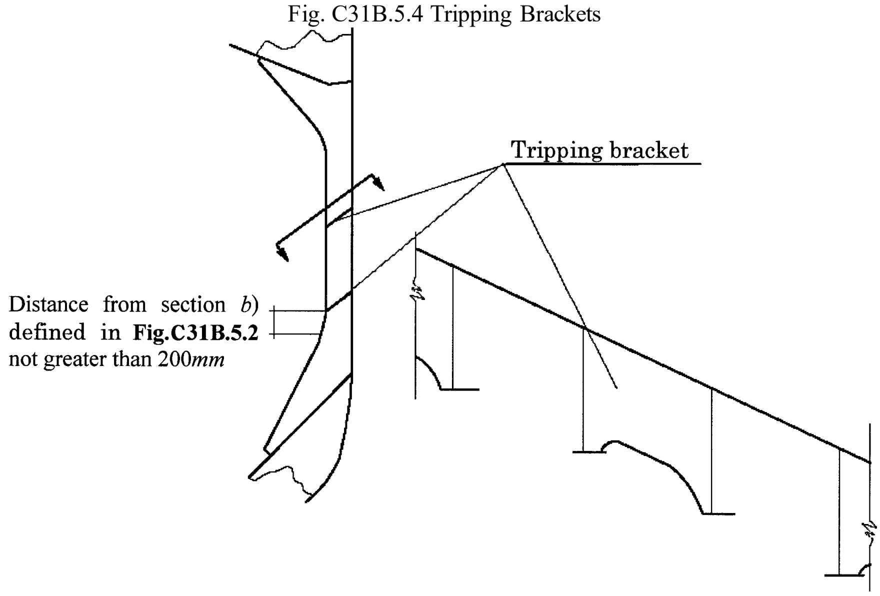
(1) Reinforcing measures are constituted by tripping brackets, located at the lower part and at midspan of side frames (see **Fig. C31B.5.4**). Tripping brackets may be located at every two frames, but lower and midspan brackets are to be fitted in line between alternate pairs of frames.

(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 **31.6** may be accepted in lieu of the compliance with the requirements in this Chapter.

Fig. C31B.5.4 Tripping Brackets



31B.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. C31B.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. C31B.5.1**) is below the load water line

$$s\,h\,\left(\frac{p_{S,U} + p_{S,L}}{2}\right)$$

(2) When the upper end of the side frame span *h* (see **Fig. C31B.5.1**) is at or above the load water line

$$s\,h'\,\left(\frac{p_{S,L}}{2}\right)$$

P_1: Wave force, in *kN*, in head sea

$$s\,h\,\left(\frac{p_{1,U} + p_{1,L}}{2}\right)$$

P_2: Wave force, in *kN*, in beam sea

$$s\,h\,\left(\frac{p_{2,U} + p_{2,L}}{2}\right)$$

h, h_B: Side frame span and lower bracket length, in *m*, defined in **Fig. C31B.5.1** and **Fig. C31B.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. C31B.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:

$$p_1 = 1.5\left[p_{11} + 135\frac{B}{2\ (B+75)} - 1.2\,(d - z)\right]$$

$$p_{11} = 3\,k_S\,C + k_f$$

(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:

$$p_2 = 13\left[0.5\,B\,\frac{50\,c_r}{2\,(B+75)} + C_B\,\frac{0.5\,B + k_f}{14}\,\left(0.7 + 2\frac{z}{d}\right)\right]$$

(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

B: Breadth of ship, in m, specified in **2.1.4, Part A**

C_B: Volume of displacement corresponding to the scantling draught d_S divided by $L_1 B_S d_S$; this value, however, is to be taken as 0.6, when less than 0.6.

B_S: Breadth (m) measured amidships at the scantling draught d_S.

d: Designed maximum load draught, in m, specified in **2.1.12, Part A**

L_1: Distance (m) measured on the waterline at the scantling draught d_S from the forward side of the stem to the centre of the rudder stock. L_1 is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught d_S. In ships without rudder stocks (e.g. ships fitted with azimuth thrusters), the Rule length L_1 is to be taken equal to 97% of the extreme length on the waterline at the scantling draught d_S.

d_S: Scantling draught (m) at which the strength requirements for the scantlings of the ship are met and represents the full load condition. d_S is to be not less than that corresponding to the assigned freeboard.

C: Coefficient defined as follows:

$10.75 - \left(\frac{300 - L_1}{100}\right)^{1.5}$ for $90 \le L_1 \le 300\ m$

10.75 for $L_1 > 300\ m$

c_r: $\left(1.25 - 0.025\frac{2\ k_r}{\sqrt{GM}}\right)k$

$k = 1.2$ for ships without bilge keel

$k = 1.0$ for ships with bilge keel

k_r: Roll radius of gyration. If the actual value of k_r 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: $C_B + \dfrac{0.83}{\sqrt{C_B}}$ at aft end of L_1

C_B between 0.2 L_1 and 0.6 L_1 from aft end of L_1

$C_B + \dfrac{1.33}{C_B}$ 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 τ_a (N/mm^2) in the side shell frames and brackets are given by:

$$\sigma_a = 0.9\sigma_F$$

$$\tau_a = 0.4\sigma_F$$

Where σ_F is the minimum upper yield stress (N/mm^2) of the material specified in **Part K**.

4 Shear strength check

When $t_M \le t_{COAT}$ in the lower part of side frames as shown in **Fig. C31B.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. C31B.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*): $t_{REN,Sa} = \dfrac{1000\ k_S\ P_{fr,a}}{d_a\ \sin\phi\ \tau_a}$

at section *b*): $t_{REN,Sb} = \dfrac{1000\ k_S\ P_{fr,b}}{d_b\ \sin\phi\ \tau_a}$

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. C31B.5.2**)

In case of separate (non integral) brackets, d_b is to be taken as the minimum web depth deducing possible scallops.

ϕ: 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 **31.6.2-7**, 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*): $Z_a = \dfrac{1000\ P_{fr,a}\, h}{m_a\, \sigma_a}$

at section *b*): $Z_b = \dfrac{1000\ P_{fr,a}\, h}{m_b\, \sigma_a}$

Where:

$P_{fr,a}$: Force defined in **-2** above

h: Side frame span, in m, defined in **Fig. C31B.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 C31B.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 $1.2Z_a$ 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. C31B.5.1**.

Table C31B.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 homogeneous loading conditions	10	17	19	22
Other cases	12	20	22	26

Notes:

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.
2. For intermediate values of the bracket length h_B, the coefficient m_b is obtained by linear interpolation between the table values.

31B.6 Steel Weathertight Hatch Covers

31B.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 **31B.6.2** and **31B.6.3** in accordance with the schedule shown in **Table C31B.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 the distance (m) measured on the waterline at the scantling draught d_S from the forward side of the stem to the centre of the rudder stock. L_1 is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught d_S. In ships without rudder stocks (e.g. ships fitted with azimuth thrusters), the Rule length L_1 is to be taken equal to 97% of the extreme length on the waterline at the scantling draught d_S. d_S is the scantling draught (m) at which the strength requirements for the scantlings of the ship are met and represents the full load condition; it is to be not less than that corresponding to the assigned freeboard.

31B.6.2 Securing Devices*

Effective devices deemed appropriate by the Society for securing weathertightness are to be provided for steel weathertight hatch covers.

31B.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.

31B.7 Restrictions for Sailing with Any Hold Empty

31B.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 ship’s 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 **31A.3**, **31A.4** and **31A.5** and having a side construction deemed appropriate by the Society, may continue sailing with any hold empty in full load condition.

Chapter 32 CONTAINER CARRIERS

32.1 General

32.1.1 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 are intended solely for the carriage of containers and which have large openings in the 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.

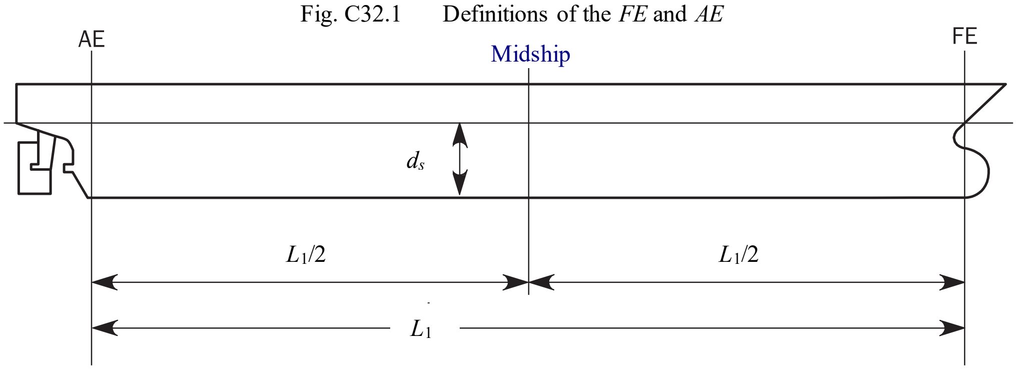
32.1.2 Definitions

1 The definitions of L_1, d_S, FE (fore end of L_1) and AE (aft end of L_1) are given in **Table C32.1** and **Fig. C32.1**.

Table C32.1 Definitions of L_1, d_S, FE and AE

	Definition
L_1	Distance (m) measured on the waterline at the scantling draught d_S from the forward side of the stem to the centre of the rudder stock. L_1 is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught d_S. In ships without rudder stocks (e.g. ships fitted with azimuth thrusters), the Rule length L_1 is to be taken equal to 97% of the extreme length on the waterline at the scantling draught d_S.
d_S	Scantling draught (m) at which the strength requirements for the scantlings of the ship are met and represents the full load condition; it is to be not less than that corresponding to the assigned freeboard.
FE	The fore end of L_1, defined as the perpendicular to the scantling draught d_S at the forward side of the stem.
AE	The aft end of L_1, defined as the perpendicular to the scantling draught d_S at a distance L_1 aft of the fore end (FE).

Fig. C32.1 Definitions of the FE and AE

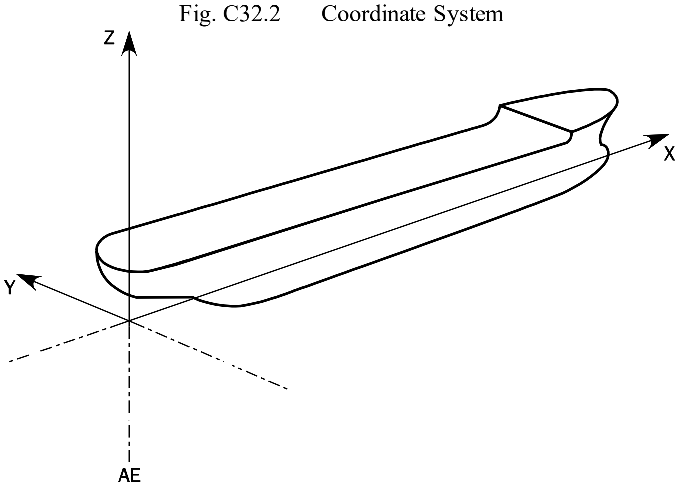


2 The definitions of the coordinate systems for ship geometry, motions, accelerations and loads are given in **Table C32.2** and **Fig. C32.2**.

Table C32.2 Definition of Coordinate System

	Definition
Origin	At the intersection of the longitudinal plane of symmetry of ship, *AE* (the aft end of L_1) and the baseline
X-axis	Longitudinal axis, positive forwards
Y-axis	Transverse axis, positive towards portside
Z-axis	Vertical axis, positive upwards

Fig. C32.2 Coordinate System

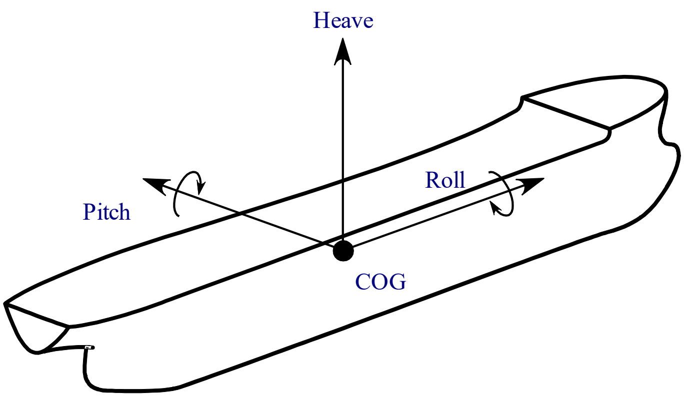


3 The definitions of positive and negative ship motions are given in **Table C32.3** and **Fig. C32.3**.

Table C32.3 Sign Convention for Ship Motions

	Definition of positive ship motions
Heave	Positive heave is translation in the Z-axis direction (positive upwards).
Roll	Positive roll motion is positive rotation about a longitudinal axis through the COG (starboard down and port up).
Pitch	Positive pitch motion is positive rotation about a transverse axis through the COG (bow downward stem up).

Fig. C32.3 Definition of Positive Motions

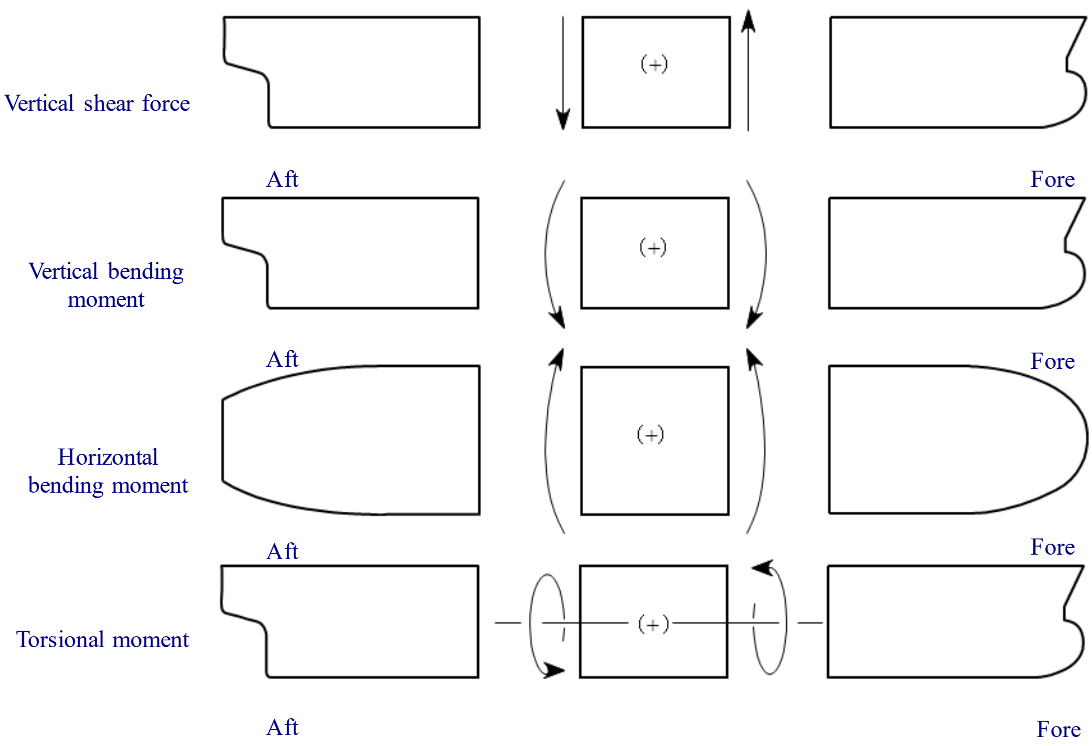


4 The definitions of positive and negative vertical shear forces, vertical bending moments, horizontal bending moments and torsional moments at any ship transverse section are as shown in **Table C32.4** and **Fig. C32.4**.

Table C32.4 Sign Conventions for Vertical Shear Force, Vertical Bending Moment, Horizontal Bending Moment and Torsional Moment

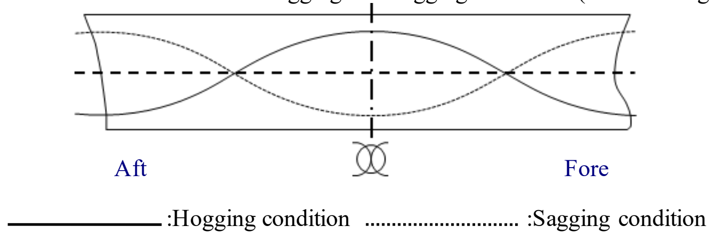
	Definition of positive force and moments
Vertical shear force (*kN*)	Positive in the case of downward resulting forces acting aft of the transverse section and upward resulting forces acting forward of the transverse section under consideration.
Vertical bending moment (*kN*)	Positive when inducing tensile stresses in strength deck (hogging bending moment) and negative when inducing tensile stresses in the bottom (sagging bending moment).
Horizontal bending moment (*kN-m*)	Positive when inducing tensile stresses in the starboard side and negative when inducing tensile stresses in the port side.
Torsional moment (*kN-m*)	Positive in the case of resulting moment acting aft of the transverse section following positive rotation around the *X*-axis and resulting moment acting forward of the transverse section following negative rotation around the *X*-axis.

Fig. C32.4 Definition of Positive Vertical Shear Force, Vertical Bending Moment, Horizontal Bending Moment and Torsional Moment



5 The definition of waves in hogging and sagging conditions is according to **Fig. C32.5**.

Fig. C32.5 Definition of Waves in Hogging and Sagging Conditions(Full Loading Condition)



32.1.3 Net Scantling Approach*

1 In **32.2** and **32.9**, the strength is to be assessed using the net scantling approach on all scantlings if not otherwise specified. In **32.3**, the stress is calculated using the gross scantling approach where the gross scantling means the built scantling, and the strength is assessed using stress corrected for the net scantling approach separately specified. In **32.4** to **32.8**, the strength is assessed using the gross scantling approach.

2 The net thickness of plating, $t_{net}(mm)$, for the plates, webs, and flanges is obtained by the following formula.

$$t_{net} = t_{as\_built} - t_{vol\_add} - \alpha t_c$$

t_{as_built}: Built thickness (mm)

t_{vol_add}: Voluntary addition (mm)

α: Corrosion addition factor whose values are defined in **Table C32.5**

t_c: Total corrosion addition (mm) whose value is defined in **-4**

3 The voluntary addition, if being used, is to be clearly indicated on the drawings.

4 The corrosion addition of the structural members considered is to be in accordance with the following **(1)** to **(3)**:

(1) The total corrosion addition, t_c (mm), for both sides of the structural member is obtained by the following formula.

$$t_c = (t_{c1} + t_{c2}) + 0.5$$

t_{c1}, t_{c2}: Corrosion addition for each of the two sides of a structural member, specified in **Table C32.6**

(2) For an internal member within a given compartment, the total corrosion addition, t_c, is obtained from the following formula.

$$t_c = 2t_{c1} + 0.5$$

t_{c1}: As specified in **(1)**

(3) The corrosion addition of a stiffener is to be determined according to the location of its connection to the attached plating.

Table C32.5 Values of Corrosion Addition Factor

Requirement		α
Stiffness assessment and yield strength assessment (**32.2.5** and **32.2.6**)		0.5
Buckling strength (**32.2.7**)	Sectional properties (stress determination)	0.5
	Buckling capacity	1.0
Hull girder ultimate strength (**32.2.8**)		0.5
Torsional strength (**32.3**)	Buckling capacity	1.0
Strength assessment by direct strength calculation (**32.9.8** and **32.9.9**)	Stress determination	0.5
	Buckling capacity	1.0

Table C32.6 Corrosion Addition for One Side of a Structural Member

Compartment type	One side corrosion addition t_{c1}, t_{c2} (mm)
Exposed to sea water	1.0
Exposed to atmosphere	1.0
Ballast water tank	1.0
Void and dry spaces	0.5
Fresh water, fuel oil and lube oil tanks	0.5
Accommodation spaces	0.0
Container holds	1.0
Compartment types not mentioned above	0.5

32.1.4 Minimum Thickness

1 The gross minimum thickness of girders, struts and their end brackets and bulkhead plates in double side spaces, the interior of which are used as deep tanks, and double bottom spaces (including bilge parts) are to be in accordance with **Table C32.7**.

2 The gross minimum thickness of watertight bulkhead and partial bulkhead constructions in cargo holds as well as girders, struts and their end brackets and bulkhead plates in double side spaces interior of which are not used as deep tanks, may be reduced by 1.0 *mm* from the thickness prescribed in **Table C32.7**.

3 The gross thickness of structural members in cargo holds, double bottom constructions and double side hull constructions is not to be less than 6 *mm*.

Table C32.7 Minimum Gross Thickness

Length of ship L (m)											
	More than or equal to	90	105	120	135	150	165	180	195	225	275
	Less than	105	120	135	150	165	180	195	225	275	
Thickness (mm)		7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5

32.2 Longitudinal Bending Strength

32.2.1 General

1 The wave induced load requirements specified in this Chapter apply to ships meeting the criteria in the following **(1)** to **(3)**:

(1) Length of ship L_1: $90m \leq L_1 \leq 500m$

(2) Proportion: $5 \leq L_1/B \leq 9,\ 2 \leq B/d \leq 6$

(3) Block coefficient at the scantling draught d_S: $0.55 \leq C'_b \leq 0.9$

C'_b: Volume of displacement corresponding to the scantling draught d_S divided by $L_1 B_S d_S$

B_S: The breadth (m) measured amidships at the scantling draught d_S.

2 For ships that do not meet all of the criteria specified in **-1(1)** to **(3)**, applied wave induced loads is specially to be obtained from the direct loading analysis method, etc.

3 Continuity of structure is to be maintained throughout the length of the ship.

4 Where significant changes in structural arrangement occur, adequate transitional structure is to be provided.

32.2.2 Longitudinal Extent of Strength Assessment*

1 The stiffness, yield strength, buckling strength and hull girder ultimate strength assessment specified in this Chapter are to be carried out in way of $0.2L_1$ to $0.75L_1$ if not otherwise specified, with due consideration given to locations where there are significant changes in hull cross section.

2 Strength assessments are to be carried out outside $0.2L_1$ to $0.75L_1$ by the method deemed appropriate by the Society. As a minimum, assessments are to be carried out at forward end of the foremost cargo hold, the aft end of the aft most cargo hold and locations where there are significant changes in hull section.

32.2.3 Loads*

1 Vertical still water bending moments, M_S(kN-m), and vertical still water shear forces, F_S(kN), are to be calculated at each section along the ship length for, in general, the design cargo and ballast loading conditions, based on amount of bunker, fresh water and stores at departure and arrival.

2 Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted in addition to those for departure and arrival conditions.

3 Where any ballasting and/or de-ballasting is intended during voyage, calculations of the intermediate condition just before and just after ballasting and/or de-ballasting any ballast tank are to be submitted to the Society and where approved included in the loading manual for guidance.

4 The permissible maximum and minimum vertical still water bending moments, $M_{S\,max}$(kN-m) and $M_{S\,min}$(kN-m), and the permissible maximum and minimum vertical still water shear forces, $F_{S\,max}$(kN) and $F_{S\,min}$(kN), in seagoing conditions at any longitudinal position are to envelop the following **(1)** and **(2)**:

(1) The maximum and minimum vertical still water bending moments and shear forces for the seagoing loading conditions defined in the loading manual

(2) The maximum and minimum vertical still water bending moments and shear forces specified by the designer

5 The loading manual is to include the relevant loading conditions, which envelop the still water hull girder loads for seagoing conditions, including the loading conditions which are separately specified by the Society.

6 The distribution of the vertical wave induced bending moments, M_W (kN-m), along the ship length is given in **Fig. C32.6**. $M_{W-Hog-Mid}$ and $M_{W-Sag-Mid}$ are to be obtained using the following formulae.

$$M_{W-Hog-Mid} = +1.5 f_R {L_1}^3 C C_W \left(\frac{B}{L_1}\right)^{0.8} f_{NL-Hog}$$

$$M_{W-Sag-Mid} = -1.5 f_R {L_1}^3 C C_W \left(\frac{B}{L_1}\right)^{0.8} f_{NL-Sag}$$

f_R: Factor, to be taken as 0.85

C: Wave parameter, to be taken as:

$$C = 1 - 1.50\left(1 - \sqrt{\frac{L_1}{L_{ref}}}\right)^{2.2} \quad \text{for } L_1 \le L_{ref}$$

$$C = 1 - 0.45\left(\sqrt{\frac{L_1}{L_{ref}}} - 1\right)^{1.7} \quad \text{for } L_1 > L_{ref}$$

L_{ref}: Reference length (m), to be taken as:

$$L_{ref} = 315 {C_W}^{-1.3}$$

C_W: Waterplane coefficient at the scantling draught d_S, to be taken as:

$$C_W = \frac{A_W}{L_1 B}$$

A_W: Waterplane area at the scantling draught d_S (m^2)

f_{NL-Hog}: Non-linear correction factor for hogging, to be taken as:

$$f_{NL-Hog} = 0.3 \frac{C_b'}{C_W} \sqrt{d_S}, \text{ not to be taken greater than 1.1}$$

f_{NL-Sag}: Non-linear correction factor for sagging, to be taken as:

$$f_{NL-Sag} = 4.5 \frac{1 + 0.2 f_{Bow}}{C_W \sqrt{C_b' L_1}^{\,0.3}}, \text{ not to be taken less than 1.0}$$

f_{Bow}: Bow flare shape coefficient, to be taken as:

$$f_{Bow} = \frac{A_{DK} - A_{WL}}{0.2 L_1 Z_f}$$

A_{DK}: Projected area in horizontal plane of uppermost deck (m^2) including the forecastle deck, if any, extending from $0.8L_1$ (see **Fig. C32.7**). Any other structures, e.g. plated bulwark, are to be excluded.

A_{WL}: Waterplane area (m^2) at the scantling draught d_S, extending from $0.8L_1$ forward

Z_f: Vertical distance (m) from the waterline at the scantling draught d_S to the uppermost deck (or forecastle deck), measured at FE (see **Fig. C32.7**). Any other structures, e.g. plated bulwark, are to be excluded.

C_b': Volume of displacement corresponding to the scantling draught d_S divided by $L_1 B_S d_S$

B_S: The breadth (m) measured amidships at the scantling draught d_S.

Fig. C32.6 Distribution of Vertical Wave Induced Bending Moment (M_W) along the Ship Length

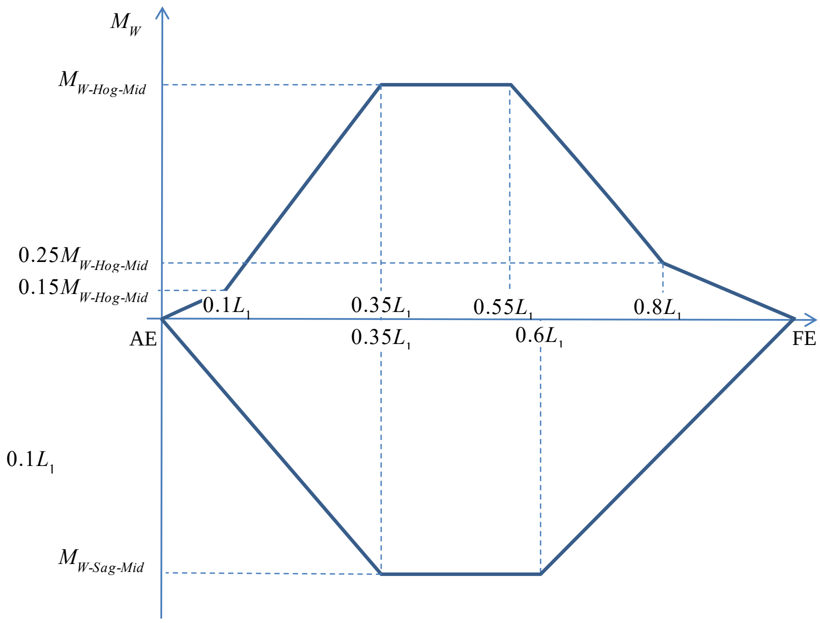
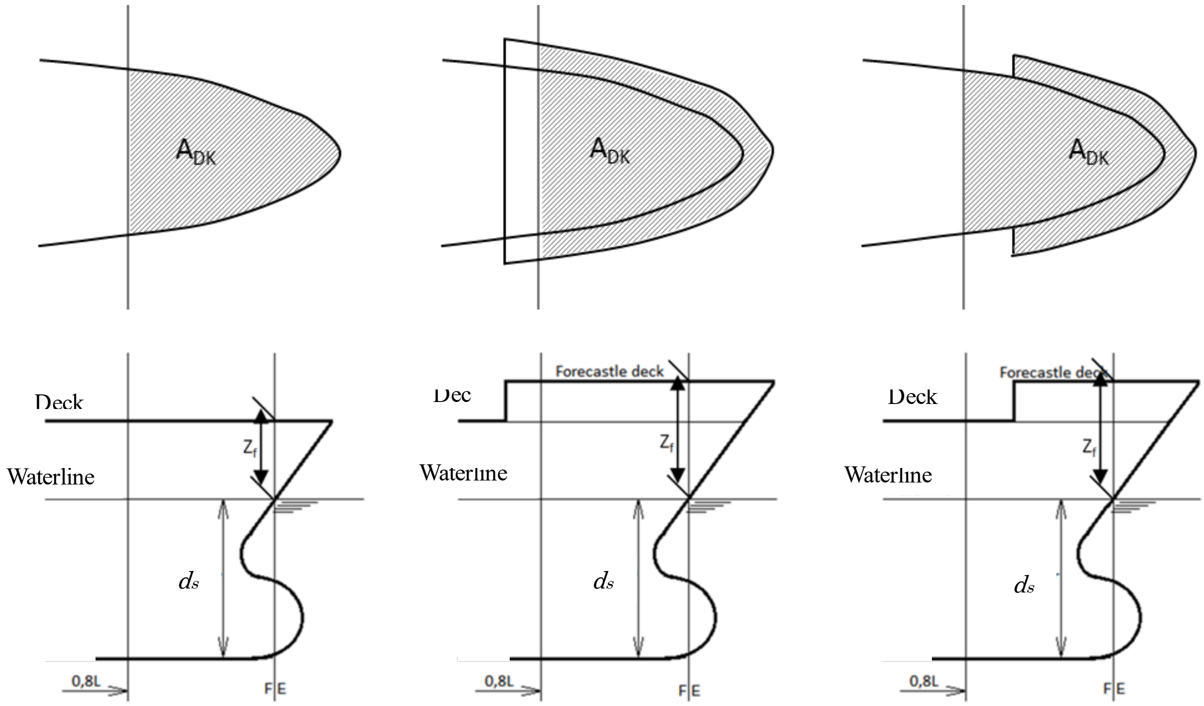


Fig. C32.7 Project Area (A_{DK}) and Vertical Distance (Z_f)



7 The distribution of the vertical wave induced shear forces, F_W (*kN*), along the ship length is given in **Fig. C32.8**. $F_{W-Hog-Aft}$, $F_{W-Hog-Fore}$, $F_{W-Sag-Aft}$, $F_{W-Sag-Fore}$ and F_{W-Mid} are to be obtained using the following formulae.

$$F_{W-Hog-Aft} = +5.2 f_R L_1^{\ 2} C C_W \left(\frac{B}{L_1}\right)^{0.8} (0.3 + 0.7 f_{NL-Hog})$$

$$F_{W-Hog-Fore} = -5.7 f_R L_1^{\ 2} C C_W \left(\frac{B}{L_1}\right)^{0.8} f_{NL-Hog}$$

$$F_{W-Sag-Aft} = -5.2 f_R {L_1}^2 C C_W \left(\frac{B}{L_1}\right)^{0.8} (0.3 + 0.7 f_{NL-Sag})$$

$$F_{W-Sag-Fore} = +5.7 f_R {L_1}^2 C C_W \left(\frac{B}{L_1}\right)^{0.8} (0.25 + 0.75 f_{NL-Sag})$$

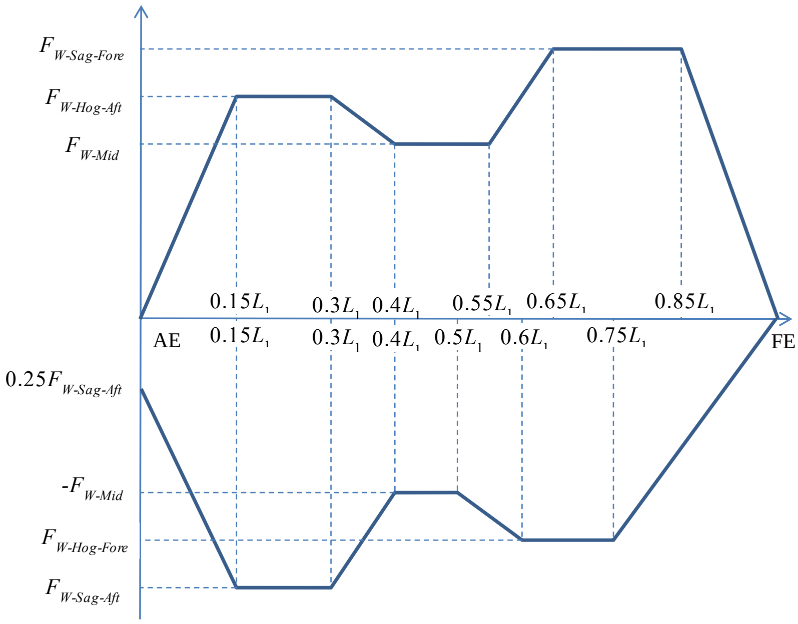
$$F_{W-Mid} = +4.0 f_R {L_1}^2 C C_W \left(\frac{B}{L_1}\right)^{0.8}$$

f_R, C_W, f_{NL-Hog} and f_{NL-Sag}: As specified in -6 above

C: As specified in -6 above. However, L_{ref} is to be obtained from the following formula:

$$L_{ref} = 330 {C_W}^{-13}$$

Fig. C32.8 Distribution of Vertical Wave Induced Shear Force (F_W) along the Ship Length



8 For the strength assessments, the maximum hogging and sagging load cases given in **Table C32.8** are to be checked. For each load case, the still water condition at each section, as defined in -1 to -5 above, is to be combined with the wave condition, as defined in -6 and -7 above. (See **Fig. C32.9** for reference)

Table C32.8 Combination of Still Water and Wave Induced Bending Moments and Shear Forces

Load case	Bending moment		Shear force	
	M_S	M_W	F_S	F_W
Hogging	$M_{S\max}$	M_{W-Hog}	F_{Smax} for $x \le 0.5L_1$	F_{Wmax} for $x \le 0.5L_1$
			$F_{S\min}$ for $x > 0.5L_1$	$F_{W\min}$ for $x > 0.5L_1$
Sagging	M_{Smin}	M_{W-Sag}	$F_{S\min}$ for $x \le 0.5L_1$	$F_{W\min}$ for $x \le 0.5L_1$
			F_{Smax} for $x > 0.5L_1$	F_{Wmax} for $x > 0.5L_1$

Notes:

$M_{S\max}$: Permissible maximum vertical still water bending moment in seagoing condition (*kN-m*) at the cross section under consideration

$M_{S\min}$: Permissible minimum vertical still water bending moment in seagoing condition (*kN-m*) at the cross section under consideration

M_{W-Hog}: Vertical wave induced bending moment in hogging at the cross section under consideration, to be taken as the positive value of M_W as defined in **Fig. C32.6**.

M_{W-Sag}: Vertical wave induced bending moment in sagging at the cross section under consideration, to be taken as the negative value of M_W as defined in **Fig. C32.6**.

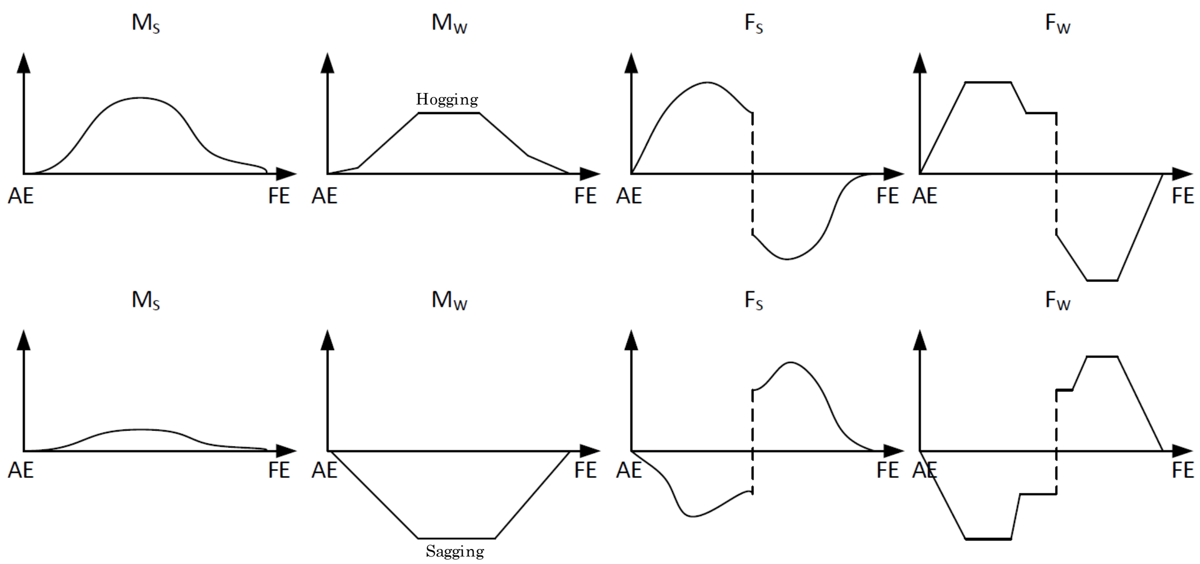
F_{Smax}: Permissible maximum vertical still water shear force in seagoing condition (*kN*) at the cross section under consideration

$F_{S\min}$: Permissible minimum vertical still water shear force in seagoing condition (*kN*) at the cross section under consideration

F_{Wmax}: Maximum value of the wave induced shear force at the cross section under consideration, to be taken as the positive value of F_W as defined in **Fig. C32.8**.

$F_{W\min}$: Minimum value of the wave induced shear force at the cross section under consideration, to be taken as the negative value of F_W as defined in **Fig. C32.8**.

Fig. C32.9 Load Combination to Determine the Maximum Hogging and Sagging Load Cases as Given in **Table C32.8**



9 The hull girder bending stress (N/mm^2) and hull girder shear stress (N/mm^2) are to be obtained from the formulae in the following **(1)** and **(2)**.

(1) Hull girder bending stress σ_{HG}

$$\sigma_{HG} = \frac{\gamma_S M_S + \gamma_W M_W}{1000I}(z - z_n)$$

γ_S, γ_W: Partial safety factors, to be taken as 1.0

M_S, M_W: Vertical still water bending moment and vertical wave induced bending moment for the load cases "hogging" and "sagging" as specified in **32.2.3-8**

I: Moment of inertia (m^4) for the cross section under consideration

z: Vertical coordinate of the location under consideration (m)

z_n: Distance from the baseline to the horizontal neutral axis (m)

(2) Hull girder shear stress τ_{HG}

$$\tau_{HG} = \frac{1000(\gamma_S F_S + \gamma_W F_W)q_v}{t}$$

γ_S, γ_W: As specified in **(1)** above

F_S, F_W: Vertical still water shear force and vertical wave induced shear force for the load cases "hogging" and "sagging" as specified in **32.2.3-8**

q_v: Shear flow at any location when shear force acts along the cross section under consideration, to be determined according to the calculation method which are separately specified by the Society

t: Thickness of plate considered (mm)

32.2.4 Minimum Section Modulus

1 The gross section modulus of the transverse section of the hull at the mid-point of L is not to be less than the value of W_{gr_min}(cm^3) obtained from the following formula:

$$W_{gr\_min} = C_1 {L_1}^2 B(C_b' + 0.7)$$

C_1: As given by the following formulae:

$$10.75 - \left(\frac{300 - L_1}{100}\right)^{1.5} \quad \text{for } L_1 \leq 300m$$

$$10.75 \quad \text{for } 300m < L_1 \leq 350m$$

$$10.75 - \left(\frac{L_1 - 350}{150}\right)^{1.5} \quad \text{for } 350m < L_1$$

C_b': Volume of displacement corresponding to the scantling draught d_S divided by $L_1 B_S d_S$.

However, the value is to be taken as 0.6, where it is less than 0.6.

B_S: The breadth (m) measured amidships at the scantling draught d_S.

2 The scantlings of longitudinal members in way of the midship part are not to be less than the scantlings of longitudinal members at the mid-point of L which are determined by the requirement in **-1** above, excluding changes in the scantlings due to variations in the sectional form of the transverse section of the hull.

32.2.5 Stiffness Assessment

The moment of inertia (m^4) is to be in accordance with the following formula:

$$I \geq 1.55 L_1 |M_S + M_W| 10^{-7}$$

M_S, M_W: Vertical still water bending moment and vertical wave induced bending moment for the load cases "hogging" and "sagging" as specified in **32.2.3-8**

32.2.6 Yield Strength Assessment

1 For each of the load cases "hogging" and "sagging" as defined in **32.2.3-8**, the equivalent hull girder stress σ_{eq}(N/mm^2) is to be in accordance with the following formula:

$$\sigma_{eq} < \sigma_{perm}$$

$$\sigma_{eq} = \sqrt{{\sigma_x}^2 + 3\tau^2}$$

where σ_x and τ are combination of hull girder stresses, to be taken as the following formulae according to the bending strength assessment and shear strength assessment, and where σ_{HG} and τ_{HG} are to be in accordance with **32.2.3-9**.

$\sigma_x = \sigma_{HG}$, $\tau = 0$, for bending strength assessment

$\sigma_x = 0$, $\tau = \tau_{HG}$, for shear strength assessment

σ_{perm}: Permissible stress (N/mm^2), to be taken as

$$\sigma_{perm} = \frac{\sigma_Y}{\gamma_1 \gamma_2}$$

σ_Y: Specified minimum yield stress of the material (N/mm^2)

γ_1: Partial safety factor for material, to be taken as

$$\gamma_1 = K\frac{\sigma_Y}{235}$$

γ_2: Partial safety factor for load combinations and permissible stress, to be taken as follows:

$\gamma_2 = 1.24$, for bending strength assessment

$\gamma_2 = 1.13$, for shear strength assessment

K: Coefficient corresponding to the kind of steel

e.g. 1.0 for mild steel, the values specified in **1.1.7-2(1)** for high tensile steel

2 The assessment locations of the bending stress and shear stress are to be in accordance with the following **(1)** and **(2)**:

(1) The assessment locations of the bending stress are the following location of cross section:

(a) at bottom

(b) at deck

(c) at top of hatch coaming

(d) at any point where there is a change of steel yield strength

(2) The assessment locations of the shear stress are all structural elements that contribute to the shear strength capability.

32.2.7 Buckling Strength Assessment*

1 For the plate panels and longitudinal stiffeners subject to hull girder bending and shear stresses, the following formula is to be applied.

$$\eta_{act} \leq 1$$

η_{act}: Maximum utilisation factor which are separately specified by the Society

2 During the buckling strength assessment, the following two stress combinations are to be considered for each of load cases "hogging" and "sagging" as specified in **32.2.3-8**.

Where, σ_{HG} and τ_{HG} are to be in accordance with **32.2.3-9**.

(1) σ_{HG}, $0.7\tau_{HG}$

(2) $0.7\sigma_{HG}$, τ_{HG}

32.2.8 Hull Girder Ultimate Strength Assessment*

1 For ships not less than 150 *m* in length L_1, the hull girder ultimate bending moment capacity M_U is to satisfy the following formula.

$$\gamma_S M_S + \gamma_W M_W \leq \frac{M_U}{\gamma_M \gamma_{DB}}$$

γ_S: Partial safety factor for the vertical still water bending moment, to be taken as follows.

$$\gamma_S = 1.0$$

γ_W: Partial safety factor for the vertical wave induced bending moment, to be taken as follows.

$$\gamma_W = 1.2$$

M_S, M_W: Vertical still water bending moment and vertical wave induced bending moment for the load cases "hogging" and "sagging" as specified in **32.2.3-8**

M_U: Hull girder ultimate bending moment capacity (kN-m), calculated by the method which is separately specified by the Society.

γ_M: Partial safety factor for the hull girder ultimate strength, to be taken as follows.

$$\gamma_M = 1.05$$

γ_{DB}: Partial safety factor for the hull girder ultimate bending moment capacity, considering the effect of double bottom bending given by the following formula. However, for cross sections where the double bottom breadth of the inner bottom is less than that at amidships or where the double bottom structure differs from at amidships (e.g., engine rooms), the factor γ_{DB} for hogging condition may be reduced subject to approval by the Society.

・For hogging condition, $\gamma_{DB} = 1.15$

・For sagging condition, $\gamma_{DB} = 1.0$

2 For ships not less than 300 m in length L or which exceed 32.26 m in breadth B, in addition to the requirements specified in **-1** above, the hull girder ultimate bending moment capacity M_{U_DB} is to satisfy the following formula for the hogging condition. Notwithstanding the provisions under this paragraph, the effect of whipping and the hull girder ultimate strength considering the effect of lateral loads can be calculated more directly where deemed appropriate by the Society. This requirement applies to the transverse section located in the vicinity of the centre of the cargo hold at midship.

$$\gamma_S M_{S\,max} + \gamma_{Wh} M_{W-Hog-Mid} \leq M_{U\_DB}$$

γ_S: Partial safety factor for the vertical still water bending moment, to be taken as follows:

$\gamma_S = 1.0$

γ_{Wh}: Partial safety factor for the vertical wave induced bending moment, considering the effect of whipping, to be taken as follows:

$\gamma_{Wh} = 1.5$

$M_{S\,max}$: Permissible maximum vertical still water bending moment at the cross section under consideration

$M_{W-Hog-Mid}$: As specified in **32.2.3-6**

M_{U_DB}: Hull girder ultimate bending moment capacity (kN-m), considering the effect of lateral loads, calculated by the method which is separately specified by the Society.

32.2.9 Calculation of Section Modulus and Moment of Inertia of Transverse Section of Hull*

The calculation of the section modulus and the moment of inertia of the transverse section of the hull specified in this Chapter 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 $0.06(B - \Sigma b)$. Σb 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.

32.3 Torsional Strength

32.3.1 Application*

1 Hatch side coamings (including top plates), strength decks, sheer strakes, topmost strakes of inner hulls/bulkheads, bottom shell plating, bilge strakes and longitudinal stiffeners attached to these members within the range from the aft end of aftmost cargo hold to the fore end of foremost cargo hold are to satisfy the criteria of torsional strength assessment specified in this section for any of the following cases:

(1) Ships not less than 200 *m* in length L_1;

(2) Ships exceeding 32.26 *m* in breadth *B*; or

(3) In cases where deemed necessary by the Society.

2 For ships to which **-1(1)** to **(3)** above are not applicable, torsional strength assessments deemed appropriate by the Society are to be carried out in cases where the widths of hatchways amidships exceed 0.7*B*. However, the distances between the outermost lines of hatchway openings are to be taken as the widths of hatchways in cases where the ship has two or more rows of hatchways.

3 Notwithstanding the requirements in this section, torsional strength assessments may be carried out in accordance with direct load analyses and direct strength calculations when deemed appropriate by the Society.

32.3.2 Verification of Calculation Method and Accuracy

1 In cases where torsional strength assessments are carried out by direct strength calculations, necessary documents and data related to the calculation method are to be submitted beforehand to the Society for approval.

2 Analysis programs are to have sufficient accuracy. If deemed necessary, the Society may require the submission of details regarding the analysis method, verification of accuracy, etc.

32.3.3 Evaluation Procedure

The evaluation procedure for torsional strength is given in the following **(1)** to **(4)** (See **Fig. C32.10**):

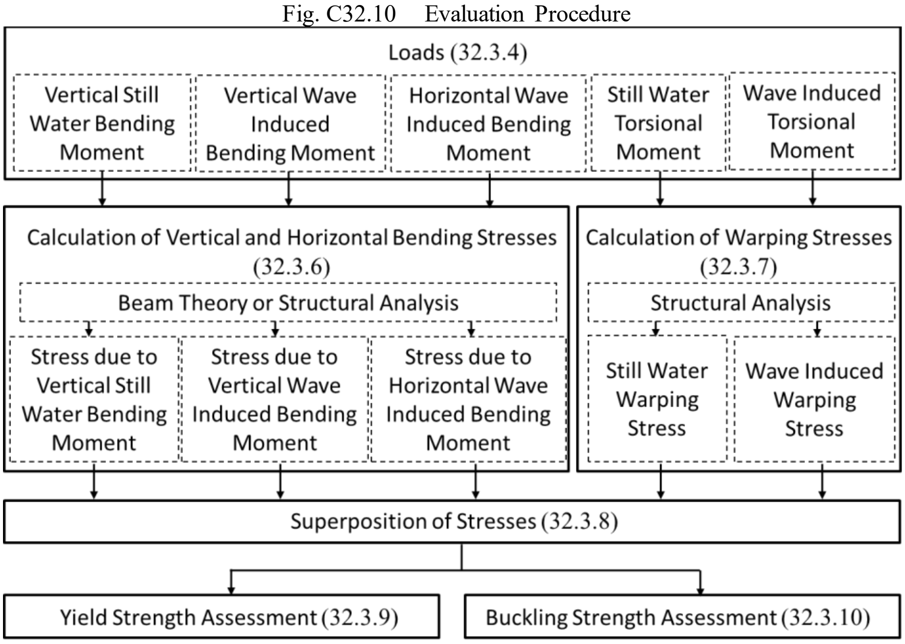
(1) Vertical still water bending moments, vertical wave induced bending moments, horizontal wave induced bending moments, still water torsional moments and wave induced torsional moments are to be considered as applied loads;

(2) Stresses due to vertical still water bending moments, vertical wave induced bending moments and horizontal wave induced bending moments are to be calculated using beam theory or structural analysis of a full ship FE model;

(3) Warping stresses due to still water torsional moments and wave induced torsional moments are to be calculated using structural analysis of a full ship FE model; and

(4) Yielding strength assessments and buckling strength assessments are to be carried out based upon evaluated stresses determined by combining the stress components.

Fig. C32.10 Evaluation Procedure



Note: Numbers in parentheses indicate section number

32.3.4 Loads*

1 The horizontal wave induced bending moments, M_{H1} and M_{H2}, are to be obtained from the following formulae:

$$M_{H1} = M_H \cdot C_{H1}$$

$$M_{H2} = M_H \cdot C_{H2}$$

M_H: As given by the following formula:

$$M_H = 0.32 C_1 C_2 {L_1}^2 d \sqrt{\frac{L_1 - 35}{L_1}} \quad (kN\text{-}m)$$

C_1: Coefficient, to be taken as follows:

$$C_1 = 10.75 - \left(\frac{300 - L_1}{100}\right)^{1.5} \quad \text{for } L_1 \leq 300\ m$$

$$C_1 = 10.75 \quad \text{for } 300\ m < L_1 \leq 350\ m$$

$$C_1 = 10.75 - \left(\frac{L_1 - 350}{150}\right)^{1.5} \quad \text{for } 350\ m < L_1$$

C_2: Coefficient, to be taken as 0.9

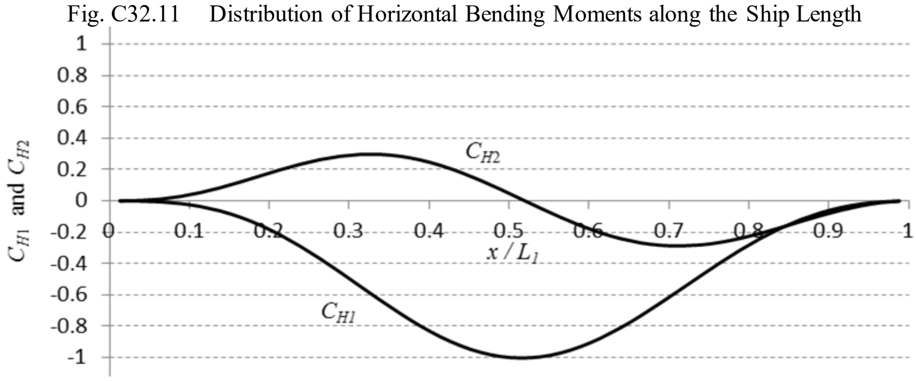
C_{H1}, C_{H2}: As given by the following formulae (See **Fig. C32.11**):

$$C_{H1} = -\cos\left(0.77\pi\left(\frac{x}{L_1} - 0.52\right)\right)\sin^2\left(\pi\frac{x}{L_1}\right) \cdot \left(\frac{1 - \exp(-6x/L_1)}{1 - \exp(-3)}\right)$$

$$C_{H2} = -\sin\left(0.77\pi\left(\frac{x}{L_1} - 0.52\right)\right)\sin^2\left(\pi\frac{x}{L_1}\right) \cdot \left(\frac{1 - \exp(-6x/L_1)}{1 - \exp(-3)}\right)$$

x: Distance from AE (m)

Fig. C32.11 Distribution of Horizontal Bending Moments along the Ship Length



2 Still water torsional moments and wave induced torsional moments are to be in accordance with the following **(1)** and **(2)**:

(1) The still water torsional moments, M_{ST1} and M_{ST2}, are to be obtained from the following formulae:

$$M_{ST1} = M_{ST\_MAX} \cdot C_{T1}$$

$$M_{ST2} = M_{ST\_MAX} \cdot C_{T2}$$

M_{ST_MAX}: The maximum of values distributed along the longitudinal direction for the permissible maximum still water torsional moment defined in the loading manual

C_{T1},C_{T2}: As given by the following formulae (See **Fig. C32.12**):

$$C_{T1} = 1.0\left[\sin\left(2\pi\frac{x}{L_1}\right) + 0.1\sin^2\left(\pi\frac{x}{L_1}\right)\right]\exp\left(-0.35\frac{x}{L_1}\right)\exp\left(-8\left(\frac{x/L_1 - 0.5}{0.5}\right)^{10}\right)$$

$$C_{T2} = 0.5\left[-\sin\left(3\pi\frac{x}{L_1}\right) + 0.65\sin^3\left(\pi\frac{x}{L_1}\right)\right]\exp\left(-0.4\frac{x}{L_1}\right)\exp\left(-8\left(\frac{x/L_1 - 0.5}{0.5}\right)^{10}\right)$$

x: Distance from AE (m)

(2) The wave induced torsional moments, M_{WT1} and M_{WT2}, are to be obtained from the following formulae:

$$M_{WT1} = M_{WT} \cdot C_{T1}$$

$$M_{WT2} = M_{WT} \cdot C_{T2}$$

M_{WT}: As given by the following formula:

$$M_{WT} = 1.3C_1C_2L_1dC_b'(0.65d + e) + 0.2C_1C_2L_1B^2C_W$$

C_1,C_2: As specified in **-1** above

C_b': Volume of displacement corresponding to the designed maximum load line divided by L_1Bd

e: Distance from baseline to shear centre at the midship section (m)

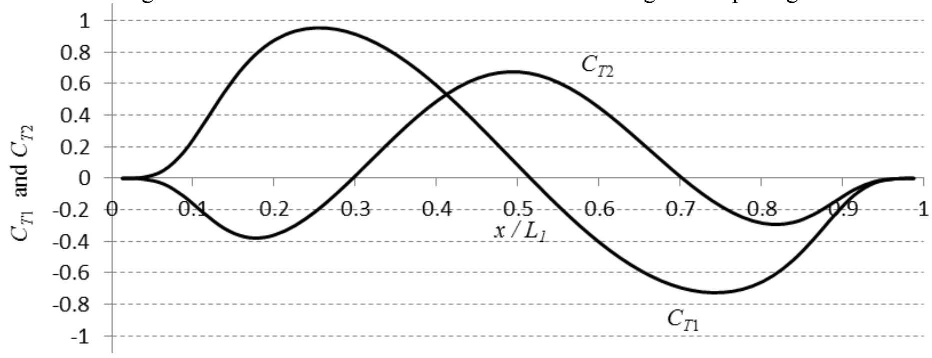
C_W: Waterplane coefficient at the designed maximum load draught, to be taken as follows:

$$C_W = \frac{A_W}{L_1B}$$

A_W: Waterplane area at the designed maximum load draught (m^2)

C_{T1},C_{T2}: As specified in **(1)** above

Fig. C32.12 Distribution of Torsional Moments along the Ship Length



32.3.5 Modelling for Structural Analysis*

1 Structural models are to be for the entire ship, both the port and starboard sides.

2 Structural models are to take into account all longitudinal members, primary supporting members and longitudinal stiffeners.

3 The thickness of models and dimensions of stiffeners are to be based upon the gross scantling approach.

4 Finite element types are to be in accordance with the following **(1)** and **(2)**:

(1) Shell elements are to be used to represent plates; and

(2) Stiffeners are to be modelled so that the model has the same sectional properties as those of the considered transverse section. Several small stiffeners may be combined into one equivalent element according to the meshing size of element.

5 The meshing of element is to be performed so as to accurately reproduce the structural responses to be assessed.

6 Structural model validity is to be verified. Stresses obtained when vertical bending moments and horizontal bending moments are applied are to be confirmed to be equivalent to the stresses calculated using beam theory.

7 Boundary conditions are to be set accordingly to correctly reflect any warping stresses caused by the torsional moment.

32.3.6 Calculation of Stresses due to Vertical Bending Moment and Horizontal Bending Moment*

1 Stresses due to vertical bending moments and horizontal moments are to be in accordance with the following **(1)** and **(2)**. The sign convention for tension stress is to be positive, while the sign convention for compressive stress is to be negative.

(1) The stress due to vertical still water bending moment, σ_S, and the stress due to vertical wave induced bending moment, σ_W, are to be obtained from the following formulae:

$$\sigma_S = \frac{M_S}{1000I} \cdot (z - z_n) \ (N/mm^2)$$

$$\sigma_W = \frac{M_W}{1000I} \cdot (z - z_n) \ (N/mm^2)$$

M_S: Permissible maximum vertical still water bending moment and permissible minimum vertical still water bending moment (kN-m) specified in **32.2.3-4** at the cross section under consideration

M_W: Vertical wave induced bending moment (kN-m) specified in **32.2.3-6** at the cross section under consideration. The combination of M_S and M_W is to be in accordance with the load cases for hogging and sagging specified in **32.2.3-**

8.

I: Moment of inertia around horizontal neutral axis (m^4) for the cross section under consideration based upon gross scantling approach

z: Z coordinate at the location under consideration (Vertical distance from base line) (m)

z_n: The distance from base line to horizontal neutral axis (m) for the cross section based upon gross scantling approach

(2) The stresses due to horizontal wave induced bending moments, σ_{H1} and σ_{H2}, are to be obtained from the following formulae:

$$\sigma_{H1} = -\frac{M_{H1}}{1000 I_H} \cdot y \ \ (N/mm^2)$$

$$\sigma_{H2} = -\frac{M_{H2}}{1000 I_H} \cdot y \ \ (N/mm^2)$$

M_{H1}: First component of horizontal bending moment (kN-m) at the cross section under consideration specified in **32.3.4-1**

M_{H2}: Second component of horizontal bending moment (kN-m) at the cross section under consideration specified in **32.3.4-1**

I_H: Moment of inertia around centre line (m^4) for the cross section under consideration based upon gross scantling approach

y: Y coordinate at the location under consideration (Horizontal distance from centre line) (m)

2 Notwithstanding the requirements of **-1** above, the stresses due to vertical bending moments and horizontal bending moments may be calculated using structural analysis of a full ship FE model. In cases where structural analysis is carried out, the effect of bending stresses locally generated in hatch corners need not be considered.

32.3.7 Calculation of Warping Stress due to Torsional Moment*

1 Warping stresses are to be calculated in accordance with the following **(1)** and **(2)** by applying torsional moments to structural models satisfying the requirements of **32.3.5**. The sign convention for tension stress is to be positive, while the sign convention for compressive stress is to be negative.

(1) The still water warping stresses, σ_{ST1} and σ_{ST2}, are to be calculated by applying the structural model the still water torsional moments, M_{ST1} and M_{ST2}, specified in **32.3.4-2(1)**.

(2) The wave induced warping stresses, σ_{WT1} and σ_{WT2}, are to be calculated by applying the structural model the wave induced torsional moments, M_{WT1} and M_{WT2}, specified in **32.3.4-2(2)**.

32.3.8 Superposition of Stresses

Evaluated stress, σ_T, is to be determined by combining each stress component in accordance with the following formula:

$$\sigma_T = C_3 \cdot \left(\sqrt{\sigma_W^2 + (\sigma_{H1} + \sigma_{WT1})^2 + (\sigma_{H2} + \sigma_{WT2})^2} + |\sigma_S| + \sqrt{\sigma_{ST1}^2 + \sigma_{ST2}^2} \right)$$

C_3: Coefficient to correct stress for net scantling approach, to be taken as 1.05

σ_S,σ_W: Stresses due to the vertical still water bending moments and vertical wave induced bending moments (N/mm^2) specified in **32.3.6-1(1)**

σ_{H1},σ_{H2}: Stresses due to the horizontal wave induced bending moments (N/mm^2) specified in **32.3.6-1(2)**

σ_{WT1},σ_{WT2}: The wave induced warping stresses (N/mm^2) specified in **32.3.7(2)**

σ_{ST1},σ_{ST2}: The still water warping stresses (N/mm^2) specified in **32.3.7(1)**

32.3.9 Yield Strength Assessment*

1 Each element for members to be assessed is to be verified according to the criteria given in the following formulae:

For hatch side coamings (including top plates), strength decks, sheer strakes and topmost strakes of inner hulls/bulkheads:

$\sigma_T \leq 200/K$ (N/mm^2)

For bottom shell plating and bilge strakes:

$\sigma_T \leq 210/K$ (N/mm^2)

σ_T: As specified in **32.3.8**

K: Coefficient corresponding to the kind of steel

e.g.,1.0 for mild steel, the values specified in **1.1.7-2(1)** for high tensile steel

2 The requirements in **-1** above need not be applied to the locations where localized stress increase is due to hatch deformation, etc. (*e.g.*, foremost cargo holds and the fore/aft ends of engine rooms and accommodation areas) provided that fatigue strength assessments are carried out. However, the evaluated stress obtained in accordance with **32.3.8** is to be less than the specified minimum yield stress of relevant steel assigned at such locations.

32.3.10 Buckling Strength Assessment*

1 The buckling strength of panels and stiffeners for members to be assessed is to be verified as being adequate.

2 A structural member is considered to have acceptable buckling strength if it satisfies the following criteria:

For hatch side coamings (including top plates), strength decks, sheer strakes, topmost strakes of inner hulls/bulkheads and longitudinal stiffeners attached to these members:

$\eta_{act} \leq 1.0$

For bottom shell plating, bilge strakes and longitudinal stiffeners attached to these members:

$\eta_{act} \leq 0.9$

η_{act}: Buckling utilisation factor based upon the applied stress obtained from structural analysis, which is separately specified by the Society.

32.4 Double Bottom Construction

32.4.1 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 **32.4**. Unless otherwise specified in **32.4**, such construction is also to be in accordance with the requirements in **Chapter 6**.

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.

3 In application of the requirements in **-1** above, the thickness of bottom shell plating and inner bottom plating in the double bottom spaces for void spaces, fuel oil tanks, etc. which do not contain sea water in service conditions may be reduced by 0.5 *mm* from the thickness prescribed in each respective applicable requirement.

32.4.2 Longitudinals

1 The section modulus of bottom longitudinals Z 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 **32.4.3** is provided midway between floors $C = 1.0$

Where a strut specified in **32.4.3** 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 C_b

Where C_b exceeds 0.85, C_b' is to be 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 $0.3\,L$.

f_B: Ratio of the section modulus Z'_σ of the transverse section of the hull on the basis of mild steel required in the following formula to the actual net section modulus of the transverse section of the hull at the bottom

$Z'_\sigma = 5.27|M_S + M_W|$ (cm^3)

M_S, M_W: Vertical still water bending moment and vertical wave induced bending moment for the load cases "hogging" and "sagging" as specified in **32.2.3-8**

K: Coefficient corresponding to the kind of steel

e.g. 1.0 for mild steel, the values specified in **1.1.7-2(1)** for high tensile steel

L': Length of ship L (m)

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

y: Horizontal distance (m) from the centre line of the ship to the longitudinals under consideration

l: Spacing of solid floors (m)

S: Spacing of longitudinals (m)

2 The section modulus Z of inner bottom longitudinals is not to be less than that obtained from the following formula. However, the section modulus 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:

$$\alpha = 15.5f_B\left(1 - \frac{z}{z_B}\right)$$

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 determined from **Table C32.9**

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 $10m$.

b_t: Tank breadth (m)

It is not to be less than $10m$.

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 C32.9 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.C13.1(a) of the Rules**)
2. "Soft connection by bracket" is a connection by bracket of the stiffener to transverse members such as beams, frames, or the equivalent thereto. (*see* **Fig.C13.1 (b) of the Rules**)

32.4.3 Vertical Struts

Where vertical struts are provided, the sectional area A is not to be less than that obtained from the following formula:

$$A = 0.9CKSb(d + 0.026L') \ (cm^2)$$

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 **32.4.2-1**

l_s: 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

32.4.4 Thickness of 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 formulae.

$$t_1 = \frac{C_1 K}{1000} \cdot \frac{B^2 d}{d_0} + 2.5 \ (mm)$$

$$t_2 = C_2 S\sqrt{1.13K(d - d_0)} + 2.5 \ (mm)$$

$$t_3 = 3.6C_3 S\sqrt{Kh} + 3.0 \ (mm)$$

C_1: b_0 or $\alpha' b_1$ given below according to the value of $\frac{B}{l_H}$:

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

b_0 or $\alpha' b_1$, whichever is greater for $0.8 \le \frac{B}{l_H} < 1.2$

$\alpha' b_1$ for $1.2 \le \frac{B}{l_H}$

l_H: Length (m) of the hold

b_0 and b_1: As given in **Table C32.10** 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.

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

f_B: As specified in **32.4.2-1**

d_0: Height (m) of centre girders

C_2: Coefficient given by the following formula, according to the value of $\frac{l}{S}$.

$0.43\frac{l}{S}+2.5$ for $1 \le \frac{l}{S} < 3.5$

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

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

S: Spacing of stiffeners (m)

h: As specified in **32.4.2-2**

K: As specified in **32.4.2-1**

C_3: Coefficient given in the following formulae according to the stiffening system of inner bottom plating used, however, for h_2 and h_3, C_3 is to be taken as 1.

(a) For transverse system

$$C_3=\frac{27.7}{\sqrt{767-\alpha^2K^2}}$$

α: As specified in **32.4.2-2**

(b) For longitudinal system

$C_3=\frac{3.72}{\sqrt{27.7-\alpha K}}$, however, C_3 is not to be less than 1.0.

α: As specified in **32.4.2-2**

Table C32.10 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_0		4.4	3.9	3.3	2.2	1.6	-	-	-
b_1		-	-	-	2.2	2.1	1.9	1.7	1.4

2 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.

32.4.5 Bottom Shell Plating

1 The thickness t of bottom shell plating is not to be less than the greater of the values obtained from the following formulae:

$$t_1=\frac{C_1K}{1000}\cdot\frac{B^2d}{d_0}+2.5 \quad (mm)$$

$$t_2=C_2C_3S\sqrt{d+0.0175L'\left(\frac{2}{B}y+1\right)+h_1}+2.5 \quad (mm)$$

Where:

d_0: Height (m) of centre girders

C_1: As specified in **32.4.4-1**. However α' is to be obtained from the following formula.

$$\alpha'=\frac{13.8}{24-15.5f_BK}$$

S: Spacing (m) of stiffeners

L', y, h_1: As specified in 32.4.2-1

C_2: 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_2 is to be obtained by linear interpolation.

C_3: Coefficient given in the following formulae according to the stiffening system of inner bottom plating used:

(a) In case of a transverse system

$$C_3 = \frac{91}{\sqrt{576-(15.5f_B)^2}}$$

f_B: As specified in 32.4.2-1

(b) In case of a longitudinal system

$$C_3 = 13\sqrt{\frac{K}{24-15.5f_B K}}$$, however, the value of C_3 is not to be less than $3.78\sqrt{K}$

f_B and K: As specified in 32.4.2-1

2 Notwithstanding the requirement in -1, the thickness t of bottom shell plating is to be not less than obtained from the following formula.

$$t = \sqrt{KL'} \ (mm)$$

L': Length of ship L (m)

However, where L exceeds 330 m, L' is to be taken as 330 m.

K : As specified in 32.4.2-1

3 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)

4 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 32.4.5 plus 2.0 mm. However, this thickness is not to be less than that of adjacent bottom shell plating.

32.5 Double Side Construction

32.5.1 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 The construction of the double side construction in holds which are exclusively loaded with containers is to be in accordance with the requirements in 32.5. Unless otherwise specified in 32.5, such construction is also to be in accordance with the requirements in Chapter 13.

3 Double side shell structures, the interiors of which are used as deep tanks, are to be in accordance with the requirements in Chapter 14 unless otherwise specified in 32.5.

4 In the application of the requirements in -2 and -3, the thickness of side shell plating and inner hull plating in double side spaces for void spaces, fuel oil tanks, etc. which do not contain sea water in service conditions may be reduced by 0.5 mm from the thickness prescribed in each respective applicable requirement.

5 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.

6 Where the width of the double side shell changes in the bilge part, the scantlings are to be at the discretion of the Society.

7 Where structures effectively support deck structures and side shell structures in the midway of holds, the requirements in 32.5 may be appropriately modified.

8 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.

9 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.

10 At the fore and aft ends of the double side structure, sufficient considerations are to be made to the continuity of construction and strength.

32.5.2 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:

$$t_1 = 0.083\frac{CKSl_H}{d_1 - a}(d + 0.038L') + 2.5 \ (mm)$$

$$t_2 = 8.6\sqrt[3]{\frac{d_1^2(t_1 - 2.5)}{kK}} + 2.5 \ (mm)$$

$$t_3 = \frac{8.5}{\sqrt{K}}S_2 + 2.5 \ (mm)$$

Where:

C: As obtained from the following formula:

$$C = (C_1 + \beta_T C_2)C_3$$

C_1 and C_2: As obtained from **Table C32.11** 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 **32.4.2-1**

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 L (m).

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

k: Coefficient obtained from **Table C32.12** 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 C32.11 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 C32.12 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 formulae, whichever is the greatest:

$$t_1 = 0.083\frac{CKSl_H}{d_1 - a}(d + 0.038L') + 2.5\ \ (mm)$$

$$t_2 = 8.6\sqrt[3]{\frac{d_1^2(t_1 - 2.5)}{kK}} + 2.5\ \ (mm)$$

$$t_3 = \frac{8.5}{\sqrt{K}}S_2 + 2.5\ \ (mm)$$

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 C32.13**, 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:

$$\beta_L = 1 + \frac{0.18\left(\frac{B}{Ds}\right)^2 - 0.5}{0.59\frac{Ds - \frac{d_0}{2}}{B - d_1}\left(\frac{d_0}{d_1}\right)^2 + 1.0}$$

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 **32.4.2-1**

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 C32.12** 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 C32.13 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

32.5.3 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

$$t = 3.6CS\sqrt{Kh} + 2.0\ \ (mm)$$

Where:

S: Spacing of stiffeners (m)

K: As specified in **32.4.2-1**

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:

$$h_2 = 0.85(h_1 + \Delta h) \ (m)$$

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 $10m$.

b_t: Tank breadth (m)
It is not to be less than $10m$.

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:

$$\alpha = 15.5 f_B \left(1 - \frac{z}{z_B}\right) \text{ where } z \leq z_B$$

$$\alpha = 15.5 f_D \frac{z - z_B}{Z'} \text{ where } z_B < z$$

$$\alpha = \frac{1}{9.81} \frac{M_H}{I_H} y_H \times 10^5$$

f_B: As specified in **32.4.2-1**

z: Vertical distance (m) from the top of the keel to the lower edge of inner hull plating

z_B: As specified in **32.4.2-2**

f_D: Ratio of the section modulus of the transverse section of hull on the basis of mild steel required in **32.4.2-1** to the net actual section modulus of the hull at the strength deck

Z': The greater of the values specified in **32.2.9(5)(a)** and **(b)**

M_H: As given by the following formula

$$M_H = 0.45 C_1 L^2 d(C_b + 0.05) C_H \ (kN\text{-}m)$$

C_1 : As given by the following formula

$$10.75 - \left(\frac{300 - L_1}{100}\right)^{1.5} \quad \text{for } L_1 \leq 300m$$

$$10.75 \quad \text{for } 300m < L_1 \leq 350m$$

$$10.75 - \left(\frac{L_1 - 350}{150}\right)^{1.5} \quad \text{for } 350m < L_1$$

C_H: Coefficient, as given in **Table C32.14**, 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.

I_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 than 1.0.

Where:

α: As specified in **(a)**

(2) Section modulus Z of longitudinal stiffeners on inner hull plating

$Z = 100C_1C_2Shl^2$ (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 **(1)(a)**

C_2: As specified in **32.4.2-2**

S: Spacing of stiffeners (m)

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

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 C32.14 Coefficient C_H

x/L	0.0	0.4	0.7	1.0
C_H	0.0	1.0	1.0	0.0

32.5.4 Side Shell Plating

1 The side shell plating below the strength deck is to be in accordance with the requirements in **32.5.4**. Unless otherwise specified in **32.5.4**, such plating is also to be in accordance with the requirements in **Chapter 16**.

2 The thickness t of side shell plating other than the sheer strake specified in **16.3.3** is not to be less than that obtained from the following formula:

$t = C_1C_2S\sqrt{d-z'+0.05L'+h_1}+2.0$ (mm)

Where:

C_1: Coefficient given in the following formulae according to the stiffening system of inner bottom plating used.

(a) For transverse system

$$C_1 = 91\sqrt{\frac{K}{576-\alpha^2K^2}}$$

K: As specified in **32.4.2-1**

α: As given in following formulae, whichever is greater

$$\alpha = 15.5f_B\left(1-\frac{z}{z_B}\right)$$

$$\alpha = \frac{1}{9.81}\frac{M_H}{I_H}y_H \times 10^5$$

z_B: As specified in **32.4.2-2**

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 **32.4.2-1**

M_H, I_H and y_H: As specified in **32.5.3(1)(a)**

(b) For longitudinal system

$C_1 = 13\sqrt{\frac{K}{24-\alpha K}}$, however, C_1 is not to be less than $3.78\sqrt{K}$

K, α: As specified in **(a)** above

S: Spacing of stiffeners (m)

C_2, L' and h_1: As specified in **32.4.5-1.**

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.

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 following formula.

$t = \sqrt{KL'}$ (mm)

L': Length of ship L (m)

However, where L exceeds 330 m, L' is to be taken as 330 m.

K: As specified in **32.4.2-1**

32.5.5 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) $Z = 90CShl^2$ (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 **32.4.2-1**

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 formulae, whichever is greater:

$\alpha = 15.5f_B\left(1-\frac{z}{z_B}\right)$ where $z \leq z_B$

$\alpha = 15.5f_D\frac{z-z_B}{Z'}$ where $z_B < z$

$\alpha = \frac{1}{9.81}\frac{M_H}{I_H}y_H \times 10^5$

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

z_B: As specified in **32.4.2-2**

f_B, f_D and Z': As specified in **32.5.3(1)(a)**

M_H, I_H and y_H: As specified in **32.5.3(1)(a)**

(2) $Z = 2.9K\sqrt{L'}Sl^2$ (cm^3)

K, L', S and l: As specified in **(1)**

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 **32.5.3(2).**

32.6 Transverse Bulkheads

32.6.1 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.

32.6.2 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.

32.7 Deck Construction

32.7.1 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 t of deck plating (including the bottom plate in case of box-shaped construction)

$$t = 0.00417 C_1 K \left(\frac{l_v^2 l_c}{w_c} \right) + 2.5 \ \ (mm)$$

Where:

K: As specified in **32.4.2-1**

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 C32.15** in accordance with the value of α

For intermediate values of α, the values of C_1 are to be determined by linear interpolation.

α: As obtained from the following formula:

$$\alpha = 0.5 l_c \sqrt[4]{\frac{3}{4 S l_v^3} \frac{I_v}{I_c}}$$

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

$$Z = 1.43 C_2 K l_v^2 l_c^2 \ \ (cm^3)$$

Where:

C_2: As obtained from **Table C32.15** 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

$$I = 0.38 \frac{l_c^4}{S l_v^3} I_v \ \ (cm^4)$$

Where:

S, l_c, l_v and I_v: As specified in **(1)**

Table C32.15 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

32.7.2 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.

32.7.3 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.

32.8 Strength at Large Flare Locations

32.8.1 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.

32.8.2 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.

32.8.3 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.

32.9 Direct Strength Calculations for Primary Structural Members

32.9.1 Application*

1 For ships of not less than 150 *m* in length L_1, the structural arrangements and scantlings of primary structural members are to be determined based upon the direct strength calculations prescribed in this section. Primary structural members are members of girder or stringer type which provide overall structural integrity for the hull envelope and cargo hold boundaries, such as the following **(1)** to **(4)**:

(1) Double bottom structure (bottom plate, inner bottom plate, girders, floors);

(2) Double side structure (shell plating, inner hull, stringers and web frames);

(3) Bulkhead structure; and

(4) Deck and cross deck structure

2 For ships of less than 150 *m* in length L_1, the structural arrangements and scantlings of primary structural members, as specified in **-1** above, may be determined based upon direct strength calculations deemed appropriate by the Society.

3 Where the structural arrangements and scantlings of primary structural members are determined in accordance with **-1** and **-2**, formulae in this chapter which can be substituted for by direct strength calculations need not be applied.

32.9.2 Verification of Calculation Method and Accuracy

1 Where the structural arrangements and scantlings of primary structural members are determined by direct strength calculation, necessary documents and data related to the calculation method are to be submitted beforehand to the Society for approval.

2 Analysis programs are to have sufficient accuracy. If deemed necessary, the Society may require the submission of details regarding the analysis method, verification of accuracy, etc.

32.9.3 Procedure for Evaluation

The procedure for evaluation of primary structural members is given in the following **(1)** to **(4)** (See **Fig. C32.13**):

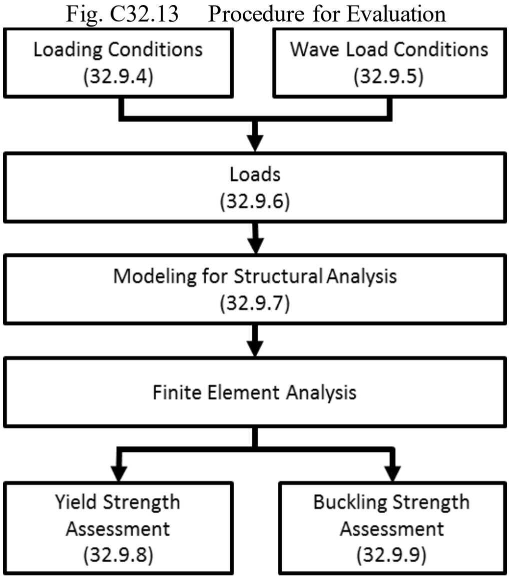
(1) Corrosion additions are deducted from the members being modelled. In principal, the longitudinal extent of the cargo hold structural model is to cover three cargo hold lengths;

(2) Each load case represents a considered combination of loading conditions and wave load conditions;

(3) Loads and boundary conditions for a load case are applied to the structural model, and stresses are determined by performing structural analysis using Finite Element Method (FEM); and

(4) Yielding strength and buckling strength are evaluated using the stresses calculated by structural analysis. The evaluation area is to be the middle hold of the three cargo hold length FE model and is to include any watertight bulkheads and their supporting members located forward and aft of the considered cargo hold.

Fig. C32.13 Procedure for Evaluation

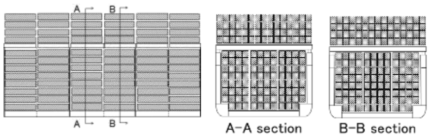
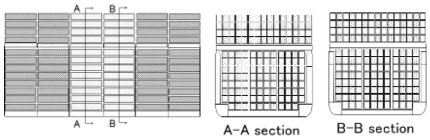
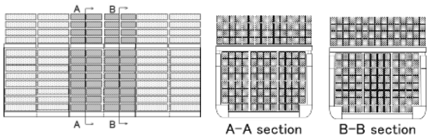
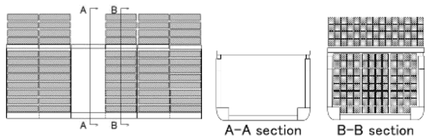


Note: Numbers in parentheses indicate section number

32.9.4 Loading Conditions

The minimum set of loading conditions for yielding strength assessment and buckling strength assessment is specified in **Table C32.16**. In addition, loading conditions specified in the loading manual are to be considered where deemed necessary.

Table C32.16 Loading Conditions

Loading condition	Loading patterns	Draught	Container weight of cargo hold to be evaluated	Ballast and fuel oil tanks	Vertical still water bending moment M_S
40' containers loading condition *FH*4		d_S	40' containers weight(1)	Empty	$M_{S\,max}$
Light 40' containers loading condition *FL*4(4)		d_S	Light 40' containers weight (2), (3)	Empty	$M_{S\,max}$
20' containers loading condition *RH*2(5)		0.9 d_S	20' containers weight(1)	Empty	$M_{S\,min}$
One bay empty condition *OH*4(6)		d_S	40' containers weight(1)	Empty	$M_{S\,max}$

Notes:

$M_{S\,max}$: Permissible maximum vertical still water bending moment in seagoing condition (*kN-m*) at the cross section under consideration.

$M_{S\,min}$: Permissible minimum vertical still water bending moment in seagoing condition (*kN-m*) at the cross section under consideration.

(1): Container unit weight is to be calculated as the permissible stacking weight divided by the maximum number of tiers planned.

(2): Light container unit weight in hold is to be taken as 50% of its related container unit weight.

(3): Light container unit weight on deck is to be taken as 50% of its related container unit weight or 17 metric tons, whichever is the lesser.

(4): For loading condition *FL*4, 40' containers are assumed to be loaded in the cargo holds not being evaluated.

(5): For loading condition *RH*2, light 40' containers are assumed to be loaded in the cargo holds not being evaluated.

(6): For one bay empty condition, if the cargo hold consists of two or more bays, then each bay is to be considered entirely empty in hold and on deck (other bays full) in turn as separate load cases.

32.9.5 Wave Load Conditions

1 The wave load conditions considered in this section are given in **Table C32.17**. The definitions of weather side down and weather side up are according to **Fig. C32.14**.

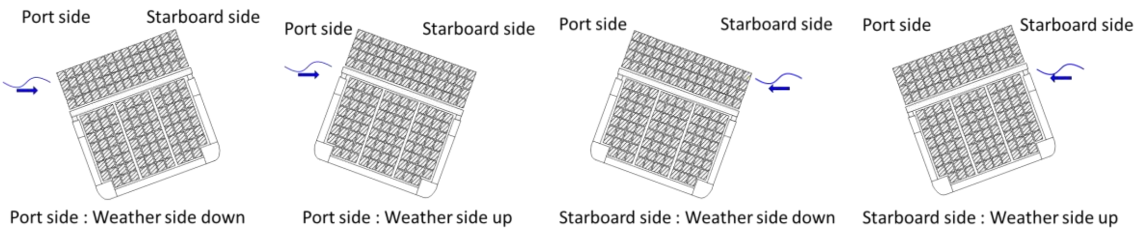
2 The wave loads may be set based upon the sea conditions in a restricted area, such as a calm water area or a coastal area, if the ship is planned for service in calm water area or coastal area and is registered under the condition of the restricted area.

3 Notwithstanding **-1** above, wave loads may be changed accordingly when the loading conditions are limited to sea areas where the effects of waves are small, such as in enclosed seas or harbours.

Table C32.17 Wave Load Conditions

Wave load condition		Heading	Conditions	
L-180	L-180-1	Head sea	Hogging	Vertical wave induced bending moment amidships reaches its maximum in head sea
	L-180-2	Head sea	Sagging	Vertical wave induced bending moment amidships reaches its maximum in head sea
L-0	L-0-1	Following sea	Hogging	Vertical wave induced bending moment amidships reaches its maximum in following sea
	L-0-2	Following sea	Sagging	Vertical wave induced bending moment amidships reaches its maximum in following sea
R	R-P1	Beam sea	Port side: weather side down	Roll of vessel reaches its maximum
	R-P2	Beam sea	Port side: weather side up	Roll of vessel reaches its maximum
	R-S1	Beam sea	Starboard side: weather side down	Roll of vessel reaches its maximum
	R-S2	Beam sea	Starboard side: weather side up	Roll of vessel reaches its maximum
P	P-P1	Beam sea	Port side: weather side down	Hydrodynamic pressure at the waterline amidships reaches its maximum
	P-P2	Beam sea	Port side: weather side up	Hydrodynamic pressure at the waterline amidships reaches its maximum
	P-S1	Beam sea	Starboard side: weather side down	Hydrodynamic pressure at the waterline amidships reaches its maximum
	P-S2	Beam sea	Starboard side: weather side up	Hydrodynamic pressure at the waterline amidships reaches its maximum

Fig. C32.14 Definitions of Weather Side Down and Weather Side Up



32.9.6 Loads

1 Ship motion and acceleration are to be in accordance with the following **(1)** to **(3)**:

(1) The pitch angle, θ, and roll angle, ϕ, are to be as given in **Table C32.18**.

(2) The acceleration at the centre of gravity of the ship due to pitch motion a_{pitch}, roll motion a_{roll}, and heave motion a_{heave} are to be as given in **Table C32.19**.

(3) The vertical acceleration a_v, transverse acceleration a_t, and longitudinal acceleration a_ℓ at the centre of gravity of a container are to be as given in **Table C32.20**.

Table C32.18 Ship Motion

Pitch angle	$\theta = \frac{5.4}{L_1{}^{1.2}\sqrt{C_b'}} H_{L-180} (rad.)$
Roll angle	$\phi = \frac{4}{T_R\sqrt{B}} H_R (rad.)$

Notes:

C_b': As specified in **32.2.4-1**.

H_{L-180}: As given by the following formula:

$$H_{L-180} = 1.1 C_1 C_2 \sqrt{\frac{L_1 + \lambda_{L-180} - 25}{L_1}}$$

H_R: As given by the following formula:

$$H_R = 0.64 C_1 C_2 \sqrt{\frac{L_1 + \lambda_R - 25}{L_1}}$$

C_1: Coefficient to be taken as follows:

$C_1 = 10.75 - \left(\frac{300 - L_1}{100}\right)^{1.5}$ for $L_1 \leq 300\ m$

$C_1 = 10.75$ for $300\ m < L_1 \leq 350\ m$

$C_1 = 10.75 - \left(\frac{L_1 - 350}{150}\right)^{1.5}$ for $350\ m < L_1$

C_2: Coefficient to be taken as follows:

$C_2 = 0.85$

λ_{L-180}: As given by the following formula:

$$\lambda_{L-180} = 0.5\left(1 + \frac{d_i}{d_s}\right) L_1 \ (m)$$

λ_R: As given by the following formula:

$$\lambda_R = \frac{g}{2\pi} T_R{}^2 \ (m)$$

d_i: Draught amidships for the relevant loading condition (m).

g: Gravity acceleration, taken as 9.81 (m/s^2).

T_R: As given by the following formula:

$$T_R = C\frac{2K_{xx}}{\sqrt{GM}} \ (s)$$

C: Coefficient, taken as 1.1

K_{xx}: Roll radius of gyration (m). If K_{xx} is not available, K_{xx} may be calculated as $K_{xx} = 0.35B$

GM: Metacentric height (m); If GM is not available, GM may be calculated from the following formulae, but is not to be taken as $0.06B$ or below.

$GM = 0.52B - 0.55D_S - 5.26$ for loading condition $FH4$, $FL4$, $OH4$

$GM = 0.52B - 0.53D_S - 4.84$ for loading condition $RH2$

Table C32.19 Acceleration of the Centre of Gravity of the Ship

Acceleration at the centre of gravity of the ship due to pitch motion	$a_{pitch} = \theta \cdot \frac{2\pi \cdot g}{\lambda_{L-180}}$ $(rad./s^2)$
Acceleration at the centre of gravity of the ship due to roll motion	$a_{roll} = \phi \cdot GM\left(\frac{\pi}{C \cdot K_{xx}}\right)^2$ $(rad./s^2)$
Acceleration at the centre of gravity of the ship due to heave motion	$a_{heave} = \frac{5.4g}{(B \cdot L_1)^{0.6}\sqrt{C'_b}} H_P$ (m/s^2)

Notes:

$C'_b, \theta, \phi, \lambda_{L-180}, GM, K_{xx}$: As specified in **Table C32.18**.

g: Acceleration due to gravity, taken as 9.81 (m/s^2).

C: Coefficient, taken as 1.1

H_P: As given by the following formula:

$$H_P = 0.93C_1C_2\sqrt{\frac{L_1 + \lambda_P - 25}{L_1}}$$

C_1 and C_2: As specified in **Table C32.18**.

λ_P: As given by the following formula:

$$\lambda_P = \left(0.2 + 0.15\frac{d_i}{d_s}\right)L_1 \quad (m)$$

d_i: Draught amidships for the relevant loading condition (m) .

Table C32.20 Acceleration at Centre of Gravity of a Container

Wave load condition		Acceleration at the centre of gravity of the container (m/s^2) (vertical acceleration)	Acceleration at the centre of gravity of the container (m/s^2) (transverse acceleration)	Acceleration at the centre of gravity of the container (m/s^2) (longitudinal acceleration)
L-180	L-180-1	$a_v = -0.3a_{heave}$	0	$a_\ell = g\theta + (z_i - z_g)a_{pitch}$
	L-180-2	$a_v = 0.3a_{heave}$	0	$a_\ell = -g\theta - (z_i - z_g)a_{pitch}$
L-0	L-0-1	0	0	0
	L-0-2	0	0	0
R	R-P1	$a_v = 0.1a_{heave} + y_i a_{roll}$	$a_t = -g\phi - (z_i - z_g)a_{roll}$	0
	R-P2	$a_v = -0.1a_{heave} - y_i a_{roll}$	$a_t = g\phi + (z_i - z_g)a_{roll}$	0
	R-S1	$a_v = 0.1a_{heave} - y_i a_{roll}$	$a_t = g\phi + (z_i - z_g)a_{roll}$	0
	R-S2	$a_v = -0.1a_{heave} + y_i a_{roll}$	$a_t = -g\phi - (z_i - z_g)a_{roll}$	0
P	P-P1	$a_v = a_{heave} + 0.5y_i a_{roll}$	$a_t = -0.5g\phi$	0
	P-P2	$a_v = -a_{heave} - 0.5y_i a_{roll}$	$a_t = 0.5g\phi$	0
	P-S1	$a_v = a_{heave} - 0.5y_i a_{roll}$	$a_t = 0.5g\phi$	0
	P-S2	$a_v = -a_{heave} + 0.5y_i a_{roll}$	$a_t = -0.5g\phi$	0

Notes:

g: Acceleration due to gravity, taken as 9.81 (m/s^2).

θ and ϕ: As specified in **Table C32.18**.

a_{pitch}, a_{roll} and a_{heave}: As specified in **Table C32.19**.

y_i: Y coordinate, in *metres*, of the centre of gravity of the container. The centre of gravity may be considered as the midpoint of the container.

z_g: Z coordinate, in *metres*, of the centre of gravity of the ship.

z_i: Z coordinate, in *metres*, of the centre of gravity of the container. The centre of gravity may be considered as the midpoint of the container.

2 Sea pressures are to be considered as external pressures acting on the hull structures. The sea pressures are the sum of hydrostatic pressures and hydrodynamic pressures, and are not to be taken as less than 0. Hydrostatic pressure and hydrodynamic pressures are to be in accordance with the following **(1)** and **(2)**.

(1) The pressure corresponding to the draught in still water is to be considered the hydrostatic pressure for each loading condition. The hydrostatic pressure is to be as given in **Table C32.21**.

(2) Hydrodynamic pressure is to be in accordance with the following requirements **(a)** to **(c)**:

(a) The hydrodynamic pressures P corresponding to the wave load conditions L-180 and L-0 are to be as given in **Table C32.22**, **Fig. C32.15** and **Fig. C32.16**;

(b) The hydrodynamic pressure P corresponding to the wave load condition R is to be as given in **Table C32.23** and **Fig. C32.17**; and

(c) The hydrodynamic pressure P corresponding to the wave load condition P is to be as given in **Table C32.24** and **Fig. C32.18**.

Table C32.21 Hydrostatic Pressure

Location	Hydrostatic Pressure (kN/m^2)
$z \le d_i$	$\rho g(d_i - z)$
$z > d_i$	0

Notes:

ρ: Density of sea water, taken as 1.025 (m/s^2).

g: Acceleration due to gravity, taken as 9.81 (m/s^2).

d_i: Draught amidships for the relevant loading condition (m).

z: Z coordinate, in *metres*, at the position considered.

Table C32.22 Hydrodynamic Pressure Corresponding to Wave Load Conditions L-180 and L-0

Wave load condition		Hydrodynamic pressure (kN/m^2)		
		$z \le d_i$	$d_i < z \le d_i + h_w$	$z > d_i + h_w$
L-180	L-180-1	$P = \max(P_{D,L-180}, \rho g(z-d_i))$	$P = P_{WL} - \rho g(z-d_i)$	$P = 0$
	L-180-2	$P = \max(-P_{D,L-180}, \rho g(z-d_i))$		
L-0	L-0-1	$P = \max(P_{D,L-0}, \rho g(z-d_i))$		
	L-0-2	$P = \max(-P_{D,L-0}, \rho g(z-d_i))$		

Notes:

$P_{D,L-180}$: As given by the following formula:

$$P_{D,L-180} = 2.3C_3\left(\frac{z}{d_i} + \frac{|2y|}{B} + 1\right)H_{L-180}$$

$P_{D,L-0}$: As given by the following formula:

$$P_{D,L-0} = 2.3C_3C_{L-0}\left(\frac{z}{d_i} + \frac{|2y|}{B} + 1\right)H_{L-0}$$

C_3: Coefficient to be taken as :

$C_3 = 0.5$ for wave load condition L-180

$C_3 = 1$ for wave load condition L-0

C_{L-0}: Coefficient to be taken as :

$C_{L-0} = 0.8$

d_i: Draught amidships for the relevant loading condition (m).

y: Y coordinate, in m, at the position considered.

z: Z coordinate, in m, at the position considered.

H_{L-180}: As specified in **Table C32.18**.

H_{L-0}: As given by the following formula:

$$H_{L-0} = 1.1C_1C_2\sqrt{\frac{L_1 + \lambda_{L-0} - 25}{L_1}}$$

C_1 and C_2: As specified in **Table C32.18**.

λ_{L-0}: As given by the following formula:

$$\lambda_{L-0} = 0.5\left(1 + \frac{2}{3}\frac{d_i}{d_s}\right)L_1 \ (m)$$

P_{WL}: Wave pressure at the waterline (kN/m^2) for the considered wave load condition, to be taken as P for $z = d_i$

h_W: Water head equivalent to the pressure at waterline, in *metres*, to be taken as follows:

$$h_W = \frac{P_{WL}}{\rho g}$$

ρ: Density of sea water, taken as 1.025 (m/s^2) .

g: Acceleration due to gravity, taken as 9.81 (m/s^2) .

Fig. C32.15 Distribution of Hydrodynamic Pressure at Midship Section (Wave Load Condition L-180-1)

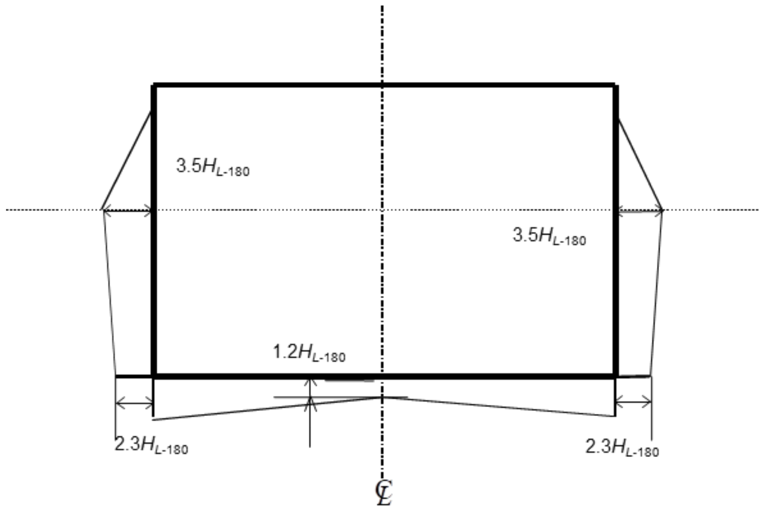


Fig. C32.16 Distribution of Hydrodynamic Pressure at Midship Section (Wave Load Condition L-0-1)

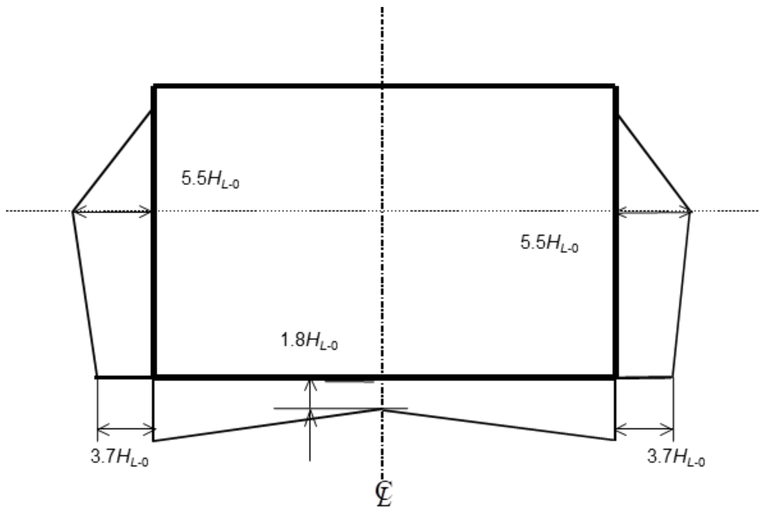


Table C32.23 Hydrodynamic Pressure Corresponding to Wave Load Condition *R*

<table>
<tr><th rowspan="2" colspan="2">Wave load condition</th><th colspan="3">Hydrodynamic pressure (kN/m^2)</th></tr>
<tr><th>$z \le d_i$</th><th>$d_i < z \le d_i + h_w$</th><th>$z > d_i + h_w$</th></tr>
<tr><td rowspan="4">R</td><td>R-$P1$</td><td>$P = \max(P_{D,R-P}, \rho g(z - d_i))$</td><td rowspan="4">$P = P_{WL} - \rho g(z - d_i)$</td><td rowspan="4">$P = 0$</td></tr>
<tr><td>R-$P2$</td><td>$P = \max(-P_{D,R-P}, \rho g(z - d_i))$</td></tr>
<tr><td>R-$S1$</td><td>$P = \max(P_{D,R-S}, \rho g(z - d_i))$</td></tr>
<tr><td>R-$S2$</td><td>$P = \max(-P_{D,R-S}, \rho g(z - d_i))$</td></tr>
</table>

Notes:

$P_{D,R-P}$: As given by the following formula:

$$P_{D,R-P} = 10y\sin\phi + \left(\frac{|2y|}{B} + 1\right)H_R$$

$P_{D,R-S}$: As given by the following formula:

$$P_{D,R-S} = -10y\sin\phi + \left(\frac{|2y|}{B} + 1\right)H_R$$

y: Y coordinate, in *metres*, at the position considered.

z: Z coordinate, in *metres*, at the position considered.

ϕ and H_R: As specified in **Table C32.18**.

P_{WL}: Wave pressure at the waterline (kN/m^2) for the considered wave load condition, to be taken as P for $z = d_i$

h_W: Water head equivalent to the pressure at waterline, in *metres*, to be taken as follows:

$$h_W = \frac{P_{WL}}{\rho g}$$

ρ: Density of sea water, taken as 1.025 (m/s^2) .

g: Acceleration due to gravity, taken as 9.81 (m/s^2) .

Fig. C32.17 Distribution of Hydrodynamic Pressure at Midship Section (Wave Load Condition *R*-*P*1)

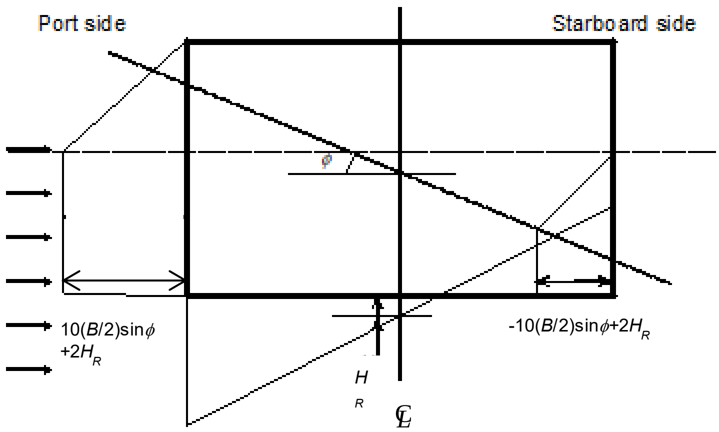


Table C32.24 Hydrodynamic Pressure Corresponding to Wave Load Condition P

Wave load condition		Transverse position	Hydrodynamic pressure (kN/m^2)		
			$z \leq d_i$	$d_i < z \leq d_i + h_w$	$z > d_i + h_w$
P	P-$P1$	$y \geq 0$	$P = \max(P_{D,P}, \rho g(z - d_i))$	$P = P_{WL} - \rho g(z - d_i)$	$P = 0$
		$y < 0$	$P = \max\left(\frac{1}{3}P_{D,P}, \rho g(z - d_i)\right)$		
	P-$P2$	$y \geq 0$	$P = \max(-P_{D,P}, \rho g(z - d_i))$		
		$y < 0$	$P = \max\left(-\frac{1}{3}P_{D,P}, \rho g(z - d_i)\right)$		
	P-$S1$	$y \geq 0$	$P = \max\left(\frac{1}{3}P_{D,P}, \rho g(z - d_i)\right)$		
		$y < 0$	$P = \max(P_{D,P}, \rho g(z - d_i))$		
	P-$S2$	$y \geq 0$	$P = \max\left(-\frac{1}{3}P_{D,P}, \rho g(z - d_i)\right)$		
		$y < 0$	$P = \max(-P_{D,P}, \rho g(z - d_i))$		

Notes:

$P_{D,P}$: As given by the following formula:

$$P_{D,P} = 2.4\left(2\frac{z}{d_i} + 3\frac{|2y|}{B}\right)H_P$$

y: Y coordinate, in *metres*, at the position considered.

z: Z coordinate, in *metres*, at the position considered, $max.(z) = d_i$

d_i: Draught amidships for the relevant loading condition (m).

H_P: As specified in **Table C32.19**.

P_{WL}: Wave pressure at the waterline (kN/m^2) for the considered wave load condition, to be taken as P for $z = d_i$

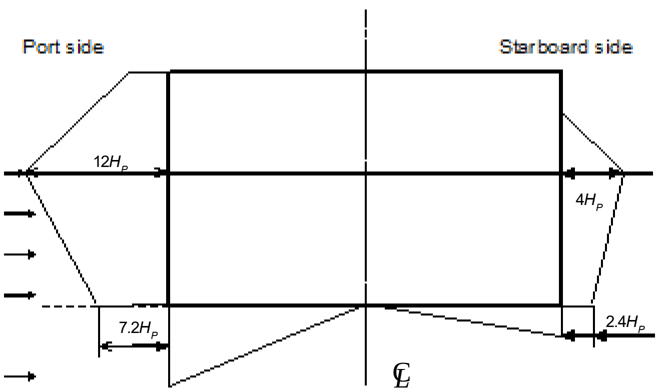
h_W: Water head equivalent to the pressure at waterline, in *metres*, to be taken as follows:

$$h_W = \frac{P_{WL}}{\rho g}$$

ρ: Density of sea water, taken as 1.025 (m/s^2) .

g: Acceleration due to gravity, taken as 9.81 (m/s^2) .

Fig. C32.18 Distribution of Hydrodynamic Pressure at Midship Section (Wave Load Condition P-$P1$)



3 For internal loads, the loads due to containers are to be considered. The loads due to containers are the sum of static and dynamic loads. The static and dynamic loads of containers are to be in accordance with the following **(1)** and **(2)**:

(1) The static loads of containers are considered to be the container weight, W_S (kN);

(2) The dynamic loads of containers, W_C (kN), are to be as given in **Table C32.25**.

Table C32.25 Dynamic Loads of Containers

Vertical load $W_{CV}(kN)$	Transverse load $W_{CT}(kN)$	Longitudinal load $W_{CL}(kN)$
$-W_S\dfrac{a_v}{g}$	$-W_S\dfrac{a_t}{g}$	$-W_S\dfrac{a_\ell}{g}$
Notes: g: Acceleration due to gravity, taken as 9.81 (m/s^2) . W_S: Container weight W_S (kN) . a_v, a_t and a_ℓ: As specified in **Table C32.19**.		

4 The effect of the weight of the hull structure is to be included in static loads, but is not to be included in dynamic loads.

5 Vertical bending moments and horizontal bending moments for direct strength calculations are to be obtained from the following equations:

Vertical bending moment: $M_{V-HG} = M_S + C_4 M_W$ (kN-m)

Horizontal bending moment: $M_{H-HG} = C_5 M_H$ (kN-m)

$C_4 \mathrm{M_{wv}}$: As specified in **Table C32.26**

$C_5 \mathrm{M_{wv}}$: As specified in **Table C32.26**

$M_S \mathrm{M_{sw}}$: Vertical still water bending moment (kN-m) at the cross section under consideration, corresponding to each loading condition. (See **Fig. C32.16**)

$M_W \mathrm{M_{wv}}$: Vertical wave induced bending moment (kN-m) at the cross section under consideration, as specified in **Table C32.26**. (See **32.2.3-6.**)

M_H: Horizontal wave induced bending moment (kN-m) at the cross section under consideration, as specified in **Table C32.26**. $M_H(+)$ or $M_H(-)$ is to be taken according to wave load conditions.

$$M_H(+) = 0.32 C_1 {L_1}^2 d_i \sqrt{\frac{L_1 - 35}{L_1}} \ (kN\text{-}m)$$

$$M_H(-) = -0.32 C_1 {L_1}^2 d_i \sqrt{\frac{L_1 - 35}{L_1}} \ (kN\text{-}m)$$

C_1: As specified in **Table C32.18**

d_i: Draught amidships for the relevant loading condition (m)

Table C32.26 Superimposition Ratio of Vertical Wave Induced Bending Moment and Horizontal Wave Induced Bending Moment

Wave load condition		C_4	M_W	C_5	M_H
L-180	L-180-1	1.0	Hogging M_{W-Hog}	—	—
	L-180-2		Sagging M_{W-Sag}		
L-0	L-0-1	0.8	Hogging M_{W-Hog}	—	—
	L-0-2		Sagging M_{W-Sag}		
R	R-P1	$0.75\frac{d_i}{d_s}-0.55$	Sagging M_{W-Sag}	$1.2-\frac{d_i}{d_s}$	Port side (Compression) $M_H(+)$
	R-P2		Hogging M_{W-Hog}		Port side (Tension) $M_H(-)$
	R-S1		Sagging M_{W-Sag}		Starboard side (Compression) $M_H(-)$
	R-S2		Hogging M_{W-Hog}		Starboard side (Tension) $M_H(+)$
P	P-P1	$\frac{d_i}{d_s}-0.55$	Sagging M_{W-Sag}	$0.7-0.6\frac{d_i}{d_s}$	Port side (Compression) $M_H(+)$
	P-P2		Hogging M_{W-Hog}		Port side (Tension) $M_H(-)$
	P-S1		Sagging M_{W-Sag}		Starboard side (Compression) $M_H(-)$
	P-S2		Hogging M_{W-Hog}		Starboard side (Tension) $M_H(+)$

Notes:

d_i: Draught amidships for the relevant loading condition (m).

M_{W-Hog}: Vertical wave induced bending moment in hogging at the cross section under consideration. (See Fig. C32.6).

M_{W-Sag}: Vertical wave induced bending moment in sagging at the cross section under consideration. (See Fig. C32.6).

32.9.7 Modelling for Structural Analysis*

1 Both the port and starboard sides of the ship are to be modelled.

2 The members to be modelled are the longitudinal members and primary supporting members within the extent of the whole analysed area. Load transmitting members such as longitudinal stiffeners, watertight bulkhead stiffeners and web stiffeners are also to be included in the model.

3 For modelling, the thickness of the model and dimensions of the stiffeners are to be based upon the net scantling approach specified in 32.1.3.

4 Finite element types are to be in accordance with the following **(1)** to **(3)**:

(1) Shell elements are to be used to represent plates;

(2) Beam elements are to be used to represent stiffeners; and

(3) Face plates of primary supporting members and brackets are to be modelled using rod or beam elements.

5 The meshing of elements is to be performed so as to accurately reproduce structural responses within the evaluation area.

6 Openings are to be modelled when deemed necessary by the Society.

7 The manner of applying loads to structural models is to be in accordance with the following **(1)** to **(3)**:

(1) Constant pressure, calculated at the element's centroid, is to be applied to the shell element of the loaded surfaces (e.g., outer shells and decks for external pressure and cargo hold boundaries for internal pressure).

(2) Loads due to containers are to be applied to the nearest nodal point from the location where the container comes into contact as the nodal load.

(3) Adjustment moments are to be applied at the fore and aft ends of the model so that the values of the vertical bending moment and horizontal bending moment at the centre of the evaluation area are not less than those of vertical bending moment and horizontal bending moment specified in 32.9.6-5.

8 Boundary conditions are to be set accordingly to correctly reflect the stress distributions caused by the adjustment moments in -7(3) above with the applicable condition being that model is simply supported at its fore and aft ends.

32.9.8 Yield Strength Assessment*

1 Each element within the evaluation area is to be verified according to the criteria given in the following equation.

$$\sigma_{ref} \leq \frac{235}{K}$$

σ_{ref}: As specified below:

For rod elements, axial stress σ_a (N/mm^2)

For shell elements, equivalent stress at the mid plane of the element σ_{eq} (N/mm^2)

$$\sigma_{eq} = \sqrt{{\sigma_1}^2 - \sigma_1 \cdot \sigma_2 + {\sigma_2}^2 + 3{\tau_{12}}^2}$$

σ_1, σ_2: In-plane normal stresses at the mid plane of the element (N/mm^2)

τ_{12}: Shear stress corresponding to σ_1, σ_2 at the mid plane of the element (N/mm^2)

K: Coefficient corresponding to the kind of steel (e.g., 1.0 for mild steel, the values specified in 1.1.7-2(1) for high tensile steel)

2 When the opening is not modelled, the stresses of any elements around opening are to be modified by a method deemed appropriate by the Society.

32.9.9 Buckling Strength Assessment*

1 The buckling strength of panels and stiffeners within the evaluation area are to be verified as being adequate.

2 A structural member is considered to have an acceptable buckling strength if it satisfies the following criterion:

$$\eta_{act} \leq 1$$

η_{act}: Buckling utilisation factor based upon the applied stress obtained from structural analysis, which is separately specified by the Society.

3 Buckling strength assessments of the web plates of primary supporting members with openings are to be carried out by a method deemed appropriate by the Society.

32.10 Fatigue Strength

32.10.1 Fatigue Strength Assessment*

For bottom longitudinals, side longitudinals, hatch corners, hatch side coamings, and areas of stress concentrations, such as bench corners in forward holds, sufficient consideration is to be given to fatigue strength. The Society may request detailed fatigue strength assessments if deemed necessary.

32.10.2 Structural Details

1 Free edges, including hatch corners of hatch side coamings, are not to have any defects such as notches that may adversely affect fatigue strength. Appropriate edge treatment, including the treatment of corner edges, is to be carried out so that edges have sufficient fatigue strength. Details of the edge treatment used are, in principle, to be clearly mentioned in relevant drawings.

2 In cases where equipment such as hatch cover pads and container pads is fitted, the ends of such equipment are to be tapered so that extreme differences in rigidity do not occur between the equipment and the hull structure. Measures such as increasing the thickness of the plating at the attachment location appropriately, etc. are also to be adopted. Consideration is to be given to equipment materials and welding procedures. In addition, a fatigue strength assessment of the relevant part is to be carried out when deemed necessary by the Society.

3 Hatch side coaming ends, including fillet-welded parts to strength decks, are to be designed so as to have sufficient fatigue strength. For this reason, fatigue strength assessments, including detailed finite element analysis, are to be carried out in principle. In addition, fillet welds for hatch side coaming ends and strength decks are, in principle, to be full penetration welds within a certain range, and boxing welds at the ends are to be smoothened out using a grinder or other means.

4 Special consideration is to be given to fatigue strength in way of drain holes and other holes installed in hatch side coamings.

32.11 Container Supporting Arrangements

32.11.1 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 sides of the ship and the loads due to the containers.

32.12 Welding

32.12.1 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 $0.25D$ 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.

32.12.2 Fillet Welding

1 Fillet welding is to be continuous.

2 The size of fillet is to be not less than 8 *mm*.

32.13 Special Requirements for Container Carriers Applying Extremely Thick Steel Plates

32.13.1 General

This section gives measures for identification and prevention of brittle fractures in container carriers to which extremely thick steel plates are applied for longitudinal structural members in the upper deck region (the upper deck plating, hatch side coaming (including top plating) and their attached longitudinals). These include measures to prevent brittle crack initiation and to arrest brittle crack propagation in case brittle crack initiates.

32.13.2 Application

1 This section is applied when using any of *KA*36, *KD*36, *KE*36, *KA*40, *KD*40, *KE*40 and *KE*47 steel plates having thickness of over 50 *mm* and not greater than 100*mm* for longitudinal structural members in the upper deck regions of container carriers.

2 Notwithstanding the requirement given in **-1** above, when as-built thickness of the hatch side coaming (including top plating) is not greater than 50 *mm*, this section may not be necessarily applied regardless of the thickness and grade of steel of the strength deck.

3 The structural members of container carriers applying extremely thick steel plates are to comply with the requirements in **32.1** to **32.12** in addition to the requirements in **32.13**.

32.13.3 Measures for Prevention of Brittle Fracture*

Measures for prevention of brittle fracture applying to extremely thick steel plates are to be utilized the combination shown in **Table C32.27** according to the thickness and grade of steel of the hatch side coaming (including top plating).

Table C32.27 Application of Measures for Prevention of Brittle Fractures

<table>
<tr><th colspan="2">Hatch side coaming (including top plating)</th><th rowspan="2">Non-destructive inspection during ship construction specified in 1.4.2-1(3), Part M of the Rules</th><th rowspan="2">Brittle crack arrest design specified in 32.13.4</th></tr>
<tr><th>Grade of steel</th><th>Thickness(mm)</th></tr>
<tr><td>KA36
KD36
KE36</td><td>$50 < t \leq 100$</td><td rowspan="2">X</td><td rowspan="2">N.A.</td></tr>
<tr><td rowspan="2">KA40
KD40
KE40</td><td>$50 < t \leq 85$</td></tr>
<tr><td>$85 < t \leq 100$</td><td>X</td><td>X(1)</td></tr>
<tr><td>KE47
(where electro-gas welding is applied at block-to-block butt joints)</td><td>$50 < t \leq 100$</td><td>X</td><td>X</td></tr>
<tr><td>KE47
(where welding procedures other than electro-gas welding are applied at block-to-block butt joints)</td><td>$50 < t \leq 100$</td><td>X</td><td>X(1)</td></tr>
</table>

(SYMBOL)
X : To be applied
N.A. : Need not to be applied
(1) : Other measures deemed by the Society to be equivalent in effectiveness to brittle crack arrest designs may be accepted.

32.13.4 Brittle Crack Arrest Design*

1 The brittle crack arrest design using brittle crack arrest steels specified in this section may be applied when *HT*36 or *HT*40 is used for the upper deck plating. In other cases, however, appropriate measures to prevent the initiation and propagation of brittle cracks deemed appropriate by the Society are to be applied.

2 Brittle crack arrest design is to be utilized to prevent large scale fractures of the hull girder by arresting propagation of the brittle crack at a proper position, even in case where brittle crack initiation occurs within the cargo hold region.

3 Following **(1)** and **(2)** are to be considered as the points of brittle crack initiation.

(1) Block-to-block butt joints both of hatch side coaming and strength deck; and

(2) Any welds other than **(1)** above.

4 Following **(1)** to **(3)** are to be considered as the cases of brittle crack propagation.

(1) Cases where the brittle crack initiates from block-to-block butt joint and runs straight along the butt joint;

(2) Cases where the brittle crack initiates from block-to-block butt joint and deviate away from butt joint and runs into base metal; and

(3) Cases where the brittle crack initiates from any welds other than **(1)** and **(2)** above and runs into base metal.

5 With the consideration of the requirements in **-4** above, measures specified in the following **(1)** to **(3)** are to be applied as brittle crack arrest design to prevent brittle crack propagation;

(1) Brittle crack arrest steel is to be provided for strength deck.

(2) Brittle crack arrest steel is to be provided for hatch side coaming; however, such steel is not necessary to be provided in the attached top plate and longitudinal stiffeners.

(3) Appropriate measures is to be provided at a point of block-to-block butt joint between hatch side coaming and strength deck in order to arrest brittle crack propagation running straight along the butt joint.

6 Notwithstanding the provisions in **-5** above, where the equivalency is verified through technical data and/or brittle fracture tests, etc., brittle crack arrest design other than those specified in **-5** above may be accepted by the Society.

32.13.5 Selection of Brittle Crack Arrest Steels*

1 The brittle crack arrest steel specified in **32.13.4-5(1)** and **(2)** is to be steel plates which are considered to have the brittle crack arrest properties specified in **3.12, Part K of the Rules**.

2 Brittle crack arrest steel properties are to comply with **Table C32.28** depending on the structural member for which it is being used and plate thickness.

3 When the brittle crack arrest steels specified in **Table C32.28** are used, the weld joints between hatch side coamings and upper decks are to be fillet welds at each side without grooves or are to be partial penetration welds. Alternative weld details may be accepted only in the vicinity of ship block-to-block butt weld joints provided additional means for preventing brittle crack propagation are implemented and its validity may be confirmed by technical data or brittle fracture tests, etc. by the Society.

Table C32.28 Brittle Crack Arrest Steel Requirement in Function of Structural Members and Thickness

Structural Members Plating(1)	Thickness t (mm)	Brittle Crack Arrest Properties
Upper Deck	$50 < t \leq 100$	Steel with suffix BCA6000 or above
Hatch Side Coaming	$50 < t \leq 80$	
	$80 < t \leq 100$	Steel with suffix BCA8000 or above

Note:

(1) Excludes attached longitudinals.

Chapter 33 DAMAGE CONTROL

33.1 General

33.1.1 Application

The requirements in this Part apply to cargo vessels of not less than 500 *gross tonnage* which are engaged in international voyages.

33.2 Damage Control

33.2.1 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.

33.3 Booklet and Plan for Damage Control

33.3.1 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.

3 The damage control plan is recommended to be prepared in the working language of the ship. Where the language used in preparation of the plan is not English, a translation into English is to be included.

33.3.2 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.

3 The Booklet is recommended to be prepared in the working language of the ship. Where the language used in preparation of the Booklet is not English, a translation into English is to be included.

33.3.3 Damage Stability Information*

Ships subject to **Chapter 4** or **Chapter 4, Part CS** are to be provided with damage stability information deemed appropriate by the Society.

Chapter 34 LOADING MANUAL AND LOADING COMPUTER

34.1 General

34.1.1 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 29** to **Chapter 32 of Part C**, **Part N**, or **Part S**

(2) Other ships deemed necessary by the Society

34.1.2 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

34.1.3 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.

34.2 Additional Requirements for Newly-built Bulk Carriers

34.2.1 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 **34.2.2** and **34.2.3**.

(1) Bulk carriers as defined in **1.3.1(13)** of **Part B**, which are contracted for construction on or after 1 July 1998

(2) Bulk carriers as defined in **31A.1.2(1)**, which are at the beginning stage of construction on or after 1 July 2006

(3) Self-unloading ships as defined in **1.3.1(19)** of **Part B**, which are contracted for construction on or after 1 July 2020

2 Notwithstanding the provisions of **-1 above**, the bulk carriers defined in **31A.1.2(1)** (excluding those bulk carriers specified in **1.3.1(13)** of **Part B** or the self-unloading ships specified in **1.3.1(19)** of **Part B**) need not comply with the requirements of **34.2.2-1(4)**, **34.2.2-2(4)** and **34.2.3-1(2)**. In addition, the requirements of **34.2.2-1(3)** may be modified so that loading manuals are to include the maximum allowable load per hold. The requirements of **34.2.2-2(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 **34.2.2**. Notwithstanding the above, items to be included in the loading manual may be in accordance with the provisions of **-2** above.

34.2.2 Loading Manual*

1 The Loading manual is to include, in addition to the requirements given in **34.1.2**, the following items.

(1) For bulk carriers conforming to **31A.5**, envelope results and permissible limits of still bending moments and shear forces in

the hold flooded condition according to the requirements given in **31A.5**

However, results deemed by the Society as too small to affect the strength of the ship may be omitted.

(2) 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 31A**

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 **34.1.2**, 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 using **Table C34.2.1** (Form 1).

(8) Typical sequences for change of ballast at sea

34.2.3 Loading Computer*

1 In addition to the requirements in **34.1.3**, 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 **31A.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.

34.3 Additional Requirements for Existing Bulk Carriers, Ore Carriers, and Combination Carriers

34.3.1 Loading Manual*

1 In addition to the requirements in **34.1.2**, the loading manual with typical loading/unloading sequences given in **34.2.2-2(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 **34.3.2** refer to ships of single deck construction with top-side tanks and hopper side tanks in cargo spaces.

34.3.2 Loading Computer

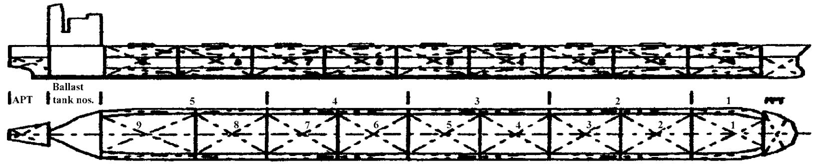
1 Bulk carriers, ore carriers and combination carriers of not less than length L_f 150 *m* conforming to **Chapter 30** or **Chapter 31** are to be provided with a loading computer as specified in **34.1.3**, except ships for which the application for classification survey during construction is submitted to the Society on or after 1 January 1994.

Table C34.2.1 LOADING/UNLOADING SEQUENCE SUMMARY FORM (FORM 1)

LOADING/UNLOADING SEQUENCE SUMMARY FORM

Vessel name	Voyage No.	Condition	Yard	Id. Number
			ClassNK	9999

Port (specific or typical) :	Condition at commencement of loading/discharging	
Total mass of cargo to be loaded/discharged :	Condition at end of loading/discharging	
Dock water density (t/m3) :	Maximum Loading/discharging rate :	Average Loading/discharging rate :
Number of loaders/dischargers :	Maximum Ballasting/Deballasting rate :	Average Ballasting/Deballasting rate :



Hold No.			7	6	5	4	3	2	1
Volume of Hold, Vh(m³)									
Height of hold, h(m)									

Note : During each pour it has to be controlled that allowable limits for hull girder shear force, bending moments and mass in holds are not exceeded. Loading/discharging operations may have to be paused to allow for ballasting/deballasting in order to keep actual values within limits.

Hold content at commencement of loading/discharging

Cargo mass									
Density (t/m³)									
Grade									

Ballasting contents at commencement of loading/discharging

Wings or peaks	APT	No. B.T.	No. B.T.	No. B.T.	No. B.T.	No. B.T.	No. B.T.	No. B.T.	FPT
Upper									
Lower/Peaks									

Commencement of loading/discharging (sea)

Taft (m)	Trim (m)	Tfwd (m)	Maximum S.F.(%)	Maximum B.M.(%)

CARGO OPERATIONS

Pour No. / Grade	Hold	Hold	Hold 7	Hold 6	Hold 5	Hold 4	Hold 3	Hold 2	Hold 1
1									
2									
3									
4									
5									
6									
7									
8									

BALLASTING OPERATIONS

Upper / Lower/Peak	APT	No. B.T.	No. B.T.	No. B.T.	No. B.T.	No. B.T.	No. B.T.	No. B.T.	FPT
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									

Values at end of pour (from harbour to sea)

Taft (m)	Trim (m)	Tfwd (m)	Maximum S.F.(%)	Maximum B.M.(%)

Total cargo onboard (t) : Remaining cargo to be loaded (t) : Total amount of bunkers onboard (t) :

Draft Survey n-1									
Draft Survey n									

Upper									
Lower/Peak									
Upper									
Lower/Peak									

Hold content at end of loading/discharging

Cargo mass									

Total mass loaded /discharged (t)		

Ballasting contents at end of loading/discharging

Wings or peaks	APT	Ball.no.5	Ball.no.4	Hold no.6	Ball.no.3	Hold no.4	Ball.no.2	Ball.no.1	FPT
Upper									
Lower/Peaks									

Values at end of loading/discharging (sea)

Taft (m)	Trim (m)	Tfwd (m)	Maximum S.F.(%)	Maximum B.M.(%)

Maximum occuring values among all conditions above

Net load on Double Bottom										tons/m²
Net load in two adjacent holds										tons

Net load on double bottom = $(Mh/V) * h \cdot T$ (t/m²)
where : Mh = Mass in hold + mass in DB (t)
V = Total volume of hold (m³)
h = height of hold from inner bottom to top of coaming (m)
T = draught (m)

Approved by : ______________

Date : ______________

Chapter 35 MEANS OF ACCESS

35.1 General Rules

35.1.1 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 **35.2** are to comply with the requirements of **35.2**.

35.1.2 Means of Access to Spaces*

1 Safe access to peak tanks, deep tanks, cofferdams, cargo oil tanks, cargo holds and other similar enclosed spaces is 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*.

35.1.3 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.

35.1.4 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.

35.1.5 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.

35.2 Special Requirements for Oil Tankers and Bulk Carriers

35.2.1 Application*

This section (**35.2**) applies to each space within the cargo area and fore peak tanks of oil tankers (as defined in **1.3.1(11) of Part B**, of not less than 500 *gross tonnage*) and bulk carriers (as defined in **1.3.1(13) of Part B**, of not less than 20,000 *gross tonnage*), in place of the requirements in **35.1**. Notwithstanding the above, the provisions in this section, except **35.2.3-1** and **-2** and **35.2.5-5**, **-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 **2.1.43 of Part A**.

35.2.2 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.

35.2.3 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 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.

35.2.4 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 ladder at each end of the tank.

(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 athwartship 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.

35.2.5 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 **35.2.3** and/or **35.2.4** 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 of 1,000 *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. Guardrail stanchions are to be attached to the permanent means of access.

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 means of 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.

35.2.6 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 **35.2.4**, 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.

Contents

GUIDANCE FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

Part C HULL CONSTRUCTION AND EQUIPMENT

C1 GENERAL

C1.1 General

C1.1.1 Application

1 For reduction of scantlings of structural members of ships to be classed for restricted service, the provisions in **1.1.1-2, Part CS of the Rules** are to apply except for those specially prescribed in this Part. In cases where the draught is defined as d_S in the **Part C of the Rules**, this requirement does not apply.

2 The steels with thicknesses above 50 *mm* up to 100 *mm* used for the rudder horn and shaft bracket can be of the grades *KD*, *KD*32, *KD*36 or *KD*40.

3 In applying **Part C of the Rules**, where the scantling draught (d_s) is larger than d specified in **2.1.2, Part A of the Rules**, d_s may be used instead of d due to reasons such as convenience of design. However, where the difference between d_s and d exceeds 300 *mm*, L, W and C_b specified in **Part A of the Rules** are to correspond with d_s.

C1.1.3 Ships of Unusual Form or Proportion, or Intended for Carriage of Special Cargoes

1 "To be protected to a degree deemed appropriate by the Society" and "special considerations are to be taken related to stowage and securing of cargoes" specified in **1.1.3-2, Part C of the Rules** mean that the ship is to be in accordance with the provisions of **23.1.3-3, Part C of the Rules** and the following **(1)** to **(3)**.

(1) For ships obviously intended to carry timber without distinction of assignment of timber freeboards according to the requirements in **Part V of the Rules**, it is recommended that they comply with **(3)**.

(2) For ships marked with timber load lines in accordance with the requirements in **Part V of the Rules**, the loading condition of timber on the exposed deck may be omitted in determining "d" specified in **2.1.12(2), Part A of the Rules**.
However, when the draught is 300 *mm* or more than "d" in the loading condition of timber on deck, special consideration is to be given to the scantlings of the hull construction.

(3) In ships intended to carry timbers, hull structural members are to be protected as specified in the following. However, where it is obvious from the specifications or other similar documents that the ship is not intended to carry log cargoes, the following requirements except sub-paragraphs **(h)** and **(j)** may be modified.

(a) Welding
Welding of hull structural members liable to sustain damage due to impact of log cargoes is to be continuous welding of at least *F*2, except that this requirement is dispensed with for structural members of the inner bottom which are covered with a closed ceiling.

(b) Deck Girders
Tripping brackets are to be fitted to hatch side girders and hatch end beams at intervals of about 1.5 *m* and their free edges are to be flanged.

(c) Hatch
Hatchway coamings are to be especially stiffened.

(d) Bulwark
It is recommended that the area of freeing ports provided on bulwarks is to be as small as possible in way of hatchway and the area is to be increased in other parts so as to maintain the total required freeing port area.

(e) Protection of Hold Frame

Protection of hold frames is to be in accordance with the following **i)** to **iv)**. However, this protection may be dispensed with for ships exceeding 130 *m* in length.

i) Hold frames are to be stiffened by one of the following:
   - Longitudinal stiffeners or tripping brackets are to be fitted at intervals of about 2 *m*.
   - Angle bars are to be fitted longitudinally at intervals of about 1.5 *m* on the flange surface of hold frames.
   - Flat bars of about 150 *mm* wide 10 *mm* thick are to be fitted longitudinally at intervals of about 0.5 *m* on the flange surface of hold frames.

ii) Angle bars or flat bars (in case of flat bars, at least 2 tiers) are to be fitted longitudinally on the flange surface of tank side brackets or on the lower bracket of hold frames of bulk carrier type ships. However, the above requirements may be dispensed with where the thickness and breadth of the flange of hold frames of bulk carrier type ships are not less than that determined by the following.
   - Thickness of bracket t = As determined by **Table C1.3 of Part C of the Rules** taking the arm length in **Fig. C1.1.3-1** as the longer arm of the bracket
   - Breadth of flange b = Value obtained from the following formula

   $128\sqrt{d_0 l}$ (mm)

   d_0: Depth of throat of bracket (m)

   l: Length of flange of bracket (m)

iii) Where hold frames come right under hatchway at forward or after part of ship, the hold frames are to be stiffened further.

iv) Consideration is to be given on arrangement and size of tripping brackets for deep hold frames or other similar deep hull structural members.

(f) Protection of Watertight Bulkhead

Hold bulkheads of ships not greater than 130 *m* in length are preferably not to be of a corrugated type but of a plane type. The side of the plane type bulkhead not fitted with stiffeners and both sides of corrugated type bulkheads are to be reinforced with square section wooden bars (about 250 mm^2 square) or steel angle bars and the like, placed at proper intervals. Protection of bulkhead stiffeners is to be in accordance with **(e)** above.

(g) Painting

All hull structural members below the line 300 *mm* above the top of the tank side brackets and lower brackets of bulkhead stiffeners (including the shell plate, bulkhead plate and piping but excluding the inner bottom plate, bilge hopper plate and slant plate of bulkhead stool) are to be coated with tar epoxy paint or other similar paint of good quality that does not easily peel off. However, where the inner plate, bilge hopper plate and slant plate of bulkhead stools are welded to the shell plate, bulkhead plate, tank side bracket, lower bracket of bulkhead stiffener, etc. and the surrounding areas are to be protected with coating.

(h) Protection of air pipes and other equipment

Air pipes, ladders, weathertight doors and equipment fitted on hull structural members which are liable to sustain damage due to impact of cargoes are to be properly protected.

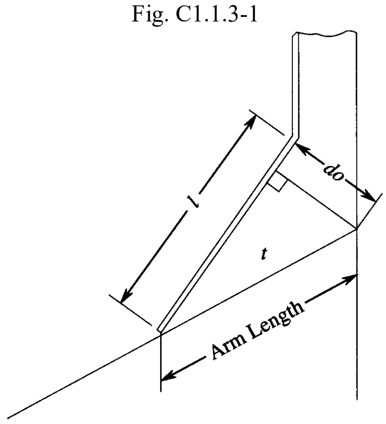
(i) Protection of Hatch Covers

Hatch covers are to be protected from timber by protective coverings such as dunnage and are to be fitted with devices to prevent them from moving due to the ship's motion (such as rolling, pitching, etc.). Where hatch covers have gaskets, the devices for preventing the gasket from sustaining excessive compression by timber loads are to be provided.

(j) Arrangement for timber deck cargoes

The stowage height of timber deck cargo and the lashing and fixing arrangements of timber deck cargoes are to be in accordance with the "International Convention on Load Lines, 1996 and Protocol of 1988 relating to the International Convention on Load Lines, 1966". Where the buoyancy of the timber deck cargo is taken into account with regard to damage stability, uprights are to be in accordance with **C4.2.3-3(1)(c)**.

Fig. C1.1.3-1



2 Ships Having Unusually Large Freeboards

(1) "Ships having unusually large freeboards" are the ships having freeboards that comply with following formula.

$f_s \geq h_s + f$

f_s: Actual summer freeboard (mm) assigned by the requirements in **V2.2.1**

h_s: Standard height (mm) of superstructure determined by the requirements in **V2.2.1**

f : Minimum summer freeboard (mm) determined by the requirements in **Part V of the Rules** on the basis of an assumed freeboard deck which is measured down from the actual freeboard deck by h_s

(2) Ships having unusually large freeboards may be treated as follows where the requirements in **Part C of the Rules** apply. However, the undermentioned treatment is not to apply to ships whose assigned freeboards are "*B*-60" or "*B*-100" type specified in **Part V of the Rules**.

(a) In the provision of "*h*" specified in **5.5.2, Part C of the Rules**, "*D*" may be replaced with "*D'*" which is the vertical distance from the top of the keel to an assumed freeboard deck.

(b) The requirements in **7.6.2-2, Part C of the Rules** may be applied to tween deck frames above an assumed freeboard deck even if they are located below the actual freeboard deck.

(c) In the provision of "*h*" specified in **10.2.1-2, Part C of the Rules**, a weather deck may be regarded as follows in relation to H_D which is the vertical distance from an assumed freeboard deck to the weather deck at side. The same may be applied to other chapters in **Part C of the Rules** where "*h*" is used.

$h_s \leq H_D < 2h_s$: Superstructure deck of first tier above the freeboard deck

$2h_s \leq H_D < 3h_s$: Superstructure deck of second tier above the freeboard deck

$3h_s \leq H_D$: Superstructure deck of third tier above the freeboard deck

(d) The requirements in **C16.1.5-2** may be applied to side shell plating above an assumed freeboard deck. Substitute "freeboard deck" and "superstructure side plating" with "assumed freeboard deck" and "side shell plating" respectively.

(e) The interpretation of **(c)** above may be applied to the provision of "*h*" specified in **18.2.1-1, Part C of the Rules**.

(f) The interpretation of **(c)** above may be applied to the provision of "*h*" specified in **19.2.1-1, Part C of the Rules**.

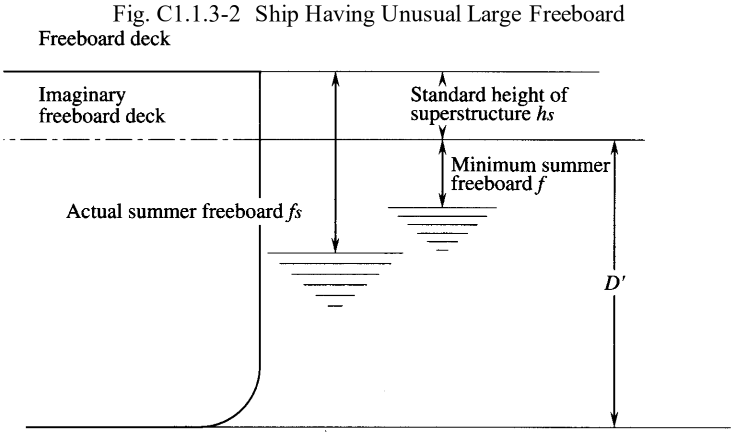
(g) i) The interpretation of **(c)** above may be applied to the provision of "Position of Exposed Deck Openings" in **20.1.2, Part C of the Rules**. The same may be applied to other chapters in **Part C** and **Part D of the Rules** where this provision is used.

ii) In Note(*3) of **Table C20.2, Part C of the Rules**, "freeboard deck" may read as "assumed freeboard deck".

(h) In the application of the requirements in **23.1**, **23.2** and **23.5, Part C of the Rules**, "freeboard deck" may be read as "assumed freeboard deck" and the interpretation of **(c)** above may be applied when determining the position of the deck. However, side scuttles for spaces below the actual freeboard deck or spaces considered as buoyancy in stability calculations are to be class *A* side scuttles, class *B* side scuttles, or equivalent thereto. In such cases, the deadlight is not to be omitted.

(i) In **13.5.3, Part D,** D' may be used in place of *D* in determining the diameters of bilge suction pipes.

Fig. C1.1.3-2 Ship Having Unusual Large Freeboard



3 Ships Having Unusually Reduced Freeboards

"Ships having unusually reduced freeboards" are ships whose freeboards are of the "*A*", "*B*-60" or "*B*-100" type, assigned in accordance with the requirements in **Part V of the Rules**.

4 "The special considerations deemed necessary by the Society" specified in **1.1.3-5, Part C of the Rules** means to be in accordance with the following **(1)** or **(2)**:

(1) For ships intended for the carriage of nickel ore with a moisture content that exceeds the transportable moisture limit, the requirements specified in **"Guidelines for the Safe Carriage of Nickel Ore"**

(2) For ships intended for the carriage of cargoes other than nickel ore, evaluation methods deemed appropriate by the Society

C1.1.7 Materials

1 Where high tensile steel are used, the construction and scantlings are to be determined in accordance with **Annex C1.1.7 "GUIDANCE FOR HULL CONSTRUCTION CONTAINING HIGH TENSILE STEEL MEMBERS"**.

2 Where the requirements in **1.1.7-2(3), Part C of the Rules** are applied, data corresponding to the standard of steels used (extent of their use, location of structural members, section rigidity, fatigue strength, minimum thickness, etc.) is to be submitted to the Society and approved.

3 When the requirements in **1.1.7-3(1), Part C of the Rules** are applied, data corresponding to the standard of steels used (e.g., extent of use, location of structural members, section rigidity, buckling strength, minimum thickness, etc.) is to be submitted to the Society for approval when deemed necessary.

4 The requirements of **1.1.7-3(2), Part C of the Rules** apply to members which do not come in contact with sea water, and the values in **(1)** and **(2)** may be deducted from the scantlings required by relevant requirements.

(1) For stainless steel

(a) Where the scantling is determined by the thickness of the plate: 1.0 *mm*

(b) Where the scantling is determined by the section modulus: 5%

(2) For stainless clad steel

Where the scantling is determined by the thickness of plate: 0.5*mm*

5 "Areas of anticipated stress concentration" specified in **1.1.7-3(3) Part C of the Rules** refers to, for example, the connections of the lower corner parts of corrugated bulkheads and inner bottom plates or the top plate of the lower stools, the connections of inner bottom plates and bilge hopper plates or lower stools, etc.

6 "Where deemed appropriate by the Society" specified in **1.1.7-3(3) Part C of the Rules** refers to cases such as where fatigue strength assessments based upon hot spot stresses obtained using the finite element method are carried out and the results are submitted to the Society for approval.

7 Where aluminium alloys specified in **Chapter 8, Part K of the Rules** are used for the main hull structure, data corresponding to the standard of the materials used (extent of their use, location of structural members, section rigidity, fatigue strength, weldability, corrosion protection, etc.) is to be submitted to the Society and approved. However, aluminium alloys whose material grade is 6005*AS*, 6061*P*, or 6061*S*, or is an alloy that does not have suitable anti-corrosion characteristics as deemed by the Society are not to be used for parts likely to come into contact with sea water during normal operation, unless approved otherwise by the Society.

8 In cases where it has been deemed appropriate by the Society, fiber reinforced plastic (FRP) may be used for equipment specified

in this Part. In this case, such usage is subject to the requirements given in **Annex C1.1.7-5 "Guidance for the Use of Fiber Reinforced Plastic (FRP)"**.

C1.1.10 (Deleted)

(Deleted)

C1.1.11 Application of Steels

1 The ships referred to as "container carriers and other than ships with similar hatch openings configuration" stated in the row for Strength deck at cargo hatch corner in the Deck Plating sections of **Table C1.1** and **C1.2, Part C of the Rules**, are ships which have hatch openings over $0.7B$ in width at the midship part.

2 In the application of steels to ship hull structure, round gunwales are to be treated as sheer strakes. The minimum width of the strake is to be 1,300 *mm* for L_1 up to 100 *m* and 2,600 *mm* for L_1 equal to and exceeding 250 *m*; with the minimum width being determined by interpolation for intermediate lengths.

3 In **1.1.11-5, Part C of the Rules**, the application of steels not more than 70 *mm* in thickness is to be in accordance with the following **(1)** and **(2)**. However, the application of steels more than 70 *mm* in thickness is to be considered by the Society based on their specifications and properties which shall be submitted for approval.

(1) For mild steel, steel grades in the $40<t\leq50$ (*mm* thickness) column of **Table C1.1, Part C of the Rules** may be used.

(2) For high tensile steels, the steel grades are to be in accordance with **Table C1.1.11-1**.

Table C1.1.11-1 Application of High Tensile Steels whose Thickness is more than 50 mm and Not more than 70 mm

Structural Member	Application		Thickness t (mm)	
			$50 < t \leq 60$	$60 < t \leq 70$
Shell Plating				
Sheer strake at strength deck	within $0.6L$ amidship		EH	
	other than those mentioned above		DH	
Side plating	within $0.4L$ amidship	within $0.1D$ downward from the lower surface of strength deck	EH	
		other than those mentioned above	DH	
Bilge strake	within $0.6L$ amidship		EH	
	other than those mentioned above		DH	
Bottom plating including keel plate	within $0.4L$ amidship		EH	
	other than those mentioned above		AH	DH
Deck Plating				
Stringer plate in strength deck	within $0.6L$ amidship		EH	
	other than those mentioned above		DH	
Strength deck strake adjoining to longitudinal bulkhead	within $0.6L$ amidship		EH	
	other than those mentioned above		DH	
Strength deck at cargo hatch corner	within $0.6L$ amidship		EH	
	other than those mentioned above		DH	
Strength deck other than mentioned above	within $0.4L$ amidship		EH	
	within $0.6L$ amidship excluding the above		AH	DH
Deck plating exposed to weather, in general	within $0.4L$ amidship		DH	EH
Longitudinal bulkhead				
Upper strake in longitudinal bulkhead adjoining to strength deck	within $0.4L$ amidship		EH	
	within $0.6L$ amidship excluding the above		AH	DH
Other than those mentioned above	within $0.4L$ amidship		DH	EH
Longitudinals				
Upper strake in sloping plate of topside tank adjoining to strength deck	within $0.4L$ amidship		EH	
	within $0.6L$ amidship excluding the above		AH	DH
Longitudinal members above strength deck including bracket and face plate of longitudinals	within $0.4L$ amidship		EH	
	within $0.6L$ amidship excluding the above		AH	DH
Cargo Hatch				
Face plate and web of cargo hatch coaming longitudinally extended on the strength deck	longitudinal members over $0.15L$ and end brackets and deck house transition	within $0.6L$ amidship	EH	
		other than those mentioned above	DH	
Other				
Other members than those mentioned above			AH	

Note:

1. Where the strength deck strake adjoined to the inner skin bulkhead is not a deck stringer plate, the deck strake may be treated as an

ordinary strength deck strake.

4 The bilge strake prescribed in Note 4 of **Table C1.1** and **C1.2, Part C of the Rules** means a single strake of the bilge keel in the longitudinal direction or where there is no bilge keel, a single strake on the line extending longitudinally forward and afterward of the bilge keel.

5 Application of steels mentioned in Note 5 of **Tables C1.1** and **C1.2, Part C of the Rules** is to be in accordance with **Table C1.1.11-2**.

Table C1.1.11-2 Special Requirements on Application of Steels for Rudder

Thickness t (*mm*)	$t \leq 15$	$15<t\leq 20$	$20<t\leq 25$	$25<t\leq 30$	$30<t\leq 40$	$40<t\leq 50$
Mild Steels	*A*	*B*	*D*		*E*	
High Tensile Steels	*AH*		*DH*		*EH*	

C1.1.12 Special Requirements for Application of Steels

1 Application of steels for ships intended to operate in areas with low air temperature

(1) Design temperature (T_D) specified in **1.1.12-1, Part C of the Rules** is to be taken as the lowest daily average air temperature over one *year* (*See* **Fig. C1.1.12-1(1)**), and is to be classified in accordance with **Table C1.1.12-1(1)**. For seasonally restricted service, the lowest temperature within the relevant period of operation may be taken.

(2) Notwithstanding the requirements in **(1)** above, for the ships specified in **1.1.1-2, Part I of the Rules**, the design temperature (T_D) specified in **1.1.12-1, Part C of the Rules** is not to be greater than either the lowest daily average air temperature over a period of one *year* (*See* **Fig. C1.1.12-1(1)**) or 13°C higher than the polar service temperature (*See* **1.2.1 (21), Part I of the Rules**) of the ship, whichever is lower; moreover, said design temperature is to be classified in accordance with **Table C1.1.12-1(1)**. For seasonally restricted service, design temperature may be taken as either the lowest temperature within the relevant period of operation or 13°C higher than the polar service temperature, whichever is lower. The above-mentioned lowest daily average air temperature over a period one year is to be determined based upon measurement data taken over at least 10 years.

(3) Application of steels exposed to the atmosphere used on ships intended to operate in areas of the low temperatures specified in **1.1.12-1, Part C of the Rules** is subject to **Table C1.1.12-1(2)** corresponding to the structural member category. Details of material class are subject to **Fig. C1.1.12-1(2)** and **Fig. C1.1.12-1(3)** corresponding to the design temperature category. However, application of steels for structural members not specified in **Table C1.1.12-1(2)** may be subject to **Table C1.1** and **Table C1.2**, **Part C of the Rules** regardless of the design temperature.

Fig. C1.1.12-1(1) Example for Determining Design Temperature

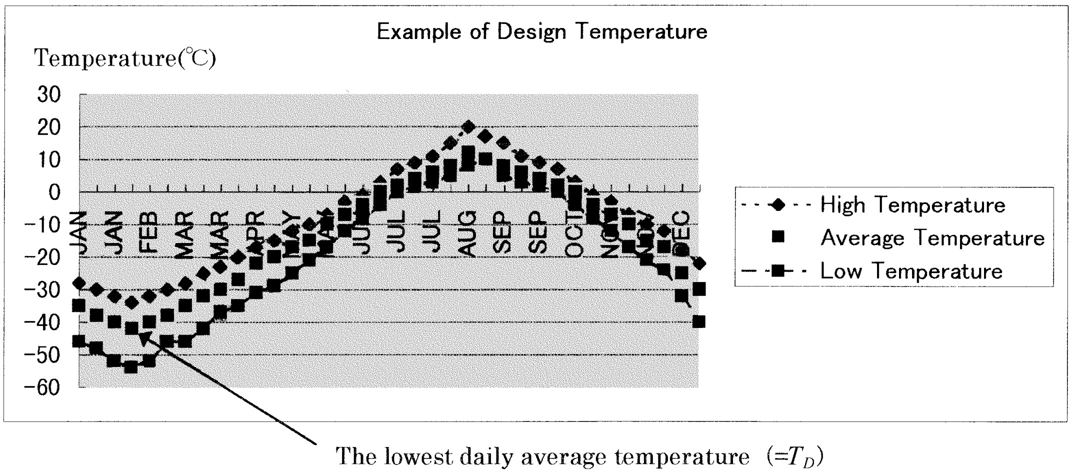


Table C1.1.12-1(1) Design Temperature Category

Range of Design Temperature (T_D) (°C)	Design Temperature Category
$-15 \leq T_D < -10$	T_{Da}
$-25 \leq T_D < -15$	T_{Db}
$-35 \leq T_D < -25$	T_{Dc}
$-45 \leq T_D < -35$	T_{Dd}
$-55 \leq T_D < -45$	T_{De}

Table C1.1.12-1(2) Application of Steels Exposed to the Atmosphere used on Ships Intended to Operate in Areas of Low Temperatures or Cold Liquid Cargo

Structural member	Material Class	
	Within 0.4L amidships	Outside 0.4L Amidship
・Deck plating exposed to weather, in general ・Side plating above $BWL^{(1)}$ ・Transverse bulkheads above $BWL^{(1)\,(2)}$ ・Cargo tank boundary plating exposed to cold liquid cargoes(3)	I	I
・Strength deck plating ・Strength deck plating at corners of hatch except for the large hatch openings ・Longitudinal members above strength deck including bracket and face plate except for web and face plate of continuous longitudinal hatch coamings ・Longitudinal bulkheads above $BWL^{(1)\,(2)}$ ・Top side tank bulkheads above $BWL^{(1)\,(2)}$	II	I
・Sheer strake at strength deck ・Stringer plate in strength deck ・Strength deck plating at corners of hatch with large hatch openings ・Deck strake at longitudinal bulkhead ・Face plate and web of continuous longitudinal hatch coamings	III	II

Notes:

(1) BWL: Ballast water line is the water line at the lowest draught condition during navigation and includes single strakes that cross it.

(2) Applicable to plating attached to hull envelope plating exposed to low air temperatures. At least one strake is to be considered in the same way as exposed plating with the strake width at least 600 mm.

(3) Ships other than liquefied gas carriers.

Fig. C1.1.12-1(2) Material Grade for Mild Steel Corresponding to Design Temperature Category

(Material symbols in this figure are indicated in Note (1) of **Table C1.1** and **Table C1.2**, **Part C of the Rules**.)

<table>
<tr><td rowspan="2"></td><td colspan="5">Design Temperature Category</td><td colspan="6">Thickness t (*mm*)</td></tr>
<tr><td>T_{Da}</td><td>T_{Db}</td><td>T_{Dc}</td><td>T_{Dd}</td><td>T_{De}</td><td>t≦10</td><td>10＜t≦20</td><td>20＜t≦30</td><td>30＜t≦40</td><td>40＜t ≦45</td><td>45＜t ≦50</td></tr>
<tr><td rowspan="7">Material Class</td><td>I</td><td></td><td></td><td></td><td></td><td colspan="2">A</td><td>B</td><td colspan="3">D</td></tr>
<tr><td>II</td><td>I</td><td></td><td></td><td></td><td>A</td><td>B</td><td colspan="2">D</td><td colspan="2">E*3</td></tr>
<tr><td>III</td><td>II</td><td>I</td><td></td><td></td><td>B*1</td><td colspan="2">D</td><td colspan="3">E*4</td></tr>
<tr><td></td><td>III</td><td>II</td><td>I</td><td></td><td colspan="2">D*2</td><td colspan="2">E*5</td><td colspan="2">*7,*9</td></tr>
<tr><td></td><td></td><td>III</td><td>II</td><td>I</td><td>D*2</td><td colspan="2">E*6</td><td colspan="3">*8,*9</td></tr>
<tr><td></td><td></td><td></td><td>III</td><td>II</td><td colspan="2">E</td><td colspan="4">*9</td></tr>
<tr><td></td><td></td><td></td><td></td><td>III</td><td>E</td><td colspan="5">*9</td></tr>
</table>

Notes

*1 Web and face plate of continuous longitudinal hatch coamings above strength deck except within 0.4L amidships are to be of grade *D* or higher.

*2 Sheer strake at strength deck and deck stringer in strength deck within 0.4L amidships with length exceeding 250 *m* are to be of grade *E* or higher.

*3 For material class I, grade *D* may be used up to 45 *mm*.

*4 For material class I, grade *D* may be used up to 35 *mm*.

*5 For material class I, grade *D* may be used up to 25 *mm*.

*6 For material class I, grade *D* may be used up to 15 *mm*.

*7 For material class I, grade *E* may be used up to 45 *mm*.

*8 For material class I, grade *E* may be used up to 35 *mm*.

*9 Steels to the satisfaction of the Society may be used.

Fig. C1.1.12-1(3) Material Grade for High Tensile Steel Corresponding to Design Temperature Category

(Material symbols in this figure are indicated in Note (1) of **Table C1.1** and **Table C1.2**, **Part C of the Rules**.)

<table>
<tr><td rowspan="2"></td><td colspan="5">Design Temperature Category</td><td colspan="6">Thickness t (*mm*)</td></tr>
<tr><td>T_{Da}</td><td>T_{Db}</td><td>T_{Dc}</td><td>T_{Dd}</td><td>T_{De}</td><td>t≦10</td><td>10＜t≦20</td><td>20＜t≦30</td><td>30＜t≦40</td><td>40＜t ≦45</td><td>45＜t ≦50</td></tr>
<tr><td rowspan="7">Material Class</td><td>I</td><td></td><td></td><td></td><td></td><td colspan="3">AH</td><td colspan="3">DH</td></tr>
<tr><td>II</td><td>I</td><td></td><td></td><td></td><td colspan="2">AH</td><td colspan="2">DH</td><td colspan="2">EH*3</td></tr>
<tr><td>III</td><td>II</td><td>I</td><td></td><td></td><td>AH*1</td><td colspan="2">DH</td><td colspan="3">EH*4</td></tr>
<tr><td></td><td>III</td><td>II</td><td>I</td><td></td><td colspan="2">DH*2</td><td colspan="2">EH*5</td><td colspan="2">FH*7</td></tr>
<tr><td></td><td></td><td>III</td><td>II</td><td>I</td><td>DH*2</td><td colspan="2">EH*6</td><td colspan="3">FH*8</td></tr>
<tr><td></td><td></td><td></td><td>III</td><td>II</td><td colspan="2">EH</td><td colspan="2">FH</td><td colspan="2">*9</td></tr>
<tr><td></td><td></td><td></td><td></td><td>III</td><td>EH</td><td colspan="2">FH</td><td colspan="3">*9</td></tr>
</table>

Notes

*1 Web and face plate of continuous longitudinal hatch coamings above strength deck except within 0.4L amidships are to be of grade *DH* or higher.

*2 Sheer strake at strength deck and deck stringer in strength deck within 0.4L amidships of ship with length exceeding

250 *m* are to be of grade *EH* or higher.

*3 For material class I, grade *DH* may be used up to 45 *mm*.

*4 For material class I, grade *DH* may be used up to 35 *mm*.

*5 For material class I, grade *DH* may be used up to 25 *mm*.

*6 For material class I, grade *DH* may be used up to 15 *mm*.

*7 For material class I, grade *EH* may be used up to 45 *mm*.

*8 For material class I, grade *EH* may be used up to 35 *mm*.

*9 Steels to the satisfaction of the Society may be used.

2 Application of steels for ships intended to carry cargoes with low temperature

In ships intended for carriage of low temperature cargoes, the application of steel materials used for longitudinal members exposed to low temperature are to be in accordance with **Table C1.1.12-2**. The application of steel materials may be specially considered if the structure is such that thermal stress can be released.

Table C1.1.12-2 Application of Materials Exposed to Low Temperatures [*1]

<table>
<tr><th rowspan="2">Design Temperature T_D (°C)</th><th colspan="7">Thickness of Material t (mm)</th></tr>
<tr><th>$t \le 10$</th><th>$10 < t \le 15$</th><th>$15 < t \le 20$</th><th>$22 < t \le 25$</th><th>$25 < t \le 30$</th><th>$30 < t \le 40$</th><th>$40 < t \le 50$</th></tr>
<tr><td>$-20 \le T < -10$</td><td>KB</td><td colspan="2">KD</td><td colspan="4">KE</td></tr>
<tr><td>$-30 \le T < -20$</td><td colspan="4">KE</td><td colspan="2">KL24A</td><td>KL24B</td></tr>
<tr><td>$-40 \le T < -30$</td><td colspan="3">KL24A</td><td colspan="3">KL24B</td><td>*2</td></tr>
<tr><td>$-50 \le T < -40$</td><td colspan="3">KL24B</td><td colspan="4">*2</td></tr>
</table>

Notes:

*1 For members exposed to a design temperature lower than -50°C or for strength decks exposed to low temperatures, the Society may require higher grade materials with a higher notch toughness depending on the thickness and the type of structure.

*2 Materials deemed appropriate by the Society.

3 Application of steels for ships intended to be loaded with cold liquid cargoes other than liquefied gas carriers

For ships other than liquefied gas carriers, intended to be loaded with cold liquid cargoes, application of steels used for cargo tank boundary plating exposed to cold liquid cargoes is subject to **Table C1.1.12-1(2)**. In this case, details of material class are subject to **Fig. C1.1.12-1(2)** and **Fig. C1.1.12-1(3)** corresponding to the design minimum cargo temperature (T_C), which category is subject to **Table C1.1.12-1(1)**. The design minimum cargo temperature (T_C) is to be specified in the loading manual.

C1.1.13 Scantlings

1 The section modulus of longitudinal stiffeners in double bottom construction and double side hull construction (with reference to **1.1.13-4**, **Part C of the Rules**)

For longitudinal stiffeners in double bottoms or double side hulls, where both ends of those stiffeners are fixed to vertical stiffeners on solid floors, horizontal stiffeners on vertical webs or struts, the section modulus required for those stiffeners may be multiplied by the value obtained from the following formula:

$$\left(1-\frac{a}{l}\right)^2\left(1-\frac{b}{l}\right)$$

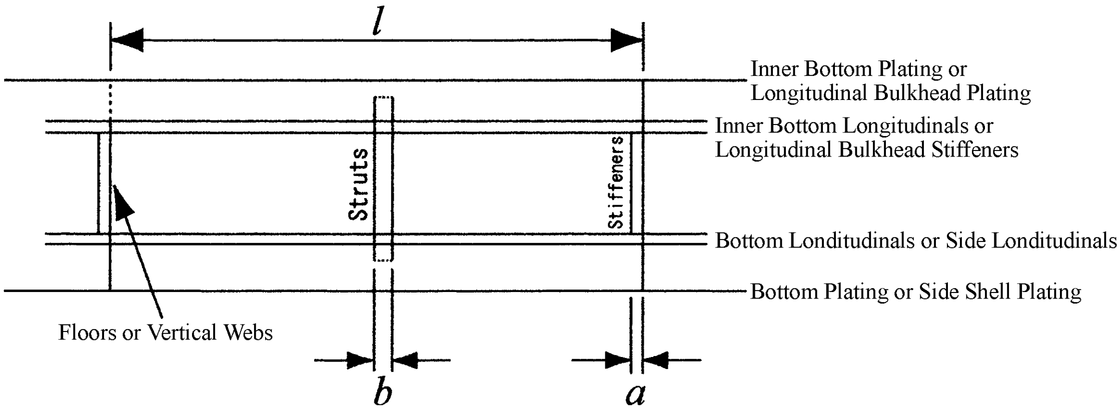
l : Distance (m) between floors or vertical webs

a : Width (m) of stiffeners of floors or vertical webs (a is zero if the stiffeners are not secured to longitudinals or other stiffeners by means of a lug connection)

b : Width of struts (m)

(*See* **Fig. C1.1.13-1**)

Fig. C1.1.13-1



C1.1.14 Connection of Ends of Stiffeners, Girders and Frames

1 The connections of stiffeners to longitudinals are to have enough fatigue strength as required by **1.1.14-3, Part C of the Rules**. This means that the stress in the end of such stiffeners obtained from the following formula is to be less than 175 (N/mm^2).

$$C_{ship}C_{cor}K_{con}K_{longi}K_{stiff}\frac{\Delta\sigma_a}{\cos\theta}\ (N/mm^2)$$

C_{ship} : Coefficient as given in **Table C1.1.14-1**

C_{cor} : Correction coefficient for corrosion, taken as 1.1

K_{con} : Coefficient considering stress concentration, as obtained from **Table C1.1.14-2**

K_{longi}: Coefficient considering shape of cross section of the longitudinal, as obtained from **Table C1.1.14-3**

K_{stiff}: Coefficient considering the shape of the end of the stiffener, as obtained from **Table C1.1.14-4**

θ : As given in **Fig. C1.1.14-3**

$\Delta\sigma_a$: Stress transferred from longitudinals into the end of stiffener, as obtained from the following formula:

$$\Delta\sigma_a = \frac{\Delta W}{0.322h'\{(A_{w1}/l_1)+(A_{w2}/l_2)\}+A_{s0}}\ (N/mm^2)$$

ΔW: Dynamic load as obtained from the following formula:

$$\Delta W = 10^3(l-0.5s)s\Delta P C_L\ (N)$$

l : Spacing (m) of floors or transverse girders

s : Spacing (m) of longitudinals

C_L: Coefficient due to position of the centre of gravity of tank in longitudinal direction, as obtained from **Table C1.1.14-5**

ΔP: As obtained from the following formula, but not less than $2\rho g\Delta h$

$$\Delta P = 2\rho a_V h_1\ (kN/m^2)$$

ρ : Density (t/m^3) of liquid in tank under consideration

h_1: Vertical distance (m) measured from the root of the longitudinals where the stiffeners under consideration are fitted to the top of tank

$$\Delta h = \frac{16}{L}(l_t-10)+0.25(b_t-10)\ (m)$$

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 hold of bulk carrier with top side tanks.

a_V: Vertical acceleration as obtained from the following formula:

$$a_V = \frac{10.5\sqrt{V+5}}{L\sqrt{C_b}}g\ \ (m/s^2)$$

g : Gravity acceleration, taken as 9.81 (m/s^2)

C_b: Block coefficient, as specified in **2.1.14, Part A of the Rules**

V : Design speed, as specified in **2.1.8**, **Part A of the Rules** (*knot*)

A_{s0}, A_{w1}, A_{w2}, l_1 and l_2: Geometry parameters as given in **Fig. C1.1.14-3**

h': As obtained from the following formula:

$h' = h_s + h'_0$ (mm)

h_s: As given **Fig. C1.1.14-3** (mm)

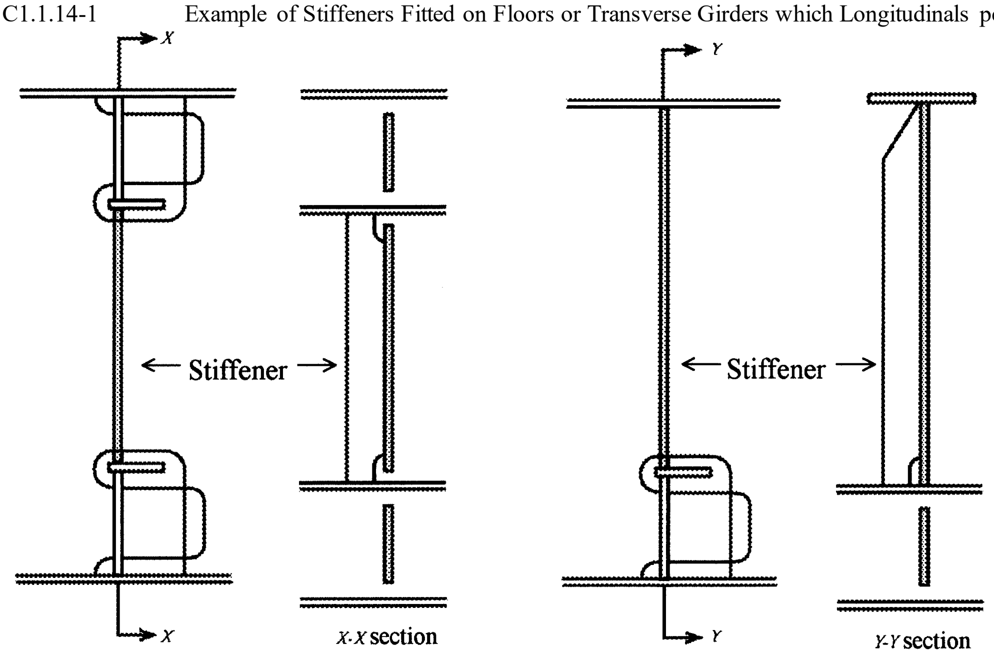
h'_0: As obtained from the following formula:

$h'_0 = 0.636b'$ (mm) For $b' \leq 150$

$h'_0 = 0.216b' + 63$ (mm) For $150 < b'$

b': Breadth (mm) of the end of the stiffener (*See* **Fig. C1.1.14-3**)

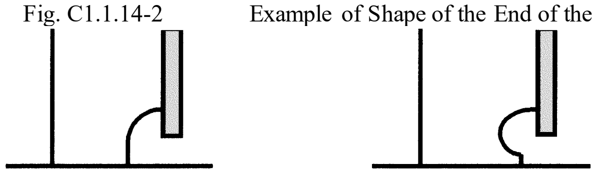
Fig. C1.1.14-1 Example of Stiffeners Fitted on Floors or Transverse Girders which Longitudinals penetrate



In case where stiffeners are provided on floors or transverse girders of which both sides are supported by parallel plates(e.g., double bottoms or double sides)

In case where stiffeners are provided on transverse girders of which one side is supported by one plate(e.g., bilge hopper tank)

Fig. C1.1.14-2 Example of Shape of the End of the Stiffener



Standard shape of the end of the stiffener

Shape of the end of the stiffener considering fatigue strength in comparison with the standard shape

Fig. C1.1.14-3 Definitions of Geometry Parameters Near Slot for Longitudinals

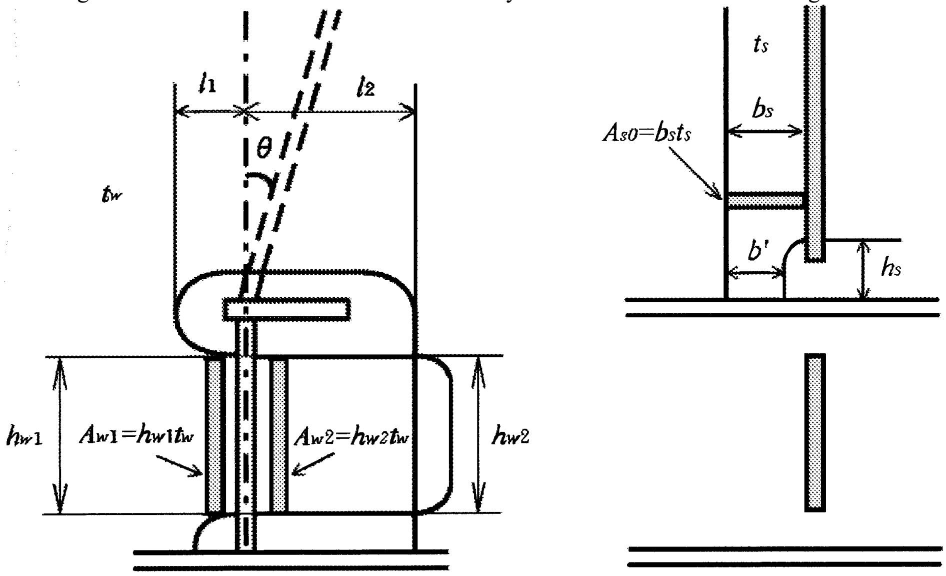


Table C1.1.14-1 Coefficient C_{ship}

Length of ship L (m)	and over	90	150	200
	less than	150	200	
C_{ship}		$0.55+\frac{L}{600}$	0.80	1.00

Table C1.1.14-2 Coefficient K_{con}

	Where the stiffeners are provided on floors or transverse girders of which both sides are supported by parallel plates (e.g., double bottoms or double sides) (See **Fig. C1.1.14-1**)	Where the stiffeners are provided on transverse girders of which one side is supported by one plate (e.g., bilge hopper tank) (See **Fig. C1.1.14-1**)
K_{con}	3.5	4.0

Table C1.1.14-3 Coefficient K_{longi}

	T-sections, flat bars, and bulb plates	L-sections and inverted angles
K_{longi}	1.0	1.3*

Note:

*: Where the longitudinals of L-sections or inverted angles are supported by brackets between one floor or one transverse girder and another, K_{longi} may be taken as 1.0.

Table C1.1.14-4 Coefficient K_{stiff}

	Standard shape of the end of the stiffener (See **Fig. C1.1.14-2**)	Shape of the end of the stiffener considering fatigue strength in comparison with the standard shape (See **Fig.C1.1.14-2**)
K_{stiff}	1.0	0.8

Table C1.1.14-5 Coefficient C_L

Position of the centre of gravity of tank in longitudinal-direction	A.P.～$0.7L$	$0.7L$ and fore
C_L	1.0	1.1

2 Notwithstanding the requirements of -1 above, the scantlings of the stiffeners may be determined by other procedures provided that documents on such analysis procedures and results of calculation are to be submitted to the Society for Approval.

C1.1.17 Workmanship

In cases where material of high tensile steel *KE*47 is used for the longitudinal structural members of upper decks region, jigs used for welding and construction work mounted directly on to any structural members using *KE*47 are, in principle, to be completely removed.

C1.1.22 Direct Calculations

Where the yield strength assessment and buckling strength assessment are made by direct strength calculations carried out under the requirements in **1.1.22**, **Part C of the Rules**, the assessment is to comply with either of the following.

(1) The strength assessment is to be carried out in accordance with **Annex C1.1.22-1** "**GUIDANCE FOR DIRECT CALCULATIONS**", and **Annex C1.1.22-2** "**GUIDANCE FOR BUCKLING STRENGTH CALCULATIONS**"

(2) Where the class notation "PS-DA" is affixed to classification characters, the strength assessment is to be carried out in accordance with the "Guideline for Direct Strength Calculation".

(3) Where the class notation "PS-DA-DLA" is affixed to classification characters, the strength assessment of primary members in all cargo spaces is to be carried out in accordance with the "Guidelines for Direct Load Analysis and Strength Assessment".

C1.1.23 Structural Details

1 In applying the requirements in **1.1.23-4**, **Part C of the Rules**, fatigue strength assessment of longitudinals in the midship part for tankers, ore carriers, bulk carriers, container carriers, ships carrying liquefied gases in bulk and ships carrying dangerous chemicals in bulk is to be in accordance with the following items **(1)** to **(3)**.

(1) For ships not less than 150 m in length L_1, the fatigue strength assessment of longitudinals that do not penetrate structural members which constrain athwartship or vertical displacements of longitudinals (such as transverse bulkheads, swash bulkheads or floors) is to be carried out in accordance with **Annex C1.1.23-1** "**GUIDANCE FOR THE FATIGUE STRENGTH ASSESSMENT OF LONGITUDINALS**". L_1 is the distance (m) measured on the waterline at the scantling draught d_S from the forward side of the stem to the centre of the rudder stock. L_1 is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught d_S. In ships without rudder stocks (e.g. ships fitted with azimuth thrusters), the Rule length L_1 is to be taken equal to 97% of the extreme length on the waterline at the scantling draught d_S. d_S is the scantling draught (m) at which the strength requirements for the scantlings of the ship are met and represents the full load condition; it is to be not less than that corresponding to the assigned freeboard.

(2) Fatigue strength assessment of longitudinals that penetrate structural members which constrain athwartship or vertical displacements of longitudinals (such as transverse bulkheads, swash bulkheads or floors) is to be in accordance with the following **(a)** and **(b)**.

(a) For ships not less than 150 m in length L_1, the fatigue assessment may be dispensed with where the scantlings of the longitudinals comply with the requirements in **(1)** above and soft brackets with sufficient fatigue strength are arranged on both sides of the structural members (bulkheads, etc.).

(b) Where the class notation "PS-FA" is affixed to classification characters, the fatigue assessment is to be carried out on the structural members penetrated by the longitudinals in accordance with **Annex C1.1.23-1** "**GUIDANCE FOR THE FATIGUE STRENGTH ASSESSMENT OF LONGITUDINALS**".

(3) A fatigue strength assessment of longitudinals other than those at the midship part is to be carried out where deemed necessary by the Society.

2 Where the class notation "PS-FA" is affixed to classification characters, the fatigue strength assessment of primary members is to be carried out in accordance with "Guidance for Fatigue Strength Assessment."

3 Where the class notation "PS-FA-DLA" is affixed to classification characters, the fatigue strength assessment of primary members in all cargo spaces is to be carried out in accordance with the "Guidelines for Direct Load Analysis and Strength Assessment."

4 For ships with hatches which fall under the following **(1)** through **(4)**, the fatigue strength of strength deck plating at hatch corners and end parts of hatch side members is to be taken into consideration by avoiding abrupt changes of the cross section, or increasing scantling of strength deck plating and hatch side members suitably.

(1) Ships with hatches in the midship part, where the breadth of the hatch exceeds $0.7B$

(2) Ships which use high tensile steel for strength deck plating and which comply with the requirements in **1.1.7-2(1)**, **Part C of**

the Rules

(3) Ships with hatches of especially high coaming height

(4) Ships which are provided with hatches of special shapes or structures

C1.1.24 Ship Identification Number

1 "Ship Identification Number" as specified in **1.1.24, Part C of the Rules** refers to the number which conforms to the *IMO* ship identification number scheme adopted by *IMO Resolution A.600(15)*.

2 "Superstructure etc." stipulated in **1.1.24-1(1), Part C of the Rules** refers to superstructures, bridges or deckhouses.

C1.2 Welding

C1.2.3 Details of Joints

1 The details of welded joints when a stern frame is built up with steel castings are to be as shown in **Fig.C1.2.3-1** as a standard.

2 The details of welded joints where large structures such as stern frames are built up by butt welding of large steel castings or steel forgings and steel plates as shown in **Fig.C1.2.3-2(a)** and **(b)** are to be taken as standard.

3 The details of welded joints where large structures such as stern frames are built up by lap welding of large steel castings or steel forgings and steel plates as shown in **Fig.C1.2.3-3(a)** and **(b)** are to be taken as standard.

Fig.C1.2.3-1 Details of Joint of Cast Steel Stern Frame

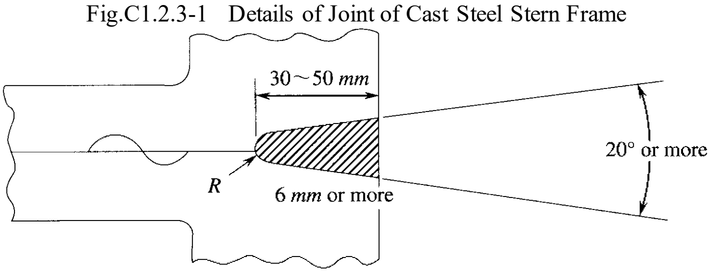


Fig.C1.2.3-2 Details of Butt Joint of Steel Castings / Forgings and Steel Plates

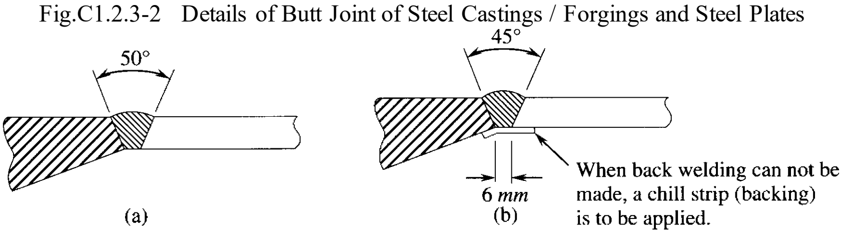
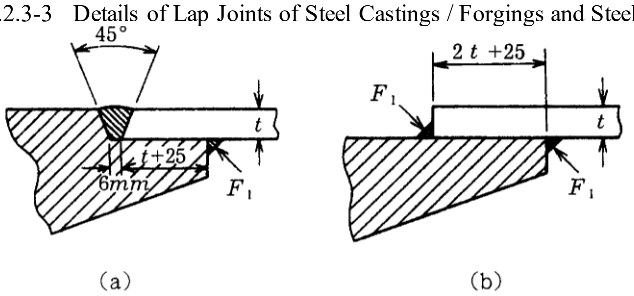


Fig.C1.2.3-3 Details of Lap Joints of Steel Castings / Forgings and Steel Plates



C2 STEMS AND STERN FRAMES

C2.1 Stems

C2.1.1 Plate Stems

1 The thickness of plate stems may be the same as that of side shell plating at the level of the freeboard deck and the same as that of the forecastle-side shell in the range of the forecastle.

2 Where the plate stem with a large radius of curvature at its fore end is not fitted with a centreline stiffener or is not reinforced by using thicker plate in accordance with **2.1.1-1, Part C** of the Rules, horizontal breasthooks are to be provided at a space not exceeding 600 *mm* apart for reinforcement.

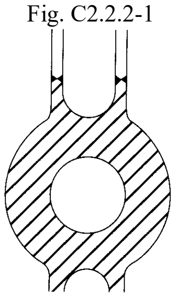
C2.2 Stern Frames

C2.2.2 Propeller Posts

1 Connection of cast steel boss and plate parts of built-up stern frame

The connection of a cast steel boss and built-up stern frame is to be well grooved and welded with full penetrations at the root as shown in **Fig. C2.2.2-1**. A cast steel boss having a shape different from that shown in **Fig. C2.2.2-1** may be used if enough consideration is paid to workmanship, at the discretion of the Society.

Fig. C2.2.2-1



2 Length of shaft hole of propeller boss

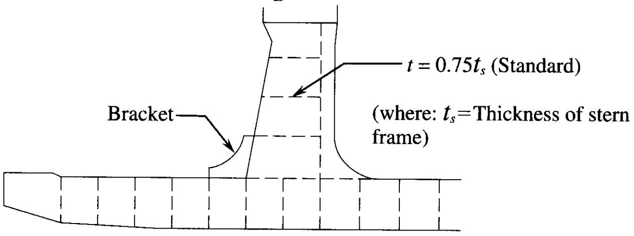
The length of the shaft hole of the propeller boss is to be greater than 1.25 *times* the inside diameter of the boss hole. Where the length of the shaft hole is less than the length of the bearing prescribed in **6.2.10, Part D** of the Rules, it is recommended that the length of the shaft hole be adjusted to match that of the bearing.

3 Round bars used for built-up stern frame

Where a round bar is used as the aft edge of a built-up stern frame, the standard radius of the round bar is at least 70% of $R(0.40L+16)$ prescribed in **2.2.2, Part C** of the Rules. At the connection of the round bar to the cast steel part or at the connection of round bars, the depth of the bevel for welding is to be at least 1/3 the diameter of the round bar.

4 The standard thickness of ribs fitted to the stern frame is 75% of the stern frame plate. (*See* **Fig. C2.2.3-1**)

Fig. C2.2.3-1



C2.2.3 Shoe Pieces

1 Connection of shoe pieces and propeller posts

The top plate of the shoe piece is to be extended forward beyond the aft end of the propeller post. A bracket of the same thickness as the stern frame is to be fitted at the connection of the shoe piece and the aft end of the propeller post to keep a sufficient continuity of strength. (*See* **Fig. C2.2.3-1**)

2 Steel bolts for fixing zinc slabs to the shoe piece must not be directly screwed into the shoe piece. They are to be directly welded to the shoe piece or screwed into steel plates welded to the shoe piece.

3 Shoe pieces of built-up construction are to be made watertight and the inside coated with effective coating material.

Where no coating is applied to the inside of the built-up shoe piece, the thickness of the shoe piece is to be increased by 1.5 *mm*.

4 Refer to **C2.2.2-4** above.

C2.2.4 Heel Pieces

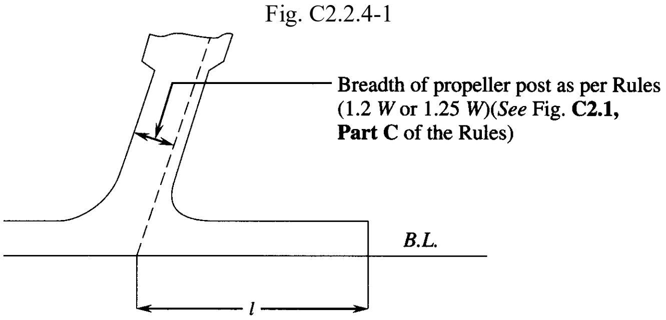
Determination of length of heel pieces

(1) In built-up stern frames, the length of heel pieces may be equal to twice the frame spacing at the position of the heel pieces providing that the thickness of flat keels connected to the heel pieces is increased by 5 *mm*.

(2) The length of heel pieces is to be measured as shown in **Fig. C2.2.4-1**.

(3) Refer to **C2.2.2-4** also.

Fig. C2.2.4-1



C2.2.5 Rudder Horns

In the application of **2.2.5**, **Part C of the Rules**, the bending moment, shear force, torque and stresses to be considered are to be determined by direct calculation or by a simplified approximation method. For direct calculation, the data to be used is to be according to **C3.4.1**. A simplified approximation method is to be as specified in the following **(1)** or **(2)**:

(1) Rudder horn of 1 elastic support

(a) Bending moment M at the section considered is to be obtained from the following formula. (*See* **Fig. C2.2.5-1**)

$M = Bz \ (M_{max} = Bd)$ (*N-m*)

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

(b) Torsional moment T_h at the section considered is to be obtained from the following formula. (*See* **Fig. C2.2.5-1**)

$T_h = Bc(z)$ (N/mm^2)

(c) Bending stress σ_b, shear stress τ and torsional stress τ_t acting on the rudder horn are to be obtained from the following formulae respectively:

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

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

Torsional stress: $\tau_t = \dfrac{1000T_h}{2A_t t_h}$ (N/mm^2)

Where:

M, B and T_h : As specified in **(a)** and **(b)** above

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

t_h: Plate thickness of the rudder horn (mm)

Z_x : As specified in **2.2.5-1(1)**, **Part C of the Rules**

A_h : As specified in **2.2.5-1(2)**, **Part C of the Rules**

(2) Rudder horn of 2 conjugate elastic support

(a) Bending moment

Bending moment (N) acting on the generic section of the rudder horn is to be obtained (N-m) from the following formulae:

- between the lower and upper supports provided by the rudder horn:

$M = F_{A1}\, z$

- above the rudder horn upper-support:

$M = F_{A1}\, z + F_{A2}\,(z - d_{lu})$

Where:

F_{A1}: Support force at the rudder horn lower-support (N) to be obtained according to **Fig. C3.4.1-7**, and taken equal to B_1

F_{A2}: Support force at the rudder horn upper-support (N) to be obtained according to **Fig. C3.4.1-7**, and taken equal to B_2

z :Distance (m) defined in **Fig. C2.2.5-2**, to be taken less than the distance d (m) defined in the same figure

d_{lu} :Distance (m) between the rudder-horn lower and upper bearings (according to **Fig. C3.4.1-7**, $d_{lu} = d - \lambda$).

(b) Shear force

The shear force B acting on the generic section of the rudder horn is to be obtained (N) from the following formulae:

- between the lower and upper rudder horn bearings:

$B = F_{A1}$

- above the rudder horn upper-bearing:

$B = F_{A1} + F_{A2}$

Where:

F_{A1}, F_{A2} : Support forces (N).

(c) Torque

The torque acting on the generic section of the rudder horn is to be obtained (N-m) from the following formulae:

- between the lower and upper rudder horn bearings:

$T_h = F_{A1}\, e_{(z)}$

- above the rudder horn upper-bearing:

$T_h = F_{A1}\, e_{(z)} + F_{A2}\, e_{(z)}$

Where:

F_{A1}, F_{A2} : Support forces (N)

$e_{(z)}$: Torsion lever (mm) defined in **Fig. C2.2.5-2**.

(d) Shear stress and torsional stress calculation

i) For a generic section of the rudder horn, located between its lower and upper bearings, the following stresses are to be calculated:

τ : Shear stress (N/mm^2) to be obtained from the following formula:

$$\tau = \frac{F_{A1}}{A_h}$$

τ_t : Torsional stress (N/mm^2) to be obtained for hollow rudder horn from the following formula:

$$\tau_t = \frac{T_h 10^{-3}}{2 F_T t_h}$$

For solid rudder horn, τ_T is to be considered by the Society on a case by case basis.

ii) For a generic section of the rudder horn, located in the region above its upper bearing, the following stresses are to be calculated:

τ : Shear stress (N/mm^2) to be obtained from the following formula:

$$\tau = \frac{F_{A1} + F_{A2}}{A_h}$$

τ_t : Torsional stress (N/mm^2) to be obtained for hollow rudder horn from the following formula:

$$\tau_t = \frac{T_h 10^{-3}}{2F_T t_h}$$

For solid rudder horn, τ_t is to be considered by the Society on a case by case basis

Where:

F_{A1}, F_{A2}: Support forces (N)

A_h: Effective shear sectional area of the rudder horn (mm^2) in Y-direction

T_h: Torque (N-m)

F_T: Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn (m^2)

t_h: Plate thickness of rudder horn (mm). For a given cross section of the rudder horn, the maximum value of τ_t is obtained at the minimum value of t_h.

(e) Bending stress calculation

For the generic section of the rudder horn within the length d the following stresses are to be calculated:

σ_b : Bending stress (N/mm^2) to be obtained from the following formula:

$$\sigma_b = \frac{M}{Z_X}$$

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

Z_X: Section modulus (cm^2) around the X-axis (see Fig. C2.2.5-2).

Fig. C2.2.5-1 Geometry of Rudder Horn (1 Elastic Support)

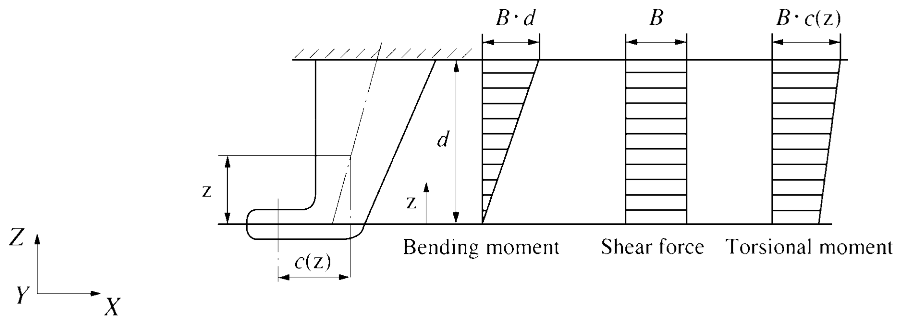
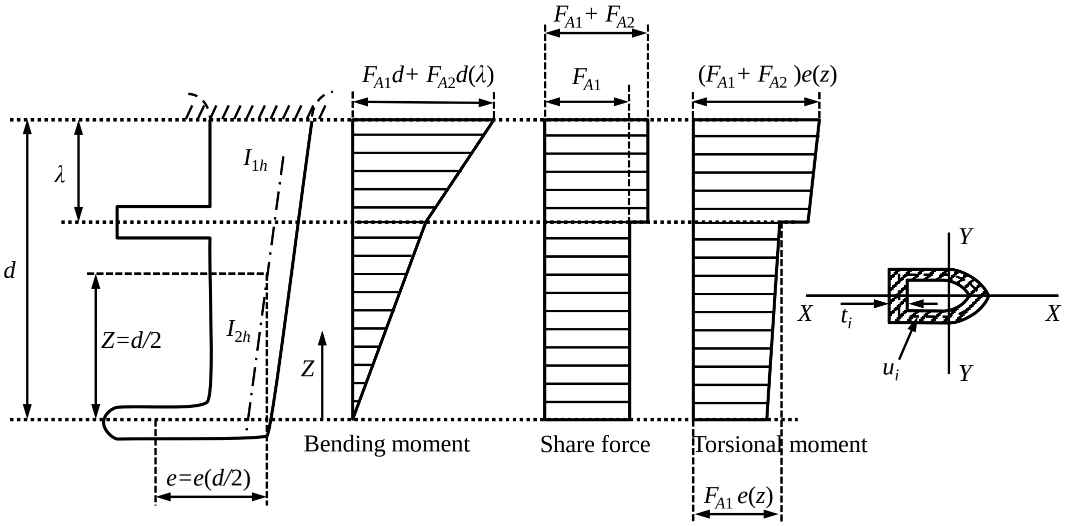


Fig. C2.2.5-2 Geometry of Rudder Horn (2 Conjugate Elastic Supports)



C3 RUDDERS

C3.1 General

C3.1.1 Application

1 Rudders having three or more pintles

The scantling of each member of rudders having three or more pintles is to be determined in accordance with the requirements in **Chapter 3, Part C** of the Rules. However, the moment and force acting on each member are to be determined by the direct calculation method, in accordance with the requirements in **C3.4**.

2 Rudders having a special shape or sectional form

Nozzle rudders are to be as specified below, unless the rudder force and rudder torque are required to be determined by tests or detailed theoretical calculation. In other rudders, the scantling of each member is to be determined by obtaining the rudder force and rudder torque through tests or detailed theoretical calculations, and correspondingly applying the requirements in **Chapter 3, Part C** of the Rules. Results of tests or theoretical calculations are to be submitted to the Society.

Nozzle rudders

The scantling of each member of nozzle rudders is to be determined in accordance with the requirements in **Chapter 3, Part C** of the Rules. In applying the Rules, the total rudder area and the rudder area ahead of the centreline of the rudder stock are to be calculated as follows:

Total rudder area A:

$2h(b_1 + b_2) + h'(a_1 + a_2)$ (m^2)

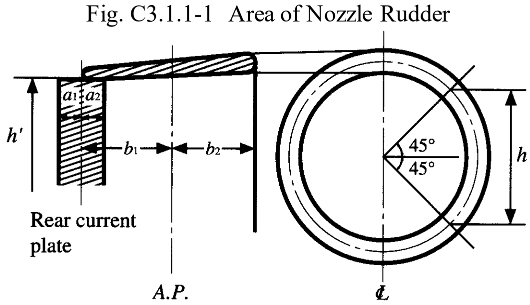
Rudder area ahead of the centreline of the rudder stock A_f:

$2hb_2$ (m^2)

Where:

a_1, a_2, b_1, b_2, h and h': Refer to **Fig. C3.1.1-1**

Fig. C3.1.1-1 Area of Nozzle Rudder



3 Rudders designed for helm angles exceeding 35°

The scantling of each member of rudders designed for helm angles exceeding 35° is to be determined in accordance with the requirements in **Chapter 3, Part C** of the Rules, on the basis of the rudder force and rudder torque obtained through tests or detailed theoretical calculations. The results of tests and theoretical calculations are to be submitted to the Society.

C3.1.2 Materials

1 If the diameter of the rudder stock is small, cast carbon steel is not to be used.

2 Rolled bar steel (*KSFR*45) may be treated in the same way as *KSF*45.

C3.1.4 Equivalence

Where steel castings with a yield stress of less than 205 N/mm^2 are used for rudder main pieces according to the provisions of **3.1.4, Part C of the Rules**, the Society may require that consideration be given to the yield stress of such castings with respect to the application of the allowable stress of rudder main pieces in way of the recesses specified in **3.6.3-3(2), Part C of the Rules**.

C3.4 Rudder Strength Calculation

C3.4.1 Rudder Strength Calculation

1 General

The bending moment, shear force, and supporting force acting on the rudder and rudder stock may be evaluated using the basic rudder models shown in **Fig. C3.4.1-1** to **Fig. C3.4.1-7**.

2 Moments and forces to be evaluated

The bending moment M_R and the shear force Q_1 acting on the rudder body, the bending moment M_b acting on the bearing, and the bending moment M_s acting on the coupling between the rudder stock and the rudder main piece and the supporting forces B_1, B_2, B_3 are to be obtained. These moments and forces are to be used for analyzing the stresses in accordance with the requirements in **Chapter 3, Part C** of the Rules.

3 Method of evaluating moments and forces

The method of evaluating moments and forces is to be as in the following **(1)** to **(3)** below. Notwithstanding the above, for Type *D* rudders with 2-conjugate elastic supports by rudder horns, the method of evaluating moments and forces is to be as in **-4**.

(1) General data

Data on the basic rudder models shown in **Fig. C3.4.1-1** to **Fig. C3.4.1-6** is as follows:

l_{10}~l_{50} : Lengths (m) of individual girders of the system

I_{10}~I_{50} : Moments (cm^4) of inertia of these girders

For rudders supported by a shoe piece, the length l_{20} is the distance between the lower edge of the rudder body and the centre of the shoe piece and I_{20} is the moment of inertia of the pintle in the shoe piece.

h_c is the vertical distance (m) from the mid-point of the length of that pintle to the centroid of the rudder area.

(2) Direct calculation

The standard data to be used for direct calculation are as follows:

Load acting on rudder body (Type *B* rudder)

$$P_R = \frac{F_R}{1000 l_{10}} \ (kN/m)$$

Load acting on rudder body (Type C rudder)

$$P_R = \frac{F_R}{1000 l_{10}} \ (kN/m)$$

Notwithstanding the above, the value is as follows for rudders with rudder trunks supporting rudder stocks.

$$P_R = \frac{F_R}{1000 (l_{10}+l_{20})} \ (kN/m)$$

Load acting on rudder body (Type *A* rudder)

$$P_{R10} = \frac{F_{R2}}{1000 l_{10}} \ (kN/m)$$

$$P_{R20} = \frac{F_{R1}}{1000 l_{30}} \ (kN/m)$$

Load acting on rudder body (Type *D* and *E* rudders)

$$P_{R10} = \frac{F_{R2}}{1000 l_{10}} \ (kN/m)$$

$$P_{R20} = \frac{F_{R1}}{1000 l_{20}} \ (kN/m)$$

Where:

F_R, F_{R1}, F_{R2}: As specified in **3.2** and **3.3, Part C** of the Rules

k: Spring constant of the supporting point of the shoe piece or rudder horn respectively, as shown below

For the supporting point of the shoe piece:

$$k = \frac{6.18 I_{50}}{{l_{50}}^3} \ (kN/m)$$

(*See* Fig. C3.4.1-1 and Fig. C3.4.1-2)

Where:

I_{50}: The moment (cm^4) of inertia of shoe piece around the Z-axis

l_{50}: Effective length (m) of shoe piece

For the supporting point of rudder horn:

$$k = \frac{1}{f_b + f_t} \ (kN/m)$$

(*See* Fig. C3.4.1-1, Fig. C3.4.1-4 and Fig. C3.4.1-5)

Where:

f_b: Unit displacement of rudder horn due to a unit force of 1 kN acting in the centre of support as shown below.

$$f_b = 1.3 \frac{d^3}{6.18 I_n} \ (m/kN)$$

Where:

I_n: The moment (cm^4) of inertia of rudder horn around the X-axis

f_t: Unit displacement due to torsion, as shown below.

$$f_t = \frac{d c^2 \Sigma u_i / t_i}{3.14 {F_T}^2} \times 10^{-8} \ (m/kN)$$

F_T: Mean sectional area (m^2) of the rudder horn

u_i: Breadth (mm) of the individual plates forming the mean sectional area of the rudder horn

t_i: Plate thickness (mm) within the individual breadth u_i

For c and d, see Fig. C3.4.1-4 and Fig. C3.4.1-5. (For the rudder horn of Type A rudders, the same values are to be also applied.)

(3) Simplified method

The moments and forces for rudders of each type may be obtained from the following formulae.

(a) Type A rudders

$$M_R = \frac{{B_1}^2 (l_{10} + l_{30})}{2 F_R} \ (N\text{-}m)$$

$$M_b = \frac{B_3 (l_{30} + l_{40})(l_{10} + l_{30})^2}{l_{10}^2} \ (N\text{-}m)$$

$$M_s = B_3 l_{40} \ (N\text{-}m)$$

$$B_1 = \frac{F_R h_c}{l_{10}} \ (N)$$

$$B_2 = F_R - 0.8 B_1 + B_3 \ (N)$$

$$B_3 = \frac{F_R {l_{10}}^2}{8 l_{40} (l_{10} + l_{30} + l_{40})} \ (N)$$

(b) Type B rudders

$$M_R = \frac{{B_1}^2 l_{10}}{2 F_R} \ (N\text{-}m)$$

$$M_b = B_3 l_{40} \ (N\text{-}m)$$

$$M_s = \frac{3 M_R l_{30}}{l_{10} + l_{30}} \ (N\text{-}m)$$

$$B_1 = \frac{F_R h_c}{l_{10} + l_{30}} \ (N)$$

$$B_2 = F_R - 0.8 B_1 + B_3$$

$$B_3 = \frac{F_R (l_{10} + l_{30})^2}{8 l_{40} (l_{10} + l_{30} + l_{40})} \ (N)$$

(c) Type C rudders

$$M_b = F_R h_c \ (N\text{-}m)$$

$$B_2 = F_R + B_3 \ (N)$$

$$B_3 = \frac{M_b}{l_{40}} \ (N)$$

The maximum moment M_c in top of the cone coupling (as shown in **Fig.C3.4.1-3**) is applicable for the connection between the rudder and the rudder stock.

Notwithstanding the above, the strength is to be checked against the following two cases for rudders with rudder trunks supporting rudder stocks.

i) pressure applied on the entire rudder area; and

ii) pressure applied only on rudder area below the middle of neck bearing.

The moments and forces for the two cases defined above may be determined according to **Fig. C3.4.1-6** and **Fig. C3.4.1-7**, respectively.

$$M_{FR1} = F_{R1} \left(CG_{1Z} - \ell_{10}\right)$$

$$M_{FR2} = F_{R2} \left(\ell_{10} - CG_{2Z}\right)$$

where A_1 and A_2 are the rudder blade area which are above the lower bearing and below respectively and symbols are as follows (*See* **Fig. C3.4.1-6** and **Fig. C3.4.1-7**)

F_{R1} : Rudder force over the rudder blade area A_1

F_{R2} : Rudder force over the rudder blade area A_2

CG_{1Z}: Vertical position of the centre of gravity of the rudder blade area A_1 from base

CG_{2Z}: Vertical position of the centre of gravity of the rudder blade area A_2 from base

$$F_R = F_{R1} + F_{R2}$$

$$B_2 = F_R + B_3$$

$$B_3 = \frac{M_{FR2} - M_{FR1}}{\ell_{20} + \ell_{40}}$$

(d) Type D rudders

$$M_R = \frac{F_{R2} l_{10}}{2} \ (N\text{-}m)$$

$$M_b = \frac{F_R {l_{10}}^2}{10(l_{20}+l_{30})} \ (N\text{-}m)$$

$$M_s = \frac{2 M_R l_{10} l_{30}}{(l_{20}+l_{30})^2} \ (N\text{-}m)$$

$$B_1 = \frac{F_R h_c}{l_{20}+l_{30}} \ (N)$$

$$B_2 = F_R - B_1, \ \min B_2 = F_R/4 \ (N)$$

$$B_3 = \frac{M_b}{l_{40}} \ (N)$$

$$Q_1 = F_{R2} \ (N)$$

(e) Type E rudders

$$M_R = \frac{F_{R2} l_{10}}{2} \ (N\text{-}m)$$

$$M_b = \frac{F_R {l_{10}}^2}{10 l_{20}} \ (N\text{-}m)$$

$$B_1 = \frac{F_R h_c}{l_{20}} \ (N)$$

$$B_2 = F_R - B_1, \min B_2 = F_R/4 \ (N)$$

$$B_3 = \frac{M_b}{l_{40}} \ (N)$$

$Q_1 = F_{R2}$ (N)

4 Method of evaluating moments and forces (Type *D* rudders with 2-conjugate elastic support)

For Type *D* rudders with 2-conjugate elastic supports by rudder horns, the method of evaluating moments and forces is to be as in **(1)** and **(2)** below.

(1) General data

K_{11}, K_{22}, K_{12} : Rudder horn compliance constants calculated for rudder horn with 2-conjugate elastic supports (**Fig. C3.4.1-7**). The 2-conjugate elastic supports are defined in terms of horizontal displacements, y_i, by the following equations:

at the lower rudder horn bearing:

$y_1 = -K_{12} B_2 - K_{22} B_1$

at the upper rudder horn bearing:

$y_2 = -K_{11} B_2 - K_{12} B_1$

Where

y_1, y_2 : Horizontal displacements (m) at the lower and upper rudder horn bearings, respectively

B_1, B_2 : Horizontal support forces (kN) at the lower and upper rudder horn bearings, respectively

K_{11}, K_{22}, K_{12} : Obtained (m/kN) from the following formulae:

$$K_{11} = 1.3 \cdot \frac{\lambda^3}{3EI_{1h}} + \frac{e^2\lambda}{GI_{th}}$$

$$K_{12} = 1.3\left[\frac{\lambda^3}{3EI_{1h}} + \frac{\lambda^2(d-\lambda)}{2EI_{1h}}\right] + \frac{e^2\lambda}{GI_{th}}$$

$$K_{22} = 1.3\left[\frac{\lambda^3}{3EI_{1h}} + \frac{\lambda^2(d-\lambda)}{EI_{1h}} + \frac{\lambda(d-\lambda)^2}{EI_{1h}} + \frac{(d-\lambda)^3}{3EI_{2h}}\right] + \frac{e^2 d}{GI_{th}}$$

d : Height of the rudder horn (m) defined in **Fig. C3.4.1-7**. This value is measured downwards from the upper rudder horn end, at the point of curvature transition, till the mid-line of the lower rudder horn pintle

λ : Length (m) as defined in **Fig. C3.4.1-7**. This length is measured downwards from the upper rudder horn end, at the point of curvature transition, till the mid-line of the upper rudder horn bearing. For $\lambda = 0$, the above formulae converge to those of spring constant Z for a rudder horn with 1-elastic support, and assuming a hollow cross section for this part

e : Rudder-horn torsion lever (m) as defined in **Fig. C3.4.1-7** (value taken at $z = d/2$)

I_{1h} : Moment of inertia of rudder horn about the x axis (m^4) for the region above the upper rudder horn bearing. Note that I_{1h} is an average value over the length λ (see **Fig. C3.4.1-7**)

I_{2h} : Moment of inertia of rudder horn about the x axis (m^4) for the region between the upper and lower rudder horn bearings. Note that I_{2h} is an average value over the length $d - \lambda$ (see **Fig. C3.4.1-7**)

I_{th} : Torsional stiffness factor of the rudder horn (m^4)

For any thin wall closed section

$$I_{th} = \frac{4F_T^2}{\sum_i \frac{u_i}{t_i}}$$

F_T : Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn (m^2)

u_i : Length (mm) of the individual plates forming the mean horn sectional area

t_i : Thickness (mm) of the individual plates mentioned above.

Note that the I_{th} value is taken as an average value, valid over the rudder horn height.

(2) Direct calculation

The standard data to be used for direct calculation are as follows:

Load acting on rudder body

$$P_{R10} = \frac{F_{R2}}{1000 l_{10}} \ (kN/m)$$

$$P_{R20} = \frac{F_{R1}}{1000 l_{20}} \ (kN/m)$$

F_R, F_{R1}, F_{R2} : As defined in **3.3.2**

Fig. C3.4.1-1 Type *A* Rudder

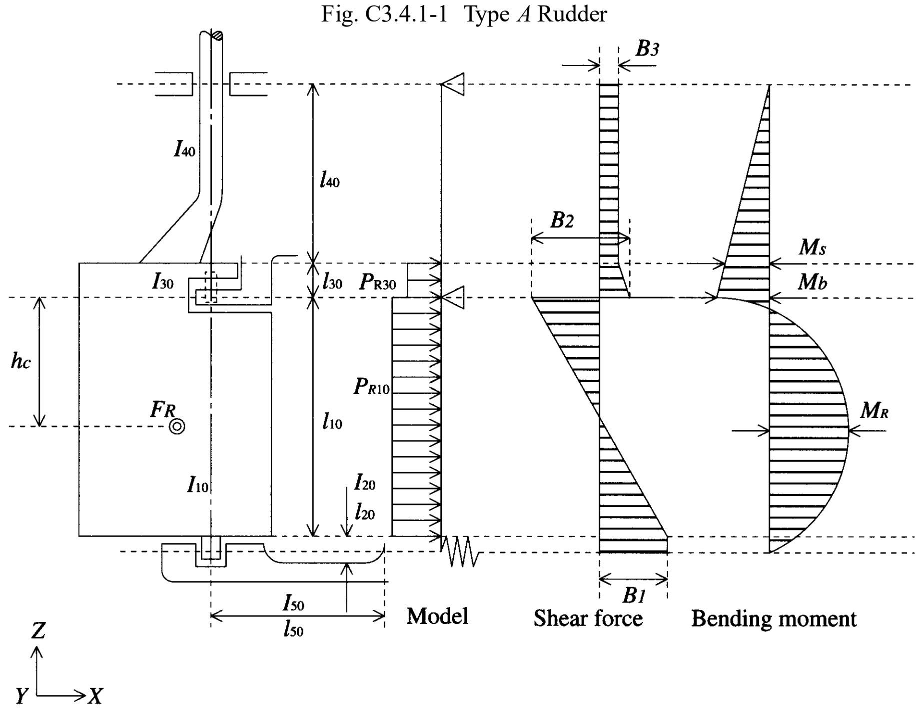


Fig. C3.4.1-2 Type *B* Rudder

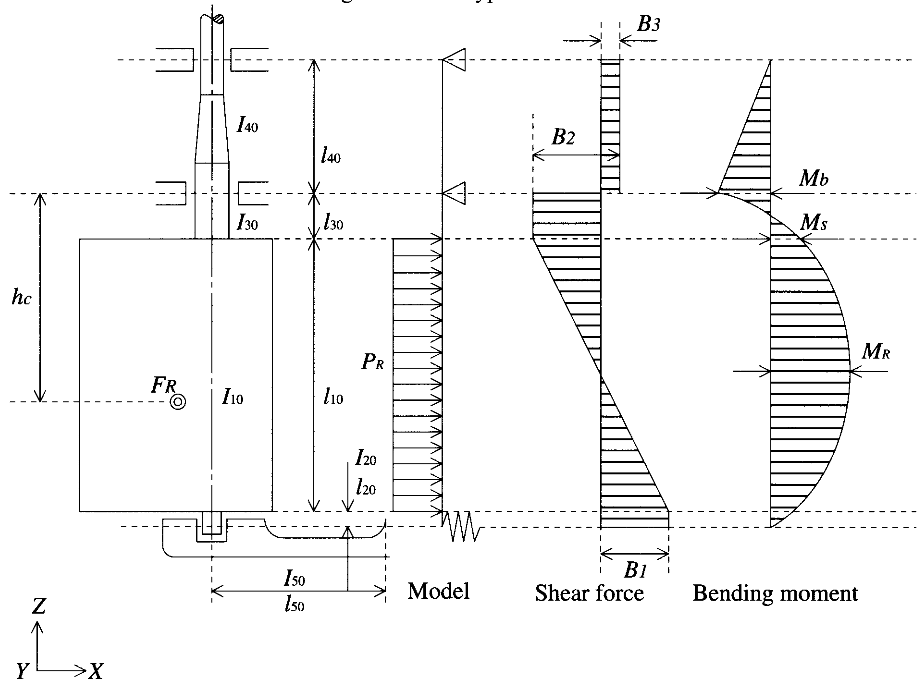


Fig. C3.4.1-3 Type C Rudder

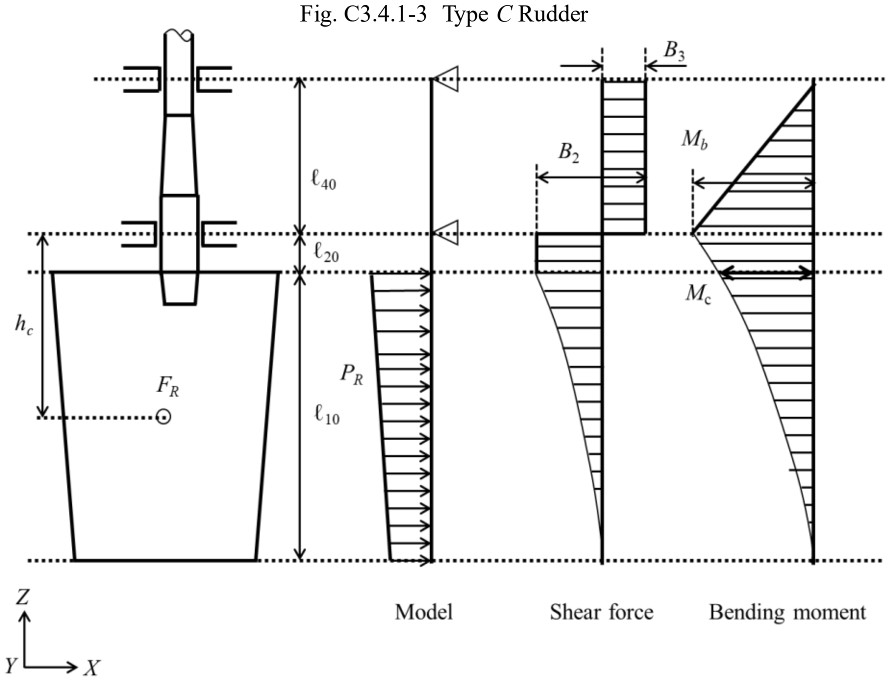


Fig. C3.4.1-4 Type D Rudder

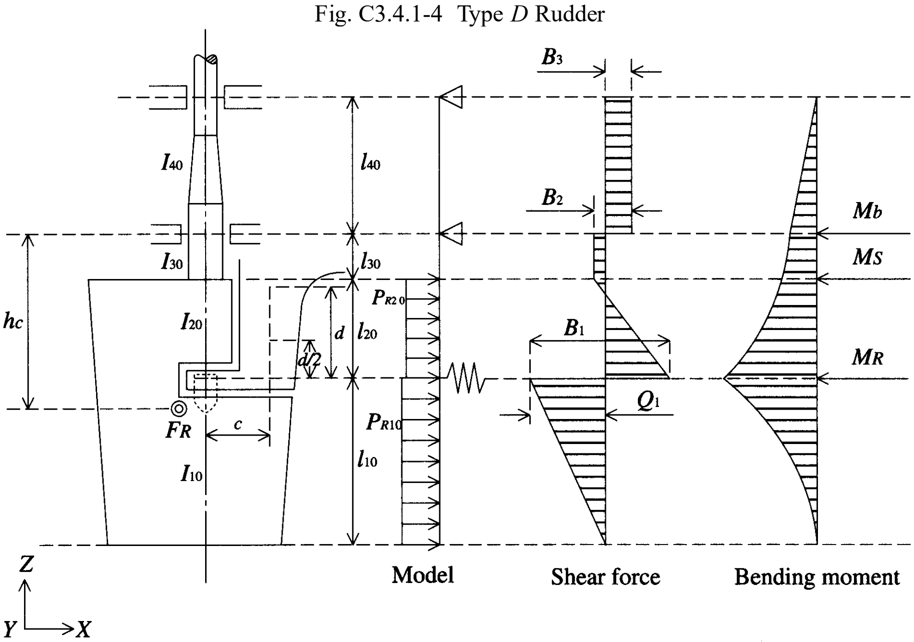


Fig. C3.4.1-5 Type *E* Rudder

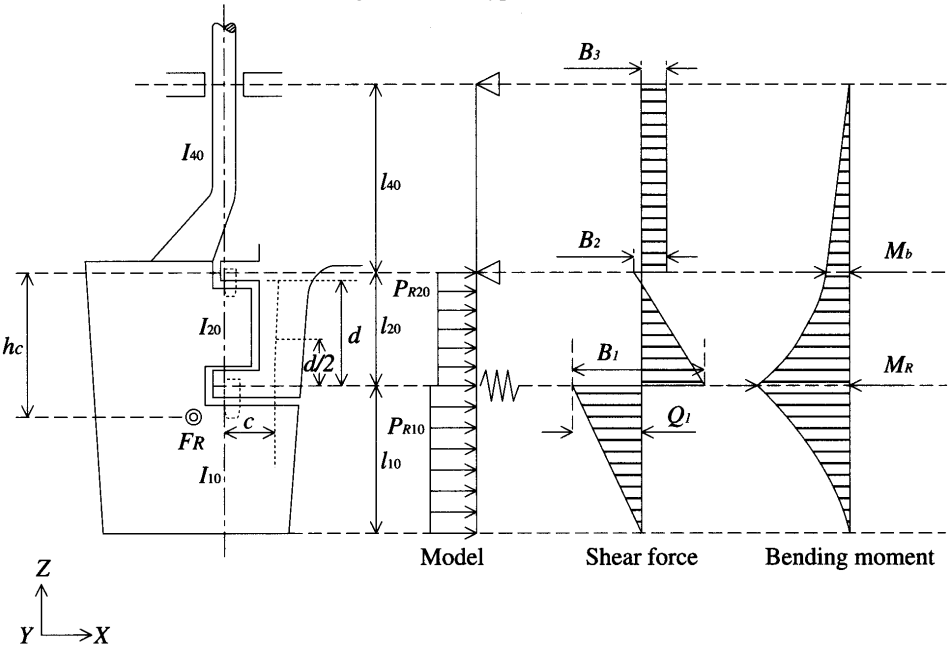


Fig. C3.4.1-6 Type *C* Rudder with Rudder Trunk Supporting Rudder Stock (Pressure Applied on the Entire Rudder Area)

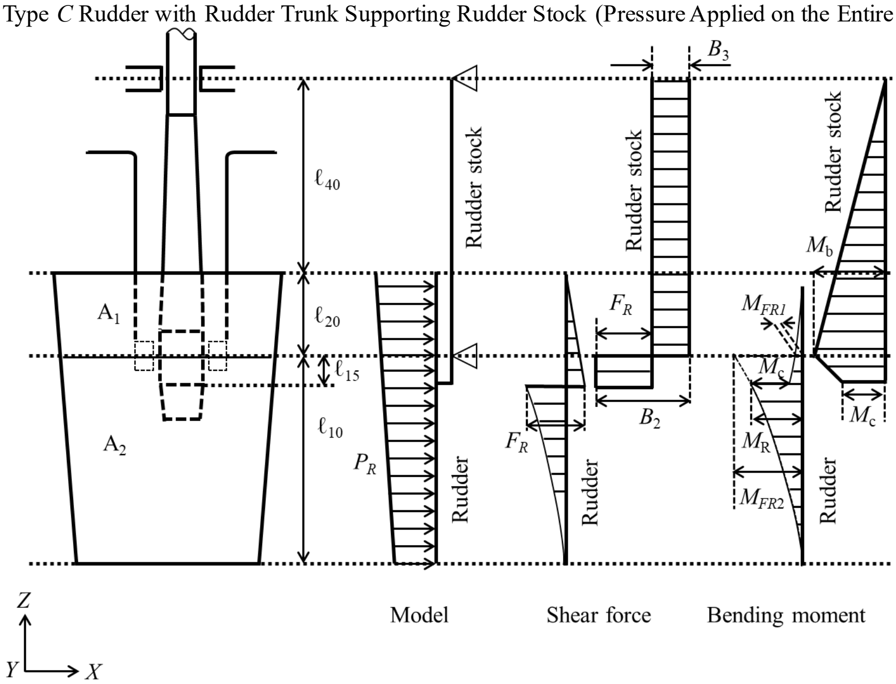


Fig. C3.4.1-7 Type *C* Rudder with Rudder Trunk Supporting Rudder Stock (Pressure Applied only on Rudder Area below the Middle of Neck Bearing)

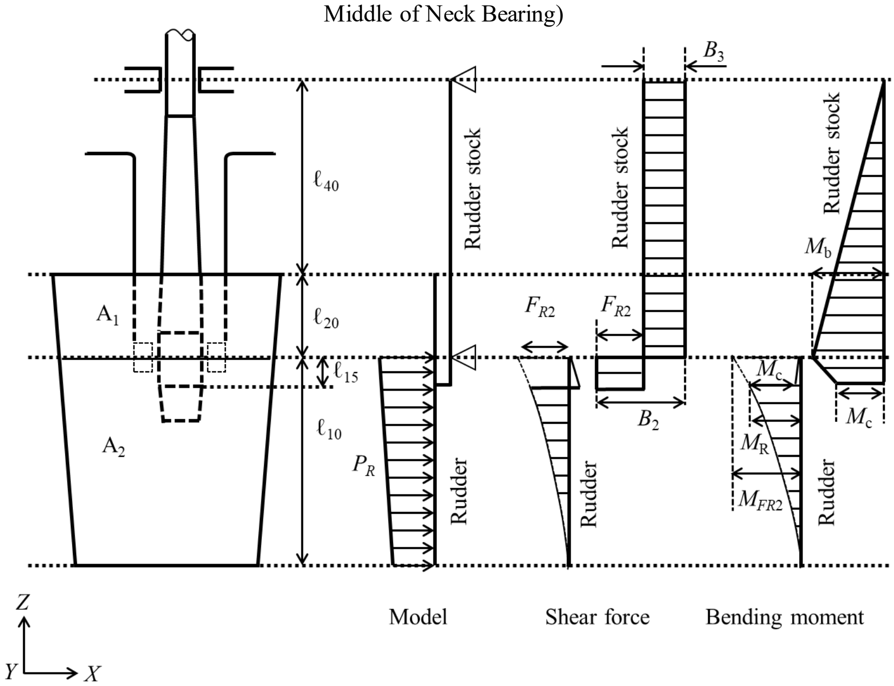
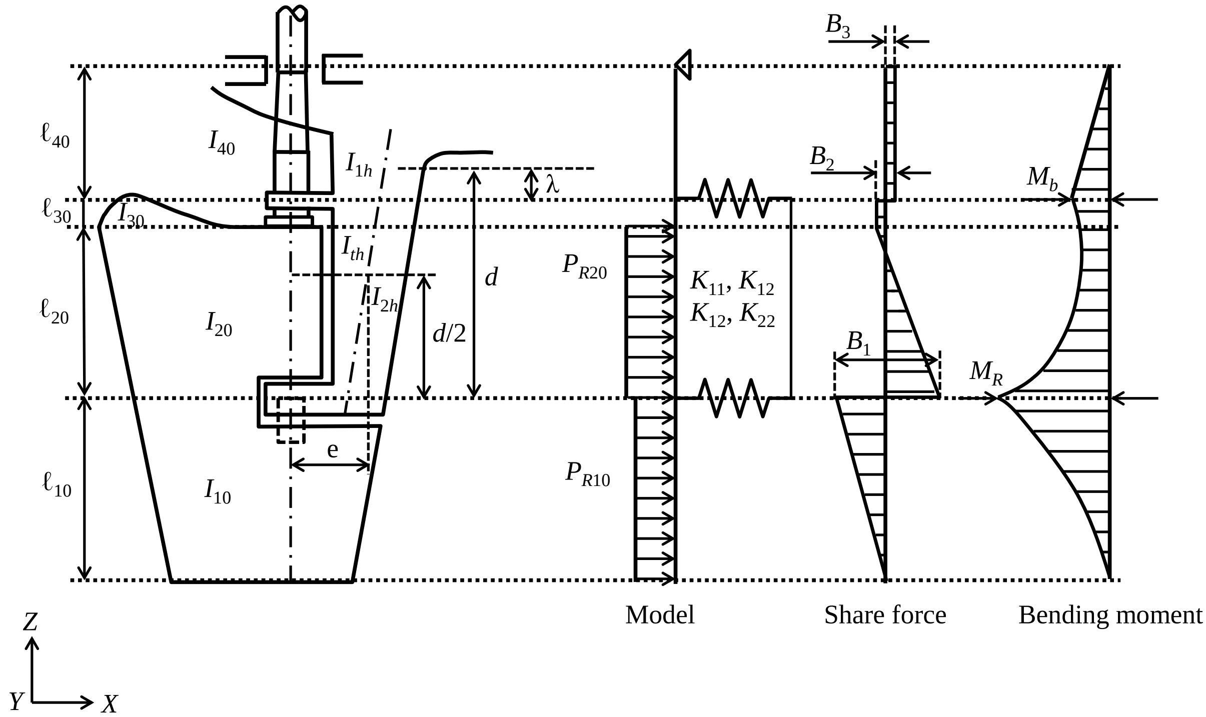


Fig. C3.4.1-8 Type *D* Rudder with 2-conjugate Elastic Supports



C3.5 Rudder Stocks

C3.5.1 Upper Stocks

1 Taper of upper stock at joint with tiller

Where the upper stocks are tapered for fitting the tiller, the taper is not to exceed 1/25 of the radius or 1/12.5 of the diameter.

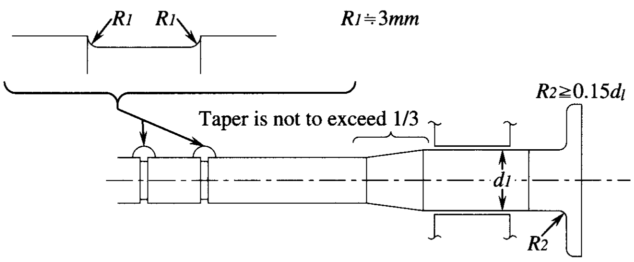
2 Keyways

(1) The depth of the keyway may be neglected in determining the diameter of the rudder stock.

(2) All corners of keyways are to be properly rounded.

3 Each part of the rudder stocks of Type B, C and D rudders specified in **3.5, Part C** of the Rules is to be so constructed as shown below.

Fig. C3.5.1-1 Rudder Stock of Type B, C and D Rudder



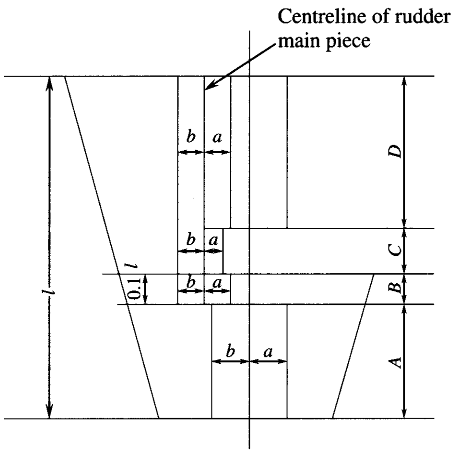
C3.6 Rudder Plates, Rudder Frames and Rudder Main Pieces

C3.6.3 Rudder Main Pieces

1 In Type D and Type E rudders, the effective breadth of the rudder plate B_e to be included in the section modulus of the main piece is to be as shown in **Fig. C3.6.3-1**. However, the cover plate which is removed to lift up the rudder is not to be included in the section modulus. These requirements also apply to Type A rudders.

2 Material factor K_m is to be for the lowest strength material among the materials used in the section considered.

Fig. C3.6.3-1 Effective Breadth of Rudder Plate



$B_e = a + b$

Where :

within the area A : $a = b = 0.1\ l$

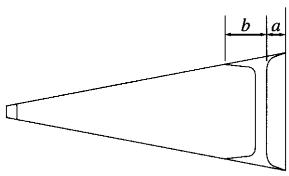
within the area B and D :

$a = b = 0.08\ l$

within the area C :

a is to be as shown below provided that a will not exceed $0.08\ l$

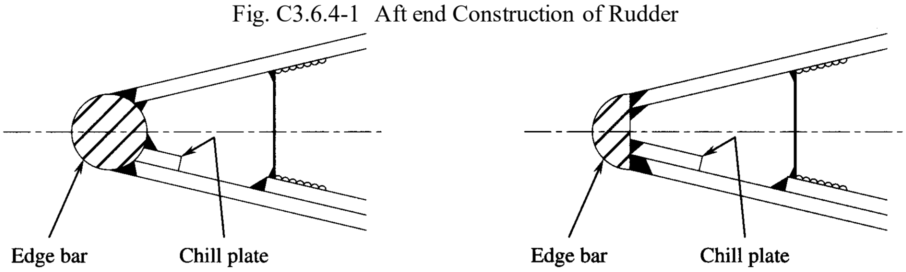
$b = 0.08\ l$



C3.6.4 Connections

In principle, edge bars are to be fitted to the aft end of the rudder. However, considering the size and form of the rudder, weldability, etc., edge bars and/or chill plates may be omitted. (*See* **Fig. C3.6.4-1**)

Fig. C3.6.4-1 Aft end Construction of Rudder



C3.8 Couplings between Rudder Stocks and Main Pieces

C3.8.1 Horizontal Flange Couplings

1 Diameters of coupling bolts in Type *A* and Type *E* rudders

In the application of **3.8.1-1, Part C** of the Rules, the diameter of the coupling bolt d_l in Type *A* and Type *E* rudders is to be determined in accordance with the requirements in **3.5.2, Part C** of the Rules, assuming that the lower stock is cylindrical.

2 Locking device for nuts of coupling bolts

The nuts of coupling bolts are to have locking devices. They may be split pins.

C3.8.2 Vertical Flange Couplings

1 Diameter of coupling bolts in Type *A* and *E* rudders

In the application of **3.8.2-1, Part C** of the Rules, the diameter of the coupling bolt d_l in Type *A* and *E* rudders is to be determined in accordance with **3.5.2, Part C** of the Rules, assuming that the lower stock is cylindrical.

2 Locking devices for nuts of coupling bolts

The nuts of coupling bolts are to have locking devices. They may be split pins.

C3.8.3 Cone Couplings with Key

1 General

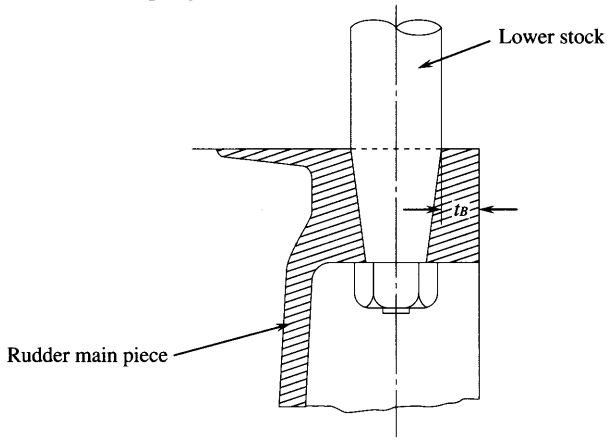
(1) The lower stock is to be securely connected to the rudder body with slugging nuts or hydraulic arrangements. Shipbuilders are to submit data on this connection to the Society.

(2) Special attention is to be paid to corrosion of the lower stock.

(3) The thickness t_B of the cast steel part of the rudder body (*See* **Fig. C3.8.3-1**) is not to be less than 0.25 *times* the required diameter of the lower stock.

(4) In the application of **3.8.3-1** to **-3, Part C** of the Rules, actual values are to be used for d_0, d_g and d_e.

Fig. C3.8.3-1 Coupling Between Lower Stock and Rudder Main Piece



2 In the application of **3.8.3-5**, the scantlings of the key are as follows in cases where all rudder torque is considered to be transmitted by the key at the couplings.

(1) The shear area A_k of keys is not to be less than:

$$A_k = \frac{30 T_R K_k}{d_k} \quad (mm^2)$$

Where:

d_k: Rudder stock diameter (*mm*) at the mid-point of length of the key

K_k: Material factor for the key as given in **3.1.2, Part C** of the Rules

T_R: Rudder torque obtained from **3.3, Part C** of the Rules

(2) The abutting surface area A_c between the key and rudder stock or between the key and rudder body, respectively, is not to be less than:

$$A_c = \frac{10T_R K_{\max}}{d_k} \ (mm^2)$$

Where:

K_{max}: The greater of the material factors (given in **3.1.2, Part C** of the Rules) between the rudder stock and the key it is in contact with or the greater of the material factors between the rudder body and the key it is in contact with

d_k and T_R: As specified in **(1)**

C3.8.4 Cone Couplings with Special Arrangements for Mounting and Dismounting the Couplings

The outer diameter of gudgeon (d_a) is recommended to be taken at the same plane in which the mean cone diameter (d_m).

C3.9 Pintles

C3.9.2 Construction of Pintles

1 Locking device for pintle nut

Split pins are not recommendable as the locking device for pintle nuts. Locking rings or other equivalent devices are to be used, as shown in **Fig. C3.9.2-1**.

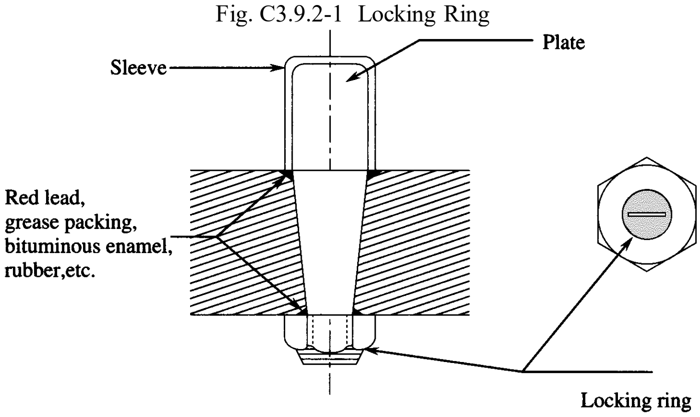
2 Preventing corrosion of pintles

To prevent corrosion of pintles, the end of the sleeve is to be filled with red lead, grease packing, bituminous enamel, rubber, etc. as shown in **Fig. C3.9.2-1**.

3 Combination of pintle and rudder frame in monoblock

In ships exceeding 80 m in length, combining the pintle and rudder frame into a monoblock is not recommended.

Fig. C3.9.2-1 Locking Ring



4 For the reaction force in bearing B specified in **3.9.2-2**, for example, B_1 defined in **Fig. C3.4.1-4** is used for Type D rudders.

C3.10 Bearings of Rudder Stocks and Pintles

C3.10.1 Minimum Bearing Surface

1 Where a metal bush is used, the sleeve is to be of a different material from the bush (for example, sleeve of *BC*3 and bush of *BC*2).

2 "The type as deemed appropriate by the Society" stipulated in **Table C3.3, Part C** of the Rules means that approval is to be made in accordance with the requirements of **Chapter 5, Part 4 of Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**.

C3.10.3 Bearing Clearances

Where a bush is non-metal, the standard bearing clearance is to be 1.5~2.0 mm in diameter.

C3.11 Rudder Accessories

C3.11.1 Rudder Carriers

1 Materials of rudder carriers and intermediate bearings

Rudder carriers and intermediate bearings are to be of steel. They are not to be of cast iron.

2 Thrust bearing of rudder carrier

(1) The bearing is to be provided with a bearing disc made of bronze or other equivalent materials.

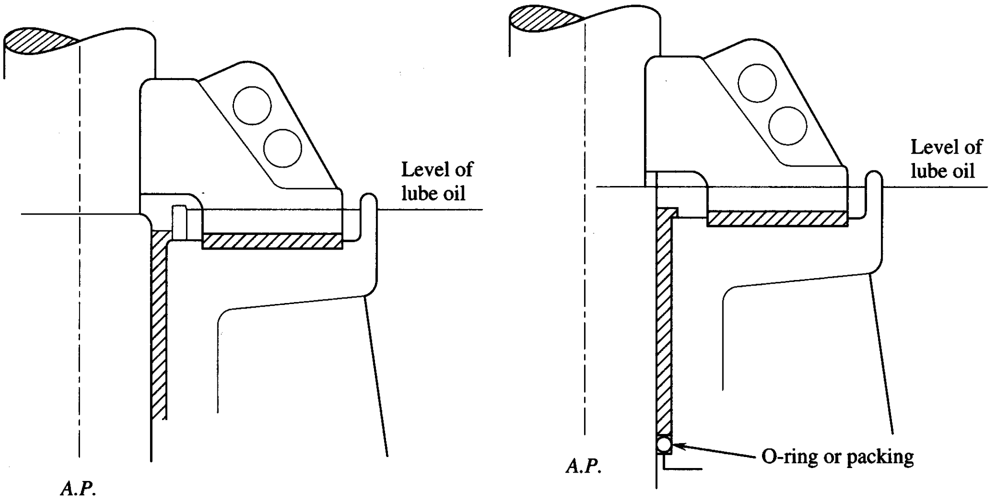
(2) The calculated bearing pressure is not to exceed 0.98 *MPa* as a standard. In calculating the weight of the rudder, its buoyancy is to be neglected.

(3) The requirements in **(1)** and **(2)** above need not be applied to bearings in cases where good lubrication can be confirmed under the assumed bearing surface pressure through documentation submitted either by manufacturers or shipyards.

(4) The bearing part is to be well lubricated by dripping oil, automatic grease feeding, or a similar method.

(5) The bearing is to be designed to be structurally below the level of lubricating oil at all times. (*See* **Fig. C3.11.1-1**)

Fig. C3.11.1-1 Rudder Carrier



3 Watertightness of rudder carrier part

(1) In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the waterline at scantling draught (without trim), two separate watertight seals or stuffing boxes are to be provided.

(2) It is recommended that the packing gland in the stuffing box have an appropriate clearance from the rudder stock corresponding to the position of the stuffing box. The standard clearance is to be 4 *mm* for the stuffing box provided at the neck or intermediate bearing, and 2 *mm* for the stuffing box at the upper stock bearing.

4 Assembly of rudder carriers

In split type rudder carriers, at least two bolts are to be used on each side of the rudder for assembly.

5 Installation of rudder carriers

(1) In ships exceeding 80 *m* in length, it is recommended that the rudder carrier is directly installed on the seat on the deck.

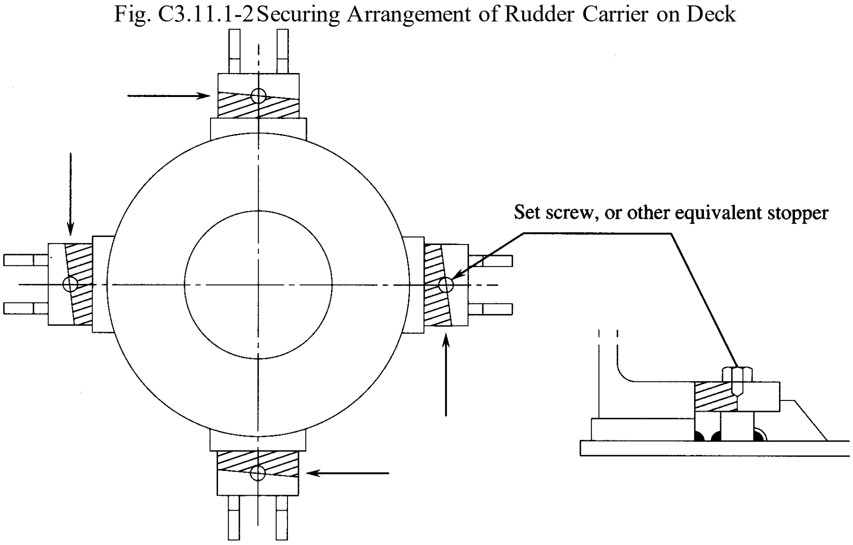
(2) A spigot type seat is not recommended to be installed on the deck.

(3) The hull construction in way of the rudder carrier is to be suitably reinforced.

6 Bolts securing rudder carriers and intermediate bearing

(1) At least one half of the bolts securing the rudder carrier and the intermediate bearing are to be reamer bolts. If stoppers for preventing the rudder carrier from moving are to be fitted on the deck, all bolts may be ordinary bolts. In using chocks as stoppers, they are to be carefully arranged so that they are not driven in, in the same direction. (*See* **Fig C3.11.1-2**)

Fig. C3.11.1-2 Securing Arrangement of Rudder Carrier on Deck



(2)

(a) In ships provided with electrohydraulic steering gears, the total sectional area of the bolts securing the rudder carriers or the bearing just under the tiller to the deck is not to be less than that obtained from the following formula:

$0.1d_u^2$ (mm^2)

Where:

d_u: Required diameter of upper stock (mm)

(b) Where the arrangement of the steering gear is such that each of the two tiller arms is connected with an actuator and two actuators function simultaneously, or is of any other type where the rudder stock is free from horizontal force, the total sectional area of bolts securing the rudder carrier to the deck may be reduced to 60% of the area required in **(a)**.

(c) Where all the bolts securing the rudder carrier to the deck are reamer bolts, the total sectional area of bolts may be reduced to 80% of the area required by **(a)** and **(b)**.

C3.11.2 Prevention of Jumping

A 2 mm clearance between the jumping stopper and its contact surface is deemed as standard.

C4 SUBDIVISIONS

C4.1 General

C4.1.1 Application

"Those ships specifically approved by the Society" refers to the following.

(1) Bulk carriers having freeboards of type B-60 or B-100 as specified in the requirements of **Part V** of the Rules; however, when carrying deck cargoes, the requirements of **Chapter 4, Part C** of the Rules apply

(2) Special purpose ships complying with the requirements of *IMO Resolution MSC*.266(84)

C4.1.2 Definitions

1 "Light service draught" stated in **4.1.2(4), Part C** of the Rules corresponds, in general, to the ballast arrival condition with 10 % consumables.

2 "Deck or decks limiting the vertical extent of flooding" stated in **4.1.2(6), Part C** of the Rules refers to the weather deck. However, when the ship has multiple decks above d_s + 12.5 (m) at the deepest subdivision draught, the deck just above d_s + 12.5 (m) is implied.

Table C4.1.2 Permeability of Compartment Regarding Timber Cargo

Space for	Permeability at draught d_s	Permeability at draught d_p	Permeability at draught d_l
Timber cargo in holds	0.35	0.70	0.95
Wood chip cargo	0.60	0.70	0.95

3 The wording "specifically accepted by the Society" stated in **4.1.2(13), Part C** of the Rules means the carriage of timber and wood chip in cargo holds. Figures specified in **Table C4.1.2** may be used as the permeability of compartment.

4 With respect to the provisions of **4.1.2(13), Part C** of the Rules, the volume of spaces under consideration is to be taken as the moulded volume.

C4.2 Subdivision Index

C4.2.1 Subdivision Index

1 If pipes, ducts or tunnels are provided within an assumed damaged compartment or group of compartments, they are to be arranged in such a way as to prevent flooding progressing to other compartments, or they are to be fitted with devices which can easily control the progress of flooding to other compartments. However, where the attained subdivision index takes into account flooding to other compartment through the pipes, ducts or tunnels, and satisfies the requirements in **4.2, Part C** of the Rules, these requirements need not apply.

2 Notwithstanding the provisions of **-1** above, minor progressive flooding may be permitted if it is demonstrated that the effects of progressive flooding of other compartments through these pipes, ducts or tunnels can be easily controlled and the safety of the ship is not impaired. However, for ships up to L_f = 150 m the provision for allowing "minor progressive flooding" is to be limited to pipes penetrating a watertight subdivision with a total cross-sectional area of not more than 710 mm^2 between any two watertight compartments. For ships of L_f = 150 m and upwards the total cross-sectional area of pipes is not to exceed the cross-sectional area of one pipe with a diameter of L_f/5000 m.

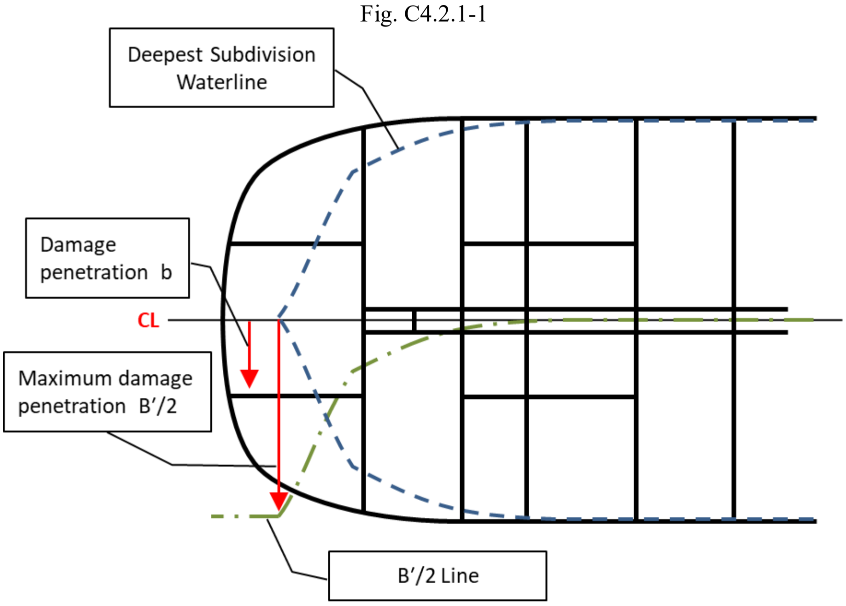
3 Where penetrations for piping, ventilation, electrical cables, etc. are provided in bulkheads, decks and shells forming a compartment, the watertight integrity of the penetrations are to be at least equivalent to the parts they penetrate.

4 With the same intent as wing tanks, the summation of the attained index A is to reflect effects caused by all watertight bulkheads and flooding boundaries within the damaged zone. It is not correct to assume damage only to one half of the ship's breadth (B') and ignore changes in subdivision that would reflect lesser contributions.

5 In the forward and aft ends of the ship where the sectional breadth is less than the ship's breadth (B') specified in **4.1.2(11), Part C** of the Rules, transverse damage penetration may extend beyond the centreline bulkhead.

6 Where, at the extreme ends of the ship, the subdivision exceeds the waterline at the deepest subdivision draught, the damage penetration b or $B'/2$ is to be taken from centreline. **Fig. C4.2.1-1** illustrates the shape of the $B'/2$ line.

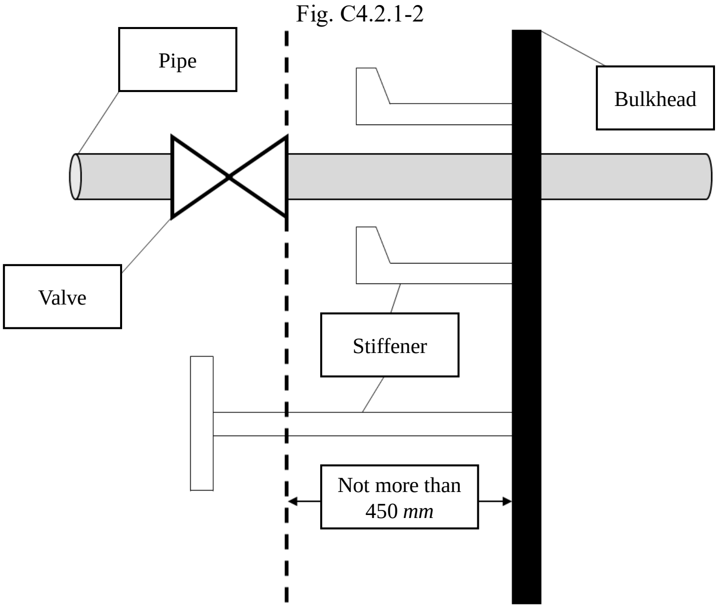
Fig. C4.2.1-1



7 Where longitudinal corrugated bulkheads are fitted in wing compartments or on the centreline, they may be treated as equivalent plane bulkheads provided the corrugation depth is of the same order as the stiffening structure. The same principle may also be applied to transverse corrugated bulkheads.

8 Pipes and valves directly adjacent or situated as close as practicable to a bulkhead or to a deck can be considered to be part of the bulkhead or deck, provided the separation distance on either side of the bulkhead or deck is of the same order as the bulkhead or deck stiffening structure. The same applies for small recesses, drain wells, etc. In no case is the separation distance on either side of the bulkhead or deck to be more than 450 *mm* measured from the valve's near end to the bulkhead or deck. An example is shown in **Fig. C4.2.1-2**.

Fig. C4.2.1-2

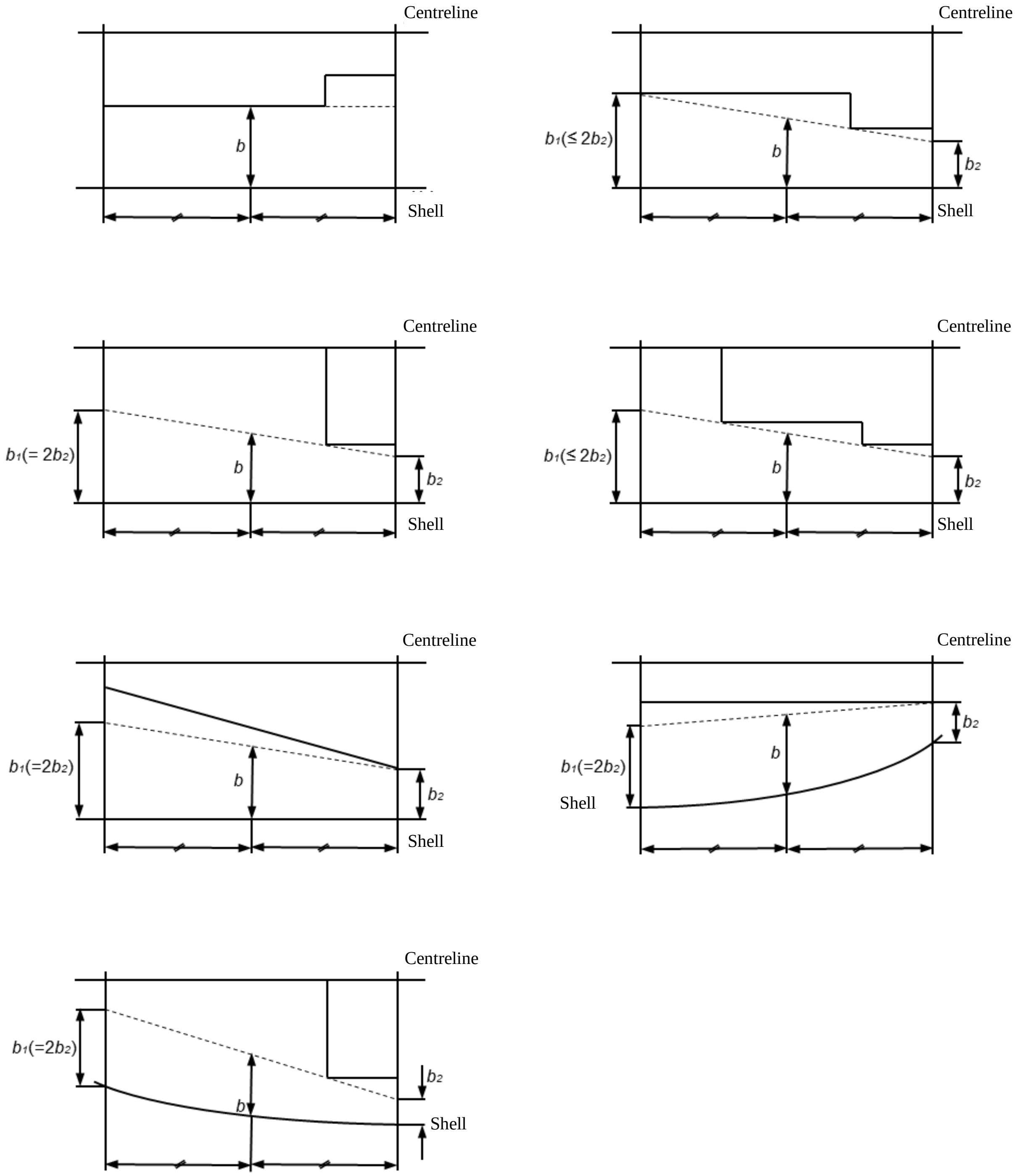


9 In setting the trim and G_0M used to calculate the subdivision index, reference is also to be made to **1.3.10-11** and **-12**, **Annex U1.2.1 "GUIDANCE FOR STABILITY INFORMATION FOR MASTER", Part U of the Guidance**.

C4.2.2 Compartment Flooding Probability (p_i)

In application of the requirement of **4.2.2-1, Part C** of the Rules, in case where the longitudinal bulkhead is not paralleled to the side shell plating, the assumed vertical plane which is considered in the determination of transverse distance (b) between longitudinal bulkhead and side shell plating is to be refer to a example specified in **Fig.C4.2.2**.

Fig. C4.2.2 Examples of Assumed Vertical Plane (In case of Single Damage Zone)



C4.2.3 Probability of Survival (s_i)

1 Openings (e.g., access openings provided in the end bulkhead of the superstructure and cargo hatchways), air pipes, and ventilators which are provided only with the weathertight closing apparatus specified in **Part C** of the Rules are to be treated as allowing progress of flooding when the water line at the final equilibrium state immerses their lower edge.

2 In applying θ_v specified in **4.2.3-1, Part C of the Rules**, an “opening incapable of being closed weathertight” includes ventilators provided with weathertight closing appliances in accordance with the requirements of **23.6.5-2, Part C of the Rules** that for operational reasons have to remain open to supply air to the engine room, emergency generator room or closed ro-ro and vehicle spaces (if the same is considered buoyant in the stability calculation or protecting openings leading below) for the effective operation of the ship. Where it is not technically feasible to treat some closed ro-ro and vehicle space ventilators as unprotected openings, an alternative arrangement that provides an equivalent level of safety may be used provided that it is deemed appropriate by the Administration.

3 The calculation of the probability of survival (s_i) in **4.2.3-10, Part C of the Rules** is to be treated as follows.

(1) Where the buoyancy of the timber deck cargo is taken into account, the cargo is to be in compliance with the following **(a)** to **(d)**:

(a) The timber deck cargo is to be stowed in accordance with the requirements of **Section 2.9**, **Part A** of the *Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 2011* (*IMO* resolution *A*.1048(27)).

(b) The timber deck cargo is to be secured by lashings, uprights or both.

(c) Lashings and uprights are to comply with the requirements of **Section 2.10**, **Part A** of the *Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 2011* (*IMO* resolution *A*.1048(27)).

(d) The height and extent of the timber deck cargo is to be in accordance with **Section 3.3.2** of **Chapter 3**, **Part A** of the *International Code on Intact Stability, 2008 (2008 IS Code)* and is to be at least stowed to the standard height of one superstructure.

(2) The permeability of the timber deck cargo is not to be less than 25 % of the volume occupied by the cargo up to one standard superstructure height.

(3) When the buoyancy of any timber deck cargo is taken into account, the timber deck cargo in way of a damaged zone is deemed ineffective to all areas in an athwartships direction. However, when the vertical extent of the damage stops at the upper deck and the coefficient (v_m) from **4.2.3-4, Part C** of the Rules is used in the calculations, the buoyancy of the timber deck cargo may be taken into account in accordance with **(2)** above even if it is directly above the damaged area.

4 Tanks and compartments taking part in such equalization is to be fitted with air pipes or equivalent means of sufficient cross-section to ensure that the flow of water into the equalization compartments is not delayed.

5 In applying the requirements specified in **4.2.3-9(2), Part C of the Rules**, with respect to equalization devices, reference is to be made to the *IMO Res. MSC*.362(92) *"Revised Recommendation on a standard method for evaluating cross-flooding arrangements"*, as amended.

6 If the final waterline immerses the lower edge of any opening through which progressive flooding takes place, the factor "*s*" may be recalculated taking such flooding into account. However, in this case the *s* value is also to be calculated without taking into account progressive flooding and corresponding opening. The smallest *s* value is to be retained for the contribution to the attained index.

C4.3 Openings

C4.3.1 Internal Openings

1 "Watertight" stated in **4.3.1-1, Part C** of the Rules means watertight integrity that is sufficient against a water head corresponding to the opening in question at the final equilibrium state and intermediate waterline.

2 With respect to the provisions of **4.3.1-2, Part C** of the Rules, watertight closing appliances are categorized as in the following **(1)** to **(3)** corresponding to their purpose and frequency of use.

(1) Watertight closing appliances which are to be *permanently closed* at sea:

Such appliances are open in port and closed before the ship leaves port. The time of opening/closing such doors is to be recorded in the log-book.

(2) Watertight closing appliances which are to be *normally closed* at sea:

Such appliances are kept closed at sea but may be used if authorized by the officer of the watch and to be closed again after use.

(3) Watertight closing appliances which are *used* at sea:

Such appliances are used regularly and may be left open provided they are ready to be immediately closed.

3 General requirements of **4.3.1-2, Part C** of the Rules are shown in **Table C4.3.1-1**.

Table C4.3.1-1 Requirements for Closing Devices for Internal Openings

Position relative to bulkhead or freeboard deck	Referenced requirement in **Part C** of the Rules	Frequency of use	Type of closing appliance	Remote closure	Open/close indicators	Audible or visual alarms	Notices	Notes
Below	**4.3.1-2(2), 13.3.4-2 13.3.5, 13.3.6**	Used	POS	Yes	Yes	Yes (Local)	No	---
	4.3.1-2(3), 13.3.5-1 13.3.8-1	Norm. Closed	S or H	No	Yes	No	Yes	*1, 6
	4.3.1-2(4), 13.3.4-3 13.3.8-2	Perm. Closed (cargo spaces)	S or H	Prohibited	No	No	Yes	*3, 4, 7
	4.3.1-2(5), 13.3.8-2	Perm. Closed (others)						
At or above	**4.3.1-2(2), 13.3.4-2 13.3.5, 13.3.6**	Used	POS	Yes	Yes	Yes (Local)	No	*2, 5
	4.3.1-2(3), 13.3.5-1 13.3.8-1	Norm. Closed	S or H	No	Yes	No	Yes	*1, 6
	4.3.1-2(4), 13.3.8-2	Perm. Closed	S or H	Prohibited	No	No	Yes	*3, 4, 7

Notes:

*1 : If hinged, this door is to be of single-action type.

*2 : Under the "International Convention on Load Lines, 1966", doors separating a main machinery space from a steering gear compartment may be hinged single-action types provided the lower sill of such doors is above the Summer Load Line and the doors remain closed at sea whilst not in use.

*3 : The time of opening such doors in port and closing them before the ship leaves port is to be entered into the logbook in the case of doors in watertight bulkheads subdividing cargo spaces.

*4 : Doors are to be fitted with devices which prevent unauthorized opening.

*5 : Under *MARPOL*, hinged watertight doors may be acceptable in watertight bulkheads of the superstructure.

*6 : Notices are to state "Kept closed at sea".

*7 : Notices are to state "Not to be opened at sea".

4 With respect to the provisions of **4.3.1-2, Part C of the Rules**, watertight closing appliances above the bulkhead deck are also to comply with the requirements for doors provided for means of escape specified in **Chapter 13, Part R of the Rules**.

C4.3.2 External Openings

General requirements of closing appliances specified in **4.3.2, Part C** of the Rules are show in **Table C4.3.1-2**.

Table C4.3.1-2 Requirements for Closing Devices for External Openings

Position relative to bulkhead or freeboard deck	Referenced requirement in Part C of the Rules	Frequency of use	Type of closing appliance	Remote closure	Open/close indicators	Audible or visual alarms	Notices	Notes
Below	4.3.2-2, 4.3.2-3, 13.3.5 and 13.3.8-2	Perm. Closed	S or H	No	Yes	No	Yes	*2, 3, 5
At or above	4.3.2-2, 13.3.5-1 and 13.3.8-1	Norm. Closed	S or H	No	Yes	No	Yes	*1, 4
	4.3.2-2, 13.3.5, 13.3.8-2	Perm. Closed	S or H	No	Yes	No	Yes	*2, 3, 5

Notes:

*1: If hinged, this door is to be of single-action type.

*2: The time of opening such doors in port and closing them before the ship leaves port is to be entered into the logbook.

*3: Doors are to be fitted with devices which prevent unauthorized opening.

*4: Notices are to state "*To be kept closed at sea*".

*5: Notices are to state "*Not to be opened at sea*".

C5 SINGLE BOTTOMS

C5.4 Floor Plates

C5.4.3 Floors in Bottom Forward

In ships which have L and C_b not more than 150 m and 0.7 respectively, and $V/\sqrt{L}$ not less than 1.4, it is recommended that the face plates of floors in way of strengthened bottom forward required in **C6.8.1-2(1)** are to be plated. The thickness of floors is to comply with the requirements in **C6.8.1-2(3)**.

However, ships that carry a certain amount of cargo regularly such as Container Ships may comply with the requirements in **5.4.3, Part C** of the Rules instead.

C6 DOUBLE BOTTOMS

C6.1 General

C6.1.1 Application

1 "Ships deemed by the Society to not require a double bottom for special reasons" stipulated in **6.1.1-2, Part C** of the Rules refer to the following.

(1) Ships complying with **Part N** or **Part S** of the Rules

(2) Ships complying with **3.2.2**, **Part 3 of the "Rules for Marine Pollution Prevention Systems"**

2 "Deemed appropriate by the Society" stipulated in **6.1.1-2, Part C** of the Rules refers to cases where the safety of the ship can be ascertained through flooding calculations.

3 Application of requirements related to the omission of double bottoms or unusual bottom arrangements in **6.1.1-3, Part C** of the Rules is to be in accordance with following **(1)** and **(2)**. For example, arrangements in which parts of the double bottom do not extend for the full width of the ship or in which the inner bottom is located higher than the partial subdivision draught (d_p) defined in **4.1.2(5), Part C** of the Rules are to be considered to be unusual bottom arrangements.

(1) When it is assumed that such spaces are subject to a bottom damage, compartments are to be arranged to demonstrate that the factor s_i, when calculated in accordance with **4.2.3, Part C** of the Rules, is not less than 1 for those service conditions which are the three loading conditions used to calculate the Attained Subdivision Index (A) specified in **4.2.1-2, Part C** of the Rules. Assumed extent of damage is to be in accordance with following **Table C6.1.1-1**. If any damage of a lesser extent than the maximum damage specified in **Table C6.1.1-1** would result in a more severe condition, such damage is to be considered.

(2) Flooding of such spaces is not to render emergency power and lighting, internal communication, signals or other emergency devices inoperable in other parts of the ship.

Table C6.1.1-1 Assumed Extent of Damage

	For 0.3L from the forward perpendicular of the ship	Any other part of the ship
Longitudinal extent	$1/3 L_f^{2/3}$ or 14.5m, whichever is less	$1/3 L_f^{2/3}$ or 14.5m, whichever is less
Transverse extent	B'/6 or 10m, whichever is less	B'/6 or 5m, whichever is less
Vertical extent, measured from the keel line	B'/20, to be taken not less than 0.76 m and not more than 2 m	B'/20, to be taken not less than 0.76 m and not more than 2 m

Notes:

1. Keel line is to be in accordance with **2.1.48, Part A** of the Rules.
2. Ship breadth (B') is to be in accordance with **4.1.2(11), Part C** of the Rules.

Fig. C6.1.1-1

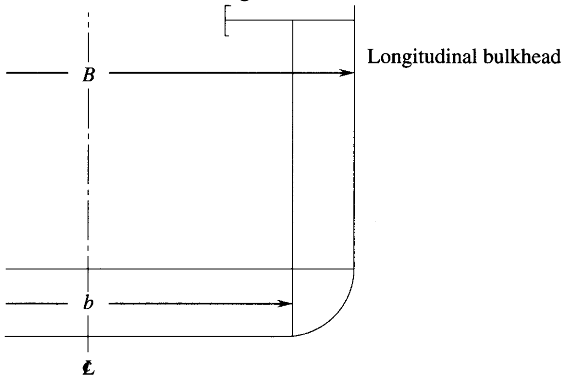


Fig. C6.1.1-2 Breadth of Ships with Inclined Sides

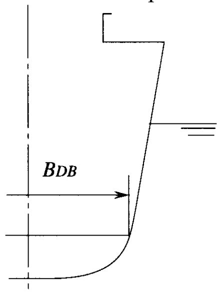
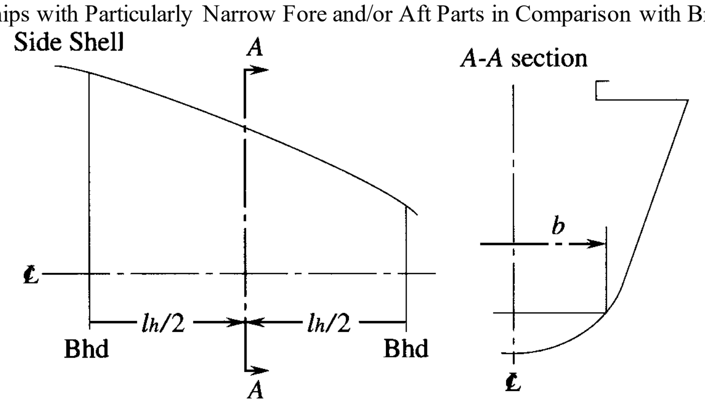


Fig. C6.1.1-3 Ships with Particularly Narrow Fore and/or Aft Parts in Comparison with Breadth Amidships



4 The scantlings of structural members of ships with a special construction are to be as follows.

(1) For ships of double-hull construction

$(B+b)\times 1/2$ is to be used instead of B.

(2) For ships with inclined sides

"B" may be replaced with "B_{DB}" which is the distance between the intersection of the extension of the inner bottom and shell plating at the widest section of the ship.

(3) For ships with a particularly narrow fore and/or aft part in comparison with the breadth amidships

The distance (b) between the intersection of the extension of the inner bottom and shell plating at the centre of the hold length (l_h) may be used in place of B.

5 In holds with pillars, the thickness of the centre girder, side girders, solid floors, inner bottom plating and bottom shell plating may be reduced in accordance with the results of direct calculation of their strength.

6 Scantlings of structural members of the double bottom for ships intended to carry steel coils are recommended to comply not only with **Chapter 6, Part C** of the Rules but also with the following requirements.

(1) The calculations specified here are based on the steel coils being stacked as shown in **Fig. C6.1.1-4** in a way that their cores point athwartships.

(2) Thickness of inner bottom plates for ships with a longitudinal framing system is to be not less than the value obtained from the following formula.

$$\sqrt{kQ\{(1.65\beta-2.3)\alpha-6\beta+12.2\}}+1.5\ \ (mm)$$

Where,

k : Coefficient for mild steel in general, 1.65.

Q : Mass of steel coils loaded per panel of inner bottom plating, as obtained from the following formula:

$$\frac{Wn_1n_2}{1000n_3}\ (ton)$$

Where steel coils are lined up in one tier with a key coil, Q is to be of 1.4 *times* the value obtained from the formula.

W: Mass of one steel coil (kg)

n_1: Number of tiers of steel coils

n_2: Number of load points per panel of inner bottom plates, as given in **Table C6.1.1-3** according to the value of n_3 and a/l_s

n_3: Number of dunnages supporting one steel coil

α : Aspect ratio of panel of inner bottom plating (taken as 3.0 when α exceeds 3.0)

β : As obtained from the following formula: c/a

a : Spacing of floors (mm)

c : Distance (mm) between load points per panel of inner bottom plating measured in the direction of the ship length, which is obtained in **Table C6.1.1-2** according to the value of n_2 and n_3

l_s : Length of a steel coil (mm)

(3) Where inner bottom plating is of high tensile steel, the formula specified in **(2)** above is to be applied as follows.

For *KA*32, *KD*32, *KE*32 or *KF*32: $0.78k$ to be used instead of k

For *KA*36, *KD*36, *KE*36 or *KF*36: $0.72k$ to be used instead of k

For *KA*40, *KD*40, *KE*40 or *KF*40: $0.68k$ to be used instead of k (However, $0.66k$ may be taken where a fatigue assessment of the structure is performed to verify compliance with the requirements of the Society.)

(4) The scantlings of longitudinals of inner bottom plating are to be determined by the simple beam theory in the following conditions.

(a) Model:

Simple beam fixed at solid floor and/or simply supported at vertical strut

(b) Allowable stress:

$8.2(24-12f_B)$ N/mm^2, where f_B is specified in **6.4.3, Part C** of the Rules

(c) Load condition:

Concentrated load at the position of dunnages where the steel coils are loaded just on longitudinals

(5) Compressive buckling strength against steel coil load is to be examined for solid floor and girder plates.

7 With respect to the provisions of **6.1.1-7, Part C** of the Rules, where the ratio of cargo weight per unit area (*kN/m*^{2}) of the inner bottom plating to *d* is less than 5.40, double bottom structures are to be in accordance with **C6.2.3-1**, **C6.3.2-1**, **C6.5.1-2** and **C6.5.6-1**. Where cargo loads can not be treated as evenly distributed loads, scantlings of double bottom structures are to be determined by taking account of load distribution for particular cargoes. Where concentrated loads act on specific points of double bottoms, scantlings of centre girders, side girders, floors, inner bottom plates and bottom plates and their stiffeners are to be determined by an appropriate strength assessment such as direct calculations.

Fig. C6.1.1-4 Securing Means for Steel Coils

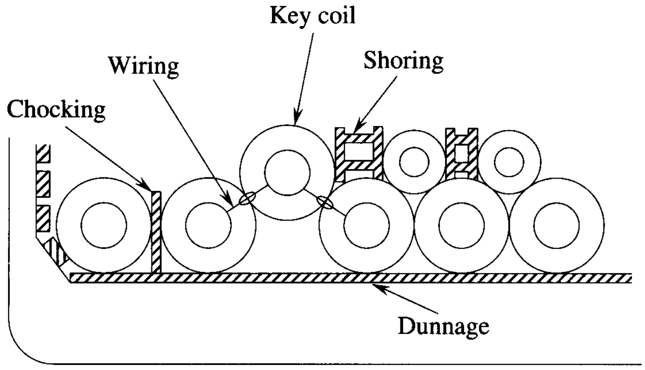


Table C6.1.1-2 Distance between Load Points in Ship Length Direction per Panel of Inner Bottom

n_2	n_3			
	2	3	4	5
1	Actual breadth of dunnage			
2	$0.5l_s$	$0.33l_s$	$0.25l_s$	$0.2l_s$
3	$1.2l_s$	$0.67l_s$	$0.50l_s$	$0.4l_s$
4	$1.7l_s$	$1.20l_s$	$0.75l_s$	$0.6l_s$
5	$2.4l_s$	$1.53l_s$	$1.20l_s$	$0.8l_s$
6	$2.9l_s$	$1.87l_s$	$1.45l_s$	$1.2l_s$
7	$3.6l_s$	$2.40l_s$	$1.70l_s$	$1.4l_s$
8	$4.1l_s$	$2.73l_s$	$1.95l_s$	$1.6l_s$
9	$4.8l_s$	$3.07l_s$	$2.40l_s$	$1.8l_s$
10	$5.3l_s$	$3.60l_s$	$2.65l_s$	$2.0l_s$

Note:

Where $n_2 \geq 11$ and/or $n_3 \geq 6$, loads on panel of inner bottom may be regarded as uniformly distributed loads.

Table C6.1.1-3 Number of Load Points per Panel

n_2	n_3			
	2	3	4	5
1	$0 < a/l_s \leq 0.5$	$0 < a/l_s \leq 0.33$	$0 < a/l_s \leq 0.25$	$0 < a/l_s \leq 0.2$
2	$0.5 < a/l_s \leq 1.2$	$0.33 < a/l_s \leq 0.67$	$0.25 < a/l_s \leq 0.50$	$0.2 < a/l_s \leq 0.4$
3	$1.2 < a/l_s \leq 1.7$	$0.67 < a/l_s \leq 1.20$	$0.50 < a/l_s \leq 0.75$	$0.4 < a/l_s \leq 0.6$
4	$1.7 < a/l_s \leq 2.4$	$1.20 < a/l_s \leq 1.53$	$0.75 < a/l_s \leq 1.20$	$0.6 < a/l_s \leq 0.8$
5	$2.4 < a/l_s \leq 2.9$	$1.53 < a/l_s \leq 1.87$	$1.20 < a/l_s \leq 1.45$	$0.8 < a/l_s \leq 1.2$
6	$2.9 < a/l_s \leq 3.6$	$1.87 < a/l_s \leq 2.40$	$1.45 < a/l_s \leq 1.70$	$1.2 < a/l_s \leq 1.4$
7	$3.6 < a/l_s \leq 4.1$	$2.40 < a/l_s \leq 2.73$	$1.70 < a/l_s \leq 1.95$	$1.4 < a/l_s \leq 1.6$
8	$4.1 < a/l_s \leq 4.8$	$2.73 < a/l_s \leq 3.07$	$1.95 < a/l_s \leq 2.40$	$1.6 < a/l_s \leq 1.8$
9	$4.8 < a/l_s \leq 5.3$	$3.07 < a/l_s \leq 3.60$	$2.40 < a/l_s \leq 2.65$	$1.8 < a/l_s \leq 2.0$
10	$5.3 < a/l_s \leq 6.0$	$3.60 < a/l_s \leq 3.93$	$2.65 < a/l_s \leq 2.90$	$2.0 < a/l_s \leq 2.4$

Note:

Where $n_2 \geq 11$ and/or $n_3 \geq 6$, loads on panel of inner bottom may be regarded as uniformly distributed loads.

C6.1.3 Drainage

1 In the application of **6.1.3-1, Part C** of the Rules, the requirements in the following **(1)** to **(3)** are to be complied with where bilge tanks are provided instead of bilge wells.

(1) Bilge tanks are to have sufficient strength as deep tanks as required in **Chapter 14, Part C** of the Rules.

(2) Drain pipes leading to bilge tanks are to comply with the requirement in **D13.5.8**.

(3) Bilge tanks are to be provided with manholes and covers for the purpose of conducting internal inspections easily.

2 "As deemed appropriate by the Society" stipulated in **6.1.3-2, Part C** of the Rules means that the requirements specified in **C6.1.1-3(1)** are satisfied.

3 "Protection equivalent to that afforded by a double bottom complying with this chapter" stipulated in **6.1.3-3, Part C** of the Rules means that the requirements specified in **C6.1.1-3(1)** are satisfied. However, wells for lubricating oil below main engines may protrude into the double bottom below the boundary line defined by the distance h (h is specified in **6.1.1-1, Part C** of the Rules) provided that the vertical distance between the well bottom and a plane coinciding with the keel line is not less than $0.5h$ or 500 *mm*, whichever is greater.

C6.1.6 Strengthening under Boilers

Considering the corrosive environment produced by high temperatures around the base of boilers, the scantlings of structural members under boilers are to be increased according to the following standards. However, where effective means for preventing corrosion or overheating are taken, the scantlings may not be required to be increased. Effective means for preventing overheating refers to means that can maintain the temperature of the upper surface of the inner bottom lower than 40°C under service conditions.

Centre girder: 3.0 *mm*

Side girders: 3.0 *mm*

Solid floors: 3.0 *mm*

Inner bottoms: 3.5 *mm*

Vertical stiffeners: 1.5 *mm*

Reverse frames of open floors and inner bottom longitudinals:

15% in section modulus

Frames of open floors and bottom longitudinals:

7% in section modulus

Vertical struts: 10% in sectional area

C6.1.8 Continuity of Strength

Where the height of adjacent double bottoms are different, it is recommended to keep the continuity of strength either by using a slope to gradually annul the height difference or by extending the lower of the two bottoms and have it overlapped by the other.

C6.2 Centre Girders and Side Girders

C6.2.1 Arrangement and Construction of Girders

1 Where side girders are unable to extend forward and/or aft due to a decrease in the breadth of the double bottom at the fore and/or aft parts, the side girders are to sufficiently lap adjacent girders in order to keep the continuity of strength.

2 Girders or half height girders are to be provided under longitudinal bulkheads to properly strengthen the double bottom.

C6.2.3 Thickness of Centre Girder Plates and Side Girder Plates

1 Where the ratio of cargo weight per unit area (kN/m^2) of the inner bottom plating to d is less than 5.40, the coefficient C_1 in the formula in **6.2.3(1), Part C** of the Rules is to be obtained from the following formula:

$$C_1 = nab$$

Where:

n: Coefficient to be determined as follows:

(a) For holds adjacent to each other and being loaded or empty simultaneously:

Where B/l_H is 1.4 and over, it is to be taken as 1.4, and where B/l_H is below 0.4, it is to be taken as 0.4.

$$\frac{1}{1.4}\left(3 - \frac{B}{l_H}\right)$$

Where:

l_H: Value specified in **6.2.3, Part C** of the Rules

(b) For other holds: 1.0

a: Value to be obtained from the following formula:

$$1.35 - \frac{h\gamma}{d}$$

Where:

h: As specified in **6.4.3-2, Part C** of the Rules

γ: As specified in **6.1.1-6, Part C** of the Rules

b: Coefficient to be taken as 0.017 for the longitudinal system and 0.020 for the transverse system

2 For ships of double-hull construction, the coefficient C_1 in the formula in **6.2.3(1), Part C** of the Rules is to be obtained from the following formula:

$$C_1 = na(b - \beta b')$$

Where:

n : Coefficient as specified in **31.2.2-3, Part C** of the Rules.

a : As specified in **-1** above, but not to be less than 0.8

b : Coefficient as specified in **-1** above

b': Coefficient to be taken as 0.004 for longitudinal system and 0.005 for transverse system

β : Coefficient to be obtained from the following formula

However, where the hold is unusually long or where the sides are constructed on the transverse framing system and the spacing of side transverses is unusually large, special consideration is to be given.

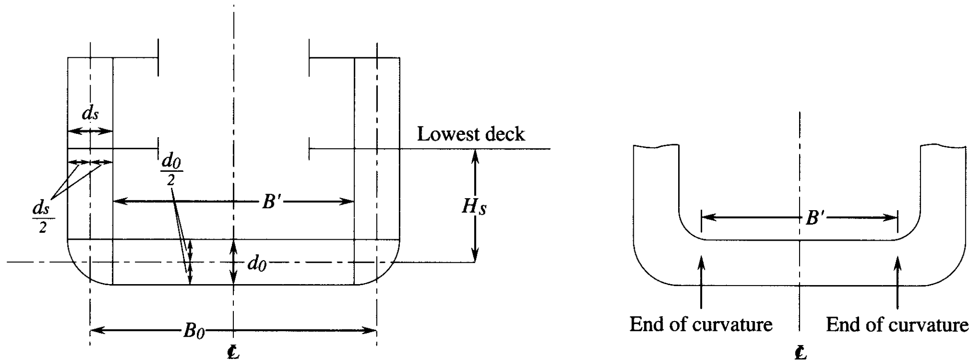
$$\frac{1}{1 + \frac{2t_0 d_0^2 H_s}{3t_s d_s^2 B_0}}$$

t_0: Mean thickness (mm) of inner bottom plating and bottom shell plating

t_s: Mean thickness (mm) of longitudinal bulkhead and side shell plating

d_0, d_s, B_0 and H_s: Distances (m) shown in **Fig. C6.2.3-1**

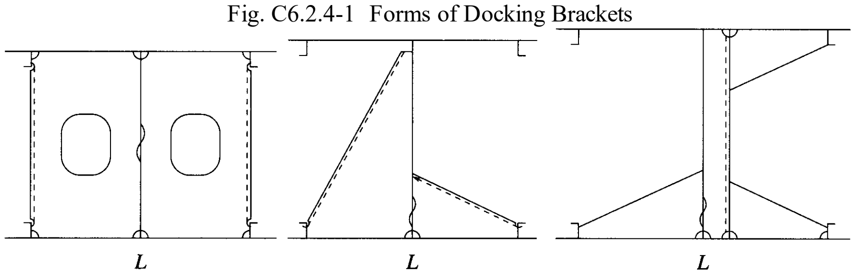
Fig. C6.2.3-1 Double Hull Construction



C6.2.4 Brackets

The thickness, size, form, etc. of brackets specified in **6.2.4, Part C** of the Rules are determined by taking into consideration the height of centre girders and their buckling strength. Examples are shown in **Fig. C6.2.4-1**.

Fig. C6.2.4-1 Forms of Docking Brackets



C6.3 Solid Floors

C6.3.2 Thickness of Solid Floors

1 Where the ratio of cargo weight per unit area (kN/m^2) of the inner bottom plating to d is less than 5.40, the coefficient C_2 in the formula in **6.3.2(1), Part C** of the Rules is to be obtained from the following formula:

$$C_2 = ab$$

Where:

a : As per **C6.2.3-1**

b : Coefficient to be determined from **Table C6.3.2-1** according to the value of $\dfrac{B}{l_H}$

l_H: As specified in **6.2.3, Part C** of the Rules

Table C6.3.2-1 Coefficient b

B/l_H		and above		0.4	0.6	0.8	1.0	1.2
		under	0.4	0.6	0.8	1.0	1.2	
b	Longitudinal system Transverse system	Where solid floors are fitted at every frame	0.036	0.034	0.031	0.028	0.023	0.021
	Transverse system	Solid floors spaced 2 or more frame spaces apart	0.025	0.024	0.021	0.020	0.016	0.015

2 The thickness of solid floors of ships of double-hull construction is to be obtained according to the following prescriptions.

(1) B' and B'' in the formula in **6.3.2(1), Part C** of the Rules are to be as follows:

B': Distance (m) between longitudinal bulkheads at the top of inner bottom plating at amidships (*See* **Fig. C6.2.3-1**)

B'': Distance (m) between longitudinal bulkheads at the top of inner bottom plating at the position of solid floor

(2) The coefficient C_2 in the formula in 6.3.2(1), Part C of the Rules is to be obtained from the following formula:

$$a(b+\beta b')$$

Where:

a : As specified in C6.2.3-1, but not to be taken as less than 0.8

b : Coefficient obtained from Table C6.3.2-1 according to the value of $\dfrac{B}{l_H}$

b': Coefficient obtained from Table C6.3.2-2 according to the value of $\dfrac{B}{l_H}$

β : As specified in C6.2.3-2

l_H: As specified in 6.2.3, Part C of the Rules

Table C6.3.2-2 Coefficient b'

<table>
<tr><td colspan="3" rowspan="2">B/l_H</td><td>and above</td><td></td><td>0.4</td><td>0.6</td><td>0.8</td><td>1.0</td><td>1.2</td></tr>
<tr><td>under</td><td>0.4</td><td>0.6</td><td>0.8</td><td>1.0</td><td>1.2</td><td></td></tr>
<tr><td rowspan="3">b'</td><td colspan="3">Longitudinal system</td><td rowspan="2">0.001</td><td rowspan="2">0.003</td><td rowspan="2">0.006</td><td rowspan="2">0.009</td><td rowspan="2">0.014</td><td rowspan="2">0.015</td></tr>
<tr><td rowspan="2">Transverse system</td><td colspan="2">Where solid floors are fitted at every frame</td></tr>
<tr><td colspan="2">Solid floors spaced 2 or more frame spaces apart</td><td>0.001</td><td>0.002</td><td>0.004</td><td>0.006</td><td>0.009</td><td>0.011</td></tr>
</table>

C6.4 Longitudinals

C6.4.3 Longitudinals

1 Where the apparent specific gravity γ of cargoes in loaded holds exceeds 0.9, the coefficient C in the formula in 6.4.3-1, Part C of the Rules is to be as follows:

Where no strut as per **6.4.4, Part C** of the Rules is provided;

Midway between the floors: 1.0

Where a strut as per 6.4.4, Part C of the Rules is provided midway between the floors;

Under deep tanks: 0.625

Elsewhere: $0.3\gamma + 0.2$

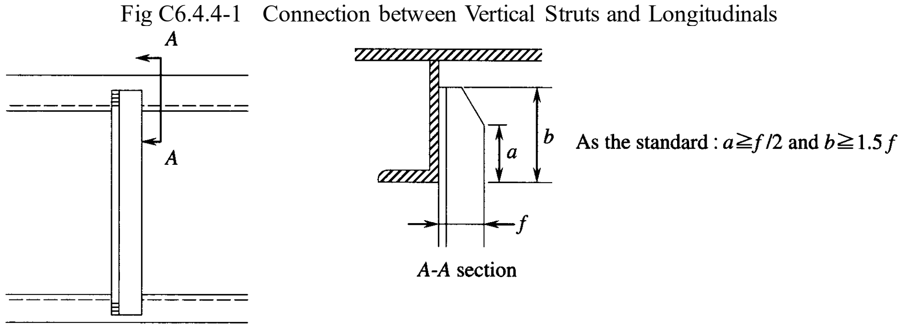
C is not to be less than 0.5.

γ: As specified in 6.1.1-6, Part C of the Rules.

C6.4.4 Vertical Struts

One-and-a-half *times* the breadth of the strut face plate is the standard amount that the vertical strut laps the web of a longitudinal. Where a sufficient lap is unable to be obtained due to welding issues, the throat of the fillet weld is to be properly increased. An example of strut face plates that are snipped is shown in Fig. C6.4.4-1.

Fig C6.4.4-1 Connection between Vertical Struts and Longitudinals



C6.5 Inner Bottom Plating, Margin Plates and Bottom Shell Plating

C6.5.1 Thickness of Inner Bottom Plating

1 Where the height of the centre girder is less than $B/16$, the thicknesses of the inner bottom plating and bottom shell plating are to be increased so that the moment of inertia of the double bottom obtained from the following formula may be equivalent to that corresponding to when the centre girder has the required height.

$$I = 1.23 \frac{t_1 t_2}{t_1 + t_2} d_0^2$$

Where:

d_0: Height (m) of centre girder

t_1: Thickness (mm) of bottom shell plating

t_2: Thickness (mm) of inner bottom plating

2 Where the ratio of cargo weight per unit area (kN/m^2) of the inner bottom plating to d is less than 5.40, the coefficient C in the first formula in **6.5.1-1, Part C** of the Rules is to be obtained from the following formula:

$$C = ab$$

Where:

a: As specified in **C6.2.3-1**

b: Coefficient b_0 or αb_1 to be obtained from the following according to the value of $\frac{B}{l_H}$

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

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

$1.2 \leq \frac{B}{l_H}$: αb_1

l_H: As specified in **6.2.3, Part C** of the Rules

b_0 and b_1: Coefficients to be obtained from **Table C6.5.1-1** according to the value of $\frac{B}{l_H}$

For transverse framing system, b_1 is to be the value obtained from the same table multiplied by 1.1.

α : Value to be obtained from the following formula:

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

f_B: As specified in **6.4.3-1, Part C** of the Rules

Table C6.5.1-1 Coefficients b_0 and b_1

B/l_H	and above		0.4	0.6	0.8	1.0	1.2	1.4	1.6
	under	0.4	0.6	0.8	1.0	1.2	1.4	1.6	
b_0		5.5	4.9	4.1	2.8	2.0	-	-	-
b_1		-	-	-	2.8	2.6	2.4	2.2	1.8

3 In ships of double-hull construction, the coefficient C in the first formula in **6.5.1-1, Part C** of the Rules is to be the greater of the values obtained from the following two formulae:

$$a(b_0 - \beta b_0')$$

$$a\alpha(b_1 - \beta b_1')$$

Where:

a : As specified in **C6.2.3-1**. a is not to be less than 0.8

b_0, b_1 and α: As specified in **-2**

b'_0 and b'_1: Values obtained from **Table C6.5.1-2**, according to the value of $\frac{B}{l_H}$

For the transverse framing system, b'_1 is to be the value obtained from the same table multiplied by 1.1.

l_H: As specified in **6.2.3, Part C** of the Rules

β : As specified in **C6.2.3-2**

Table C6.5.1-2 Coefficients b'_0 and b'_1

B/l_H	and above		0.4	0.6	0.8	1.0	1.2	1.4	1.6
	under	0.4	0.6	0.8	1.0	1.2	1.4	1.6	
b'_0		3.1	2.5	1.8	1.0	0.5	-	-	-
b'_1		-	-	-	1.1	1.1	0.8	0.7	0.4

4 Where fork-lift trucks are used for handling cargoes, **C17.3.5** is to be applied for determining the thickness of the inner bottom plating.

5 Butt joints of inner bottom plating in the midship part are generally not to be arranged at the knuckle line of the inner bottom.

C6.5.5 Bottom Shell Plating

1 Where the ratio of cargo weight per unit area (kN/m^2) of the inner bottom plating to d is less than 5.40, the thickness of bottom shell plating is to be determined as follows:

In the region of double bottoms under cargo holds, the thickness of bottom shell plating is not to be less than that obtained from the formula in **16.3.4, Part C** of the Rules or from the first formula in **6.5.1-1, Part C** of the Rules whichever is greater. In applying the latter formula, coefficient C described in **C6.5.1-2** and α obtained from the following formula are to be used.

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

Where:

f_B: As specified in **6.4.3-1, Part C** of the Rules

2 The thickness of bottom shell plating of ships of double-hull construction is to be determined as follows.

In the region of double bottoms under cargo holds, the thickness of bottom shell plating is not to be less than that obtained from the formula in **16.3.4, Part C** of the Rules, or from the first formula in **6.5.1-1, Part C** of the Rules whichever is greater. In applying the latter formula, coefficient C described in **C6.5.1-3** and α obtained from the following formula are to be used.

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

Where:

f_B: As specified in **6.4.3-1, Part C** of the Rules

C6.6 Tank Side Brackets

C6.6.1 Tank Side Brackets

Where inner bottom plating slopes down to the centre line or where the ships have bilge hopper tanks, the thickness of tank side brackets may be of the value required in **6.2.4-2, Part C** of the Rules. In other words, the increase in thickness stipulated in **6.6.1-1, Part C** of the Rules is not required.

C6.8 Construction and Strengthening of the Bottom Forward

C6.8.1 Application

1 Here, “ballast condition” means the ordinary ballast condition where only ballast tanks such as clean ballast tanks, segregated ballast tanks and ballast holds are ballasted. This ballast condition excludes exceptional cases where cargo tanks are ballasted in heavy weather conditions to ensure the safety of the ship.

2 In ships of which L and C_b are not more than 150 m and 0.7 respectively and $V/\sqrt{L}$ is not less than 1.4, the construction of the bottom forward is to be as required in the following **(1)**, **(2)** and **(3)**. However, ships that carry a certain amount of cargo regularly such as Container Ships may comply with the requirements in **6.8.2** to **6.8.4, Part C** of the Rules instead.

(1) Construction

The construction of the strengthened bottom forward is to be in accordance with **6.8.3, Part C** of the Rules. However, the vertical stiffeners for the solid floors specified in **6.8.3-3, Part C** of the Rules are to be provided on all shell stiffeners. Where the bottom longitudinals or longitudinal shell stiffeners are extended through the solid floors, slots are to be reinforced with collar plates.

(2) Scantlings of longitudinal shell stiffeners or bottom longitudinals

(a) In ships having a bow draught of not more than $0.025L$ in 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:

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

Where:

l : Spacing (m) of solid floors

λ : $0.774l$.

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

P : Slamming impact pressure (kPa) obtained from the following formula:

$$2.48\frac{LC_1C_2C_3}{\beta} \ (kPa)$$

C_1: Coefficient given in **Table C6.8.1-1**. For intermediate values of $V/\sqrt{L}$, C_1 is to be obtained by linear interpolation.

C_2: Coefficient obtained from 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:

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

b : Horizontal distance (m) measured at the station $0.2L$ from the stem, from the centre line of the ship to the intersection of the horizontal line $0.0025L$ above the top of the keel with the shell plating (*See* **Fig. C6.8.1-2**)

C_3: Coefficient obtained from the following formula:

$$C_3 = 1.9 - 0.9\left(\frac{d_f}{0.025L}\right)$$

Where:

d_f: Minimum bow draught in ballast condition

(b) In ships having a bow draught of more than $0.025L$ but less than $0.037L$ 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 **(a)** and **6.4, Part C** of the Rules.

(3) Thickness of solid floors

The thickness of solid floors in way of the strengthened bottom forward is obtained from the following requirements **(a)** and **(b)**, whichever is greater:

(a) The thickness obtained from the following formula.

$$\frac{PS\,b_1}{196(b_1-d_1)} + 2.5 \ (mm)$$

P : Slamming impact pressure given by **(2)(a)**. In ships having a bow draught of more than $0.025L$ but less than $0.037L$ in ballast condition, this requirement is to be applied using the actual bow draught in ballast condition.

S : Spacing (m) of solid floors

b_1: Breadth (m) of solid floor panel between the midpoints of the spaces on either side of a bottom longitudinal (excluding longitudinal shell stiffeners provided in between bottom longitudinals)
(*See* **Fig. C6.8.1-3**)

d_1: Total breadth (m) of openings (lightening holes, slots, etc.) at the level of the floor in question ($d_1 = d_2 + d_3$) Where, the openings are reinforced with doubling plates, the sectional area may be considered.

(b) The thickness obtained from the following formula.

$$1.1\sqrt[3]{PSb_2{}^2} + 2.5 \ (mm)$$

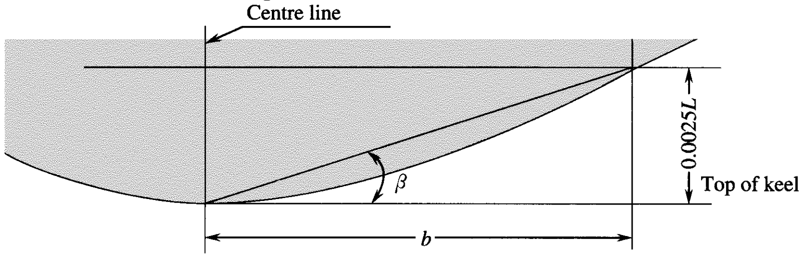
P and S: As specified in **(a)**.

b_2: Spacing (m) of bottom longitudinals (*See* **Fig. C6.8.1-3**)

Table C6.8.1-1 Value of C_1

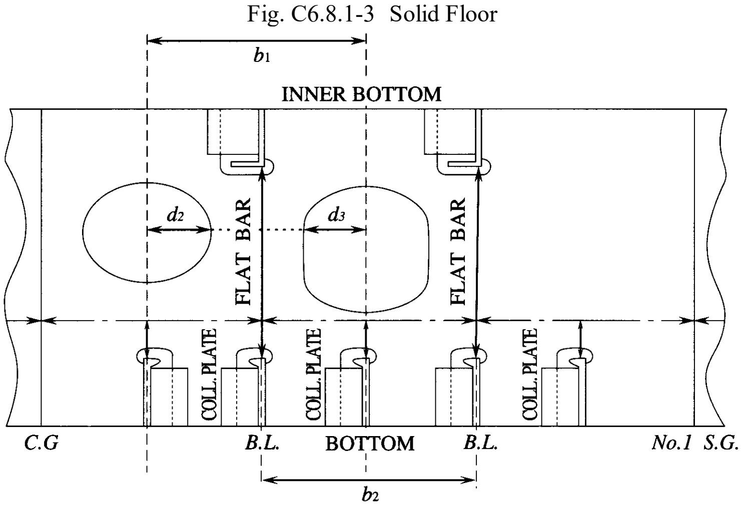
$V/\sqrt{L}$	1.4	1.5	1.6	1.7	1.8
C_1	0.31	0.33	0.36	0.38	0.40

Fig. C6.8.1-2 Measurement of b



(Hull section at the station $0.2L$ from the stem)

Fig. C6.8.1-3 Solid Floor



3 With respect to the requirements of **6.8**, **Part C** of the Rules, ships of which L and C_b are not less than 150 m and 0.7 respectively may comply with the following.

(1) Slamming impact pressure P specified in **6.8.4-1**, **Part C** of the Rules may be given by the following formula. The slamming impact pressure is to be calculated at the mid-span point for each longitudinal shell stiffener or bottom longitudinal.

$$P = 1.14 \cdot \frac{v^2}{\beta} \ (kPa)$$

β: As given by the following formula

Where the value of $^1/_\beta$ is greater than 11.43, it is to be taken as 11.43.

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

b: The horizontal distance (m) from the ship's centre line to the outer shell at a height $0.025L$ above the top of the keel for the transverse section under consideration (*See* **Fig. C6.2, Part C** of the Rules)

v: Relative speed between the ship's bottom and sea surface for the position under consideration as given by the following formula

$$v = C_0\left(\frac{2\pi}{T_P}\left(\sqrt{C_4} + 0.45H_W\cos\phi + 0.18\lambda\sin\phi\right) + 0.51C_7V\sin\phi\right) \ (m/s)$$

C_0: As given by the following formula

$$C_0 = 1 - 0.015 \cdot \left(\frac{L-150}{150}\right)$$

C_4: As given by the following formula

The value is not to be less than zero.

$$C_4 = (l + 0.05L)^2{\phi_0}^2 - (0.025L')^2$$

l: Longitudinal distance (m) from the midship to the considered position

ϕ_0: Pitch angle (rad) as given by the following formula

$$\phi_0 = \frac{3.3 \cdot (C_7 \cdot V + 5)^{0.2}}{L^{1.2}\sqrt{C_b}} \cdot H_W$$

H_w: Significant wave height (m) as given by the following formula

However, this value may not be greater than the greater of $0.055L$ and 11.5.

$$H_w = C_5C_6$$

C_5: As given by the following formula

$L \le 300$: $\quad C_5 = 10.75 - \left(\frac{300-L}{100}\right)^{1.5}$

$300 < L \le 350$: $\quad C_5 = 10.75$

$350 < L$: $\quad C_5 = 10.75 - \left(\frac{L-350}{150}\right)^{1.5}$

C_6: As given by the following formula

$$C_6 = \sqrt{\frac{L + \lambda - 25}{L}}$$

C_7: As given by the following formula

This value is not to be less than 0 and not to be greater than 1.

$$C_7 = \frac{V/\sqrt{L} - 1.1}{0.4}$$

λ : Wave length as given by the following formula

$$\lambda = 0.6 \cdot \left(1.5 + \frac{(0.0075L + 0.025L')}{2d}\right) L \ (m)$$

T_P: Natural period of pitch motion as given by the following formula

$$T_P = \sqrt{\frac{2\pi\lambda}{g}} \ (sec)$$

ϕ : As given by the following formula

However, this value may not be greater than $0.015 + \phi_0$.

$$\phi = 0.015 + \tan^{-1}\left(\frac{0.025L'}{l+0.05L}\right) \ (rad)$$

(2) For the examination of positions within ballast tanks which are filled by sea water in ballast condition, the slamming impact pressure P specified in **(1)** above may be reduced by ΔP as given by the following formula. It is to be stated in the ship's

loading manual that such ballast tanks are to be filled up in heavy weather conditions.

$\Delta P = 5h$ (kPa)

h: Depth (m) of the ballast tank

4 In way of the strengthened bottom forward, structural arrangements other than those specified in **6.8.3**, **Part C** of the Rules may be adopted subject to the following **(1)** to **(3)**.

(1) Solid floors of a longitudinal stiffened system and girders in a transverse stiffened system are to comply with the provisions of **C6.8.1-2(3)**. The slamming impact pressure P acting on the solid floors of a longitudinal stiffened system may be corrected by multiplying the coefficient C_9 specified in **(3)** below.

(2) The thickness of solid floors and girders is not to be less than the value obtained by the following **(a)** and **(b)**, whichever is greater.

(a) $t_1 = K \cdot \frac{C_8 \cdot P \cdot S \cdot l}{226 \cdot (d_0 - d_1)} + 2.5$ (mm)

K: As specified in **1.2.1-2(2)** of **Annex C1.1.7-1** "**GUIDANCE FOR HULL CONSTRUCTION CONTAINING HIGH TENSILE STEEL MEMBERS**"

P: The applicable slamming impact pressure as specified in **6.8.4-1, Part C** of the Rules, **C6.8.1-2** or **C6.8.1-3**

In ships having a bow draught of more than $0.025L'$ but less than $0.037L'$ in ballast condition, the slamming impact pressure of when the bow draught is $0.037L'$ is to be obtained by linear interpolation from the following formula.

The slamming impact pressure is not to be less than the value obtained by the following formula.

$P = 1.015L$ (kPa)

C_8: As given by the following formula

This value is not to be less than 0.1 and not to be greater than 1.

$$C_8 = \frac{3}{A}$$

A: Area (m^2) considered in the strength examination, as given by the following formula

$A = S \times l$

S: Spacing (m) of solid floors (or girders) when solid floors (or girders) are under consideration

l: Spacing (m) of girders (or solid floors) when solid floors (or girders) are under consideration

d_0: Depth (m) of floors or girders at the considered position

d_1: Depth (m) of openings in the floors or girders at the considered position

(b) The value given by the requirements of **6.3.2(2)**, **Part C** of the Rules, using the value of t_1 as given by **(a)** above, in the mentioned requirements. The provisions of **6.3.2(2)**, **Part C** of the Rules can also apply to girders by reading "solid floors" as "girders."

(3) In the calculation of the section modulus of longitudinal shell stiffeners and bottom longitudinals, the slamming impact pressure P may be corrected by multiplying by the coefficient C_9 as given by the following formula. The coefficient C_9 is not to be less than 0.1 and not to be greater than 1.

$$C_9 = \frac{3}{l}$$

l: As given in **6.8.4-1**, **Part C** of the Rules

C6.8.2 Strengthened Bottom Forward

In ships of which L and C_b are less than 150 m and 0.7 respectively and the bow draught is less than $0.025L$ in ballast condition, the area of the strengthened bottom forward of the ship is to be expanded as follows. However, ships that carry a certain amount of cargo regularly such as Container Ships need not comply.

(1) The after end of the strengthened area is to be extended the distance a afterwards from the position required in **6.8.2-1 of Part C**.

$a = 0$ $(C_b = 0.7)$

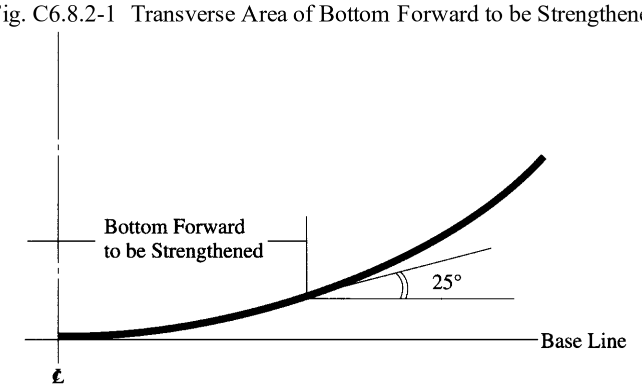
$a = 0.05L$ $(C_b \leq 0.6)$

For intermediate values of C_b, a is to be obtained by linear interpolation.

(2) In addition to **(1)** above, bottom areas whose tangential slope to the base line is less than 25 degrees are required to be

strengthened. (*See* **Fig. C6.8.2-1**)

Fig. C6.8.2-1 Transverse Area of Bottom Forward to be Strengthened



C7 FRAMES

C7.1 General

C7.1.8 Consideration of Bow Impact Pressure

1 For ships with large bow flares that operate at high speed (car carriers, ro-ro cargo ships, LNG carriers or refrigerated LPG carriers, etc.), the thickness t_w of web plates and the plastic section modulus Z_p of transverse frames and side longitudinals, which are fitted where the bow flare located above the load line and forward of 0.2L is considered to endure large wave impact pressure, are not to be less than those obtained from the following formulae.

Required thickness of web plate

$$\frac{648PSl_s}{h_0\sigma_y\cos\theta_s}\ (mm)$$

Required plastic section modulus

$$\frac{PSl_s{}^2}{16\sigma_y\cos\theta_s}\times 10^3\ (cm^3)$$

S : Frame spacing (m) measured along the shell plating (See **Fig. C7.1.8-2**)

l_s: Unsupported length (m) of frame as obtained from the following formula

$l_s = l - l_{b1} - l_{b2}$

l : Length (m) of frame measured along the shell plating (See **Fig. C7.1.8-1**)

l_{b1} and l_{b2}: Bracket length (m) for span correction as obtained from the following formulae

$$l_{b1} = b_1\left(1-\frac{h_0}{h_1}\right)\times 10^{-3}$$

$$l_{b2} = b_2\left(1-\frac{h_0}{h_2}\right)\times 10^{-3}$$

b_1, b_2, h_0, h_1 and h_2 : Refer to **Fig. C7.1.8-1** (mm)

σ_y: Specified yield stress (N/mm^2) of the material

θ_s : Frame list angle (deg) to side shell (See **Fig. C7.1.8-2**)

P : Slamming impact pressure (kPa) as obtained from the following formula

$$P = \frac{1}{2}\rho\, C_e K_p\left(\frac{v_n}{\cos\beta_0}\right)^2$$

ρ : Sea water density, 1.025 (t/m^3)

β_0: Relative impact angle (deg) between wave surface and a point under consideration on ship's surface as obtained from the following formula

$\beta_0 = \phi - \phi_b$

ϕ: As obtained from the following formula (deg)

$$\phi = \tan^{-1}\left(\frac{1}{\tan\beta_k\cos\gamma}\right)$$

β_k: As obtained from the following formula

$\beta_k = \beta_{k1} - \sqrt{45-\beta}$, where $\beta \le 45°$

$\beta_k = \beta_{k1} + \sqrt{\beta-45}$, where $\beta > 45°$

β: Shell angle (deg) at the section under consideration (See **Fig.C7.1.8-3**)

β_{k1}: As obtained from the following formula

$\beta_{k1} = 45\{0.95(0.8 - X/L)(1.2 - X/L) + 1\} - 0.02(Dz - d)(Dz - d - 20)$

X: Longitudinal distance (m) from the aft end of L to the section under consideration

Dz: Vertical distance (m) from base line at the middle of L to the section under consideration

γ: Shell angle (*deg*) at the section under consideration (See **Fig. C7.1.8-3**)

ϕ_b: As obtained from the following formula

$$\phi_b = \left(\frac{\phi_{bF}-33}{0.15}\right)(X/L - 0.8) + 33, \text{ where } 0.8 \le X/L < 0.95$$

$\phi_b = \phi_{bF}$, where $0.95 \le X/L$

ϕ_{bF}: As obtained from the following formula

$\phi_{bF} = 35$, where $L < 200$

$\phi_{bF} = -L/25 + 43$, where $200 \le L < 400$

$\phi_{bF} = 27$, where $400 \le L$

K_p: Coefficient obtained from the formula in **Table C7.1.8-1**

C_e: Coefficient obtained from the following formula

$$C_e = \frac{\beta_0}{40} + 0.25, \text{ where } \beta_0 \le 30°$$

$C_e = 1.0$, where $\beta_0 > 30°$

v_n: Maximum relative velocity (*m/s*) between wave surface and point under consideration on ship's surface as obtained following formula

$$v_n = \frac{v_x \tan\beta_k + v_z \tan\alpha \tan\beta_k}{\sqrt{\tan^2\alpha + \tan^2\beta_k + \tan^2\alpha \tan^2\beta_k}}$$

v_x: Longitudinal relative velocity (*m/s*) at point under consideration on ship's surface as obtained following formula. However, v_x is to be greater than 0.

$v_x = (1 - C_1)v_{x0}$

C_1 : Coefficient obtained from the formula in **Table C7.1.8-2**

v_{x0}: Longitudinal relative velocity (*m/s*) at the waterline as obtained from following formula

$$v_{x0} = v_s + C_2\sqrt{Lg}$$

v_s : $0.36V$ (*m/s*)

V : Ship speed (*kt*)

g : Acceleration due to gravity, 9.81 (m/s^2)

C_2: Coefficient obtained from the formula in **Table C7.1.8-2**

v_z : Relative velocity (*m/s*) at point under consideration on ship's surface in the direction of ship's depth. However, v_z is to be greater than 0.

$v_z = (1 - C_3)v_{z0}$

C_3 : Coefficient obtained from the formula in **Table C7.1.8-2**

v_{z0}: Relative velocity (*m/s*) at the waterline in the direction of ship's depth as obtained from the following formula

$$v_{z0} = C_4\sqrt{Lg}$$

C_4 : Coefficient obtained from the formula in **Table C7.1.8-2**

α : As obtained from the following formula (*deg*)

$$\alpha = \tan^{-1}\left(\frac{\tan\beta_k}{\tan\gamma}\right)$$

Z_p : Plastic section modulus (cm^3) of frame, where the frame is joined to shell plate with a right angle, as obtained from the following formula

$$Z_p = 0.1A_f h + \frac{1}{2000}h^2 t_w$$

A_f: Sectional area of flange (cm^3)

h : Depth of web plate (*mm*)

t_w: Thickness of web plate (*mm*)

Fig. C7.1.8-1 Modified Span Length of Frames

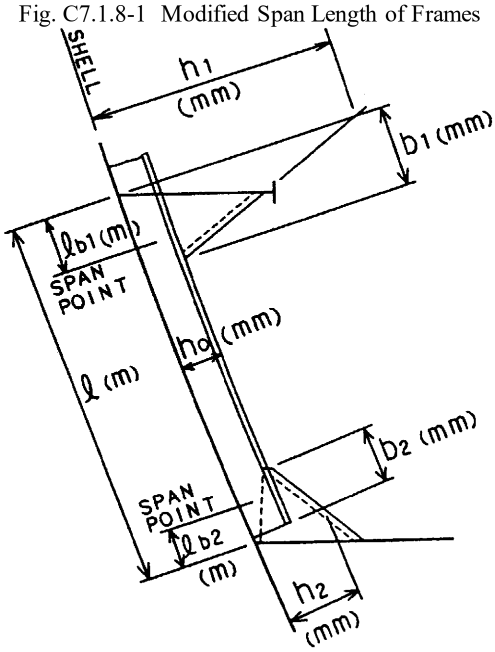


Fig. C7.1.8-2

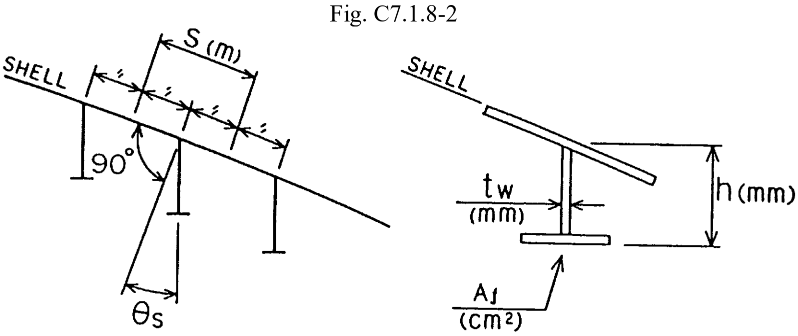


Fig. C7.1.8-3 Shell Angle

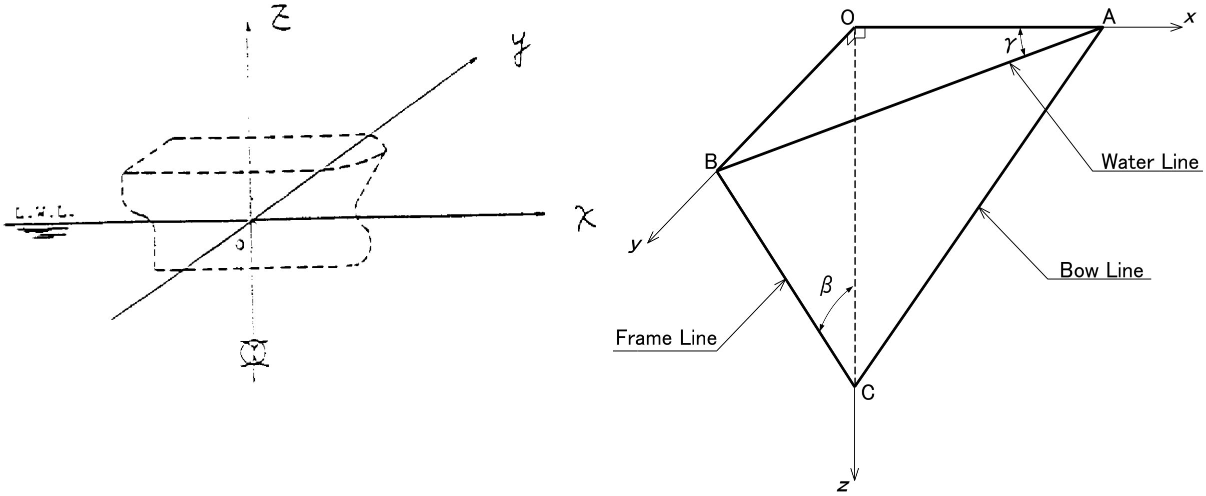


Table C7.1.8-1 Coefficient K

β_0	K
$\beta_0 < 3°$	255.85
$3° \leq \beta_0 < 4°$	$758.60e^{-0.3623\beta_0}$
$4° \leq \beta_0 < 6°$	$453.91e^{-0.2339\beta_0}$
$6° \leq \beta_0 < 10°$	$335.41e^{-0.1835\beta_0}$
$10° \leq \beta_0 < 15°$	$173.61e^{-0.1176\beta_0}$
$15° \leq \beta_0 < 18°$	$80.523e^{-0.0664\beta_0}$
$18° \leq \beta_0$	$1+\frac{\pi^2}{4}\cot^2\beta_0$

Table C7.1.8-2 Coefficients C_1, C_2, C_3 and C_4

C_1	$(4.40\xi - 6.31)\varsigma$
C_2	$0.095\xi + 0.191F_n - 0.127$
C_3	$\left(\frac{11.8}{\xi - 0.459} + 4.96\right)\varsigma^2$
C_4	$(-0.629F_n + 0.338)\xi + 0.666F_n - 0.109$

Notes:

ξ : $x/(L/2)$ (however, ξ is to be greater than 0.6)

x: Longitudinal distance (m) to the section under consideration from the midship

ς : $z/(L/2)$ (however, ς is to be greater than 0)

z: Height (m) from the load line to the section under consideration

F_n: $v_s/\sqrt{Lg}$

2 For ships with large bow flares that operate at high speed (car carriers, ro-ro cargo ships, LNG carriers or refrigerated LPG carriers, etc.), the scantling of web frames supporting side longitudinals, which are fitted where the bow flare located above the load line and forward of 0.2L is considered to endure large wave impact pressure is to be in accordance with the requirements of side stringers supporting transverse frames in **C8.1.4**.

3 For ships whose L and C_b are not less than 250m and 0.8 respectively, the provisions of **3.3, Section 1, Chapter 10, Part 1, Part CSR-B&T of the Rules** are to be applied.

C7.3 Transverse Hold Frames

C7.3.2 Scantlings of Transverse Hold Frames

The scantlings of hold frames which are considered to support the loads from steel coils when the ship is rolling are recommended to be determined in accordance with not only **7.3.2, Part C** of the Rules but also the conditions mentioned below based on the simple beam theory.

(1) Model:

Simple beam simply supported at deck and fixed at inner bottom

(2) Allowable stress: 196 N/mm^2

(3) Loading condition:

Hydraulic pressure from ship side and mass of steel coils calculated by the following **(a)** or **(b)**

(a) When steel coils are loaded lined up in one tier

$$\frac{C_1 W \sin\theta k}{1000n} \quad (ton)$$

Where:

W: Mass of one steel coil (kg)

C_1: Coefficient according to arrangement of key coils.

When the key coil is between the first and second steel coil from the ship side: 4.0

When the key coil is closer to the centre line than the second steel coil from the ship side: 3.0

θ: Maximum heeling angle of ship (*degree*)

k: Coefficient according to transverse acceleration direction due to ship motion; normally taken as 1.0

n: Number of frames supporting one steel coil

(b) When steel coils are loaded lined up in two tiers

$$\frac{C_2 W \sin\theta m}{1000n} \quad (ton)$$

Where:

C_2: Coefficient defined according to arrangement of steel coils; normally taken as 0.7. However, where steel coils in lower tiers are arranged so closely that the contact pressure on each other is considered large enough, the value may be reduced.

W', θ and n: As specified in **(a)** above.

m: Total number of steel coils loaded in the relevant transverse frame section

C7.3.3 Transverse Hold Frames Supported by Web Frames and Side Stringers

Where the arrangement of side stringers complies with **7.3.3-2, Part C** of the Rules, the scantlings of frames are to be determined applying the requirements in **7.3.3-1, Part C** of the Rules in the following manner. However, the scantlings may be derived by another method deemed satisfactory by the Society.

(1) Where the difference between unsupported spans of any adjacent frames is more than 25%.

If l_2/l is 1.25 or over, $l_2/1.25$ is to be used instead of l.

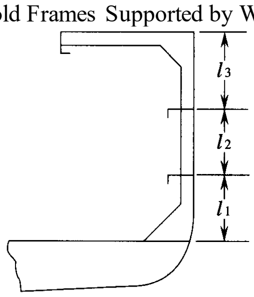
If l_3/l_2 is 1.25 or over, but l_2/l is less than 1.25, no modification is required.

(2) Where the difference between the largest and smallest spans is more than 50%.

If the lowest span is smallest, use the (maximum span)/1.5 instead of l.

In cases other than the above, no modification is required.

Fig. C7.3.3-1 Transverse Hold Frames Supported by Web Frames and Side Stringers



C7.5 Cantilever Beam Systems

C7.5.3 Connection of Cantilever Beams to Web Frames

1 To prevent the buckling of end brackets of cantilever beams connected to web frames, stiffeners are to be fitted to the brackets, with suitable spacing, in order to keep their panels small as shown in **Fig. C7.5.3-1**.

2 Within the range of 1/2 of the throat depth of the end bracket from the side of the face plate, stiffeners such as inverted angles are to be arranged in the direction of compression at the spacing obtained from the following formula. This spacing is deemed as the standard.

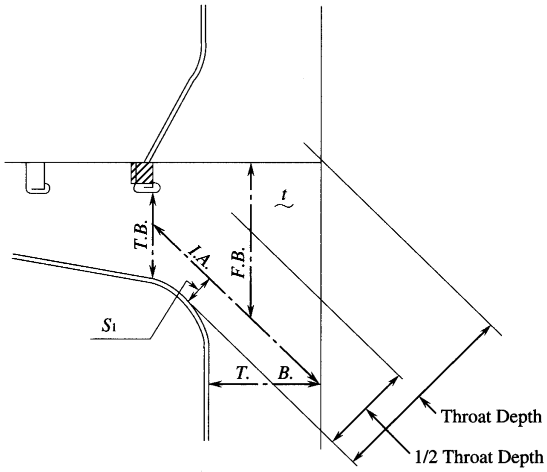
$$S_1 = 35(t - 2.5)$$

Where:

S_1: Spacing (*mm*) of stiffeners (*See* **Fig. C7.5.3-1**)

t : Thickness (*mm*) of bracket

Fig. C7.5.3-1 Reinforcement of Brackets

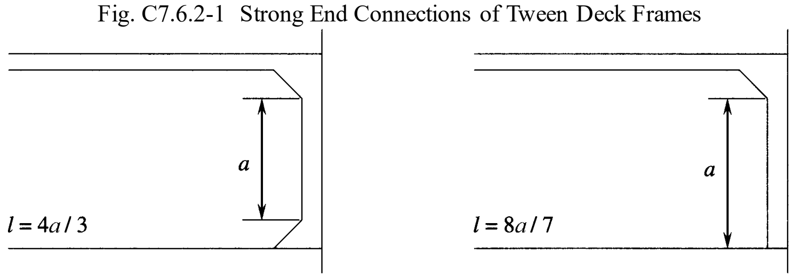


C7.6 Tween Deck Frames

C7.6.2 Scantlings of Tween Deck Frames

Where ends of tween deck frames are connected with brackets that have an arm length longer than $l/8$, the requirements of **7.6.2, Part C** of the Rules may be applied in the manner shown in **Fig. C7.6.2-1**.

Fig. C7.6.2-1 Strong End Connections of Tween Deck Frames



C7.6.3 Special Precautions Regarding Tween Deck Frames

In ships with multiple decks such as pure car carriers that have freeboards shorter than the length given in **Table C7.6.3-1**, the tween deck frames above the freeboard deck are to be generally reinforced according to the ship's length as follows.

(1) Range of reinforcement is at least up to the tween deck frames of the first tier above the freeboard deck.

(2) The section modulus of tween deck frames is to be determined applying the requirements of **7.6.2-2, Part C** of the Rules. However, the coefficient C is to be obtained from **Table C7.6.3-2**, according to the description of the tween deck frames. The section modulus of parts forward of the collision bulkhead and abaft the after peak bulkhead is not to be less than the values determined applying the requirements in **7.7.1** and **7.8.1, Part C** of the Rules.

Table C7.6.3-1 Standard Value of Freeboard

Length of Ship: L (m)	$75>L$	$75 \leq L < 125$	$125 \leq L$
Freeboard (m)	0.36	0.40	0.46

Table C7.6.3-2 Coefficient C

Description of tween deck frames	C
Superstructure frames for $0.125L$ from fore end and cant frames at stern	0.89
Superstructure frames for $0.125L$ from aft end	0.74
Superstructure frames excluding above	0.54

C8 WEB FRAMES AND SIDE STRINGERS

C8.1 General

C8.1.4 Consideration of Bow Impact Pressure

1 For ships with large bow flares that operate at high speed (car carriers, ro-ro cargo ships, LNG carriers or refrigerated LPG carriers, etc.), the thickness t_{wG} of web plates and the section modulus Z_G of side stringers supporting transverse frames and the web frames supporting these side stringers fitted where the bow flare located above the load line and forward of $0.2L$ is considered to endure large wave impact pressure are not to be less than those obtained from the following formulae.

Required thickness of web plate

$$\frac{433 P S_G l_G}{d_{wG} \sigma_y \cos\theta_G} \ (mm)$$

Required section modulus

$$\frac{P S_G l_G^2}{24 \sigma_y \cos\theta_G} \times 10^3 \ (cm^3)$$

P : Slamming impact pressure (kPa) as specified in **C7.1.8-1**

S_G: Spacing (m) of girder measured along the shell plating (See **Fig. C8.1.4-2**)

l_G: Unsupported length (m) of girder taking into account geometry of girder at end parts

Where the girder has arched end parts such as in **Fig.C8.1.4-1**, this length is to be modified by considering it to be a triangle, as follows.

(1) Join R-ENDs together. (AB)

(2) Draw a line $A'B'$ tangent with arc, parallel to AB.

(3) Put point A'' so that $AA'' = (2/3)AA'$ and B'' so that $BB'' = (2/3)BB'$. Consider triangle $OA''B''$ as a triangle bracket and apply the following formula.

$l_G = l - l_{b1} - l_{b2}$

l : Length (m) of girder measured along the shell plating (See **Fig.C8.1.4-1**)

l_{b1} and l_{b2}: Bracket length (m) for span correction as obtained from the following formulae

$$l_{b1} = b_1\left(1 - \frac{d_{wG}}{h_1}\right) \times 10^{-3}$$

$$l_{b2} = b_2\left(1 - \frac{d_{wG}}{h_2}\right) \times 10^{-3}$$

b_1, b_2, h_1 and h_2: Refer to **Fig.C8.1.4-1** (mm)

d_{wG}: Depth (mm) of web plate

σ_y: Specified yield stress (N/mm^2) of the material

θ_G: Angle (deg) between girder and vertical axis of shell plate (See **Fig.C8.1.4-2**)

Z_G: Section modulus (cm^3) of girder as obtained from the following formula

$$Z_G = 0.1 A_{fG} d_{wG} + \frac{1}{3000} {d_{wG}}^2 t_{wG}$$

A_{fG}: Sectional area (cm^2) of flange

t_{wG}: Thickness (mm) of web plate of girder

Fig.C8.1.4-1

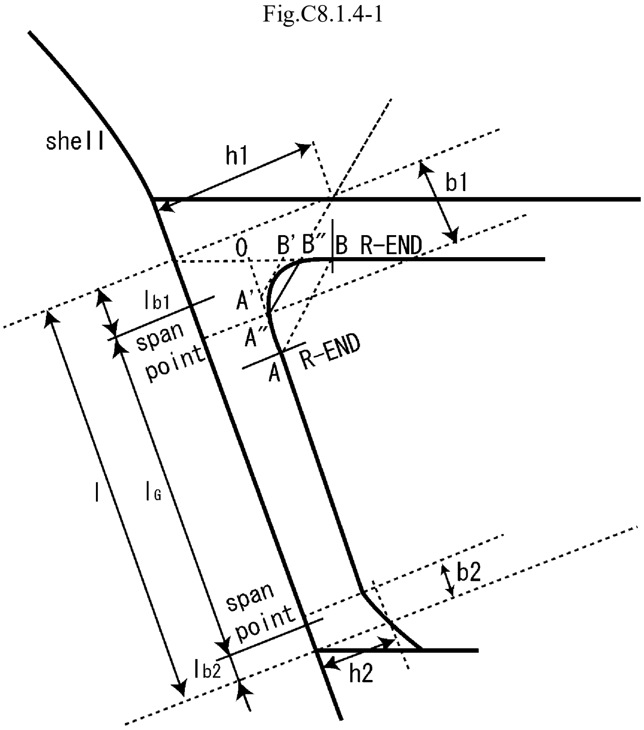
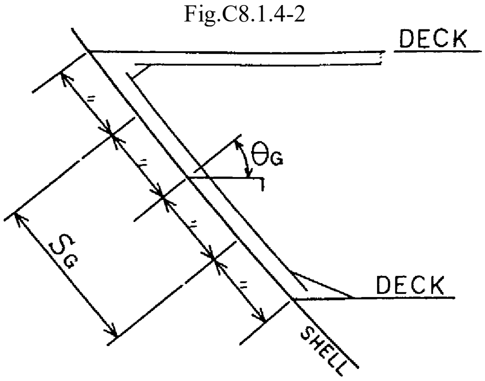


Fig.C8.1.4-2



2 The buckling strength of the web plates of girders supporting frames in -1 above is to be in accordance with the following. Compressive stress σ_a for the web plates is not to exceed the critical value σ^*_{acr} obtained from the following.

$\sigma^*_{acr} = \sigma_{acr}$ (N/mm^2), where $\sigma_{acr} \leq \frac{\sigma_y}{2}$

$\sigma^*_{acr} = \sigma_y\left(1 - \frac{\sigma_y}{4\sigma_{acr}}\right)$ (N/mm^2), where $\sigma_{acr} > \frac{\sigma_y}{2}$

σ_y: As specified in -1 above

σ_{acr}: Reference buckling stress of the web plates as obtained from the following formula

$$3.6E\left(\frac{t_{wG}}{S}\right)^2 \ (N/mm^2)$$

E: Modulus of elasticity, 2.06×10^5 (N/mm^2)

t_{wG}: As specified in -1 above

S: Spacing (mm) of web stiffeners connected to side longitudinals or transverse frames

σ_a: Compressive stress working on the web plates as obtained from the following formula

$$\frac{0.5PS_G}{t_{wG}\cos\theta_G} \ (N/mm^2)$$

P, S_G and θ_G: As specified in -1 above

3 The buckling strength of the web plates at the ends of girders in **-1** above is to be in accordance with the following **(1)** and **(2)**.

(1) Shearing stress τ for the web plates at the ends of girders is not to exceed the critical value τ_{cr}^* obtained from the following.

$$\tau_{cr}^* = \tau_{cr} \ (N/mm^2), \text{ where } \tau_{cr} \leq \frac{\tau_F}{2}$$

$$\tau_{cr}^* = \tau_F\left(1 - \frac{\tau_F}{4\tau_{cr}}\right) \ (N/mm^2), \text{ where } \tau_{cr} > \frac{\tau_F}{2};$$

$$\tau_F = \frac{\sigma_y}{\sqrt{3}}$$

σ_y : As specified in **-1** above

τ_{cr}: Shear buckling stress for web plates of girders at end parts as obtained from the following formula

$$0.9k_s E\left(\frac{t_{wG}^*}{d_{wG}^*}\right)^2 \ (N/mm^2)$$

k_s: Coefficient as obtained from **Table C8.1.4-1** depending on a_G/d_{wG}^*

For intermediate values of a_G/d_{wG}^*, k_s is to be obtained by linear interpolation.

a_G: Length (mm) of web plate at end parts (See **Fig.C8.1.4-3**)

E: As specified in **-2** above

t_{wG}^* : Thickness (mm) of web plate at the end of girder

d_{wG}^*: Mean depth (mm) of web plate at the end of girder

τ: Shear stress for web plate at end part as obtained from the following formula

$$\frac{250PS_G l}{d_{wG}^* t_{wG}^* \cos\theta_G} \ (N/mm^2)$$

P, S_G, l and θ_G: As specified in **-1** above

(2) Bending stress σ_b for the web plates at end parts is not to exceed the critical value σ_{bcr}^* obtained from the following.

$$\sigma_{bcr}^* = \sigma_{bcr} \ (N/mm^2), \text{ where } \sigma_{bcr} \leq \frac{\sigma_y}{2}$$

$$\sigma_{bcr}^* = \sigma_y\left(1 - \frac{\sigma_y}{4\sigma_{bcr}}\right) \ (N/mm^2), \text{ where } \sigma_{bcr} > \frac{\sigma_y}{2}$$

σ_y:As specified in **-1** above

σ_{bcr}: Bending buckling stress of the web plates as obtained from the following formula

$$0.9k_b E\left(\frac{t_{wG}^*}{d_{wG}^*}\right)^2 \ (N/mm^2)$$

k_b: Coefficient as obtained from **Table C8.1.4-2** depending on a_G/d_{wG}^*

For intermediate values of a_G/d_{wG}^*, k_b is to be obtained by linear interpolation.

E : As specified in **-2** above

t_{wG}^*, a_G and d_{wG}^*: As specified in **(1)** above

σ_b: Bending stress working on the web plates as obtained from the following formula

$$\frac{PS_G {l_G}^2}{24Z_G^* \cos\theta_G} \times 10^3 \ (N/mm^2)$$

P, S_G, l_G and θ_G: As specified in **-1** above

Z_G^*: Sectional modulus (cm^3) of web plate at end parts

$$Z_G^* = 0.1A_{fG}d_{wG}^* + \frac{1}{3000}{d_{wG}^*}^2 t_{wG}^*$$

A_{fG}: As specified in **-1** above

Fig.C8.1.4-3

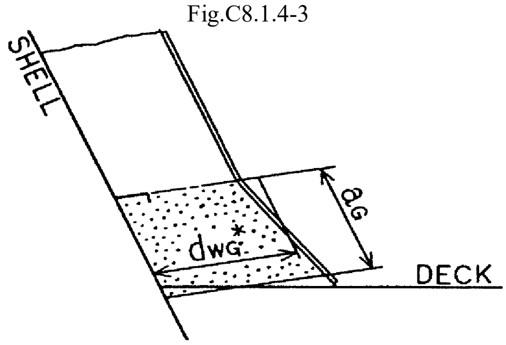


Table C8.1.4-1 Coefficient k_s

a_g/d^*_{wG}	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
k_s	64	38	25	19	15	12	10	9	8	7

Table C8.1.4-2 Coefficient k_b

a_g/d^*_{wG}	0.5 and under	0.6	0.7	0.8	0.9 and over
k_b	12	10	8.8	8.0	7.8

4 For ships whose L and C_b are not less than 250m and 0.8 respectively, the provisions of **3.3, Section 1, Chapter 10, Part 1, Part CSR-B&T of the Rules** are to be applied.

C9 ARRANGEMENTS TO RESIST PANTING

C9.1 General

C9.1.2 Swash Plates

The scantlings of swash plates in fore and aft peak tanks used as deep tanks are to comply with **9.2.2-2(2), Part C** of the Rules.

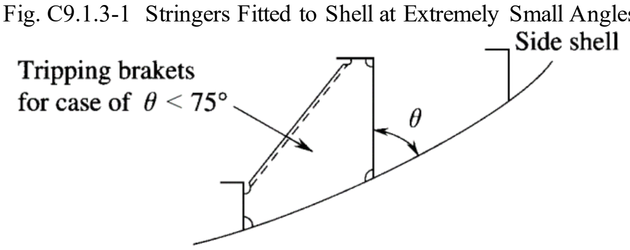
C9.1.3 Stringers Fitted to Shell at Extremely Small Angles

Where the angle between the web of stringers and the shell plating is smaller than 75°, the stringer is to be treated as follows unless approved otherwise by the Society (*See* **Fig. C9.1.3-1**). In general, even where stringers and girders attach to the shell at an angle, the actual section modulus is to be calculated against a neutral axis parallel to the shell plating.

(1) Face plates are to be fitted on the side of open bevels.

(2) Tripping brackets are to be fitted spaced suitably.

Fig. C9.1.3-1 Stringers Fitted to Shell at Extremely Small Angles



C9.4 Arrangements to Resist Panting Between Both Peaks

C9.4.1 Arrangements to Resist Panting Abaft of Collision Bulkhead

As a method for the reinforcement prescribed in **9.4.1, Part C** of the Rules, it is recommended to provide side stringers in line with stringer plates or on side stringers in way of the fore peak tank in association with web frames provided at suitable intervals between the collision bulkhead and 0.15L from the fore end. Where it is impracticable to provide web frames and side stringers, at least the following reinforcements in **(1)** or **(2)** are to be provided.

(1) The moment of inertia of the hold frames (including the aft wall of connecting trunk construction) abaft the fore end bulkhead of the foremost cargo hold is to be not less than that obtained from the following formula. For connecting trunk construction, the connecting trunk aft wall is to be treated as a web frame and half the width of the connecting trunk centre line side wall may be treated as the flange of the frame when applying this formula.

$4.13hl^4/n$ (cm^4)

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

L': Length of ship (m)

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

l : Distance (m) from the top of inner bottom plating at side (the top of bilge hopper tank at side for ships having bilge hopper tanks) to the top of deck beams above the frames at side (the bottom of top side tank at side for ships having top side tanks)

n : Number of frames from the bulkhead to the frame in question (n = 1, 2, 3, etc.)

(2) Where the provisions in **(1)** above are not directly applicable, side shell plates are to be stiffened taking into account the effect of the deformation of hold frames on the side shell near the fore end bulkhead of the foremost cargo hold and the structural continuity to the fore structure.

C10 BEAMS

C10.1 General

C10.1.2 Connections of Ends of Beams

1 The connection method of the ends of longitudinal beams shown in **Fig. C10.1.2-1** is standard.

2 The connection method of transverse beams by means of brackets shown in **Fig. C10.1.2-2** is standard.

Fig. C10.1.2-1

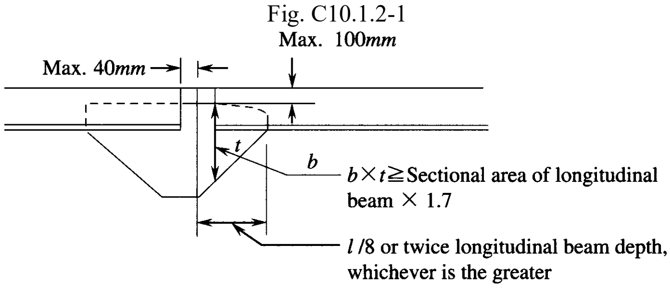
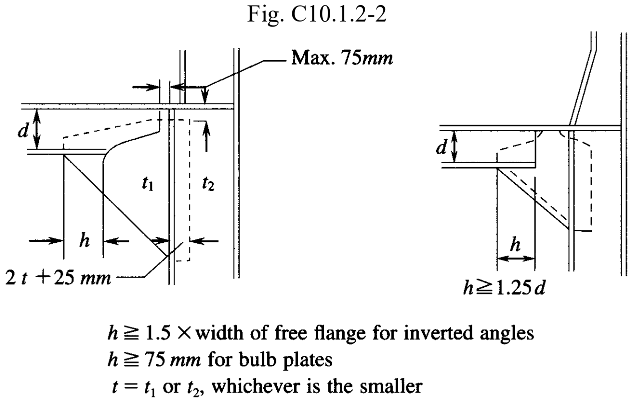


Fig. C10.1.2-2



C10.2 Deck Load

C10.2.1 Value of *h*

Suitable documents which specify values of the deck load h (kN/m^2) prescribed in **10.2.1-1, Part C** of the Rules (e.g. Loading Manual) are to be provided on board to aid the ship's master.

C10.3 Longitudinal Beams

C10.3.3 Section Modulus of Longitudinal Beams

The section modulus of longitudinal beams outside the line of hatchway openings of the strength deck fore and aft of the midship part may be determined by interpolation between the requirements of **10.3.3-1** and **10.3.3-2, Part C** of the Rules. Interpolation may be performed at the middle of each building block in the direction of the ship's length. However, where the length of the block is over 15 *metres*, the block is to be subdivided into appropriate lengths.

C10.4 Transverse Beams

C10.4.2 Proportion

1 Where the span/depth ratio of transverse beams exceeds 30 in strength decks or 40 in effective decks and superstructure decks,

the section moduli of these beams are to be increased by the corresponding ratios.

2 In ships such as Bulk Carriers and Ore Carriers over 200 *metres* in length, the proportion of transverse beams inside the line of hatchway openings of the strength deck is to be determined by taking into account the buckling strength. It is recommended that where the span is divided by the minimum radius of gyration (slenderness ratio: l/k), the value is below 60.

C10.8 Unusually Long Machinery Openings

Where the length of machinery openings exceed 20 m, a cross tie is to be provided at the mid-length of the opening.

C10.9 Deck Beams Supporting Vehicles

C10.9.1 Section Modulus of Beams

1 The section modulus of beams of decks loaded with wheeled vehicles (hereinafter referred to as "car decks") is not to be less than that obtained from the following formula. Where the span length or moment of inertia changes along the continuous beam, the scantlings of the beam are to be determined by direct strength calculation as specified in **10.9.1-2**.

C_1C_2M (cm^3)

Where:

C_1: Coefficient determined as follows:

C_1: 1.0 for $b/S \leq 0.8$

C_1: 1.25-0.31 b/S for b/S >0.8

Where:

S : Beam spacing (m)

b : Length (m) of wheel print measured at right angle to beams (*See* **Fig. C10.9.1-1**)

For vehicles with ordinary pneumatic tires, values in **Table C10.9.1-1** may be used.

C_2: Coefficient determined from **Table C10.9.1-2**

M : M_1, M_2 and M_{3j} obtained from the following formulae, whichever is the greatest ($kN \cdot m$):

$$M_1 = \frac{1}{15}\left[\sum_{i=1}^{N_I} 4P_{Ii}\alpha_{Ii}\left\{1-\left(\frac{\alpha_{Ii}}{l}\right)^2\right\} + \sum_{j=1}^{N_{II}} P_{IIj}\alpha_{IIj}\left(1-\frac{\alpha_{IIj}}{l}\right)\left(7-5\frac{\alpha_{IIj}}{l}\right) - \sum_{k=1}^{N_{III}} P_{IIIk}(l-\alpha_{IIIk})\left\{1-\left(\frac{l-\alpha_{IIIk}}{l}\right)^2\right\}\right]$$

$$M_2 = \frac{1}{15}\left[-\sum_{i=1}^{N_I} P_{Ii}\alpha_{Ii}\left\{1-\left(\frac{\alpha_{Ii}}{l}\right)^2\right\} + \sum_{j=1}^{N_{II}} P_{IIj}\alpha_{IIj}\left(1-\frac{\alpha_{IIj}}{l}\right)\left(2+5\frac{\alpha_{IIj}}{l}\right) + \sum_{k=1}^{N_{III}} 4P_{IIIk}(l-\alpha_{IIIk})\left\{1-\left(\frac{l-\alpha_{IIIk}}{l}\right)^2\right\}\right]$$

$$M_{3j} = \left| R_{II}\alpha_{IIj} - \sum_{r=0}^{j-1} P_{IIr}(\alpha_{IIj}-\alpha_{IIr}) - \left(\frac{M_2-M_1}{l}\right)\alpha_{IIj} - M_1 \right|$$

Where:

$P_{II0} = 0,\ \alpha_{II0} = 0$

l: Span (m) of beam between support points

P_{Ii}, P_{IIj} and P_{IIIk}: Maximum design wheel load (kN) between support points

Where the maximum design wheel loads between support points are given in tons, the values of P_{Ii}, P_{IIj} and P_{IIIk} should be multiplied by 9.81 to convert them into kN. Subscript "I_i" means the ith load point from left end of the Ith beam. Subscript "II_j (or II_r)" means the jth (or rth) load point from left end of the IIth beam. Subscript "III_k" means the kth load point from left end of the IIIth beam. (*See* **Fig. C10.9.1-2**)

α_{Ii}, α_{IIj} and α_{IIIk}: Distance (m) from each support point to the point of action of wheel load (*See* **Fig. C10.9.1-2**), when wheels are so arranged that M may be at its maximum value

N_I, N_{II} and N_{III} : Number of wheel loads between each span

R_{II}: The value obtained from following the formula

$$R_{II} = \frac{1}{l}\sum_{j=1}^{N_{II}} P_{IIj}(l - \alpha_{IIj})$$

Fig. C10.9.1-1 Measurement of Wheel Print Length

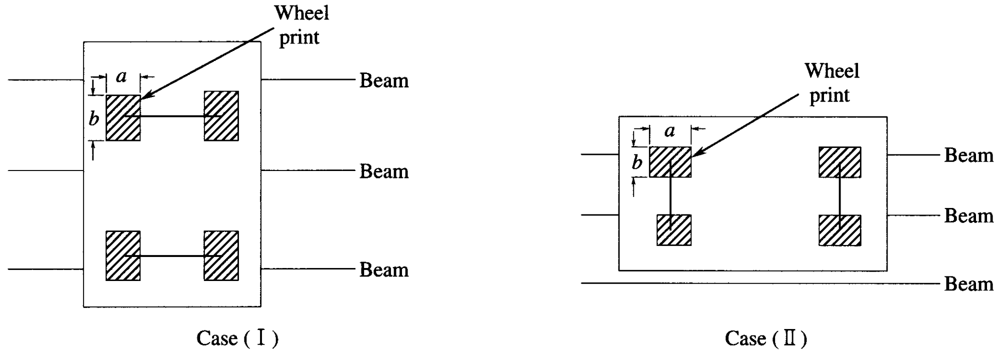


Fig. C10.9.1-2 Measurement of P_{Ii}, α_{Ii}, l etc.

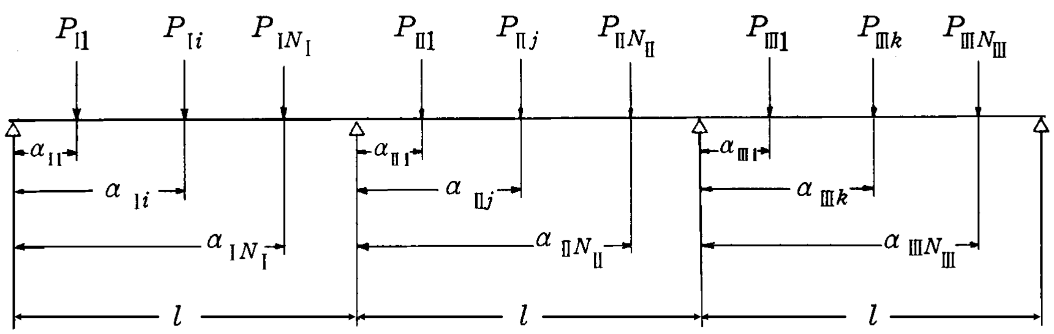


Table C10.9.1-1 Wheel Print Length (Pneumatic Tires)

	Wheel print length parallel to axle in Fig.C10.9.1-1, *a* in Case (I), *b* in Case(II)	Wheel print length right angles to axle in Fig.C10.9.1-1, *b* in Case (I), *a* in Case (II)
Single tire	Tire width	$\sqrt{P}/20$
Double tire	2×Tire width. Gap between tires, if any, may be added	$9\sqrt{P}/250$

Note:

P: Maximum design wheel load (kN). Where the maximum design wheel load is given in tons, the value of P should be multiplied by 9.81 to convert it into kN.

TableC10.9.1-2. Value of C_2

		Vehicles exclusively used for cargo handing	Other vehicles
Longitudinal beams of strength decks in mid ship region	Decks where vehicles are exclusively loaded (except weather deck)	$\frac{5.6K}{1-0.34f_{DH}K}$	$\frac{7.0K}{1-0.64f_{DH}K}$
	Elsewhere	$\frac{6.1K}{1-0.34f_{DH}K}$	$\frac{7.7K}{1-0.64f_{DH}K}$
Elsewhere	Decks where vehicles are exclusively loaded (except weather deck)	$5.6K$	$7.0K$
	Elsewhere	$6.1K$	$7.7K$

Note:

f_{DH}: Ratio of the section modulus of transverse section of hull at deck according to the requirements in **Chapter 15, Part C** of the Rules when mild steel is used to the actual section modulus of hull at strength deck. Where the ratio is less than $0.79/K$, f_{DH} is to be assumed as $0.79/K$

K: Coefficient corresponding to the material, as specified in **1.1.7-2, Part C** of the Rules

2 Scantlings of beams of car decks may be determined by the direct calculation methods shown below.

(1) The model of structures and the method of calculation are to be those approved by the Society.

(2) Loads are to be assumed as follows:

(a) 1.5×maximum design wheel load for loaded condition with vehicles on car decks

(b) 1.2×maximum design wheel load for vehicles used for cargo handling only (fork-lifts or similar vehicles used for handling cargo in ports only)

(3) The allowable stresses for calculation of the section modulus are to be as shown in **Table C10.9.1-3**.

(4) To take into account the effects of corrosion and similar wear, the section moduli obtained in **(1)**, **(2)** and **(3)** above are to be multiplied by 1.1 for decks exclusively loaded with vehicles (except the weather deck) and 1.2 for other decks.

Table C10.9.1-3 Permissible Stress (N/mm^2)

Members	Vehicles used for cargo handling only	Other vehicles
Longitudinal beams of strength decks in midship region	$\frac{235}{K}-80f_{DH}$	$\frac{235}{K}-150f_{DH}$
Elsewhere	$\frac{235}{K}$	$\frac{235}{K}$

C10.9.2 Structural Details

1 The method used to weld the stiffeners to the car deck is to be at least in accordance with the requirements specified in **Table C10.9.2-1** according to the type of stiffener and frequency of vehicular traffic.

2 Notwithstanding **-1** above, the requirement stipulated in **Note 3** of **Table C1.5,** of the Rules applies. Where continuous welding is carried out only on one side, at least $F2$ welding is to be carried out on the other side, as specified below.

(1) Up to 0.1 l from the end of the stiffener, where l is the total length of the stiffener

(2) 0.1 l' on either side of the intersection of stiffeners and girders, where l' is the span of the stiffeners

Table C10.9.2-1 Method of Fillet Weld(*4)

	Deck panels on which vehicular traffic is frequent(*1)	Panels other than those specified in the left column
General type	*F*2 (Both sides or One side)	*F*4 or *F*2 (One side)
Channel type(*2)	*F*2 (Both sides)	*F*4
Channel type(*3)	*F*2 (Web side of stiffener flange)	*F*4 (Web side of stiffener flange)

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): Channel type stiffeners as shown in **Fig.C10.9.2-1**, which are joined to the deck with spot-welds or intermittent welds

(∗ 3): Channel type stiffeners as shown in **Fig.C10.9.2-2**, which are joined to the deck with a full penetration weld

(∗ 4): "*F*2" and "*F*4" in this table is as specified in **Table C1.4**

Fig.C10.9.2-1

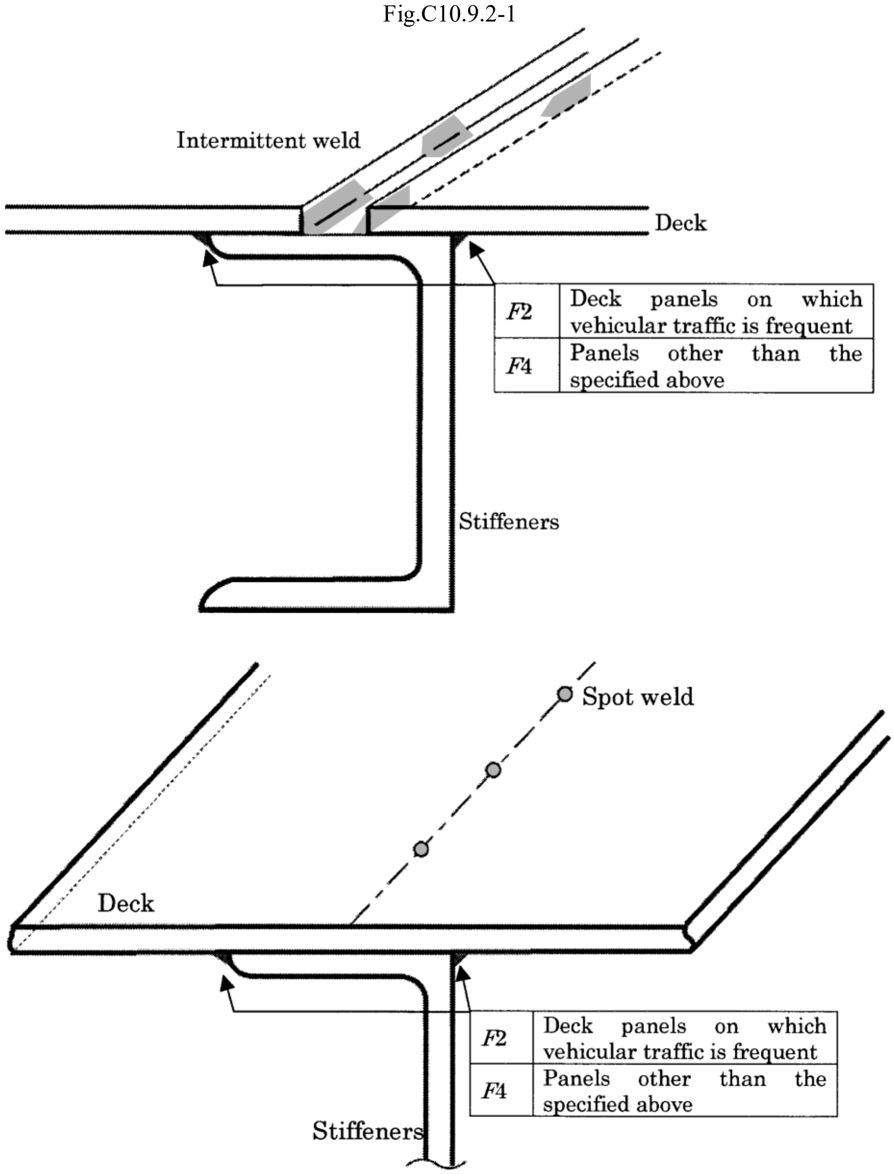
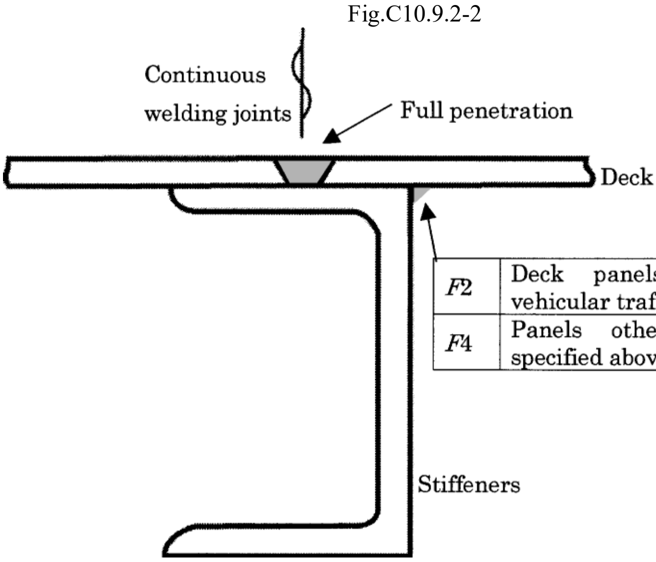


Fig.C10.9.2-2



$F2$	Deck panels on which vehicular traffic is frequent
$F4$	Panels other than the specified above

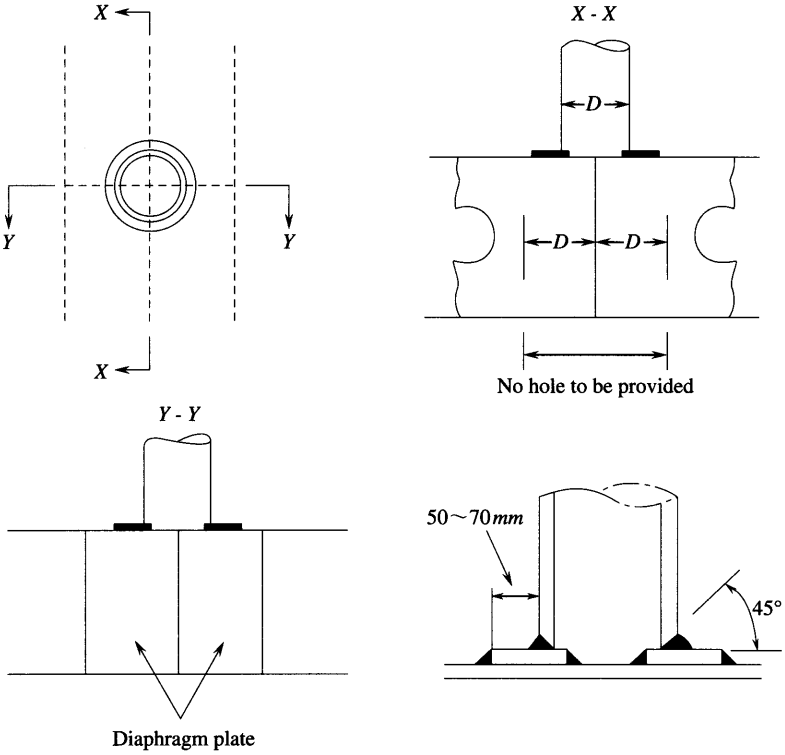
C11 PILLARS

C11.1 General

C11.1.2 Pillars in Holds

The reinforcement under pillars is to be as shown below.

Fig. C11.1.2-1



C11.2 Scantlings

C11.2.1 Sectional Area of Pillars

The sectional area of pillars which can be regarded as fixed at both ends may be obtained from the following formula:

$$\frac{0.223w}{2.72-\frac{0.5l}{k_0}} \ (cm^2)$$

C12 DECK GIRDERS

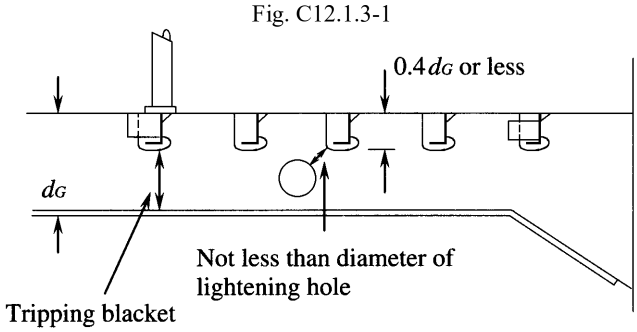
C12.1 General

C12.1.3 Construction

1 At the upper and lower ends of pillars and other places where concentrated loads are expected, girders are to be fitted with tripping brackets and slots in the girders are to be fitted with collars. Under the end bulkheads of superstructures, only collars are required. Collars are also to be fitted at the slots near the toes of end brackets.

2 Butt joints of girder webs are to be away from slots. Butt joints of face plates are to be away from knuckled parts. The depth of slots is not to exceed $0.4d_G$. If this limit is exceeded, collars are to be fitted. This depth is not to exceed $0.5d_G$. These requirements may be suitably modified for superstructures. (*See* **Fig. C12.1.3-1**)

Fig. C12.1.3-1



3 Sizes of lightening holes are to be as follows:

Girder with slot: $d \le \frac{d_G}{4}$

Girder without slot: $d \le \frac{d_G}{3}$

Where:

d_G: Depth of girder

d : Diameter of lightening hole

No lightening hole is to be provided near the toes of brackets or under pillars where shearing force is augmented. The distance between the lightening hole and slot is not to be less than the diameter of the lightening hole.

4 In ships such as RO-RO ships, the scantlings of girders may be determined by direct calculation of strength.

5 Where the value obtained from the following formula is not less than 1.6, special consideration is to be given to the beams on the shell side or bulkhead side around the mid-span of girders because of added stress due to forced deflection.

$$\frac{I_b \cdot l^4}{I_g \cdot Sb^3}$$

Where:

I_b and I_g : Actual moment of inertia (cm^4) of beam and girder, respectively

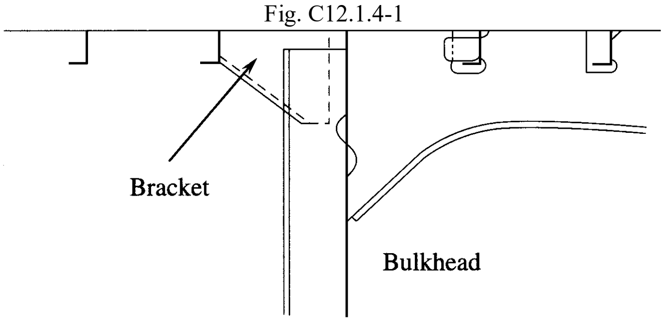
b and l : Span (m) of beam and girder, respectively

S : Beam spacing (m).

C12.1.4 End Connection

1 Where a girder stops at a bulkhead, a bracket is to be fitted on the reverse side. (*See* **Fig. C12.1.4-1**)

Fig. C12.1.4-1



2 Continuity of Deck Girders

(1) The standard depth of a bracket is twice the depth of a web. If the depth of the bracket is smaller than this standard, suitable equivalent means, such as attaching a gusset plate, is to be provided. (*See* **Fig. C12.1.4-2**)

(2) The girder included in the calculation of the section modulus is to completely penetrate the bulkhead (including the web and face plate) or is to be connected in a way that ensures an equivalently secure bond. (*See* **Fig. C12.1.4-3**)

(3) Where deck girders are discontinuous, they are to be sufficiently overlapped. (*See* **Fig. C12.1.4-4**)

Fig. C12.1.4-2

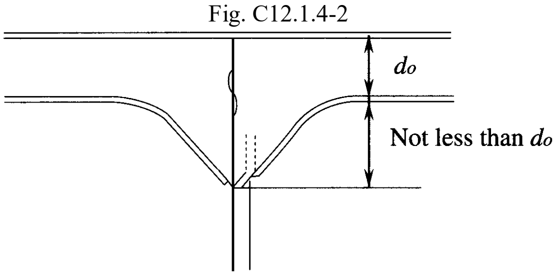


Fig. C12.1.4-3

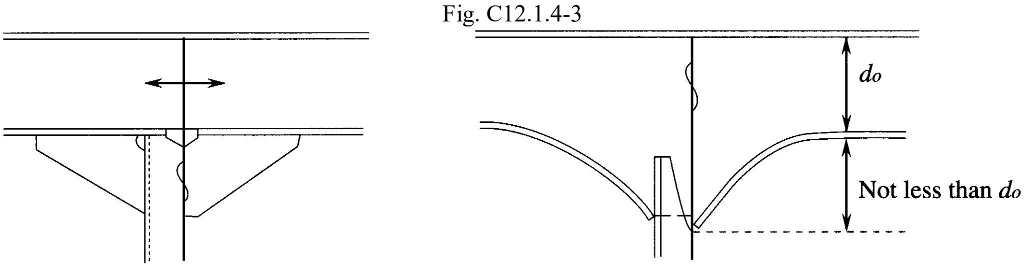
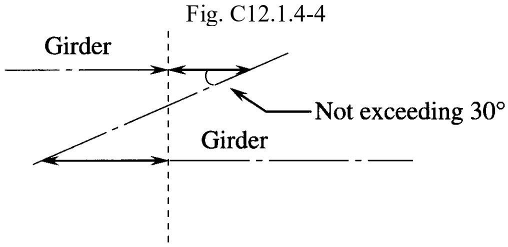


Fig. C12.1.4-4



C12.2 Longitudinal Deck Girders

C12.2.1 Section Modulus of Girders

The section modulus of longitudinal deck girders outside the line of hatchway openings of the strength deck fore and aft of the midship part is generally determined by interpolation as stipulated in **12.2.1-1** and **12.2.1-2, Part C** of the Rules. Interpolation is to be performed at the centre of the girder's span. However, this may be modified when taking into consideration factors such as the length of building blocks.

C12.7 Movable Car Deck Girders

C12.7.2 Strength Requirement

"The method of assessment … as deemed appropriate by the Society" in **12.7.2-4**, **Part C** of the Rules means an assessment method that can take into account the elastic buckling effects of compression panels of the car deck. Otherwise, an elastic FEM analysis using the shell elements model and a buckling strength check of compression panels in accordance with the requirements of **Annex C1.1.22-2 "GUIDANCE FOR BUCKLING STRENGTH CALCULATION" may be conducted**.

C13 WATERTIGHT BULKHEADS

C13.1 Arrangement of Watertight Bulkheads

C13.1.1 Collision Bulkheads

1 The position of the collision bulkhead is to be determined as shown below.

(1) In case of a Bulbous Bow (*See* **Fig. C13.1.1-1**)

(When the stem has a hollowed part over the waterline at 85% of the least moulded depth measured from the top of the keel)

(2) In case of a Collision Bulkhead with a Step or Recess (*See* **Fig. C13.1.1-2**)

Fig. C13.1.1-1

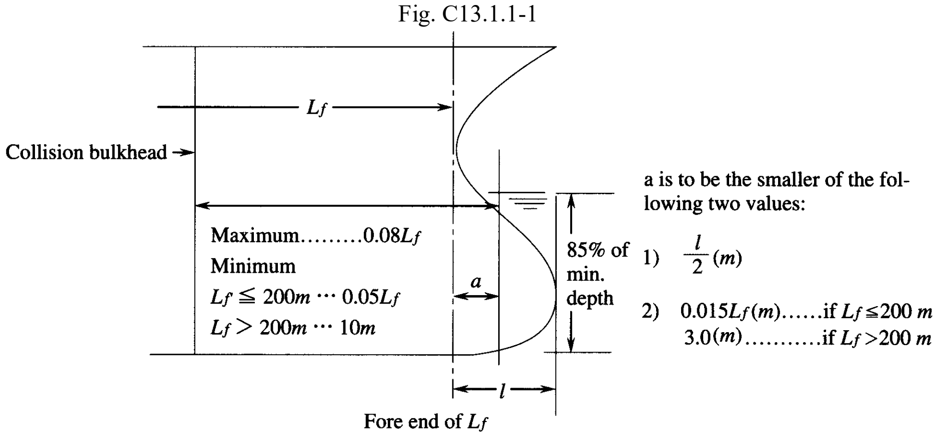
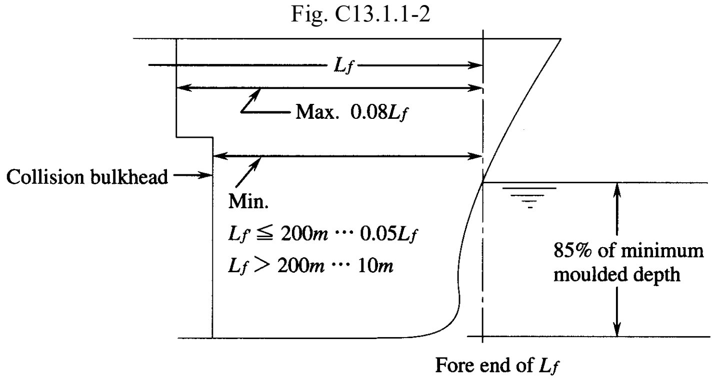


Fig. C13.1.1-2



2 In ships with bow doors, the collision bulkhead under the deck just above the freeboard deck is to comply with the requirements mentioned in **13.1.1-1**, **13.1.1-2** or **13.1.5(2), Part C** of the Rules.

3 "Special structural reasons which are approved by the Society" in **13.1.1-1, Part C** of the Rules are reasons approved on the basis that an application is submitted together with calculations verifying that no part of the bulkhead deck will be immersed even when the compartment forward of the collision bulkhead is flooded under loaded conditions (without trim) corresponding to the load line.

C13.1.2 After Peak Bulkheads

Measures to minimize the danger of water penetrating into the ship in case of damage to stern tube arrangements are to be taken.

C13.1.4 Hold Bulkheads

1 Where the distance between two neighbouring bulkheads is less than $0.7\sqrt{L}$ m, these two bulkheads are not counted as two bulkheads.

2 "As determined by the Society in each case" as prescribed in **Table C13.1** in **Chapter 13, Part C** of the Rules means the number of bulkheads arranged in accordance with the following **(1)** and **(2)**.

(1) The ships has sufficient transverse strength of hull

(2) The final waterline does not exceed the upper surface of the bulkhead deck at the side of the ship even after any compartment, except the machinery space, has been flooded under the loading condition corresponding to the summer load water line. The permeability used in flooding calculations is to be in accordance with **Table C13.1.4-1** and **Table C13.1.4-2.** However, the following ships are exempted from this calculation.

(a) Tankers in compliance with the requirements of **3.2.2, Part 3 of the Rules for Marine Pollution Prevention Systems**

(b) Ships carrying liquefied gases in bulk or ships carrying dangerous chemicals in bulk

(c) Bulk carriers in compliance with the requirements of **31A.2, Part C** of the Rules

(d) Ships in compliance with the requirements of **Chapter 4, Part C** of the Rules (including ships specified in **C4.1.1**)

Table C13.1.4-1. Permeability of Cargo Spaces

Cargo spaces	Permeability
empty	0.95
loaded with general cargo	0.60
loaded with timber	0.55
loaded with ore	0.50
loaded with cars or containers	$0.95-0.35\times\frac{V_C}{V_0}$

Notes:

V_C: Volume (m^3) occupied by cars and/or containers

V_0: Moulded volume (m^3) of the compartment

Table C13.1.4.-2. Permeability of Deep Tanks

Cargo condition	Permeability
empty	0.95
filled	0

Note:

For spaces loaded with special kinds of cargo, a suitable permeability is used depending on the kind of cargo.

3 Where the number of watertight bulkheads is smaller than that specified in **13.1.4-1, Part C** of the Rules, due attention is to be paid to the transverse strength of the hull in accordance with the requirements of **13.1.4-2, Part C** of the Rules, and the number of watertight bulkheads may be in accordance to one of the following **(1)** to **(3)**. Where the number of watertight bulkheads is decreased from that required according to the following **(2)**, an application for the omission of bulkheads stating the reasons for such omission is to be submitted by the shipowner to the Society.

(1) The number of bulkheads specified by the requirements of **-2(1)** or **(2)** above

(2) For ships of special types, the number is in accordance with **(a)**, **(b)** or **(c)**

(a) Ships carrying long cargoes (rails, sheet piles or similar long cargoes), train ferries, and car carriers, may omit one bulkhead where the required number is 5 or less, and 2 bulkheads where the required number is 6 or more

(b) Ships having conveyor systems for handling cargoes may omit all the hold bulkheads, if necessary

(c) Ships other than those specified above are, as a rule, not regarded as special type ships

(3) Where special consideration is given for improving safety of ships by means such as that of a double hull, the arrangement of watertight bulkheads may be different from that required in the Rules.

C13.1.5 Height of Watertight Bulkheads

A “long forward superstructure” means a forward superstructure having a length not less than $0.25L_f$.

C13.2 Construction of Watertight Bulkheads

C13.2.3 Stiffeners

1 Scantlings of bulkhead stiffeners just under deck girders

The scantlings of bulkhead stiffeners supporting under-deck girders are to comply with the following formula:

$$C\frac{Z_0}{Z}+\frac{W}{A}\leq C$$

Z_0: Required section modulus (cm^3) of stiffener

Z : Actual section modulus (cm^3)

C : 17.7

A : Sectional area (cm^2) of stiffener (may include attached plate)

W: Axial load (kN) of stiffener obtained from the following formula:

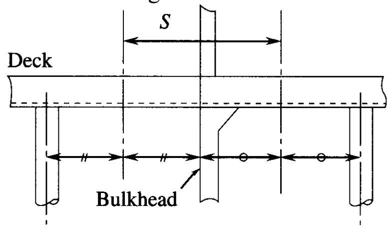
Sbh

S : Distance (m) between mid-spaces of adjacent girders supported by stiffeners (*See* **Fig. C13.2.3-1**)

b and h : As specified in **12.2.1, Part C** of the Rules.

In ships having two or more decks, W for the upper tier deck need not be taken into consideration.

Fig. C13.2.3-1



2 Scantlings of bulkhead stiffeners just under cargo gears and deck girders

The scantlings of bulkhead stiffeners just under cargo gears and deck girders are to comply with **-1** above using the value obtained from following formula as the axial load on the stiffener. Where the stiffeners support only tare weight of cargo gears, the first term in the formula may be zero.

$Sbh+P$ (kN)

S, b and h : As specified in above **-1**

P : Tare weight of cargo gears (kN)

For derrick systems, it may be acceptable to use the value shown in **Table C13.2.3-1** according to the type of derrick system and the arrangement of derrick booms.

Table C13.2.3-1 Tare Weight of Derrick Systems (kN)

Arrangement of Derrick Booms	Type of Derrick Post	
	Independent type	Gate type
Booms arranged only on fore or aft side	$2.0w$	$2.3w$
Booms arranged on both sides	$2.7w$	$3.0w$

Note:

Where, w : Safe working load (kN) of each boom

For booms arranged on both sides, the average value is to be taken.

3 Dimensions of brackets of bulkhead stiffeners

The dimensions of brackets of bulkhead stiffeners are to be as indicated in **Fig. C13.2.3-2**.

4 Support of stiffeners at decks

Where a deck terminates at the bulkhead, the stiffeners are to have ribs at the level of the deck. (*See* **Fig.C13.2.3-3**)

Fig. C13.2.3-2

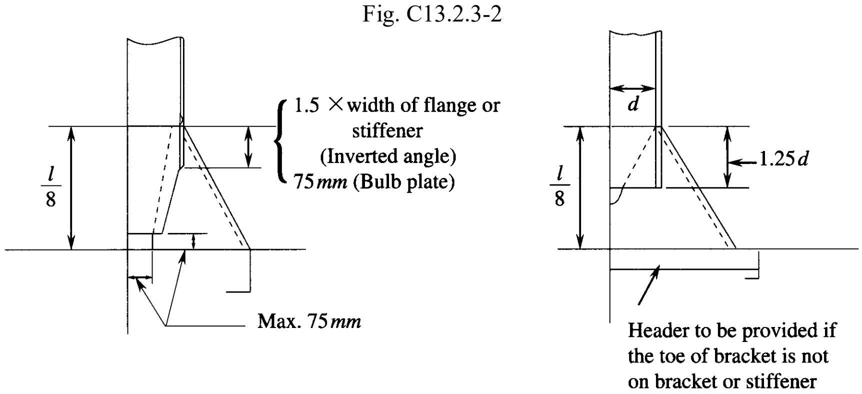
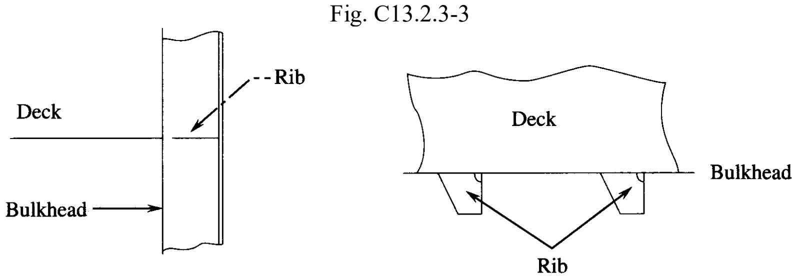


Fig. C13.2.3-3



C13.2.4 Corrugated Bulkheads

1 Section modulus of corrugated bulkheads

Where the end connection of corrugated bulkheads is remarkably effective, the coefficient C in **13.2.4-2, Part C** of the Rules may be the value taken from **Table C13.2.4-1** in calculating the section modulus per half pitch. "Remarkably effective" means the following:

(1) The value of m_1 specified in **Table C13.2.4-1.** is greater than 0.2 for the connection of the upper end of the corrugated bulkhead to the deck

(2) The value of m_2 specified in **Table C13.2.4-1.** is greater than 0.6 for the connection of the upper end of the corrugated bulkhead to the stools

(3) The plate thickness of lower stools is not less than half the thickness of the face plates of the corrugated bulkhead for the connection of the lower end of the corrugated bulkhead to the stools

2 Construction of corrugated bulkheads

(1) Stiffeners are to be provided at the ends of under-deck girders.

(2) Where brackets are fixed to bulkhead plates, pads or headers are to be fitted at the bracket toe.

(3) The angle of corrugation is to be not less than 45°.

(4) Girders fitted to corrugated bulkheads are to be balanced girders, except where the strength of such girders is at least equivalent to that of girders fitted to flat bulkheads. In calculating the actual section modulus of the girder, the depth of the girder is to be taken as shown in **Fig. C13.2.4-3**. The bulkhead plate of corrugated bulkheads is not to be included into the section modulus of the girder as an effective attached plate.

(5) The lower end of the corrugated bulkhead is to be constructed as shown in **Fig. C13.2.4-4** (A) or (B). The construction of the upper end is recommended to follow the construction of the lower end.

Table C13.2.4-1 Coefficient C

		C		
Col.	Other ends	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
1	Supported by horizontal or vertical girders or lower end of bulkhead welded directly to decks or inner bottoms	As per the Rules	$\dfrac{4}{2+m_1+\dfrac{Z_2}{Z_0}}$	$\dfrac{4}{2+m_2+\dfrac{Z_2}{Z_0}}$
2	Lower end of bulkhead welded to stool efficiently supported by ship structure	$\dfrac{4.8\left(1+\frac{l_H}{l}\right)^2}{2+\dfrac{Z_1}{Z_0}+\dfrac{Z_H}{Z_0}}$	$\dfrac{4.8\left(1+\frac{l_H}{l}\right)^2}{2+m_1+\dfrac{Z_H}{Z_0}}$	$\dfrac{4.8\left(1+\frac{l_H}{l}\right)^2}{2+m_2+\dfrac{Z_H}{Z_0}}$
		Not to be less than value of Column 1		

Notes:

In the above table, Z_0, Z_1, Z_2, l_H and l are to be as per the Rules.

m_1 is to be obtained from the following formula for the upper end but it need not exceed Z_1/Z_0.

$$\frac{1}{Z_0}\left[Z_S+\left(\frac{l_L+d_0}{l_L-d_0}+1.0\right)Z_L\right]$$

Z_S is the section modulus (cm^3) of the continuous stiffener at the upper end (*See* **Fig. C13.2.4-1**).

l_L and Z_L are the span (m) and section modulus (cm^3) of the longitudinal member connected to the upper end. (*See* **Fig. C13.2.4-1**)

d_0 is as per the Rules.

m_2 is to be obtained from the following formulae, whichever is smaller.

$$\frac{1}{Z_0}\times\frac{1050At}{n}$$

$$3.6\left(\frac{l}{l_0}\right)^2-3$$

A : Area (m^2) enclosed by periphery upper stool (*See* **Fig. C13.2.4-2**)

t : Average plate thickness (mm) of upper stool (*See* **Fig. C13.2.4-2**)

n : Number of pitches of corrugation supported by upper stool (*See* **Fig. C13.2.4-2**)

l_0 : Distance (m) between insides of upper and lower stools (*See* **Fig. C13.2.4-2**)

Z_H: Section modulus (cm^3) per half pitch of lower end of lower stool (*See* **Fig. C13.2.4-2**)

Fig. C13.2.4-1

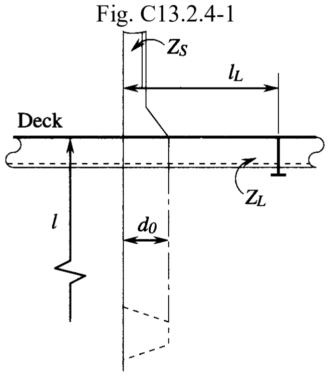


Fig. C13.2.4-2

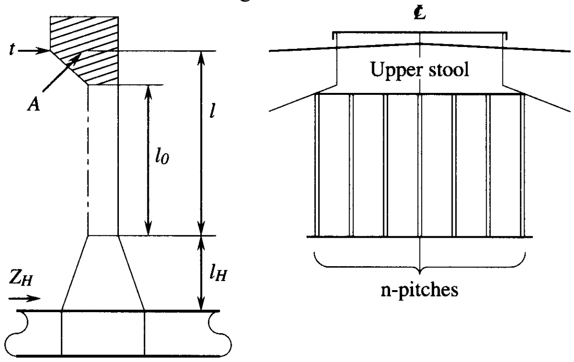


Fig. C13.2.4-3. Depth of Girder

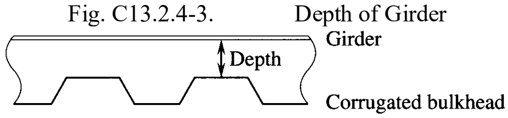
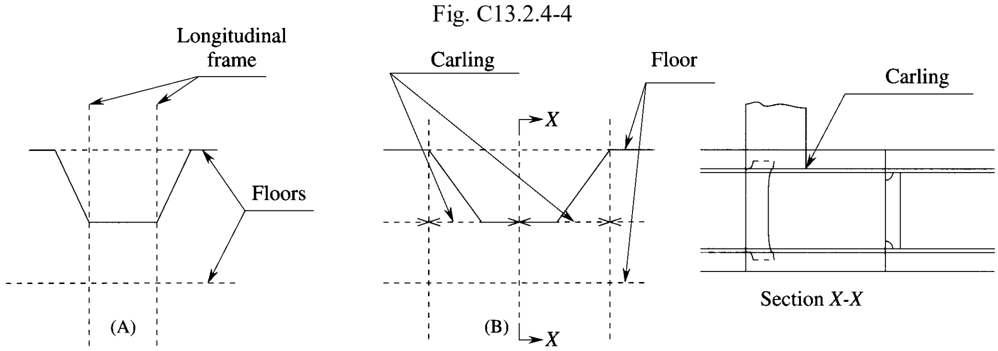


Fig. C13.2.4-4



C13.3 Watertight Doors

C13.3.1 General

1 With respect to the provisions of **13.3, Part C** of the Rules, watertight doors are categorized as the following **(1)** to **(4)** corresponding to their purpose and frequency of use.

(1) Watertight doors which are to be permanently closed at sea

Such doors are open in port and closed before the ship leaves port (*e.g.* bulkhead doors for loading/unloading). The time of opening/closing such doors is to be entered in the log-book.

(2) Watertight doors which are to be normally closed at sea

Such doors are kept closed at sea but may be used if authorized by the officer of the watch and to be closed again after use.

(3) Watertight doors which are used at sea

Kept closed, but may be opened during navigation when authorized by the Administration to permit the passage of passengers or crew, or when work in the immediate vicinity of the door necessitates it being opened. The door, however, is to be immediately closed after use.

2 The requirements of **13.3, Part C** of the Rules apply to watertight doors required by other regulations regarding damage stability requirements. Watertight doors located above the bulkhead deck are to also comply with the requirements for doors provided for means of escape specified in **Chapter 13, Part R** of the Rules.

3 With respect to the provisions of **13.3**, **Part C** of the Rules, **Table C4.3.1-1** and **Table C4.3.1-2** are also referenced as general requirements for watertight doors.

C13.3.2 Types of Watertight Doors

Watertight doors provided in watertight bulkheads are to be of a sliding type as far as is practicable. If hinged doors are used, they are to be accessible at any time.

C13.3.3 Strength and Watertightness

1 "Where deemed necessary by the Society" in **13.3.3-1, Part C** of the Rules refer to cases other than those specified in the following **(1)** to **(3)**.

(1) The prototype of such doors has been tested by design water pressure

(2) The design of such doors has been verified to have enough strength and watertightness by direct structural analysis

Where watertight doors utilize gasket seals, a prototype pressure test to confirm that the compression of the gasket material is capable of accommodating any deflection is to be carried out.

(3) Such doors are complying with a standard deemed appropriate by the Society

2 Hydrostatic tests specified in **13.3.3-1, Part C** of the Rules are to be carried out as follows:

(1) The head of water used for the hydrostatic test is to correspond at least to the head measured from the lower edge of the door opening (at the location in which the door is to be fitted in the ship) to 1 m above the freeboard deck. However, for watertight doors subject to **4.3.1** and **4.3.2, Part C of the Rules**, the head is not to be less than the height of the final damage waterline or the intermediate waterline, whichever is greater.

(2) The acceptable leakage rate at the test is not to be greater than the following values.

(a) Doors with gaskets: No leakage

(b) Doors with metallic sealing: 1 l/min

(3) Notwithstanding **(2)** above, the following leakage rate may be accepted for hydrostatic tests on large doors located in cargo spaces employing gasket seals or guillotine doors located in conveyor tunnels.

(a) For doors of design head exceeding 6.10 m:

$$\frac{(P+4.572)\cdot h^3}{6568} \quad (l/min)$$

P: Perimeter of door opening (m)

h: Test head of water (m)

(b) For doors with a design head not exceeding 6.10 m, the acceptable leakage rate is the value calculated by the formula specified in **(a)** above or 0.375 l/min, whichever is greater.

C13.3.4 Control

1 Where it is necessary to start the power unit for remote operation of the watertight door required by **13.3.4, Part C** of the Rules, means to start the power unit is also to be provided at remote control stations.

2 Remote controls required by **13.3.4, Part C** of the Rules, are to be in accordance with the following.

(1) The operating console at the navigation bridge is to have a "master mode" switch with the following two modes of control. This switch is normally to be in the "local control" mode. The "doors closed" mode is only used in an emergency or for testing purposes. Special consideration is to be given to the reliability of the "master mode" switch.

(a) "Local control" mode

This mode is to allow any door to be locally opened and locally closed after use without automatic closure.

(b) "Doors closed" mode

This mode is to permit doors to be opened locally and automatically reclose the doors upon release of the local control mechanism.

(2) The operating console at the navigation bridge is to be provided with a diagram showing the location of each door, with visual indicators to show whether each door is open or closed. A red light is to indicate that a door is fully open and a green light is to indicate that a door is fully closed. When the door is closed remotely, the red light is to indicate the intermediate position by flashing. The indicating circuit is to be independent of the control circuit for each door.

3 Where remote control is required by **13.3.4, Part C** of the Rules, signboard/instructions are to be placed in way of the door advising how to act when the door is in the "doors closed" mode.

4 With respect to the provisions of **13.3.4, Part C** of the Rules, where a watertight door is located adjacent to a fire door, both doors are to be capable of independent operation, remotely if required and from both sides of each door.

5 "Navigation bridge" stated in **13.3.4, Part C** of the Rules means the place where the watch officer is always present and normally implies the navigation bridge deckhouse.

6 With respect to the provisions of **13.3.4-1, Part C** of the Rules, operation capability with the ship listed at 30 degrees to either side is to be verified by tests such as the prototype test.

7 With respect to the provisions of **13.3.4-1, Part C** of the Rules, power operated doors are also to be capable of being opened and closed by power, in addition to by hand.

C13.3.5 Indication

1 For watertight doors with dogs/cleats for securing watertightness, position indicators required by **13.3.5, Part C** of the Rules are to be provided to show whether all dogs/cleats are fully and properly engaged or not.

2 With respect to the provisions of **13.3.5, Part C** of the Rules, a position indicator may not be required for doors which are designed to confirm easily whether the doors are open or closed from either side and, if applicable, all dogs/cleats are fully and properly engaged or not.

3 The door position indicating system required by **13.3.5, Part C** of the Rules is to be of a self-monitoring type and the means for testing it are to be provided at the position where the indicators are fitted.

4 "Position indicators on the bridge showing whether the doors are open or closed" required by **13.3.5, Part C** of the Rules is to be in accordance with **C13.3.4-2(2)**.

C13.3.6 Alarms

An audible alarm required by **13.3.6-2, Part C** of the Rules is to have a sound distinctive from any other alarms in the area, which will sound whenever the door is remotely closed.

C13.3.7 Source of Power

"Electrical installations for devices specifies in **-1**" stated in **13.3.7-2, Part C** of the Rules refers to electrical motors for opening and closing the doors and their control components; indicators that show whether the doors are opened or closed; audible alarms; and limit switches for ensuring the door position and their associated cables.

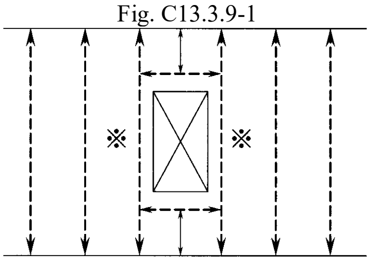
C13.3.8 Notices

"A device which prevents unauthorized opening" stipulated in **13.3.8-2, Part C** of the Rules can be a lock that prevents access to closing and/or operating apparatus.

C13.3.9 Sliding Doors

The section moduli of stiffeners adjacent to both sides of sliding doors (indicated with an asterisk in **Fig. C13.3.9-1**) are to be determined by the formula for stiffeners of deep tank bulkheads. The upper end of *h* in the formula is to be the bulkhead deck at the centreline of hull.

Fig. C13.3.9-1



C14 DEEP TANKS

C14.1 General

C14.1.2 Application

The construction of deep tanks is to comply with the requirements for the construction of watertight bulkheads stipulated in C13.2 in addition to the requirements in this Chapter.

C14.1.3 Divisions in Tanks

1 Length of deep tanks

The length of deep tanks is not to exceed the following limits.

(1) Where no longitudinal bulkhead is provided or a longitudinal bulkhead is provided on the centreline only:

$0.15L_f$ (m) or 10 m, whichever is greater

(2) Where two or more longitudinal bulkheads are provided:

$0.2L_f$ (m) except that the limit is to be $0.15L_f$ (m) in the bow and stern parts of bulk carrier type ships

Further, where the breadth of the wing tank is less than $4L+500$ (mm), the inner wall cannot be regarded as a longitudinal bulkhead.

2 Divisions

(1) Except in the bow and stern parts, deep tanks extending from side to side of the ship are to have longitudinal divisions in the ship's centreline. However, when it can be confirmed by the stability data that such bulkheads will be unnecessary, they might be omitted.

(2) In fresh water tanks extending from side to side of the ship, fuel oil tanks or other tanks which may not be kept completely full during navigation, wash plates or deep girders are to be provided on the centreline as well as in positions approximately $B/4$ distant from the ship's sides, except when it can be confirmed by the data on the rolling period of the ship and the inherent period of oscillation of water or oil in the tanks, that they will be unnecessary.

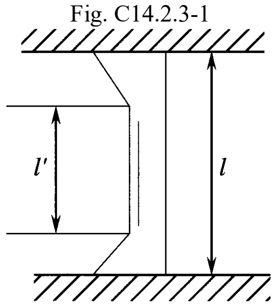
C14.2 Deep Tank Bulkheads

C14.2.3 Bulkhead Stiffeners

1 Span of stiffeners

For stiffeners having "Connection Type A," the span may be taken as $4l'/3$ if the arm length of brackets exceed $l/8$. For "Connection Type A," *see* Fig. C14.2.3-1.

Fig. C14.2.3-1



2 End connection of stiffeners at the top of deep tanks

Stiffeners of deep tank bulkheads, which are not in line with stiffeners of tween deck bulkheads at the top of the tank, are to have bracket ends.

3 Scantlings of bulkhead stiffeners supporting under-deck girders

The scantlings are to be calculated according to C13.2.3-1, taking C as 9.81.

C14.2.4 Corrugated Bulkheads

1 Upper and lower structures supporting corrugated bulkheads

(1) In cases where stools are not fitted with corrugated bulkheads, the standard upper and lower structures supporting the corrugated bulkheads are to be in accordance with **Table C14.2.4-1**.

Table C14.2.4-1 Upper and Lower Structures Supporting Corrugated Bulkheads

Type of corrugated bulkhead		Location	Supporting structure
Vertically corrugated bulkhead	Transverse	Lower	Floors with a thickness that is the same as that of the lower part of a corrugated bulkhead are to be arranged beneath both flanges of the corrugated bulkhead or a floor with a thickness that is the same as that of the lower part of a corrugated bulkhead is to be arranged beneath one flange of the corrugated bulkhead and a bracket with a web depth that is not less than 0.5 times the depth of the corrugation is to be arranged beneath the other side flange of the corrugated bulkhead. (See **Fig.C14.2.4-1.**)
	Longitudinal	Upper	An on-deck longitudinal girder or an on-deck longitudinal with a web thickness of not less than 80% of the thickness of the upper part of a corrugated bulkhead is to be arranged above both flanges of the corrugated bulkhead.
		Lower	Girders (center girders or side girders) with a thickness that is the same as that of the lower part of a corrugated bulkhead are to be arranged beneath both flanges of the corrugated bulkhead or a girder with a thickness that is the same as that of the lower part of a corrugated bulkhead is to be arranged beneath one flange of the corrugated bulkhead and an inner bottom longitudinal with a web depth that is not less than 0.5 times the depth of the corrugation or an equivalent stiffener is to be arranged beneath the other side flange of the corrugated bulkhead.
Horizontally corrugated bulkhead	Transverse	Lower	A floor with a thickness that is the same as that of the lower part of a corrugated bulkhead is to be arranged beneath the web of the corrugated bulkhead.
	Longitudinal	Upper	An on-deck longitudinal girder with a web thickness that is not less than 80% of the thickness of the upper part of a corrugated bulkhead is to be arranged above the web of the corrugated bulkhead.
		Lower	A girder (center girder or side girder) with a thickness that is the same as that of the lower part of a corrugated bulkhead is to be arranged beneath the web of the corrugated bulkhead.

(2) In cases where a stool is fitted with a corrugated bulkhead, the standard lower stool and structures supporting such a lower stool are to be in accordance with the following **(a)** and **(b)**:

(a) The thickness of the top plate and the uppermost part of the side plating of the lower stool is to be the same as that of the lower part of the corrugated bulkhead.

(b) At the bottom of a lower stool, floors in a double bottom are to be arranged beneath the side plating of the lower stools for transverse corrugated bulkheads and girders (center girders or side girders) are to be arranged beneath the side plating of the lower stools for longitudinal corrugated bulkheads. In addition, the thickness of the upper part of floors and girders are to be the same as that of the side plating of the lower stool.

(3) In cases **(1)** and **(2)** above, any openings such as slots or scallops providing penetration for stiffeners to a floor, web of transverses or girders are to be eliminated or covered by collar plates.

2 Section modulus of corrugated bulkheads

Where the width d_H in the direction of the ship's length of the lower stool of the corrugated bulkhead at the inner bottom is less than 2.5 *times* the web depth d_0 of the corrugated bulkhead, the span l between supports is to be measured as shown in **Fig. C14.2.4-2**. Further, the section modulus per half pitch of the corrugated bulkhead and the section modulus of the lower stool at the inner bottom are to be obtained from the formulae in **14.2.4-2, Part C of the Rules**, using the value of C in **Table C14.2.4-2**.

3 Construction of corrugated bulkheads

The corrugation angle, ϕ, of a corrugated bulkhead is not to be less than 55 degrees. (See **Fig. C14.2.4-3.**)

4 In evaluating the corrugated bulkheads of compartments intended to carry liquid cargoes with specific gravity, ρ, more than 1.0, the scantlings of the corrugated bulkheads are to be calculated by multiplying h by ρ before using the formulae specified in **14.2.4-1** to **-3, Part C of the Rules**.

Fig. C14.2.4-1 Example of Structures Supporting Vertically Corrugated Bulkheads (Transverse Bulkheads)

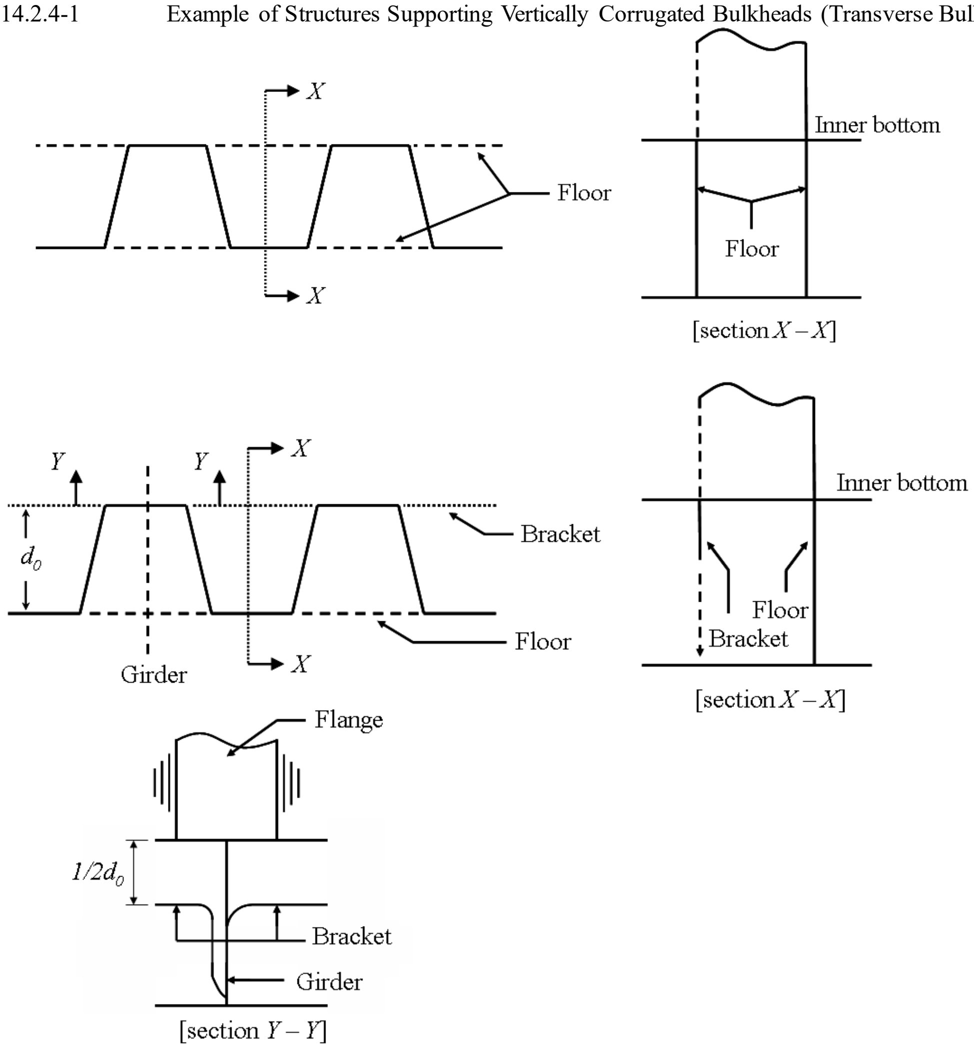


Fig. C14.2.4-2. Measurement of l where $d_H/d_0<2.5$

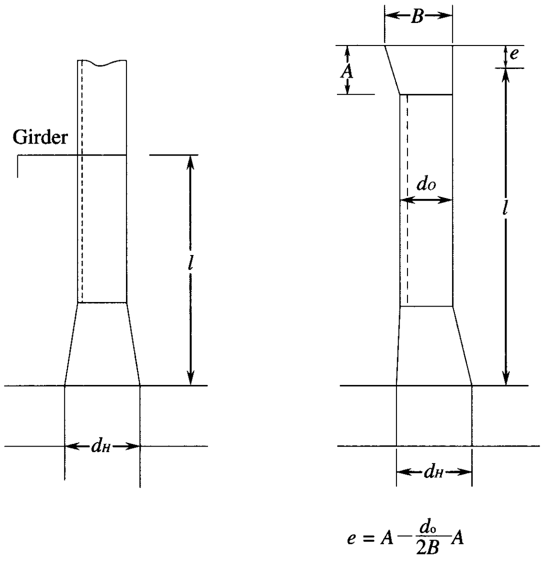


Fig. C14.2.4-3. Definition of the Corrugation Angle of a Corrugated Bulkhead

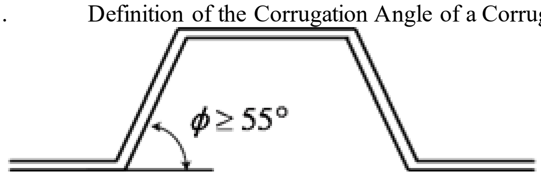


Table C14.2.4-2 Coefficient C

Upper end support	Supported by girder	Connected to deck	Connected to stool
Section modulus of corrugated bulkhead	1.00	0.85	0.78
Section modulus of stool at bottom	1.00	1.50	1.35

C14.2.5 Girders Supporting Bulkhead Stiffeners

Girders fitted to corrugated bulkheads are to be balanced girders. Where it is difficult to form a balanced girder, the neutral axis of the girder is to be brought as close as possible to the bulkhead plate.

C15 LONGITUDINAL STRENGTH

C15.1 General

C15.1.1 Special Cases in Application

The ships stated in 15.1.1-2, Part C of the Rules are to be treated as follows.

(1) Ships of unusual proportion

"Ships of unusual proportion" stated in 15.1.1(1), Part C of the Rules refer to ships that have L/B<5 or B/D_s>2.5, and adequate consideration is to be given regarding overall strength of the ships in addition to the requirements in Chapter 15, Part C of the Rules.

(2) Ships with especially large hatches

Ships that have hatches with a breadth exceeding 0.7B in the midship part are to have their torsional strength examined in accordance with the requirements in C32.3.

(3) Ships with especially small C_b

Where C_b' specified in 15.2.1-1, Part C of the Rules is less than 0.65, $Z\sigma$ specified in 15.2.1-1, Part C of the Rules is to be obtained by multiplying by the following coefficient according to the value of C_b'.

$C_b' \leq 0.60$: 1.05

$0.60 < C_b' < 0.65$: 1.65-C_b'

(4) Ships with large flares and high ship speed

According to the values of K_v and K_f obtained from the following formulae, M_w specified in 15.2.1-1, Part C of the Rules is to be increased in accordance with the requirements in **(a)** and **(b)**.

$$K_v = 0.2V/\sqrt{L_1}$$

$$K_f = (A_d - A_W)/L_1 h_B$$

Where:

A_d: Area (m^2) projected onto a horizontal plane of exposed deck forward of 0.2L_1 aft of the fore end (including the part forward of the fore end)

Where a forecastle is provided, the horizontal project area of the forecastle overlaps the aforementioned area.

A_W: Water plane area (m^2) corresponding to the designed maximum load line within the forward 0.2L_1

h_B: Vertical distance (m) from designed maximum load line to exposed deck at the side of fore end

(a) Where K_v exceeds 0.28

C_2 specified in 15.2.1-1, Part C of the Rules is to be replaced with the value given in Table C15.1.1-1 according to the values of K_v and x which is the distance (m) from aft end of L to the position of the considered hull transverse section. For intermediate values of K_v and/or x, the value is to be determined by interpolation.

(b) Where $(K_v + K_f)$ exceeds 0.40

C_2 specified in 15.2.1-1, Part C of the Rules is to be replaced with the value given in Table C15.1.1-2 according to the values of (K_v+K_f) and x only under sagging conditions. For intermediate values of (K_v+K_f) and/or x, the value is to be determined by interpolation.

(5) Other ships

(a) Ships with inclined sides

Where the requirements in 15.2.1 and 15.3.1, Part C of the Rules apply, B may be replaced with B_{WL} which is the moulded breadth corresponding to the designed maximum load line at the widest section of the ship. (*See* Fig. C15.1.1)

(b) Ships whose tanks have approved corrosion control specified in 1.1.21, Part C of the Rules

For the hull section that is constructed from longitudinal strength members in tanks provided with approved corrosion control specified in 1.1.21, Part C of the Rules, $Z\sigma$ specified in 15.2.1-1, Part C of the Rules may be reduced by up to 5%. However, the moment of inertia of the hull section is not to be less than the value specified in 15.2.1-3, Part C of the Rules.

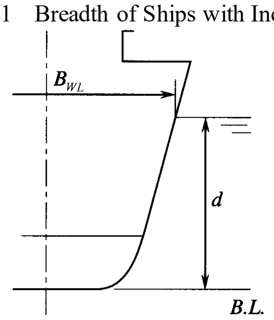
Table C15.1.1-1 Modified Value of C_2

K_v	X		
	$0.65L_1$	$0.75L_1$	$1.0L_1$
0.28	1.0	5/7	0
0.32 and over	1.0	0.8	0

Table C15.1.1-2 Modified Value of C_2

$K_v + K_f$	X		
	$0.65L_1$	$0.75L_1$	$1.0L_1$
0.40	1.0	5/7	0
0.50 and over	1.0	0.8	0

Fig. C15.1.1 Breadth of Ships with Inclined Sides



C15.1.2 Continuity of Strength

With respect to the provision of **15.1.2**, **Part C of the Rules**, continuity of strength is to be maintained throughout the length of the ship. Where significant changes in structural arrangements occur, adequate transitional structures are to be provided.

C15.2 Bending Strength

C15.2.1 Bending Strength at the Midship Part

1 With respect to the provisions of **15.2.1, Part C of the Rules**, calculation of the longitudinal bending moment in still water is to be as follows.

(1) To perform the calculation of longitudinal bending moment in still water, the method of calculation used is to be submitted for prior approval by the Society.

(2) For ships intended to be built under Classification survey, calculation sheets for longitudinal strength in still water corresponding to the actual loading plans and the data necessary for the calculations are to be submitted to the Society.

(3) In the Classification Survey, longitudinal strength calculations in still water are to be performed at the time of completion of the ship on each type of operating condition, and the necessary data and results of these calculations are to be included in the loading manual specified in **34.1.1, Part C of the Rules**.

(4) Where ballast conditions in the actual loading plans (including intermediate conditions specified in **1.3.1-2** and **-3 in Annex C34.1.2**) involve partially filled ballast tanks, such conditions where such ballast tanks are assumed to be empty or full are to be included with the calculation sheets for longitudinal strength specified in **(2)** above. Where two or more ballast tanks are partially filled simultaneously at departure, arrival or during the intermediate conditions specified in **1.3.1-2** and **-3 in Annex C34.1.2**, all possible combinations with these ballast tanks empty or full are to be considered.

(5) In cargo loaded conditions, the requirements of **(4)** above are to apply to the peak tanks only.

(6) For large wing ballast tanks of ore carriers as defined in **1.3.1(13)(b), Part B of the Rules**, an examination for partially filled ballast tanks specified in **(4)** above, may be according to the following.

(a) Where the ship's trim exceeds one of the following conditions when one or two pairs of these tanks are empty or have full ballast water filling levels, it is sufficient to demonstrate compliance with maximum, minimum, and intended partial filling levels of these tanks such that the ship's condition does not exceed any of these trim limits.

i) Trim by stern of 3% of the ship's length (L_1)

ii) Trim by bow of 1.5% of ship's length (L_1)

iii) Any trim that cannot maintain propeller immersion (I/D) of not less than 25%, where:

I = the distance from propeller centreline to the waterline

D = propeller diameter

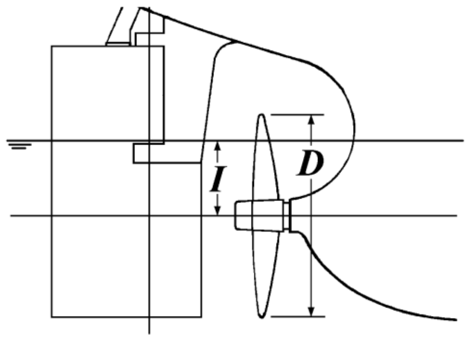
(b) In the application of the provisions of **(a)** above, where two or more pairs of these tanks are intended to be partially filled, filling levels of all other wing ballast tanks are to be considered between empty and full.

(c) In the application of the provisions of **(a)** above, the maximum and minimum filling levels of the above mentioned pairs of side ballast tanks are to be indicated in the loading manual specified in **34.2.1, Part C of the Rules**.

(7) The provisions of **(4)** to **(6)** above need not apply to ballast water exchange using the sequential method. However, bending moment and shear force calculations for each de-ballasting or ballasting stage in the ballast water exchange sequence are to be included in the loading manual or ballast water management plan of any vessel that intends to employ the sequential ballast water exchange method.

(8) For the application of the provisions of **(4)** to **(6)** above, reference is to be made to **ANNEX C15.2.1**.

Fig. C15.2.1-1 Propeller Immersion



C15.2.2 Bending Strength at Sections other than the Midship Part

"Where the Society considers that the application of requirements of **-1** above is inappropriate" stated in **15.2.2-2**, **Part C** of the Rules refers to cases in which the bending strength for the locations categorised in the following **(1)** to **(3)** is examined. In these cases, the bending strength is to be in accordance with the requirement specified in **15.2.1-1**, **Part C** of the Rules by using the coefficient C_2 obtained from the dotted line in **Fig. C15.2**.

(1) Locations categorized in the following **(a)** to **(d)** for all ships:

(a) In way of the forward end of the engine room

(b) In way of the forward end of the foremost cargo hold

(c) At any locations where there are significant changes in the hull cross-section

(d) At any locations where there are changes in the framing system

(2) In addition to the locations specified in **-1** above, locations categorized in the following **(a)** to **(c)** for ships with large deck openings. However, locations categorized in **(b)** and **(c)** are for only those ships with cargo holds aft of the superstructure, deckhouse or engine room.

(a) At or near to the aft and forward quarter length positions

(b) In way of the aft end of the aft-most holds

(c) Aft end of the deckhouse or engine room

(3) In addition to the locations specified in **-1** and **-2** above, locations where deemed necessary by the Society for those ships categorised in the following **(a)** and **(b)**:

(a) Ships with a C_b of less than 0.7

(b) Ships whose longitudinal bending moments in still water at parts other than the midship part are equal to or greater than that at the midship part

C15.2.3 Calculation of Section Modulus of Transverse Section of Hull

1 Unit of section modulus of transverse section of hull

The section modulus Z (cm^3) is to have five significant figures.

2 Members included in longitudinal strength

The ratio of inclusion of members effective for longitudinal strength is to be as follows.

(1) All intercostal plates may be included if the fillet welding complies with **Note 1** of **Table C1.5, Part C**.

(2) All doubling plates may be included if fitted during ship construction or 90% if fitted during conversion or addition.

(3) For side stringers, slots for frames are to be deducted.

(4) Scallops complying with the following conditions need not be deducted from the sectional area. (*See* **Fig. C15.2.3-1**)

  (a) d_s not exceeding $d/4$ nor exceeding $7t$, maximum 75 mm

  (b) S more than $5b$ and more than $10d_s$

(5) As for the longitudinal continuous decks between hatchways of ships having 2 or 3 rows of cargo hatches, the ratio of sectional area to be included in the calculation of the section modulus is to be obtained from **Table C15.2.3-1**. For intermediate values of ξ and l/L, linear interpolation is to be applied.

(6) Where the sectional area of longitudinals, which are unable to be continued due to factors such as the arrangement of small hatch openings are compensated by adjacent ones, they may be included in the calculation of the section modulus of the transverse section.

(7) Where the car deck plating of exclusive car carriers are intermittently welded in lap joints, they are not to be included in the calculation of the section modulus of the transverse section.

Fig. C15.2.3-1 S, b and d_s of Scallops

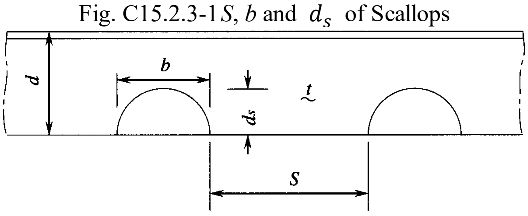


Table C15.2.3-1 Ratio of Inclusion of Sectional Area

	Hatches in 2 rows			Hatches in 3 or more rows		
ξ	l/L					
	0.10	0.20	0.30	0.10	0.15	0.20
0	0.96	0.85	0.70	0.96	0.91	0.85
0.5	0.65	0.57	0.48	0.89	0.80	0.69
1.0	0.48	0.43	0.36	0.83	0.73	0.62
2.0	0.32	0.29	0.25	0.73	0.63	0.53
3.0	0.24	0.22	0.18	0.65	0.57	0.47

Notes:

ξ = Values obtained from the following formula:

$$\frac{ab^3}{lI_c}\left\{\frac{1+2\mu}{6(2+\mu)}\times 10^4 + 2.6\frac{I_c}{a_c b^2}\right\}$$

Where:

I_c : Moment of inertia (cm^4) of deck between hatches, including hatch coamings

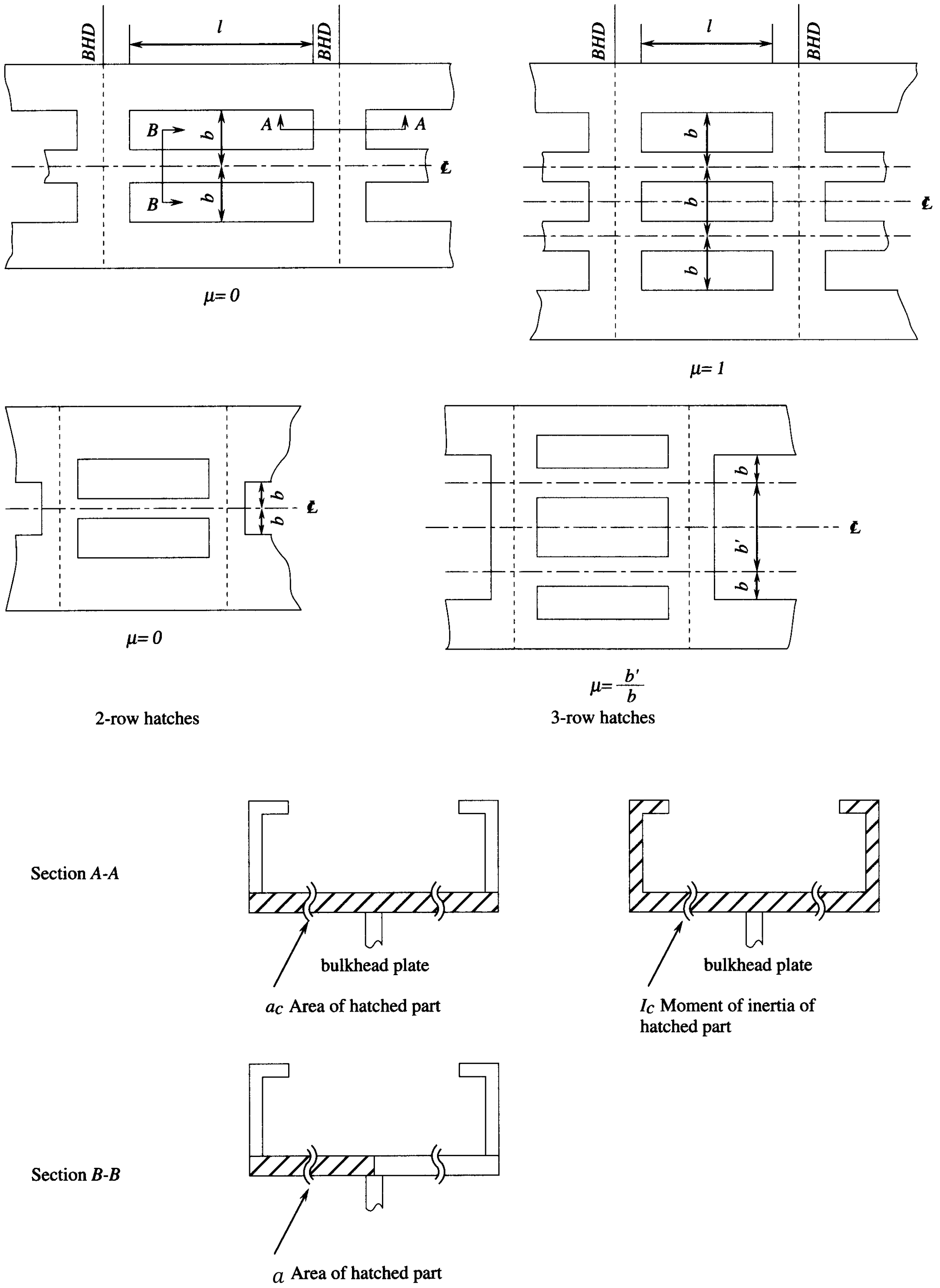
a_c: Effective shear area (cm^2) of deck between hatches

a : Sectional area (cm^2) of continuous deck between hatches (port or starboard side half)

l : Length (m) of hatch

μ , : As per **Fig. C15.2.3-2** (m)

Fig. C15.2.3-2. l, b and μ



3 Openings in strength decks

Openings in strength decks outside the line of hatch openings are to be treated as mentioned below.

(1) Where the shape and dimensions do not meet the conditions in Table C15.2.3-3, reinforcement by means of rings, thicker plates, etc. is required (*See* Fig. C15.2.3-3 and Fig. C15.2.3-4)

(2) Where the intervals between centres of holes e do not meet the conditions in Fig. C15.2.3-5, reinforcement as per **(1)** above is needed.

Table C15.2.3-3

	Elliptic holes	Circular holes
Oil tankers	$\frac{a}{b} \leq \frac{1}{2}, a \leq 0.06B$ $(a_{max} = 900\ mm)$	$a \leq 0.03B$ $(a_{max} = 450\ mm)$
Cargo ships	$\frac{a}{b} \leq \frac{1}{2}, a \leq 0.03(B - b_H)$ $(a_{max} = 450\ mm)$	$a \leq 0.015(B - b_H)$ $(a_{max} = 200\ mm)$

Fig. C15.2.3-3 Where Elliptic Hole and Circular Hole are in Same Cross-section

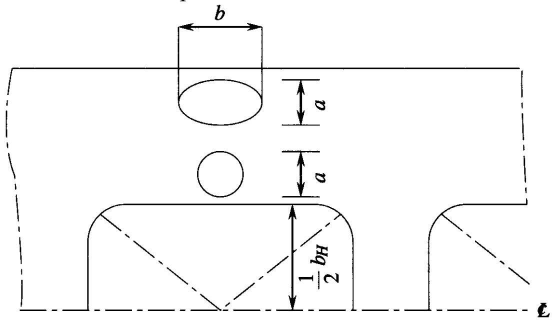


Fig. C15.2.3-4 Reinforcement by Means of Ring

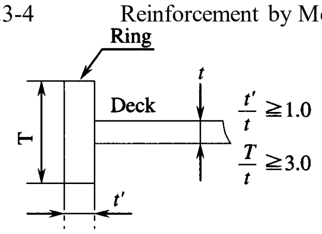
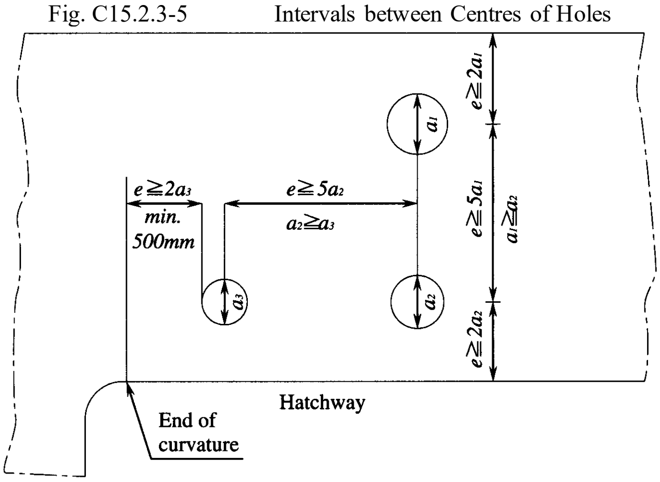


Fig. C15.2.3-5 Intervals between Centres of Holes



C15.3 Shearing Strength

C15.3.1 Thickness of Shell Plating of Ships without Longitudinal Bulkheads

1 Ships with bilge hopper tanks and/or topside tanks

Where the sloping plates of the bilge hopper tank and topside tank are joined to the side shell plating and are considered to be effective to carry a part of the shearing force, the shear current at the transverse section of the hull under consideration may be calculated directly and the thickness of the side shell plating forming a part of the bilge hopper tank and topside tank may be determined. However, when performing this direct calculation and determining the thickness of plating, shearing force given in **(1)** is made to act on the transverse section of the hull, and shearing stresses which develop in the side shell plating forming a part of the bilge hopper tank and topside tank and in the sloping plates are obtained, and these values are to be less than the allowable stress given in **(2)**.

(1) The value of shearing force acting on the transverse section of the hull is obtained from the following formulae, whichever is greater.

$|F_s + F_w(+) - \Delta F_c|$ (kN)

$|F_s + F_w(-) - \Delta F_c|$ (kN)

F_s, $F_w(+)$ and $F_w(-)$: As specified in **15.3.1-1, Part C** of the Rules

ΔF_c: As specified in the following **-2**

(2) Allowable stress in side shell plating within bilge hopper tank or topside tank and in sloping plate

$\frac{90}{K}$ (N/mm^2)

K : Coefficient corresponding to the kind of steel

e.g. 1.0 for mild steel, the values specified in **1.1.7-2(1) of the Rules** for high tensile steel

2 Modification of shearing force in still water where cargo is loaded in every other hold

Where a loaded hold (or a ballast hold) adjoins an empty hold by a transverse bulkhead, the shearing force in still water at the transverse section of the hull under consideration may be determined as the following F_c.

$F_c = F_s - \Delta F_c$ (kN)

F_s : Shearing force (kN) in still water obtained by using the calculation method specified in **15.3.1-1, Part C** of the Rules

ΔF_c: Value (kN) obtained from the following **(1)** through **(3)**

(1) At the bulkhead aft of hold

$-C(F_{SF} - F_{SA} - F_T)$

(2) At the bulkhead fore of hold

$C(F_{SF} - F_{SA} - F_T)$

(3) At a section in the hold

The value obtained by applying linear interpolation of the values of **(1)** and **(2)** depending on the distance between the transverse section under consideration and the bulkhead aft or fore of the hold which contains the transverse section

F_{SA},F_{SF}: Shearing forces (kN) in still water (F_s) at the bulkheads aft and fore of the hold, respectively, in the loading condition concerned, applying the calculation method as specified in **15.3.1-1, Part C** of the Rules

F_T : Mass (kN) of ballast in the topside tank which is contained in the hold concerned

C : Coefficient which depends on the values of k as specified in **31.2.1-4, Part C** of the Rules and B/l_H as given in **Table C15.3.1-1**. For intermediate values of k, linear interpolation is to be applied.

3 Simplified formula for m/I

The ratio m/I, specified in **15.3.1-1, Part C** of the Rules, may be simplified to $1/(90D_s)$.

Table C15.3.1-1 Coefficient C

	B/l_H											
k and above / below	0.4	0.4 0.6	0.6 0.8	0.8 1.0	1.0 1.2	1.2 1.4	1.4 1.6	1.6 1.8	1.8 2.0	2.0 2.2	2.2 2.4	2.4
10.0	0.092	0.115	0.159	0.197	0.230	0.255	0.275	0.289	0.300	0.308	0.314	0.317
5.0	0.088	0.110	0.152	0.190	0.223	0.250	0.270	0.286	0.298	0.307	0.313	0.315
2.0	0.081	0.101	0.140	0.177	0.210	0.238	0.261	0.279	0.293	0.302	0.310	0.312
1.0	0.075	0.094	0.131	0.166	0.200	0.230	0.254	0.273	0.288	0.300	0.307	0.310
0.0	0.063	0.079	0.112	0.145	0.179	0.211	0.238	0.261	0.279	0.291	0.302	0.306

C15.3.2 Thickness of Side Shell Plating and Longitudinal Bulkhead Plating of Ships Having One to Four Rows of Longitudinal Bulkheads

Where Type *C*, Type *D* or Type *E* ships specified in **Fig. C15.6, Part C** of the Rules are provided with bilge hoppers in the double hull, the values of α_2 and *R* specified in **C15.3.2 in Part C** of the Rules are to be construed as those tabulated in **Table C15.3.2-1** in applying the rules, except where the Society deems otherwise. However, the thickness of the side shell plating and slant plates forming bilge hoppers is not to be less than 1.2 *times* the values determined by the requirements of the rules.

Table C15.3.2-1 Values of Coefficients α_2 and *R*

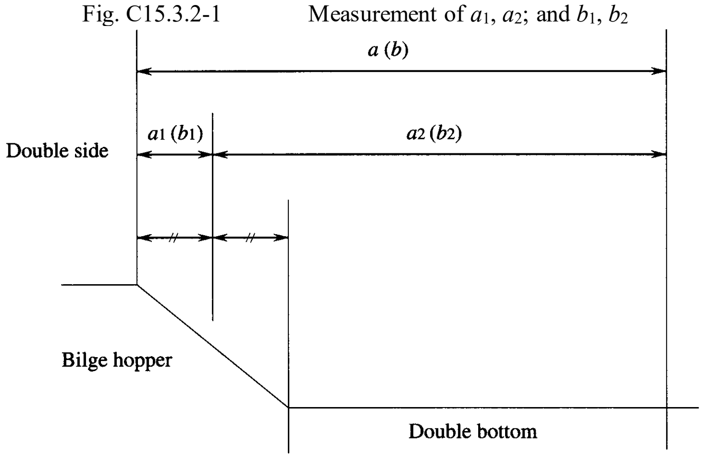
<table>
<tr><th>Type</th><th colspan="2">Application</th><th>α_2</th><th>R</th></tr>
<tr><td rowspan="3">C</td><td colspan="2">Side shell</td><td>$1-\frac{1.08k_2A_{DL}}{A_s+A_{DL}}$</td><td rowspan="3">$4.9(W_a(a_1+\beta a_2)+W_c c)S$</td></tr>
<tr><td rowspan="2">Longitudinal bulkhead</td><td>Bilge hopper slant plate</td><td>$\frac{1.19k_2A_{DL}}{A_s+A_{DL}}$</td></tr>
<tr><td>Others</td><td>$\frac{1.08k_2A_{DL}}{A_s+A_{DL}}$</td></tr>
<tr><td rowspan="4">D</td><td colspan="2">Side shell</td><td>$1-\frac{1.07k_2A_{DL}}{A_s+A_{DL}}$</td><td rowspan="3">$4.9(W_b(b_1+0.5b_2)$
$+W_c c)S$</td></tr>
<tr><td rowspan="2">Outer longitudinal bulkhead</td><td>Bilge hopper slant plate</td><td>$\frac{1.15k_2A_{DL}}{A_s+A_{DL}}$</td></tr>
<tr><td>Others</td><td>$\frac{1.07k_2A_{DL}}{A_s+A_{DL}}$</td></tr>
<tr><td colspan="2">Centre longitudinal bulkhead</td><td>2</td><td>$9.8W_b b_2 S$</td></tr>
<tr><td rowspan="4">E</td><td colspan="2">Side shell</td><td>$1-\frac{1.06k_2A_{DL}}{A_s+A_{DL}}$</td><td rowspan="3">$4.9(W_b(b_1+0.5b_2)+W_c c)S$</td></tr>
<tr><td rowspan="2">Outer longitudinal bulkhead</td><td>Bilge hopper slant plate</td><td>$\frac{1.11k_2A_{DL}}{A_s+A_{DL}}$</td></tr>
<tr><td>Others</td><td>$\frac{1.06k_2A_{DL}}{A_s+A_{DL}}$</td></tr>
<tr><td colspan="2">Inner longitudinal bulkhead</td><td>1</td><td>$9.8\,(\beta W_a a+0.5W_b b_2)\,S$</td></tr>
</table>

Notes:

a_1, a_2, b_1, b_2: As specified in **Fig. C15.3.2-1** according to the arrangement of bulkheads

A_s, A_{DL}, W_a, W_b, W_c, S, a, c, β, k_2: As specified in **15.3.2, Part C of the Rules**

Fig. C15.3.2-1 Measurement of a_1, a_2; and b_1, b_2



C15.4 Buckling Strength

C15.4.1 General

1 "Other measures as deemed appropriate by the Society" specified in **15.4.1-3, Part C of the Rules** refer to buckling strength assessments in **(1)** and apply to plate members in transverse system. However, in cases where buckling strength is assessed by **(1)**, the transverse section of the hull in which the plates are located is to satisfy the requirements in **(2)** regarding hull girder ultimate strength.

(1) Buckling Strength Assessment

(a) Criteria of Buckling Strength Assessment

Buckling strength of plate panels is to satisfy the following criteria. "Plate panel" refers to the part of the plating between stiffeners and/or primary supporting members where all edges are forced to remain straight due to the surrounding structure/neighbouring plates.

$$\eta_{plate} \leq 1$$

η_{plate}: Buckling utilisation factor, to be taken as follows:

$$\eta_{plate} = \frac{\sigma_a}{\sigma_{cy}} \text{ for compressive stress}$$

$$\eta_{plate} = \frac{|\tau_a|}{\tau_c} \text{ for shear stress}$$

σ_a : Compressive stress working on the plates considered, as given in **15.4.2-1, Part C of the Rules**. However, σ_a may be taken at mid-point of the length of the plate panel, and edge stress ratio $\psi_y$of plate panel may be regarded as 1.

τ_a : Shear stress working on the plates considered, as given in **15.4.2-2, Part C of the Rules**

σ_{cy}: Ultimate buckling stress (N/mm^2) of plate panels in direction parallel to the shorter edge of the buckling panel as defined in **(b)ii)**

τ_c : Ultimate buckling stress (N/mm^2) of plate panels subject to shear, as defined in **(b)ii)**

(b) Ultimate Buckling Stress

i) Boundary Condition for Plates

The boundary conditions for plates are to be considered as simply supported, see cases 2 and 15 of **Table 4, Annex C32.2.7 "Guidance for Buckling Strength Assessment"**. If the boundary conditions differ significantly from simple support, a more appropriate boundary condition can be applied according to the different cases of **Table 4, Annex C32.2.7 "Guidance for Buckling Strength Assessment"** subject to the agreement of the Society.

ii) Ultimate Buckling Compressive Stress and Ultimate Buckling Shear Stress

Ultimate buckling compressive stress σ_{cy} (N/mm^2) of plates is to be taken as follows:

$$\sigma_{cy} = C_y \sigma_{YP}$$

Ultimate buckling shear stress τ_c (N/mm^2) of plates is to be taken as follows:

$$\tau_c = C_\tau \frac{\sigma_{YP}}{\sqrt{3}}$$

σ_{YP}: Specified minimum yield stress (N/mm^2) of the plate

C_y,C_τ: Reduction factors defined in **Table 4, Annex C32.2.7 "Guidance for Buckling Strength Assessment"**. In addition, c_1 and reference degree of slenderness λ used for calculating C_y and C_τ are to be taken as follows:

$$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

α: Aspect ratio of the plate panel, to be taken as follows:

$$\alpha = \frac{a}{b}$$

a: Length of the longer side of the plate panel (mm)

b: Length of the shorter side of the plate panel (mm)

$$\lambda = \sqrt{\frac{\sigma_{YP}}{K\sigma_E}}$$

K: Buckling factor K_y or K_τ, as defined in **Table 4, Annex C32.2.7 "Guidance for Buckling Strength Assessment"**. However, buckling factor K_y which is calculated according to case 2 of **Table 4, Annex C32.2.7 "Guidance for Buckling Strength Assessment"** to be multiplied by correction factor F_{tran}. Correction factor F_{tran} is to be taken as follows:

- For plate panels of side shell:
  - When the two adjacent frames are supported by one tripping bracket fitted in way of the adjacent plate panels:

    $F_{tran} = 1.25$
  - When the two adjacent frames are supported by two tripping brackets each fitted in way of the adjacent plate panels:

    $F_{tran} = 1.33$
  - Elsewhere:

    $F_{tran} = 1.15$
- For plate panels other than side shell, when ends of stiffeners arranged at longer side of plate panels have lug-connections:

  $F_{tran} = 1.15$
- Elsewhere:

  $F_{tran} = 1$

σ_E: Elastic buckling reference stress, to be taken as follows:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{b}\right)^2$$

E : Young's modulus (N/mm^2), to be taken as 2.06×10^5

ν : Poisson's ratio, to be taken as 0.3

t_p: Thickness of plate panels (mm) considering standard deductions specified in **Table C15.2, Part C of the Rules**. In cases where plates within a plate panel are different in thickness, area-averaged thickness may be used.

(2) Hull Girder Ultimate Strength Assessment

The following formula is to be satisfied:

$$\gamma_S M_S + \gamma_W M_W \le \frac{M_U}{\gamma_M \gamma_{DB} \gamma_{CORR}}$$

γ_S : Partial safety factor for the longitudinal bending moment in still water, to be taken as follows:

$\gamma_S = 1.0$

γ_W : Partial safety factor for wave induced longitudinal bending moment, to be taken as follows

$\gamma_W = 1.2$

M_S, M_W : Longitudinal bending moment in still water and wave induced longitudinal bending moment as given in **15.2.1-1, Part C of the Rules**.

M_U: Hull girder ultimate bending moment capacity, calculated by the method defined in **Annex C32.2.8-1 "Guidance for the Hull Girder Ultimate Strength Assessment"**. M_U is to be calculated using gross scantling. In addition, the following is to be used for calculation in lieu of the load-end shortening curve $\sigma_{CR5} - \varepsilon$ defined in **2.2.3-7, Annex C32.2.8-1 "Guidance for the Hull Girder Ultimate Strength Assessment"**.

$$\sigma_{CR5} = \min\begin{cases} \sigma_{YP}\Phi \\ \Phi\sigma_{YP}\left[\frac{s}{\ell}\left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2}\right) + \left(1 - \frac{s}{\ell}\right)\left(\frac{0.06}{\beta_E} + \frac{0.6}{\beta_E^2}\right)\right]\end{cases}$$

σ_{YP} : Minimum yield stress of the material of the considered plate (N/mm^2)

Φ, β_E, s, ℓ : As specified in **2.2.3-7, Annex C32.2.8-1** **"Guidance for the Hull Girder Ultimate Strength Assessment"**

γ_M : Partial safety factor for the hull girder ultimate strength, to be taken as follows

$\gamma_M = 1.05$

γ_{DB} : Partial safety factor for the hull girder ultimate bending moment capacity, considering the effect of double bottom bending, to be taken as follows

・For hogging condition : $\gamma_{DB} = 1.1$

・For sagging condition : $\gamma_{DB} = 1.0$

γ_{CORR} : Partial safety factor considering corrosion, to be taken as follows

$\gamma_{CORR} = 1.1$

C15.4.3 Elastic Buckling Stresses of Plates

When examining the buckling strength of plates with openings, the elastic buckling stress σ_E' or τ_E' obtained from the following formulae are to be used in place of σ_E or τ_E for determination of critical buckling stress in **15.4.5, Part C** of the Rules:

$\sigma_E' = \gamma \sigma_E$ (N/mm^2)

$\tau_E' = \gamma \tau_E$ (N/mm^2)

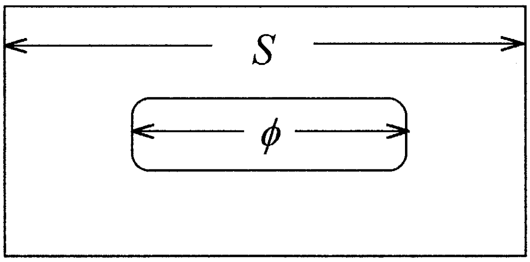
σ_E and τ_E : Elastic buckling stress without the opening, obtained from **15.4.3-1** and **-2**, **Part C** of the Rules, respectively.

γ : Reduction factor due to the opening, given by the following. When the opening is reinforced properly, it may be taken as 1.0:

$$\gamma = \frac{1}{\{1 + \phi/(2S)\}^2}$$

ϕ : Span (m) of the major axis of the opening

S : Span (m) of the side of the panel along the major axis of the opening



C15.4.7 Other Special Requirements

For high speed ships with large flares, the buckling strength of strength deck plating and adjacent members is to be examined in addition to the application of **C15.1.1(4)** for when compressive buckling stress instantaneously increases due to factors such as slamming.

C16 PLATE KEELS AND SHELL PLATING

C16.1 General

C16.1.5 Consideration for Ships whose Designed Maximum Load Line is Far from the Strength Deck

1 "Ships whose designed maximum load line is far from the strength deck" refers to ships whose freeboard deck is lower than the strength deck.

2 Where the distance from the designed maximum load line to the strength deck is unusually large, the thickness of side shell plating of the superstructure and the side shell plating between the imaginary freeboard deck specified in **C1.1.3-2(1)** and the strength deck (referred to as "superstructure side plating" in **C16.1.5**) is to be obtained from the following **(1)** to **(3)**. However, where this requirement is applied, the requirements in **16.3.1, Part C** of the Rules do not need to be applied.

(1) The thickness of superstructure side shell plating from the freeboard deck (or the imaginary freeboard deck in ships where the imaginary deck is regarded as the freeboard deck for the rest of **C16.1.5**) to a height of $2h_s$ above the freeboard deck is to be obtained from the formulae in **16.3.2, Part C** of the Rules, where $(d-0.125D+0.05L'+h_1)$ in the first term may be replaced by $(d-0.125D+0.05L'+h_1)D/(D+2h_s)$

Where

h_s: Standard height of superstructures specified in **V2.2.1**

(2) The thickness of superstructure side plating from a height equal to twice h_s (as per **(1)**) above the freeboard deck to the strength deck is not to be less than that obtained from the following formula:

$0.7\sqrt{(L+50)}\ (mm)$

(3) The thickness of superstructure side plating from the freeboard deck to a height h_s (as per **(1)**) above the freeboard deck forward of $0.25L_f$ aft of F.P. is not to be less than that obtained from **(1)** above or **16.5.1, Part C** of the Rules, whichever is greater.

C16.3 Shell Plating below the Strength Deck

C16.3.3 Sheer Strakes for Midship Part

Precautions regarding sheer strakes

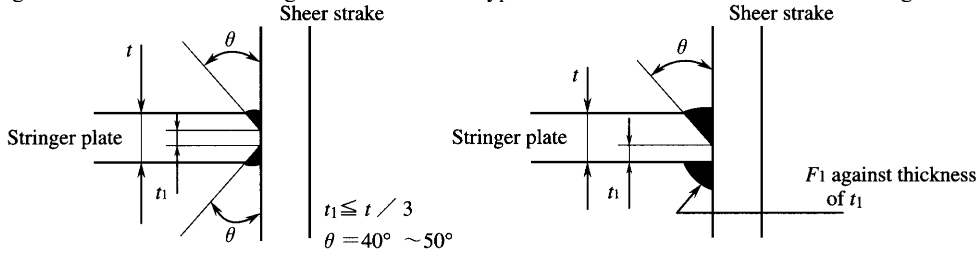
(1) The upper edges of sheer strakes are to be properly smoothed.

(2) Bulwarks are not to be directly welded to sheer strakes in the range of $0.6L$ amidships. Furthermore, fixtures such as eye plates are not to be directly welded on to the upper edge of sheer strakes, except in the fore and aft end parts.

(3) Special care should be taken where fixtures, gutter bar ends, etc. are directly welded on to the curved parts of round gunwales.

(4) At least for $0.6L$ amidships, the standard manner of welding construction of T-type joints between sheer strakes and stringer plates of the strength deck is to be as shown in **Fig. C16.3.3-1**. However, where the thickness of stringer plates is less than 13 mm, fillet welds of F_1 grade may be acceptable without edge preparation.

Fig. C16.3.3-1 Welding Construction of T-type Joints between Sheer Strakes and Stringer Plates



C16.3.5 Bilge Strakes for Midship Part

1 Where longitudinal frames are omitted in the bilge part in the midship part, the distance from the end of the bilge curvature to the nearest longitudinal frame outside the curved part is not to exceed 1/2 of the spacing of longitudinal frames.

2 In determining the thickness of bilge strake in the midship part according to the formula in **16.3.5-1, Part C** of the Rules, the following condition is to be met.

$$\frac{1000R}{t} \geq 2\left(\frac{l}{R}\right)^2$$

Where:

R: Radius (m) of bilge circle

l : Spacing (m) of solid floors, bottom transverse or bilge brackets

t : Thickness (mm) of bilge strake in midship part

3 The bilge strakes in the midship part are to be carefully worked so that deformations of the bilge circle may not exceed 1/3 of the thickness of bilge strakes amidships.

4 The "special consideration" referred to in **16.3.5-4, Part C of the Rules** refers to the following:

(1) Bilge keels are not to be welded directly to bilge strakes. They are to be attached by pad plates such as flat bars.

(2) Pad plates are, in principle, to have the same yield stress as bilge strakes. However, the use of grade *A* steel is deemed acceptable.

(3) The butt welds of bilge keels and bilge strakes are to be appropriately separated from those of pad plates.

(4) Scallops are, in principle, not allowed in bilge keels.

(5) The following **(a)** and **(b)** are recommended for bilge keel ends:

  (a) Bilge keel ends are to be not less than 50 mm and not greater than 100 mm from pad plate ends.

  (b) Bilge keel ends are to be suitably tapered and rounded.

(6) The following **(a)** and **(b)** are recommended for the supporting structures for bilge keel ends:

  (a) Where bilge keel ends are supported by transverse support members, such members are to be located, as much as possible, at the mid positions between the bilge keel ends and the pad plate ends. (*See* **Fig. C16.3.5-1**)

  (b) Where bilge keel ends are supported by longitudinal stiffners, such stiffeners are to extend at least to the nearest transverse member located both to the fore and the aft of zone '*A*'. (*See* **Fig. C16.3.5-2**)

Fig. C16.3.5-1 Example of Bilge Keel end Design Supported by Transverse Member

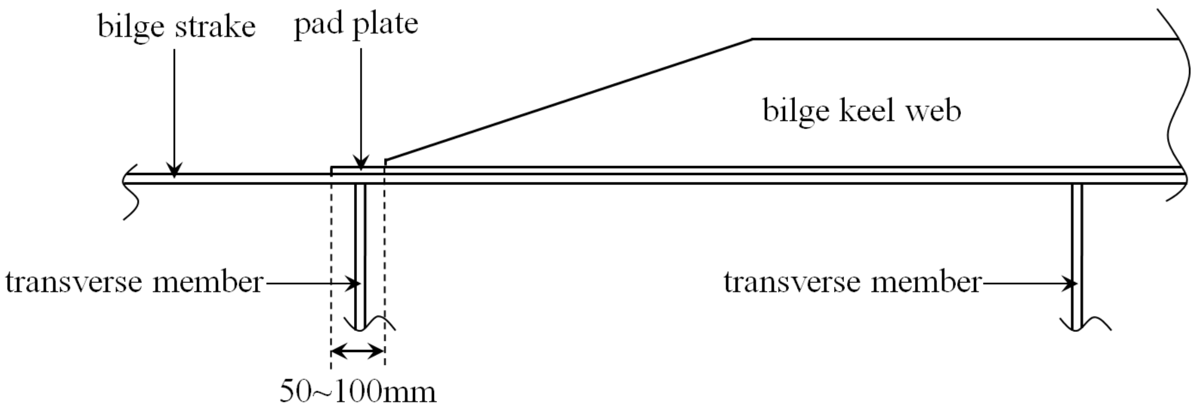
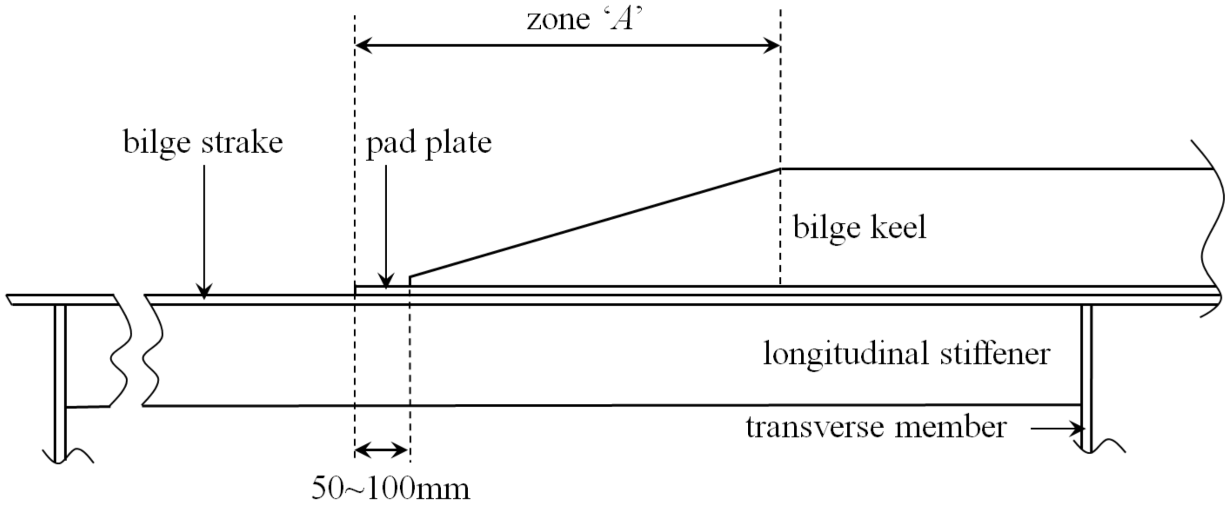


Fig. C16.3.5-2 Example of Bilge Keel End Design Supported by Longitudinal Stiffener



C16.4 Special Requirements for Shell Plating

C16.4.1 Consideration of Bow Impact Pressure

1 For ships with large bow flares that operate at high speed (car carriers, ro-ro cargo ships, LNG carriers or refrigerated LPG carriers, etc.), the thickness of shell plating above the load line for 0.2L forward is not to be less than that obtained from the following formula:

$$S\sqrt{\frac{\psi P}{\sigma_y}\times 10^3}\ (mm)$$

S : Spacing (m) of frames or spacing of girders or longitudinal shell stiffeners measured along the shell plating, whichever is the smaller

σ_y: Specified yield stress (N/mm^2) of materials

ψ : As obtained from following formula

$$\psi = \frac{3\eta^2 - 2\sqrt{1+3\eta^2}+2}{12\eta^2}$$

η : Spacing (m) of frames or spacing of girders or longitudinal shell stiffeners measured along the shell plating, whichever is the greater, divided by S

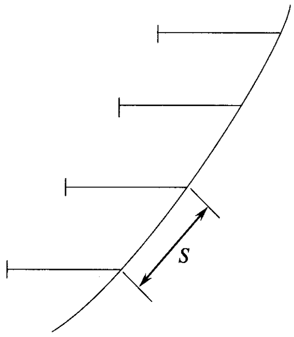
P : Slamming impact pressure (kPa) as specified in **C7.1.8-1**

2 For ships whose L and C_b are not less than 250m and 0.8 respectively, the provisions of **3.3, Section 1, Chapter 10, Part 1, Part CSR-B&T of the Rules** are to be applied.

C16.4.2 Where the Distance between Frames of Shell Plating Differs Remarkably from the Frame Spacing

Where the spacing of stiffening members on shell plating is remarkably different from the spacing of frames, the actual space S is to be used in calculating the thickness of shell plating. (*See* **Fig. C16.4.2-1**)

Fig. C16.4.2-1 Measurement of Spacing of Stiffening Members



C16.4.4 Shell Plating of Bottom Forward

1 In ships of which L and C_b are not more than 150 m and 0.7 respectively, and $V/\sqrt{L}$ is not less than 1.4, the thickness of shell plating at the strengthened bottom forward specified in **C6.8.2** is to be determined in accordance with **16.4.4, Part C** of the Rules using P in **C6.8.1-2(2)(a)**.

However, ships that carry a certain amount of cargo regularly such as Container Ships may comply with the requirements in **C16.4.4** instead.

2 In the application of the requirements of **16.4.4, Part C** of the Rules, for ships of which L and C_b are not less than 150 m and 0.7 respectively, the slamming impact pressure P specified in **C6.8.1-3** may apply. The slamming impact pressure is to be calculated at the centre position for each considered panel.

C16.4.5 Shell Plating adjacent to Stern Frame or in way of Spectacle Bossing

Where the spacing of transverse frames in the aft-peak exceeds 610 mm or the length of ship exceeds 200 m, the thickness of shell plating adjacent to the stern frame or in way of the spectacle bossing is to be equivalent to the standards given by **Table C16.4.5-1**. For intermediate values of spacing of transverse frames or ship length (L), they are to be obtained by interpolation.

Table C16.4.5-1 Standard Thickness (mm) of Shell Plating adjacent to Stern Frame or in way of Spectacle Bossing

Spacing of transverse frames(mm)	Length of ship L (m)				
	90	150	200	250	300
610	12.5	18.0	22.5	-	-
700	14.5	20.0	24.5	27.0	-
800	-	22.5	27.0	29.5	32.0
900	-	-	30.0	32.5	35.0

C16.6 Compensation at Ends of Superstructure

C16.6.1 Strengthening Method

The manner of construction at the ends of superstructures is to be as shown in **Fig. C16.6.1-1** or **Fig. C16.6.1-2**.

(1) The side shell plating of the superstructure is to be well extended beyond the end of the superstructure to terminate with an ample radius ($R \geq 900$ mm).

(2) Butt welding joints of sheer strakes at the strength deck is to be off by at least 150 mm from the R-end.

(3) The rate of thickening of shell plating in the region of 0.4L amidships is to be as shown in **Fig. C16.6.1-1** and **Fig. C16.6.1-2** (even when an expansion joint is not provided, the rate of thickening is to be the same). The rate of thickening is to be zero in the region 0.2L from the fore and aft ends of the ship. At intermediate points, the rate is to be determined by linear interpolation.

(4) Where the superstructure is set in, no thickening of shell plating is needed.

C16.7 Local Compensation of Shell Plating

C16.7.1 Openings in Shell

Compensation for openings

(1) Openings in shell plating of 300 *mm* or more in size are to be compensated by doubling plate or by thickening of the plate.

(2) In the end parts of the hull, proper modifications may be accepted in regards to the compensation for openings.

(3) The radius at the corners of openings is to be at least 100 *mm*.

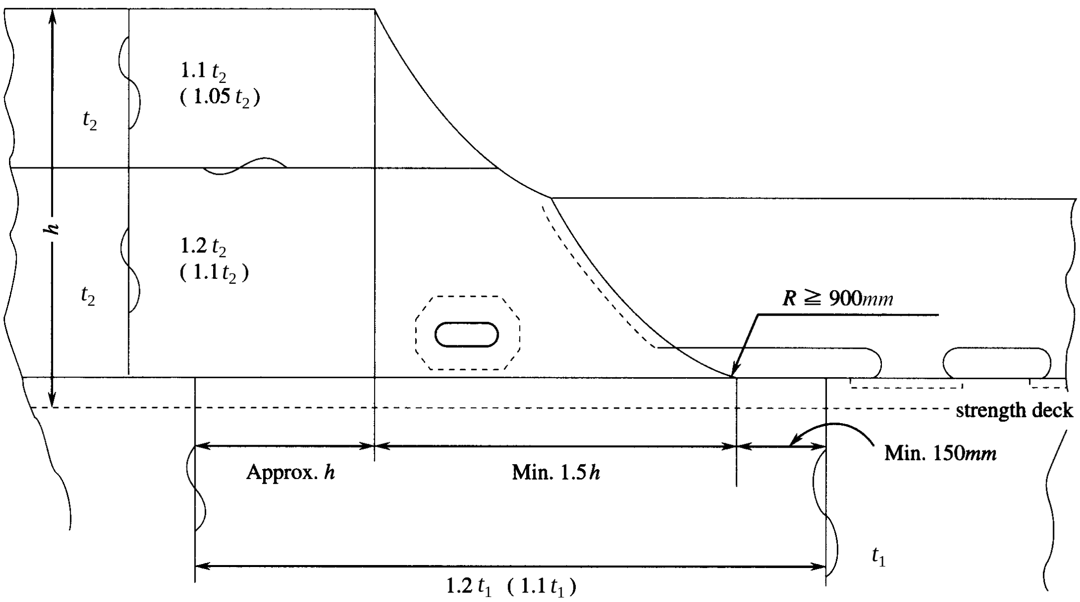
C16.7.2 Thickness of Sea Chest

Refer to C16.7.1 for compensation of openings.

C16.7.3 Location of Openings

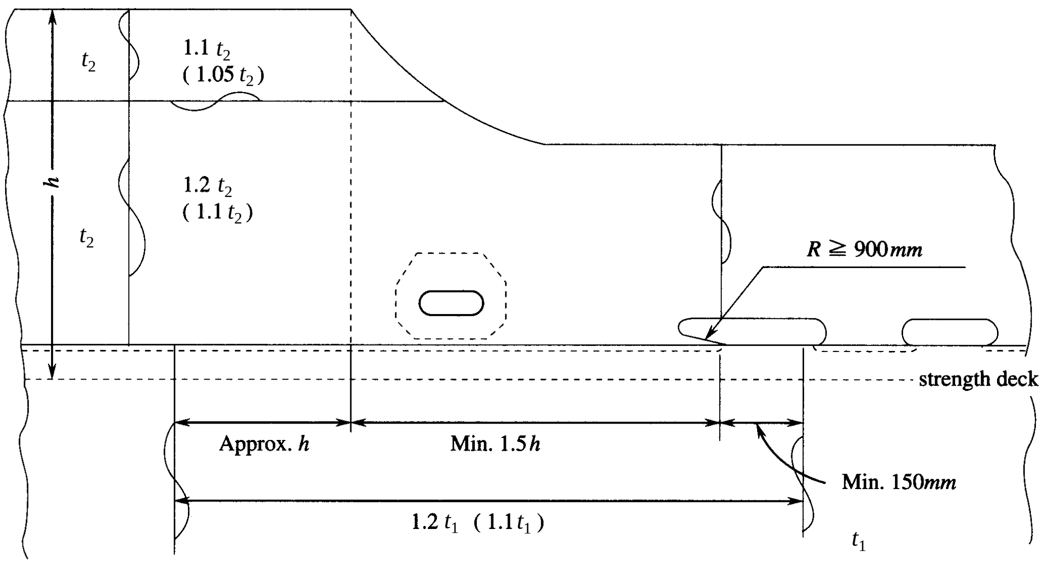
Refer to C16.7.1 for compensation of openings.

Fig. C16.6.1-1 Construction at the End of Superstructure (With Expansion Joint)



Notes: 1. t_1 = Thickness of sheer strake
2. t_2 = Thickness of superstructure side plating
3. Figures without brackets ( ) show the case where the superstructure deck is regarded as the strength deck.
4. Figures in brackets ( ) show the case where the superstructure deck is not the strength deck.

Fig. C16.6.1-2 Construction at the End of Superstructure (Without Expansion Joint)



Notes: For symbols, the **Notes** to **Fig. C16.6.1-1** are to be referred to.

C17 DECKS

C17.1 General

C17.1.1 Steel Deck Plating

1 Decks which are not fully plated

(1) Stringer plates

Decks not fully plated are to have stringer plates of an appropriate breadth and of a thickness not less than that determined for deck plating in accordance with the requirements in **17.3, Part C** of the Rules for the positions concerned. The stringer plates of effective decks are to be effectively connected to the shell plating.

(2) Tie plates

Tie plates are to be provided along hatch sides, in way of pillars, on the under-deck girders and under deckhouse coamings. These tie plates are to have an appropriate breadth and a thickness not less than that determined for deck plating in accordance with the requirements in **17.3, Part C** of the Rules for the positions concerned.

(3) In way of transverse bulkheads and at the ends of deck openings

In way of transverse bulkheads and at the ends of deck openings, the deck is to be suitably plated with steel plates.

2 Wooden decks

(1) Materials

(a) The materials of wooden deck planking are to be of a good quality well seasoned and without rots, saps, cracks and defective knots.

(b) The term "hard wood" means materials such as teak, and the term "soft wood" those such as cedar.

(2) Scantlings of wooden deck planking

Deck planks are to be effectively arranged and fixed, and their thickness is not to be less than 63 *mm* for soft wood and 50 *mm* for hard wood. The thickness may be suitably reduced in spaces appropriated for living accommodation and navigation works only.

C17.1.2 Watertightness of Decks

1 Where the rudder stock penetrates the deck lower than 1.5 *m* above the load line, special attention is to be given to the watertightness at the penetration.

2 With respect to the provisions of **17.1.2-2, Part C** of the Rules, decks required to be watertight are to be in accordance with following **(1)** and **(2)**.

(1) Deck structures are to comply with related provisions of **Chapter 17, Part C** of the Rules for the pressure due to head of water in the most severe conditions at the intermediate or final stages of flooding specified in **Chapter 4, Part C** of the Rules. In this case, such decks are to be regarded as the part of the deck which forms bulkhead recesses.

(2) Where the trunks and other constructions penetrating watertight deck are provided, such trunks are to be capable of withstanding the pressure due to a head of water up to the bulkhead deck and head of water in the most severe conditions at the intermediate or final stages of flooding specified in **Chapter 4, Part C** of the Rules.

C17.1.4 Compensation for Openings

1 All corners of openings in decks, such as hatchways, are to be well rounded, properly smoothed and reinforced, as necessary, by thickening the deck plating or by means of doubling plates.

(1) Regions where thicker plating or doubling plates are required

Strength deck: Within $0.75L$ ⊠

Effective 2nd deck: Within $0.6L$ ⊠

3rd deck and lower decks: No doubling needed, as a rule

Superstructures and long deckhouse:

Doubling within $0.6L$ ⊠ for decks immediately above the strength deck

(2) Plate thickening and doubling plates may be properly reduced depending upon their locations. (*See* **Fig. C17.1.4-1**)

(3) The dimensions and thickness of doubling plates or ranges of thickening are to be determined considering the degree of stress concentration around the openings.

(4) The minimum radii at the corners are to be as follows:

Within $0.5L$ ⊠ of strength deck: 250 *mm*

Elsewhere: 200 *mm*

The radius may be suitably reduced for small openings. For companionways and similar small openings, the radius at the corners may be 150 *mm* in the strength deck outside the line of openings and 75 *mm* or so elsewhere.

(5) For corners of openings having a radius not less than 600 *mm* or having a parabolic or similar shape, neither doubling plates nor thickening of the plating is required. The recommended corner shape is as shown in **Fig. C17.1.4-2**.

(6) No welded joints are permitted at the corners of openings in the strength deck. The welded joints are to be properly off the end of the curvature. (*See* **Fig. C17.1.4-3**)

Fig. C17.1.4-1

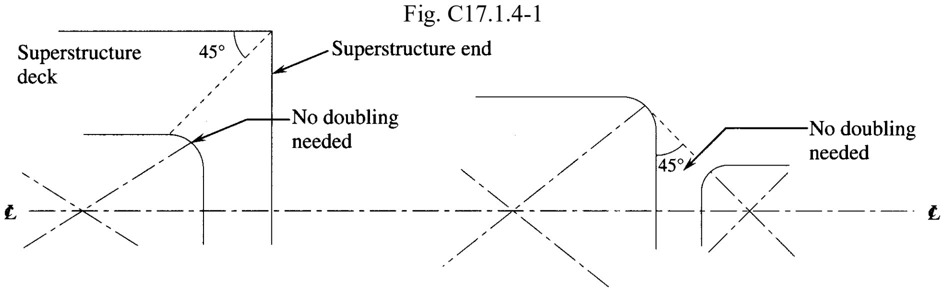


Fig. C17.1.4-2

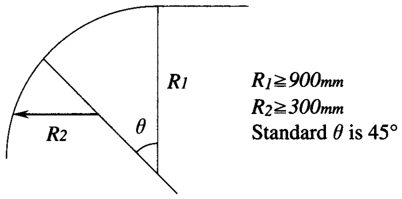
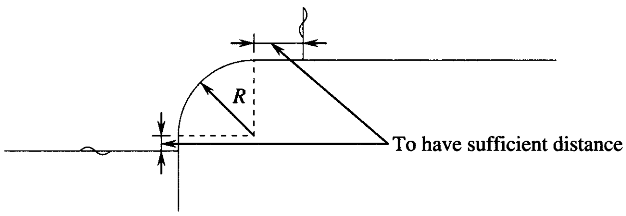
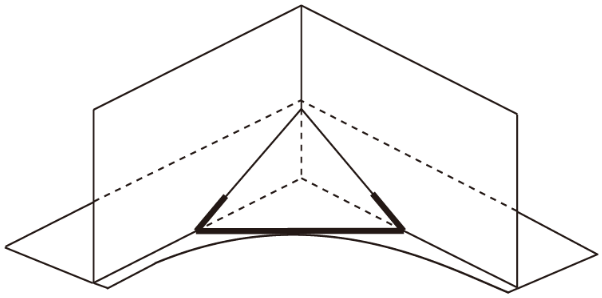


Fig. C17.1.4-3



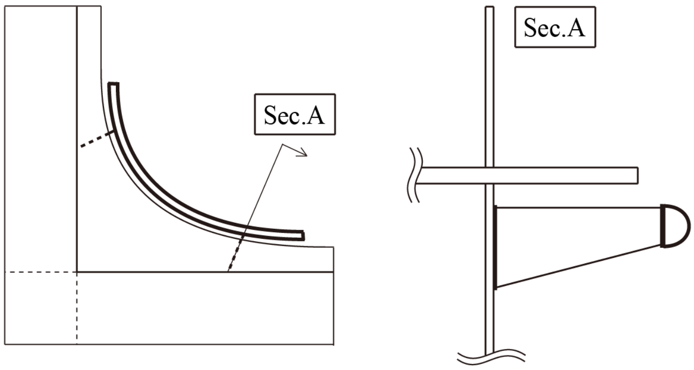
2 Where attachments such as slant plates or protective means are provided as stated in **17.1.4-2, Part C of the Rules**, such attachments are to be provided as referred to the method shown in **Fig. C17.1.4-4** or **Fig. C17.1.4-5**.

Fig. C17.1.4-4 Example of the Method for Providing Slant Plates



Note:
The connections between slant plates and strength deck (indicated in the bold line) are not to be welded.

Fig. C17.1.4-5 Example of the Method for Providing Protective Means



Note:
Protective means (i.e. half round bars) are to be provided on hatch side girders and hatch end beams.

C17.1.5 Rounded Gunwales

Where rounded gunwales are made of steel plate of Grade *D* or Grade *E*, the inner radius of the curvature is not to be less than 20 *times* the thickness of the gunwale plate. However, where the width of the sheer strake that is bent to form the rounded gunwale is not less than 500 *mm* plus the plate width of the strake prescribed in **C1.1.11** or the method of bending work is especially approved by the Society, the radius may be reduced down to 15 *times* the plate thickness.

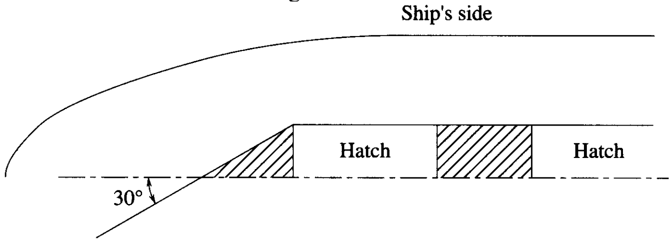
C17.2 Effective Sectional Area of Strength Deck

C17.2.2 Effective Sectional Area of Strength Deck

1 Members to be included in the calculation of the actual sectional area of strength deck

In addition to the deck plating, members attached to the deck plating, such as stringer angles and longitudinal beams, which are included as longitudinal strength members are to be included in the calculation of the actual sectional area. The shaded areas in the figure below are not to be included in the calculation. (*See* **Fig. C17.2.2-1**)

Fig. C17.2.2-1



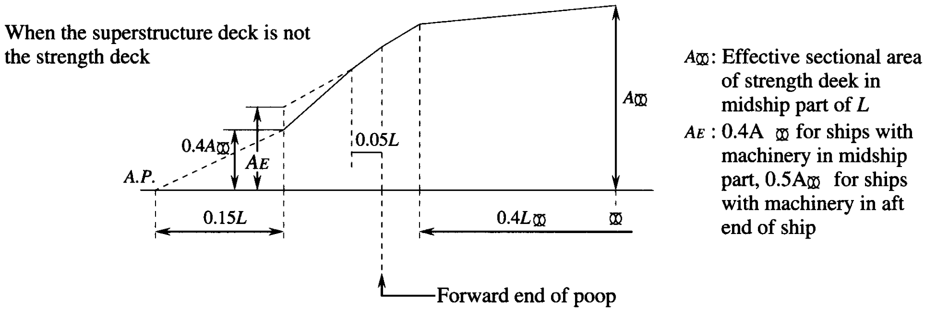
2 Where round gunwales are provided, the sectional area is to be calculated assuming that the plate of the round gunwale is horizontally extended to the ship's side.

3 In the requirements of **17.2.2-3, Part C** of the Rules, "the value approved by the Society" means the value obtained by applying the provisions of **C15.2.2**.

C17.2.4 Effective Sectional Area of Strength Deck within Long Poop

When the superstructure deck is not the strength deck (*See* **Fig. C17.2.4-1**)

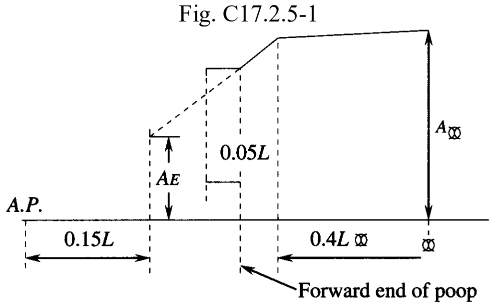
Fig. C17.2.4-1



C17.2.5 Deck within Superstructure where Superstructure Deck is Designed as Strength Deck

In case of poop deck (*See* **Fig. C17.2.5-1**)

Fig. C17.2.5-1



A ⊠ and *AE* are as specified in **Fig. C17.2.4-1**

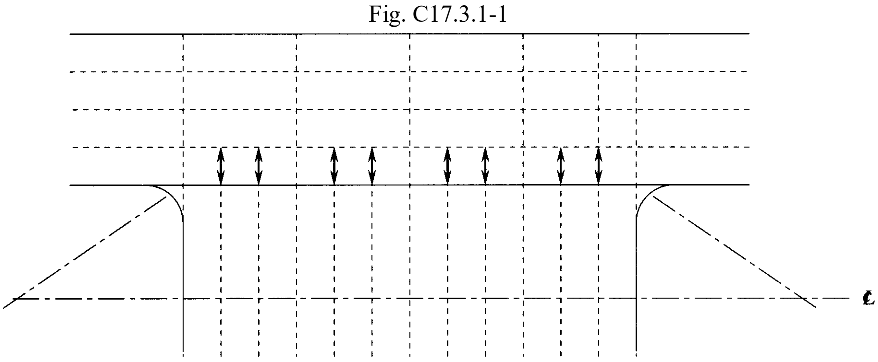
C17.3 Deck Plating

C17.3.1 Thickness of Deck Plating

1 Prevention of Deck Buckling

The deck within the line of openings is recommended to be constructed using the transverse framing system. (*See* **Fig. C17.3.1-1**)

Fig. C17.3.1-1



C17.3.5 Thickness of Deck Plating Loaded with Wheeled Vehicles

The thickness of deck plating loaded with wheeled vehicles is to be determined according to **(1)** or **(2)** below. The thickness of plating of the weather deck is to be 1 *mm* thicker than that obtained from these formulae.

(1) Where the distance between the centres of wheel prints in a panel is not less than ($2S + a$):

$$C\sqrt{\frac{2S-b'}{2S+a}\cdot\frac{P}{9.81}}+1.5\ \ (mm)$$

Where:

C: Coefficient obtained from **Table C17.3.5-1**

S: Beam spacing (m)

P: Maximum designed wheel load (kN), or, if $b > S$, a value equal to the maximum designed wheel load multiplied by the value of S/b

Where the maximum designed wheel load is given in tons, the value of P should be multiplied by 9.81 to convert it into kN.

b' : b or S, whichever is the smaller

a and b : Dimensions of wheel print as shown in **Fig. C10.9.1-1**

However, for vehicles with ordinary pneumatic tires, values of a and b in **Table C10.9.1-1** may be used.

(2) Where the distance between centres of wheel prints in a panel is less than ($2S + a$) (*See* **Fig. C17.3.5-1**):

$$C\sqrt{\frac{2S-b'}{2S+a+e}\cdot\frac{nP}{9.81}}+1.5\ \ (mm)$$

Where:

C, S, a, b' and P: As specified in **(1)** above

e: Sum of distances (m) between centres of wheel prints where wheels are placed side by side at a spacing of less than ($2S + a$) in one panel (*See* **Fig. C17.3.5-1**)

n: Number of wheel loads in the range of e

Table C17.3.5-1 Values of C

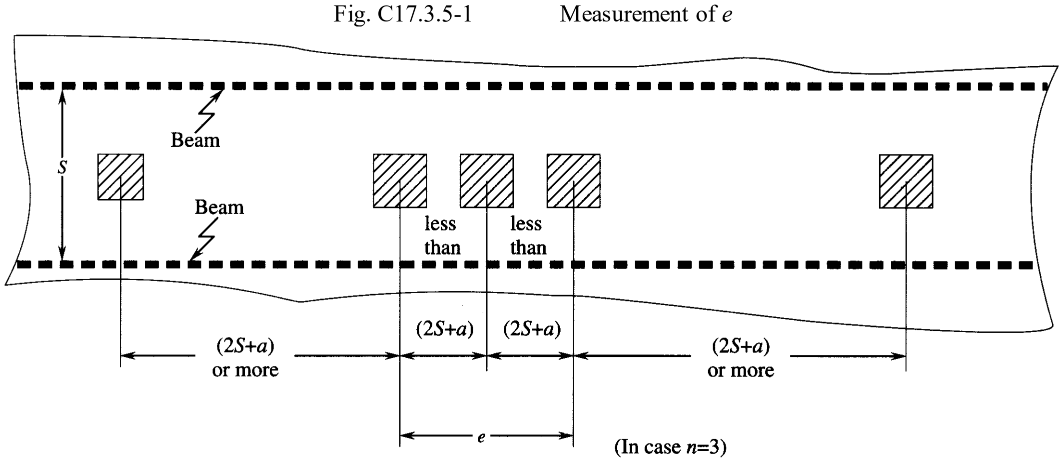
		Vehicles exclusively used for cargo handling	Other vehicles
Midship part of strength deck	Longitudinal framing	$4.6\sqrt{K}$	$\dfrac{3.64\sqrt{K}}{\sqrt{1-0.64f_{DH}K}}$
	Transverse framing	$4.9\sqrt{K}$	$\dfrac{5.15\sqrt{K}}{\sqrt{1-0.41f_{DH}{}^2K^2}}$
Elsewhere		$4.6\sqrt{K}$	$5.2\sqrt{K}$

Note:

f_{DH}: Value as specified in **C10.9.1-1**

In longitudinal framing system, f_{DH} is not to be less than 0.79/K.

Fig. C17.3.5-1 Measurement of e



C18 SUPERSTRUCTURES

C18.1 General

C18.1.1 Application

With respect to the provisions of **Chapter 18, Part C of the Rules**, the determination of the position of tiers above the freeboard deck may be treated in the same manner as the provisions of **C1.1.3-2(2)(c)**.

C18.2 Superstructure End Bulkheads

C18.2.4 End Bulkheads of Raised Quarterdecks

The fore end intact bulkheads of raised quarterdecks specified in **18.2.4-1, Part C of the Rules** may be provided with side scuttles of the non-opening type fitted with deadlights specified in **23.5, Part C of the Rules** and manholes with bolted covers.

C18.3 Closing Means for Access Openings in Superstructure End Bulkheads

C18.3.1 Closing Means for Access Openings

Where the sill of an access opening is liable to hinder the passage of heavy spare parts or similar, a portable sill may be used subject to approval by the Society under the following conditions.

(1) Portable sills are to be installed before the ship leaves port.

(2) Portable sills are to be gasketed and fastened by closely spaced through-bolts.

(3) Whenever sills are replaced after removal, the weathertightness of the sills and relevant doors is to be verified by hose testing. The dates of removal, replacement and hose testing are to be recorded in the ship's log-book.

C18.4 Additional Requirements for Bulk Carriers, Ore Carriers and Combination Carriers, etc.

If this requirement hinders hatch cover operation, the aft bulkhead of the forecastle may be fitted forward of the forward bulkhead of the foremost cargo hold provided the forecastle length is not less than 7% of the length for freeboard defined in **Part A 2.1.3**.

C19 DECKHOUSES

C19.1 General

C19.1.1 Application

With respect to the provisions of **Chapter 19, Part C** of the Rules, the determination of the position of tiers above the freeboard deck may be treated in the same manner as the provisions of **C1.1.3-2(2)(c)**.

C19.2 Construction

C19.2.3 Closing Means for Access Openings

"Standard quarterdeck height" and "standard superstructure height" in **19.2.3-2**, **Part C** of the Rules refer to those defined in Regulation 33 of the "*International Convention on Load Lines,* 1966 *and Protocol of* 1988 *relating to the International Convention on Load Lines,* 1966."

C20 HATCHWAYS, MACHINERY SPACE OPENINGS AND OTHER DECK OPENINGS

C20.1 General

C20.1.2 Position of Exposed Deck Openings

1 In the application of the requirements of **20.1.2, Part C** of the Rules, "superstructure decks" include top decks of superstructures, deckhouses, companionways and other similar deck structures.

2 "Exposed raised quarter decks" in the definition of Position I specified in **20.1.2, Part C** of the Rules refers to exposed superstructure decks lower than h_S specified in **V2.2.1** above the freeboard deck.

3 "Exposed superstructure decks" in the definition of Position I specified in **20.1.2, Part C** of the Rules refers to exposed superstructure decks lower than $2h_S$ specified in **V2.2.1** above the freeboard deck.

4 "Exposed superstructure decks located at least one standard height of superstructure above the freeboard deck" in the definition of Position II specified in **20.1.2, Part C** of the Rules refers to exposed superstructure decks located at least h_S specified in **V2.2.1** above the freeboard deck and lower than $2h_S$ specified in **V2.2.1** above the freeboard deck.

5 "Exposed superstructure decks located at least two standard heights of superstructure above the freeboard deck" in the definition of Position II specified in **20.1.2, Part C** of the Rules refers to exposed superstructure decks located at least $2h_S$ specified in **V2.2.1** above the freeboard deck and lower than $3h_S$ specified in **V2.2.1** above the freeboard deck.

C20.2 Hatchways

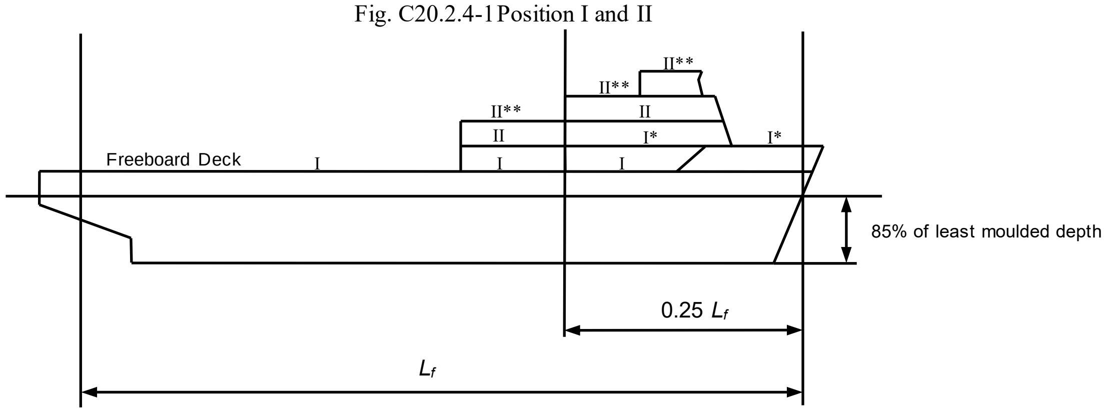
C20.2.4 Design Loads

1 Design vertical wave load P_{HC} as specified in **20.2.4(1), Part C** of the Rules is to comply with the following requirements.

(1) Positions I and II may be determined in accordance with **Fig. C20.2.4-1** and **-2**.

(2) Where an increased freeboard is assigned, the design load for hatch covers according to **20.2.4(1), Part C** of the Rules on the actual freeboard deck may be as required for a superstructure deck, provided the summer freeboard is such that the resulting draught will not be greater than that corresponding to the minimum freeboard calculated from an assumed freeboard deck situated at a distance at least equal to one superstructure standard height (as per Regulation 33 of the "*International Convention on Load Lines,* 1966 *and Protocol of* 1988 *relating to the International Convention on Load Lines,* 1966") below the actual freeboard deck (see **Fig. C20.2.4-2**).

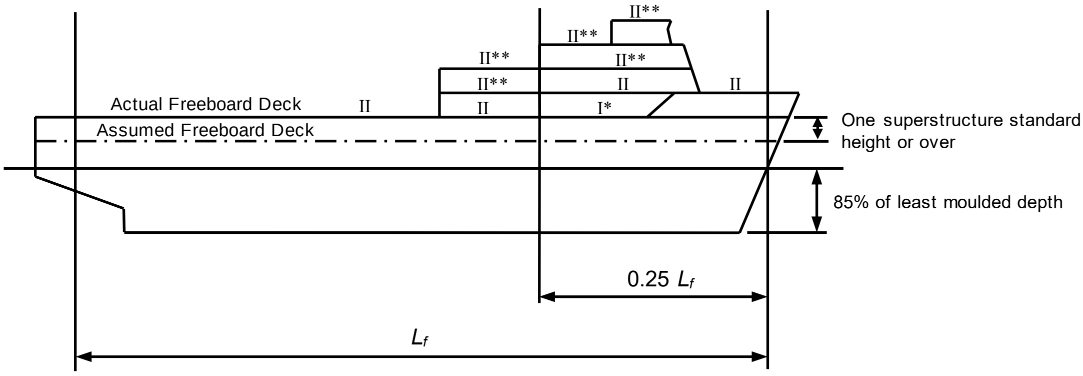
Fig. C20.2.4-1 Position I and II



* Exposed superstructure decks located at least one superstructure standard height above the freeboard deck

** Exposed superstructure decks of vessels having length L_f of greater than 100*m* located at least one superstructure standard height above the lowest Position II deck

Fig. C20.2.4-2 Position I and II for an Increased Freeboard

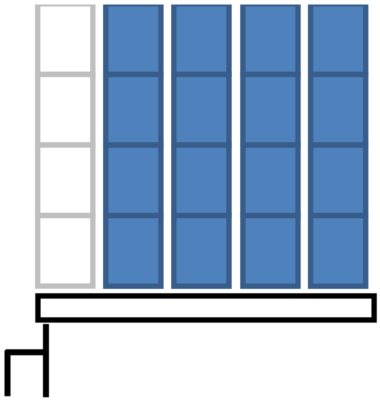
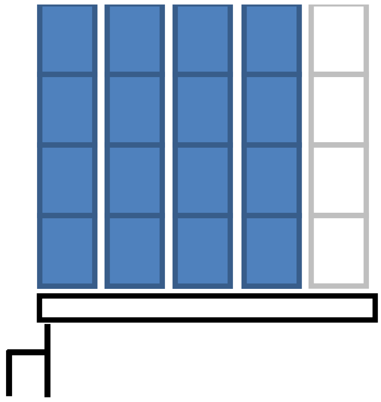
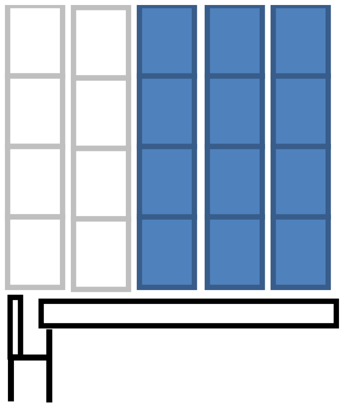
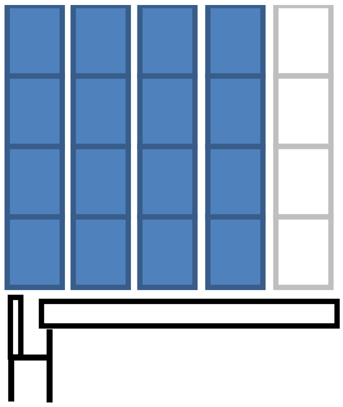
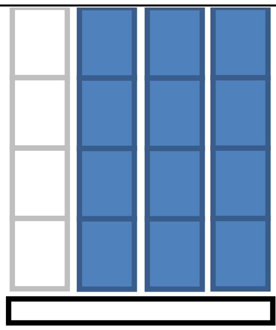
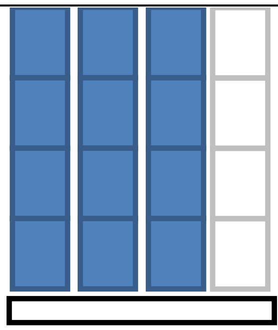


* Exposed superstructure decks located at least one superstructure standard height above the freeboard deck

** Exposed superstructure decks of ships having length L_f of greater than 100*m* located at least one superstructure standard height above the lowest Position II deck

2 In the application of the requirements of **20.2.4(4)(a)** and **(c)**, **Part C** of the Rules, load cases with the partial loading of containers on hatch covers are to be considered (see **Fig. C20.2.4-3**). However, where deemed necessary by the Society, load cases other than those specified in **Fig. C20.2.4-3** are to be separately considered.

Fig. C20.2.4-3 Partial Loading of Containers on Hatch Covers

Heel direction		
Hatch covers supported by the longitudinal hatch coaming with all container stacks located completely on the hatch cover		
Hatch covers supported by the longitudinal hatch coaming with the outermost container stack supported partially by the hatch cover and partially by container stanchions		
Hatch covers not supported by the longitudinal hatch coaming (centre hatch covers)		

3 The partial load cases specified in **Fig. C20.2.4-3** may not cover all partial load cases critical for the hatch cover lifting specified in **20.2.10-2, Part C**.

4 In the case of mixed stowage (e.g., 20-*foot* + 40-*foot* container combined stacks), the foot point forces at the fore and aft ends of the hatch cover are not to be higher than those resulting from the design stack weight for the 40-*foot* containers, and the foot point forces at the middle of the cover are not to be higher than those resulting from the design stack weight for the 20-*foot* containers.

C20.2.5 (Deleted)

C20.2.6 (Deleted)

C20.2.10 Closing Arrangements

"At the discretion of the Society" prescribed in **20.2.10-2, Part C** of the Rules refers to the following case:

(1) The case in which the height h_E (mm) of the transverse cover guides above the hatch cover supports is not less than that obtained from the following formula (see **Fig. C20.2.10-1**):

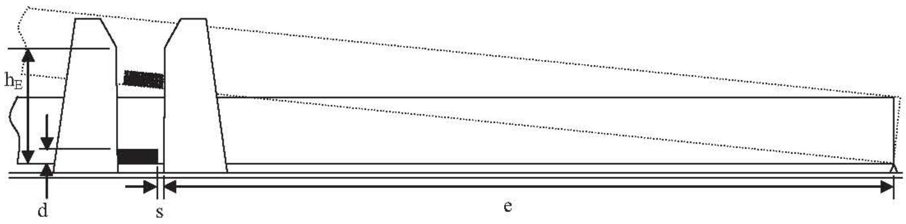
$h_E = 1.75\sqrt{2se+d^2} - 0.75d$, however, in no case is h_E to be less than the height of the cover edge plate plus 150 mm.

e: Largest distance (mm) from the inner edges of the transverse cover guides to the ends of the cover edge plate

s: Total clearance (mm) within the transverse cover guide, with $10 \le s \le 40$

d: Distance between the upper edge of transverse stopper and the hatch cover supports

Fig. C20.2.10-1 Height of Transverse Cover Guides



C20.2.12 Steel Hatchway Covers for Container Carriers

1 In the application of the requirements of **20.2.12, Part C** of the Rules, the height of coamings above the upper surface of the deck where the hatchway covers are fitted is to be at least 600 *mm*.

2 In the application of the requirements of **20.2.12-1, Part C** of the Rules, the following requirements **(1)** through **(4)** are to be complied with:

(1) The hatchway covers concerned may be fitted to hatchways located on weatherdecks which are at least two standard superstructure heights (as per Regulation 33 of the "*International Convention on Load Lines*, 1966") above an actual freeboard deck or an assumed freeboard deck from which the freeboard can be calculated which will result in a draught not less than that corresponding to the freeboard actually assigned. Where any part of a hatchway is forward of a point located one quarter of the ship's length ($0.25L_f$) from the forward perpendicular, that hatchway is to be located on a weatherdeck at least three standard superstructure heights above the actual or assumed freeboard deck.

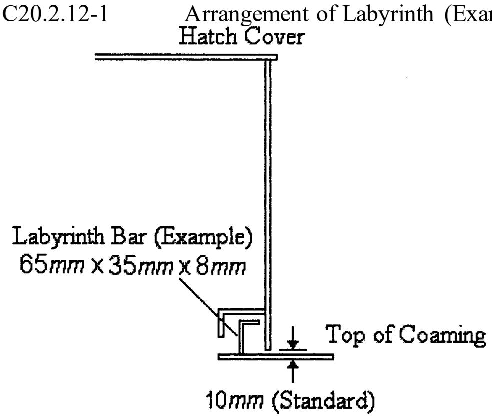
(2) The non-weathertight gaps between hatch cover panels are to be considered as unprotected openings in the application of **Part U** and **Chapter 4, Part C** of the Rules. They are to be as small as possible commensurate with the capacity of the bilge system and expected water ingress, and the capacity and operational effectiveness of the fixed gas fire-extinguishing system required in **Part R** of the Rules, and are not to be more than 50 *mm*.

(3) Labyrinths, gutter bars, or other equivalent means are to be fitted close to the edges of each panel in way of the gaps to minimize the amount of water that can enter the container hold from the top surface of each panel. In general, the height of such means is not to be less than 65 *mm* from the top of the coaming and gutter bars or from the top of the panel, and the gaps between hatch covers and the top of the coaming are not to exceed 10 *mm*. (See **Fig. C20.2.12-1**)

(4) Bilge alarms are to be provided in each hold fitted with non-weathertight covers.

3 In the application of **20.2.12-2**, **Part C** of the Rules, relevant requirements specified in MSC/Circ.1087 may be applied.

Fig. C20.2.12-1 Arrangement of Labyrinth (Example)



C20.2.13 Additional Requirement for Small Hatches Fitted on Exposed Fore Decks

1 General

(1) The strength of, and securing devices for, small hatchways fitted on the exposed fore deck in **20.2.13**, **Part C** of the Rules are to comply with the requirements of this paragraph.

(2) Small hatchways in the context of this requirement are hatchways designed for access to spaces below the deck and are capable of being closed weathertight or watertight, as applicable. Their opening is normally 2.5 m^2 or less.

(3) Notwithstanding the provisions of **(1)** above, hatchways designed for emergency escape need not comply with the requirements of **-3(1)(a)**, **-3(1)(b)**, **-4(3)** and **-5**.

(4) The securing devices of the hatchways for emergency escape are to be of a quick-acting type (e.g., one action wheel handles are provided as central locking devices for latching/unlatching of hatch cover) operable from both sides of the hatch cover.

(5) Small hatchways providing access to cargo holds on container ships need not comply with this **C20.2.13** (except for **C20.2.13-2**) in cases where the following **(a)** to **(c)** are satisfied. Such hatch covers fitted at small hatchways are to be treated as non-weathertight regardless of whether they actually are weathertight.

(a) The non-weathertight hatchways are fitted to weather decks which are at least two standard superstructure heights (as per Regulation 33 of the "International Convention on Load Lines, 1966") above an actual freeboard deck or an assumed freeboard deck from which the freeboard can be calculated which will result in a draught not less than that corresponding to the freeboard actually assigned. Where any part of the hatchway is forward of a point located one quarter of the ship's length ($0.25L_f$) from the forward perpendicular, that hatchway is to be located on a weather deck at least three standard superstructure heights above the actual or assumed freeboard deck.

(b) The hatchway coamings are not less than 600 *mm* in height.

(c) Bilge alarms are provided in each hold fitted with non-weathertight hatchways.

2 Strength

(1) For small rectangular steel hatch covers, plate thickness, stiffener arrangement and scantlings are to be in accordance with **Table C20.2.13-1** and **Fig. C20.2.13-1**. Stiffeners, where fitted, are to be aligned with the metal-to-metal contact points, required in **-4(1)**. Primary stiffeners are to be continuous. All stiffeners are to be welded to the inner edge stiffener. (See **Fig. C20.2.13-2**)

(2) For rectangular hatchways, the upper edge of hatchway coamings is to be suitably reinforced by a horizontal section, normally not more than 170 to 190 *mm* from the upper edge of the coamings.

(3) For small hatch covers of a circular or similar shape, the cover plate thickness and reinforcement is to be according to the requirements of the Society.

(4) For small hatch covers constructed of materials other than steel, the required scantlings are to provide equivalent strength.

Table C20.2.13-1 Scantlings for Small Steel Hatch Covers on the Fore Deck

Nominal size (*mm* × *mm*)	Cover plate thickness (*mm*)	Primary stiffeners	Secondary stiffeners
		Flat Bar (*mm* × *mm*); number	
630 × 630	8	-	-
630 × 830	8	100 × 8 ; 1	-
830 × 630	8	100 × 8 ; 1	-
830 × 830	8	100 × 10 ; 1	-
1030 × 1030	8	120 × 12 ; 1	80 × 8 ; 2
1330 × 1330	8	150 × 12 ; 2	100 × 10 ; 2

Fig. C20.2.13-1 Arrangement of Stiffeners

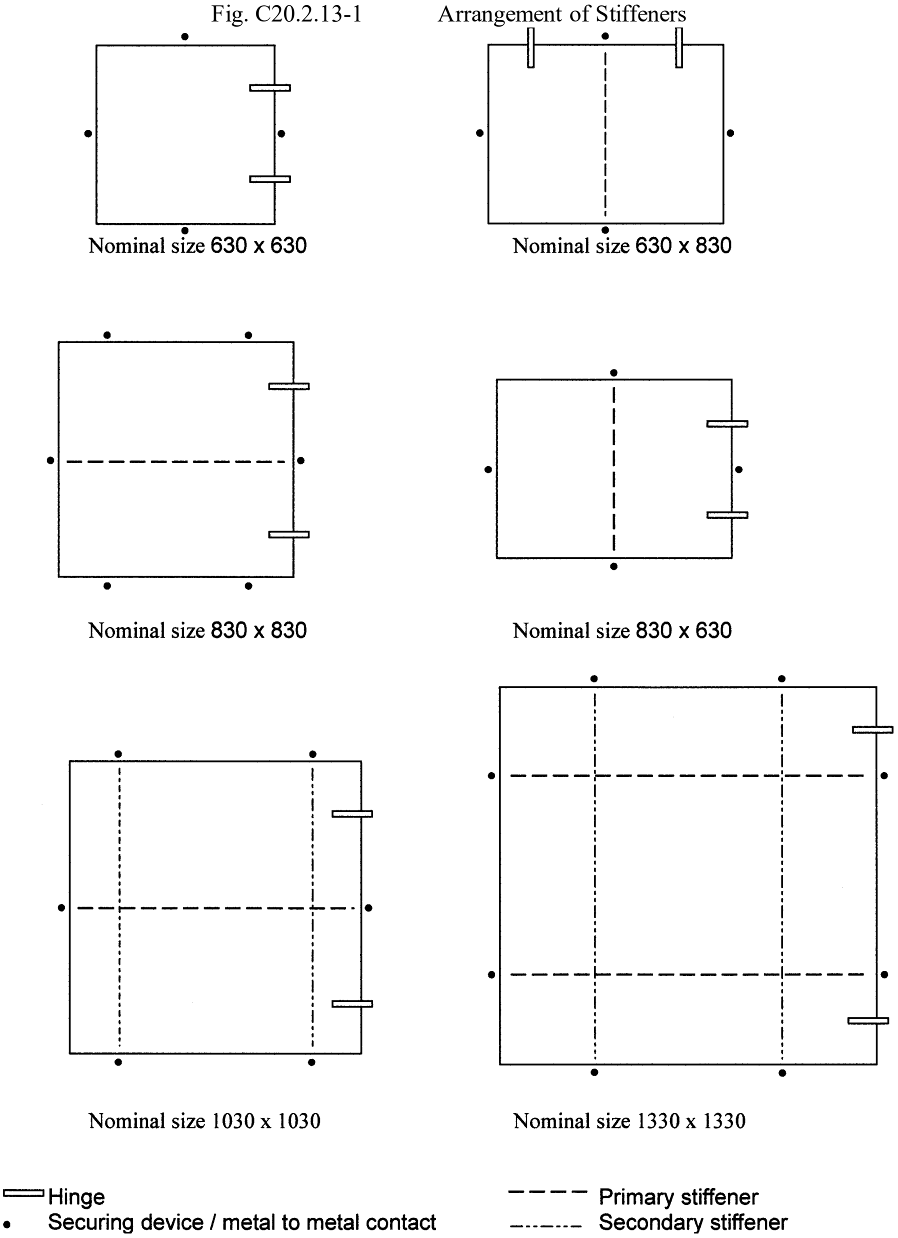
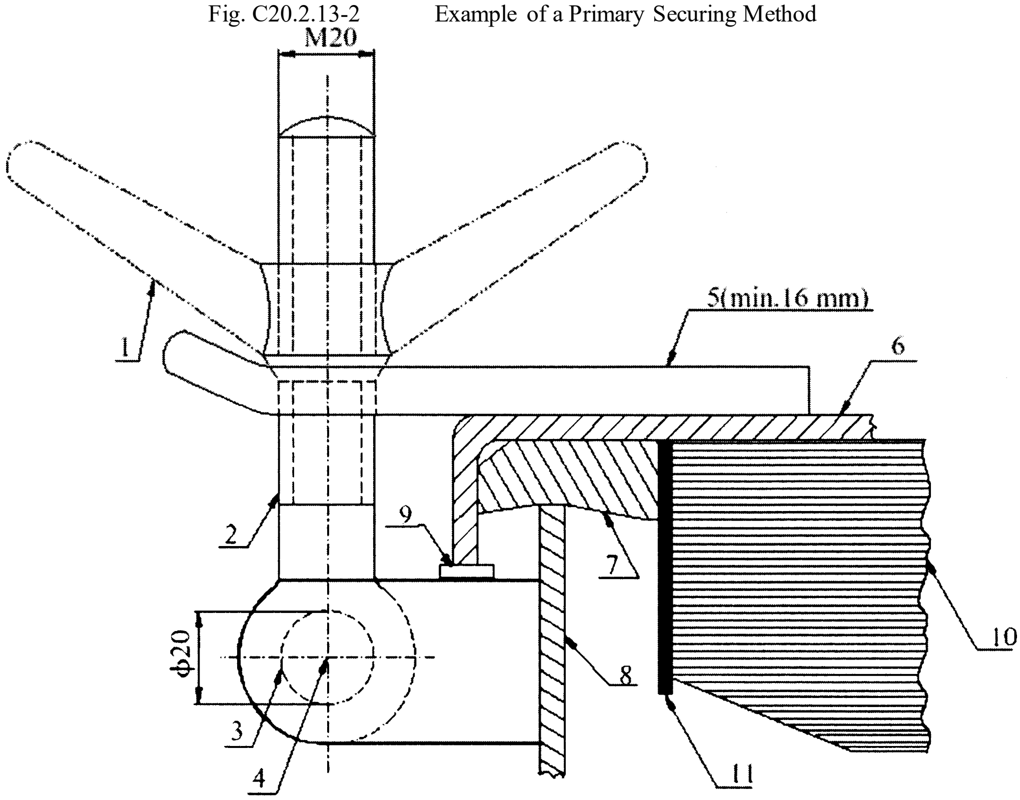


Fig. C20.2.13-2 Example of a Primary Securing Method



(Note : Dimensions in millimeters)

1. Butterfly nut
2. Toggle Bolt
3. Toggle bolt pin
4. Center of toggle bolt pin
5. Fork(clamp) plate
6. Hatch cover
7. Gasket
8. Hatch coaming
9. Bearing pad welded on the bracket of a toggle bolt for metal to metal contact
10. Stiffener
11. Inner edge stiffener

3 Primary Securing Devices

(1) Small hatchways located on an exposed fore deck subject to the application of this requirement are to be fitted with primary securing devices such that their hatch covers can be secured in place and weathertight by means of a mechanism employing any one of the following methods:

(a) Butterfly nuts tightening onto forks (clamps)

(b) Quick acting cleats

(c) Central locking device

(2) Dogs (twist tightening handles) with wedges are not acceptable.

4 Requirements for Primary Securing Devices

(1) Hatch covers are to be fitted with a gasket of elastic material. This is to be designed to allow metal-to-metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged. (See item 9 of **Fig.C20.2.13-2**) The metal-to-metal contacts are to be arranged close to each securing device in accordance with **Fig.C20.2.13-1**, and of sufficient capacity to withstand the bearing force.

(2) The primary securing device is to be designed and manufactured such that the designed compression pressure is achieved by one person without the need of any tools.

(3) For a primary securing device that uses butterfly nuts, the forks (clamps) are to be of a robust design. They are to be designed to minimize the risk of the butterfly nuts being dislodged while in use; by means of curving the forks upward, a raised surface on the free end, or a similar method. The plate thickness of unstiffened steel forks is not to be less than 16 *mm*. An example

arrangement is shown in **Fig.C20.2.13-2**.

(4) For small hatch covers located on an exposed deck forward of the foremost cargo hatch, the hinges are to be fitted such that the predominant direction of green sea force will cause the cover to close, which means that the hinges are normally to be located on the fore edge.

(5) On small hatchways located between the main hatchways, for example between Nos. 1 and 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green sea force in beam seas and bow quartering conditions.

5 Secondary Securing Device

Small hatchways on the fore deck are to be fitted with an independent secondary securing device (e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit) which is capable of keeping the hatch cover in place, even in the event that the primary securing device becomes loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

C20.2.14 Steel Hatchway of Ballast Holds

1 Gross scantlings of steel hatchway covers and similar covers as well as hatch coamings provided on exposed upper decks in way of cargo holds used as deep water ballast tanks for ships are to comply with the following requirements.

(1) The thickness of top plating is not to be less than that obtained from the following formula. However, in the case of double plating type hatch covers, only the plates that actually bear the load need comply.

$1.15s\sqrt{h}\times 10^{-3}+3.0$ (mm)

s : Spacing (mm) of stiffeners

h : As obtained by the following formula (kN/m^2)

$9.81\times 0.85(16a/L+0.25b+h')$

a : Length (m) of hatchways

b : Breadth (m) of hatchways

h': Vertical distance (m) to the highest point of top plates of tanks from the highest points of hatch covers when ships are inclined at angles of 15° and $(900/L)°$ by rolling and pitching, respectively. In any case, h' is not to be less than zero. (*See* **Fig.C20.2.14-1**)

L : Length (m) of ship

(2) The scantlings of stiffeners are to comply with the following formulae.

Section modulus at mid-span:

$C_1Kk_1shl^2\times 10^{-3}(cm^3)$

Moment of inertia at mid-span:

$C_2k_2shl^3\times 10^{-3}(cm^4)$

Cross sectional area of web plates at the ends of stiffeners:

$C_3Kshl\times 10^{-3}(cm^2)$

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

l : Unsupported span (m)

C_1, C_2 and C_3: Coefficients given by **Table C20.2.14-1**

K: Coefficient corresponding to the kind of steel

(e.g., 1.0 for mild steel, the values specified in **1.1.7-2(1) of the Rules** for high tensile steel)

k_1 and k_2: Coefficient given by **Table C20.7, Part C of the Rules**

h : As given by the following formulae according to the arranged direction of stiffeners (kN/m^2)

Transverse direction (where hatch covers are opened/closed in the longitudinal direction):

$9.81\times 0.85(12a/L+0.125b+h')$

Longitudinal direction (where hatch covers are opened/closed in the transverse direction):

$9.81\times 0.85(8a/L+0.188b+h')$

a, b, h' and L : As specified in **(1)**

(3) Thicknesses and depths of the webs of girders are not to be less than 7 mm and $l/25$ (where l is the span of girder), respectively. The girders are to be provided with tripping brackets at intervals of about 3 m.

(4) Construction and scantlings of hatchway coamings are also to comply with the requirements of **Chapter 14** as well as **Chapter**

20, Part C of the Rules.

Fig. C20.2.14-1 How to measure h'

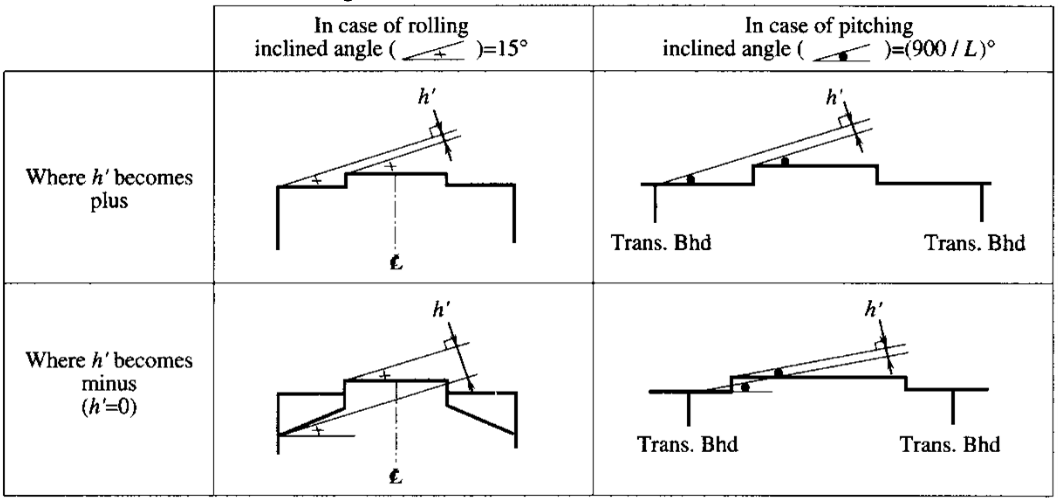


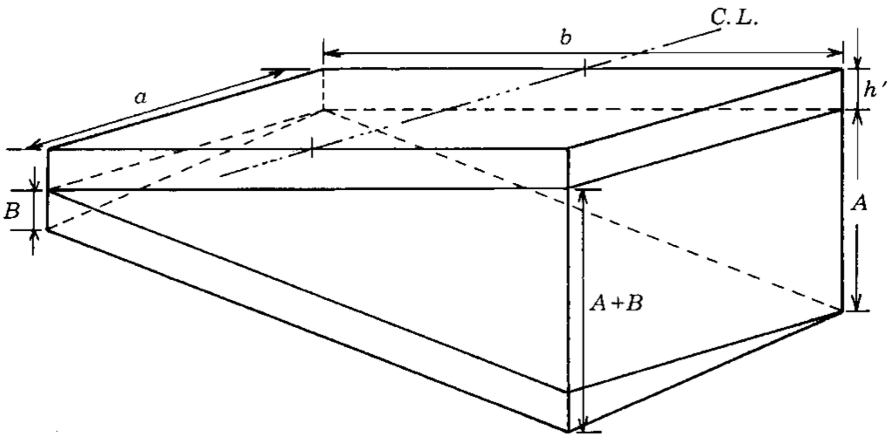
Table C20.2.14-1 Coefficients C_1, C_2 and C_3

C_1	C_2	C_3
1.07	1.81	0.064

2 Where scantlings of structural members of steel hatch covers are determined based upon direct calculations, the scantlings are determined in accordance with **C20.2.5** using the following load.

(1) The load due to water ballast is to be 0.85 *times* the value specified in **Fig.C20.2.14-2**. However, the corner on which the maximum load acts is to be at an arbitrary place. Where only girders are modelled and the Society deems it appropriate, the values specified in **-1(2)** above may be used.

Fig. C20.2.14-2



Notes:

A: Additional water head due to the rolling motion obtained from $0.25b$

B: Additional water head due to the pitching motion obtained from $16a/L$

h', a, b and L: As specified in **C20.2.14-1(1)**

C20.3 Machinery Space Openings

C20.3.5 Miscellaneous Openings in Machinery Casings

In applying the requirements of **20.3.5-1, Part C** of the Rules, the ventilator coamings above the upper surface of the deck is to extend 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 **20.1.2, Part C** of the Rules. Ventilator openings are not to be fitted with weathertight closing appliances. However, ventilator openings are to be fitted with closing means specified in **20.3.5-3, Part C** of the Rules.

C20.4 Companionways and Other Deck Openings

C20.4.2 Companionways

Grouping into deckhouse and companion

(1) A structure is regarded as a deckhouse where its inside is always accessible through access openings provided on the top of the structure or through under-deck passageways, even when all access openings in the boundary walls are closed.

(2) A structure is regarded as a companion where its inside is not accessible through any other way, when all access openings in the boundary walls are closed.

C21 MACHINERY SPACES AND BOILER ROOMS

C21.2 Main Engine Foundations

C21.2.2 Ships with Double Bottoms

1 The following method for determining scantlings of double bottom construction in engine rooms is standard. Other methods approved by the Society may be acceptable.

(1) Thickness of centre girders is not to be less than the value obtained from the following formula.

$$5.7 + 0.056L \ \ (mm)$$

(2) Thickness of side girders and solid floors is not to be less than the value obtained from the following formula.

When the ship is over 100 m in length:

$$6.5 + 0.035L \ \ (mm)$$

When the ship is not over 100 m in length:

$$0.6\sqrt{L} + 4.0 \ \ (mm)$$

2 Girder plates beneath seat plates of the main engine are generally to penetrate inner bottom plates. Where they are unable to penetrate, the inner bottom plates are to be suitably thicker than required and rider plates are to be welded with edge preparation.

If man holes are provided in girder plates, their number is to be minimized as far as possible.

3 Where main engines are directly installed on to inner bottom plates, the compartments beneath main engines are recommended to be cofferdams. Where they are used as deep tanks, cap nuts, packing, etc. are to be fitted to the foundation bolts in order to keep water/oil-tightness.

C23 BULWARKS, GUARDRAILS, FREEING ARRANGEMENTS, CARGO PORTS AND OTHER SIMILAR OPENINGS, SIDE SCUTTLES, RECTANGULAR WINDOWS, VENTILATORS AND GANGWAYS

C23.1 Bulwarks and Guardrails

C23.1.1 General

In 23.1.1-2(2), Part C of the Rules, "measures deemed appropriate by the Society" implies that **(1)** and **(2)** below need to be satisfied.

(1) Stanchions are to be of increased breadth as in **(a)** to **(c)** below, depending on their arrangement. The figure of these stanchions is given in **Fig.C23.1.1-1**.

(a) At least every third stanchion is to be of increased breadth: $kb_s \geq 2.9b_s$

(b) At least every second stanchion is to be of increased breadth: $kb_s \geq 2.4b_s$

(c) Every stanchion is to be of increased breadth: $kb_s \geq 1.9b_s$

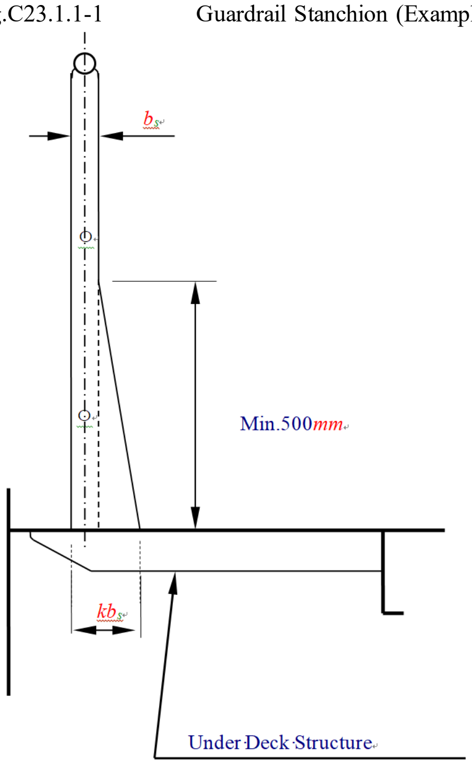
kb_s: increased breadth (mm) of stanchion

b_s: breadth (mm) of stanchion according to standards approved by the Society

Stanchions of increased breadth are to be welded to the deck with double continuous fillet welds and a minimum leg size of 7mm or as specified by standards approved by the Society.

(2) Stanchions with increased breadth, as described in **(1)** above, are to be aligned with the members below the deck. These members are to be a minimum of 100×12mm flat bar welded to the deck by double continuous fillet welds. The stanchions with increased breadth need not be aligned with under deck structures for deck plating exceeding 20mm.

Fig.C23.1.1-1 Guardrail Stanchion (Example)



C23.1.2 Dimensions

Where bulwarks and/or guardrails specified in **23.1.2, Part C** of the Rules interfere with the ship's normal operation due to their height, the height may be reduced on the condition that suitable alternative protection devices such as portable guardrails are provided.

C23.1.3 Construction

In cases where the base of a bulwark stay adopts a gusset type, "special consideration" in **23.1.3-4, Part C of the Rules** means the following **(1)** to **(3)**:

(1) The gusset plate is to be made of steel with the same yield stress as the steel of the upper deck to which the gusset plate is attached.

(2) The toes of gusset plates are to have a soft nose design.

(3) Pad plates are to be provided beneath the gusset plates. In addition, the breadth of such pad plates is to be as narrow as practicable. The pad plates are to be made of steel with the same yield stress as the steel of the upper deck to which the pad plate is attached.

C23.2 Freeing Arrangements

C23.2.1 General

1 The "adequate provisions for freeing the space within superstructures" referred to in **23.2.1-3, Part C** of the Rules is subject to the following.

(1) The minimum freeing port area on each side of the ship for the open superstructure (A_s) is not to be less than that obtained from the following formula.

$$A_s = \frac{A_1 b_0 h_s}{2 l_t h_w}\left\{1-\left(\frac{l_w}{l_t}\right)^2\right\} \ (m^2)$$

A_1: As given by the following formulae

Where l_t is not more than $20m$: $0.7+0.035l_t$ (m^2)

Where l_t is more than $20m$: $0.07l_t$ (m^2)

l_t : As given by the following formula:

$l_w + l_s$ (m)

l_w : Length (m) of the open deck enclosed by bulwarks

l_s : Length (m) of the common space within the open superstructure

b_0 : Breadth (m) of the openings in the end bulkhead of the enclosed superstructure

h_s : One standard superstructure height (m) according to the requirement in **Part V**

h_w: The distance (m) of the well deck above the freeboard deck

(2) The minimum freeing port area on each side of the ship for the open well (A_w) is not to be less than that obtained from the following formula.

$$A_w = \frac{A_2 h_s}{2h_w} \ (m^2)$$

A_2: As given by the following formulae

Where l_w is not more than $20m$: $0.7+0.035l_w + a$ (m^2)

Where l_w is more than $20m$: $0.07l_w + a$ (m^2)

a : As obtained from the following formulae

Where h is more than $1.2m$: $0.04l_w(h-1.2)$ (m^2)

Where h is not more than $1.2m$, but not less than $0.9m$: 0 (m^2)

Where h is less than $0.9m$: $-0.04l_w(0.9-h)$ (m^2)

h : Average height (m) of bulwarks above the deck

l_w, h_s and h_w: As specified in **(1)**

(3) In ships either without sheer or with less sheer than the standard, the minimum freeing port area obtained from **(1)** and **(2)** above is to be multiplied by 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 **Part V**

2 The requirements in **23.2.1-4, Part C** of the Rules apply to type "*A*" or "*B*-100" ships with especially reduced freeboards.

3 The requirements in **23.2.2-4, Part C** of the Rules apply to type "*A*" or "*B*-100" ships with especially reduced freeboards having trunks.

C23.2.2 Freeing Port Area

1 A flush-decker having an effective deckhouse is to be considered to have two wells afore and abaft the deckhouse, and each of these wells is required to have a freeing port area as prescribed in **23.2.2, Part C** of the Rules. The term "effective deckhouse" means a structure having a breadth not less than 80% of the breadth of ship and the width of passageways at its sides does not exceed 1.5m.

2 Where a divisional bulkhead extending from side to side is provided at the forward end of deckhouse, the ship is to be considered to have two wells afore and abaft the bulkhead, irrespective of the breadth of deckhouse, and each of these wells is required to have the freeing port area prescribed in **23.2.2, Part C** of the Rules.

3 In ships complying with the provisions of **C23.2.1-2**, the guardrails installed on more than half the length of the exposed parts of the freeboard deck may be replaced by freeing ports in the lower parts of the bulwarks, for at least 33% of the total area of bulwarks. In ships complying with the provisions of **C23.2.1-3**, the guardrails installed on half the length of trunks may be replaced by freeing ports in the lower parts of the bulwarks, for at least 33% of the total area of bulwarks.

4 In type "*B*-60" ships, freeing ports in the lower parts of bulwarks are to have an area not less than 25% of the total area of bulwarks.

5 Where freeing ports have rails or other fixtures that reduce the area of the opening, the projected area caused by these fixtures is to be deducted from the actual freeing port area during calculations.

6 Where a recess in the side shell or superstructure of a pure car carrier or similar ship forms a well, adequate freeing ports are to be provided in accordance with the requirements of **23.2.2-3, Part C** of the Rules.

7

(1) "Where a ship is provided with a trunk or a hatch side coaming which is continuous or substantially continuous between detached superstructures" stipulated in **23.2.2-3, Part C** of the Rules refers to the case where F_0 is not greater than F_1, and F_0 and F_1 are shown below.

F_0: Free flow area (m^2) through which water runs across the deck given by the following formula

$$\sum(l_i h_i - a_i)$$

l_i : Distance (m) between hatchways, and between hatchways and superstructures and deckhouses

h_i: Height (m) of bulwarks

a_i: Projected area (m^2) of structures which prevent free flow in $l_i h_i$

F_1: As specified in **23.2.2-1** and **-2, Part C** of the Rules (m^2)

(2) Where F_0 is greater than F_1, but not greater than F_2, the freeing port area (F) is to be increased by the following formula. F_0 and F_1 are shown in **(1)** above, and F_2 is shown below.

$$F = F_1 + F_2 - F_0 \ \ (m^2)$$

F_2 : As specified in **23.2.2-3, Part C** of the Rules (m^2)

(3) Where F_0 is greater than F_2, F is to be equal to F_1. F_0, F_1 and F_2 are shown in **(1)** and **(2)** above.

C23.2.3 Arrangement of Freeing Ports

In ships without sheer or having very small sheer, the area of freeing ports is to be distributed throughout the whole length of the well.

C23.3 Bow Doors and Inner Doors

C23.3.1 Application

1 "Bow doors" referred to in **23.3.1, Part C** of the Rules mean the doors provided forward of the collision bulkhead.

2 The "securing device", "supporting device" and "locking device" referred to in **23.3, Part C** of the Rules mean the following devices.

(1) Securing device: a device used to keep the door closed by preventing it from rotating about its hinges.

(2) Supporting device: a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device that transmits loads from the door to the ship's structure.

(3) Locking device: a device that locks the securing device in the closed position.

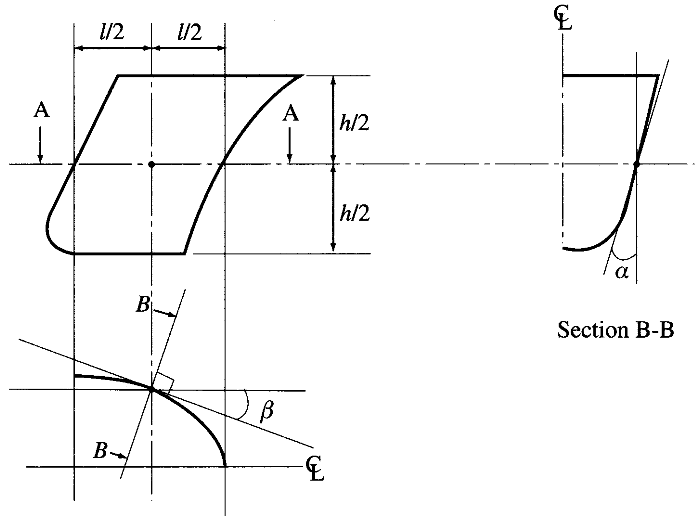
C23.3.4 Design Loads

The "flare angle" and "entry angle" referred to in **23.3.4, Part C** of the Rules mean the following angles. (*See*, **Fig.C23.3.4-1**)

(1) Flare angle at the point to be considered is defined as the angle between a vertical line and the tangent to the side shell plating, measured in a vertical plane normal to the horizontal tangent to the shell plating.

(2) Entry angle at the point to be considered is defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane.

Fig. C23.3.4-1 Flare Angle and Entry Angle



C23.3.5 Scantlings of Doors

In applying the formula specified in **16.3.2, Part C** of the Rules, coefficient C_2 may be taken as $3.78\sqrt{K}$.

C23.3.6 Scantlings of Inner Doors

In applying the formula specified in **16.3.2, Part C** of the Rules, coefficient C_2 may be taken as $3.78\sqrt{K}$.

C23.3.7 Securing and Supporting of Doors

"All load transmitting elements" referred to in **23.3.7-2(9), Part C** of the Rules include pins, supporting brackets and back-up brackets.

C23.3.8 Securing and Locking Arrangement

1 Making opening and closing systems as well as securing and locking devices "interlocked in such a way that they can only operate in the proper sequence" as stipulated in **23.3.8-1(3), Part C** of the Rules means providing safeguards such as an interlocking system, where the doors can be closed only if securing and locking devices are released.

2 Making operating panels "inaccessible to unauthorized persons" as stipulated in **23.3.8-1(5), Part C** of the Rules means providing safeguards such as installing a locking device on the operating panel.

3 In the application of **23.3.8-1(6), Part C** of the Rules, if gravity or friction cannot maintain the door mechanically closed, securing devices such as mechanical pins are to be provided.

4 Indicator lights in the navigation bridge and on local operating panels specified in **23.3.8-2(1), Part C** of the Rules are to indicate closing and securing conditions for each door. In addition, the required visual alarms are to indicate opening and lock-releasing conditions for each door. A common indicator can be used for both the securing and locking devices.

5 Visual and audible alarms specified in **23.3.8-2(1), Part C** of the Rules are to be linked with the mode selection switch specified in **23.3.8-2(3), Part C** of the Rules. The audible alarms may be equipped with a silence function switch.

6 Systems "designed on the fail safe principle" stipulated in **23.3.8-2(2)(a), Part C** of the Rules means as follows.

(1) The indication panel is provided with:

(a) A power failure alarm

(b) A lamp test

(c) A separate indication for door closed, door locked, door not closed, and door not locked

(2) Limit switches electrically close when the door is closed (when more limit switches are provided they may be connected in series)

(3) Limit switches electrically close when securing arrangements are in place (when more limit switches are provided they may be connected in series)

(4) Two electrical circuits (separate cables even if using multicore cable) with one for the indication of door closed/unclosed and the other for door locked/unlocked

(5) When the limit switches malfunction, an indication to show: unclosed, unlocked, and securing arrangement not in place - as appropriate

7 "A backup power source" referred to in **23.3.8-2(2)(c), Part C** of the Rules may be regarded as a source of power (e.g., emergency generator with automatic start or electrical batteries) which is capable of supplying power within 45 *seconds* of a failure of the main source of power, or another secure supply of power (e.g., UPS) which is capable of supplying power for 18 *hours*.

8 In order to ensure that the sensors are "protected from water" as specified in **23.3.8-2(2)(d), Part C** of the Rules, the sensors are required to have at least IP55 enclosures.

9 The "water leakage detection system" referred to in **23.3.8-2(4), Part C** of the Rules is to be designed on the fail safe principle.

10 The "television surveillance system" referred to in **23.3.8-2(5), Part C** of the Rules is to be designed on the fail safe principle.

11 The "audible alarm function" referred to in **23.3.8-2(6), Part C** of the Rules is to be designed on the fail safe principle.

C23.3.10 Operating and Maintenance Manual

The "Operating and Maintenance Manual" specified in **23.3.10-1 in Part C** of the Rules is to include the following sentences.

The following recorded inspections of the door supporting and securing devices are to be carried out by the ship's staff;

(1) Inspections at monthly intervals

(2) Inspections following incidents that could result in damage, including heavy weather or contact in the region of doors

C23.4 Side Shell Doors and Stern Doors

C23.4.1 Application

1 "Side shell doors" and "stern doors" stipulated in **23.4.1, Part C** of the Rules refer to the doors provided between the collision bulkhead and the after peak bulkhead and those provided after the after peak bulkhead.

2 The definitions of "securing device", "supporting device" and "locking device" referred to in **23.4, Part C** of the Rules are to be as specified in **C23.3.1**.

C23.4.2 Arrangement of Doors

Shipside doors used for pilot transfer are to be in accordance with Regulation 23.5, Chapter V, SOLAS Convention.

C23.4.4 Design Loads

Where more than one securing and supporting devices are provided, vertical and horizontal forces may be considered as uniformly distributed between the devices.

C23.4.5 Scantlings of Doors

In applying the formula specified in **16.3.2, Part C** of the Rules, coefficient C_2 may be taken as:

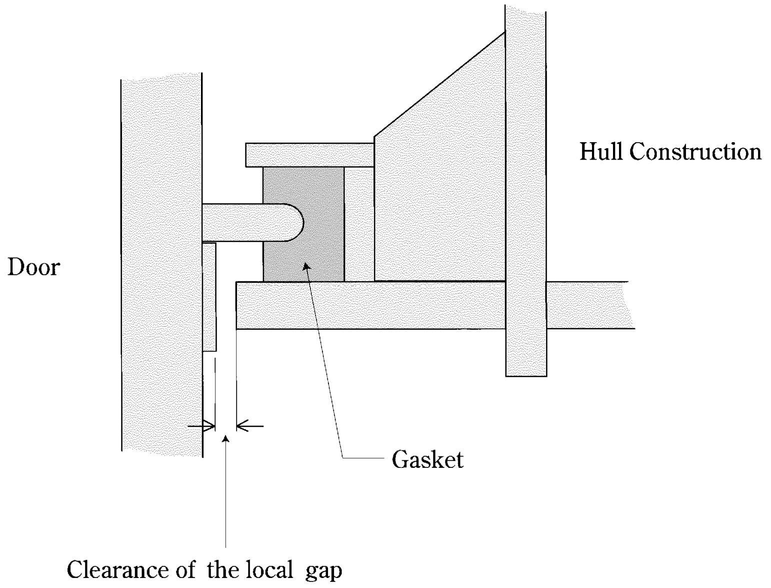
$$3.78\sqrt{K}$$

K: As specified in **23.4.3-1, Part C of the Rules**

C23.4.6 Securing and Supporting of Doors

The "maximum design clearance between securing and supporting devices" stipulated in **23.4.6-1(4), Part C** of the Rules refers to the permissible clearance of the local gap of the door in the secured condition. An example is shown in **Fig.C23.4.6-1**. "All load transmitting elements" referred to in **23.4.6-2(4), Part C** of the Rules includes pins, supporting brackets and back-up brackets.

Fig C23.4.6-1 Maximum Design Clearance between Securing and Supporting Devices



C23.4.7 Securing and Locking Arrangement

1 Making opening and closing systems as well as securing and locking devices "interlocked in such a way that they can only operate in the proper sequence" as stipulated in **23.4.7-1(3), Part C** of the Rules means providing safeguards such as an interlocking system, where the doors can be closed only if securing and locking devices are released.

2 Making operating panels "inaccessible to unauthorized persons" as stipulated in **23.4.7-1(5), Part C** of the Rules means providing safeguards such as installing a locking device on the operating panel.

3 In the application of **23.4.7-1(6), Part C** of the Rules, if gravity or friction cannot maintain the door mechanically closed, securing devices such as mechanical pin are to be provided.

4 The "Ro-Ro spaces" referred in to **23.4.7-2, Part C** of the Rules means spaces not normally subdivided in any way and extending to either a substantial length or the entire length of ship in which goods can be loaded and unloaded normally in a horizontal direction. (Refer to **3.2.41, Part R** of the Rules)

5 Indicator lights in the navigation bridge and on local operating panels specified in **23.4.7-2(2), Part C** of the Rules are to indicate closing and securing conditions for each door. In addition, the required visual alarms are to indicate opening and lock-releasing conditions for each door. A common indicator can be used for both the securing and locking devices.

6 Visual and audible alarms specified in **23.4.7-2(2)(b), Part C** of the Rules are to be linked with the mode selection switch specified in **23.4.7-2(4), Part C** of the Rules. The audible alarms may be equipped with a silence function switch.

7 Systems "designed on the fail safe principle" stipulated in **23.4.7-2(3)(a), Part C** of the Rules means as follows.

(1) The indication panel is provided with:

(a) A power failure alarm

(b) A lamp test

(c) A separate indication for door closed, door locked, door not closed, and door not locked

(2) Limit switches electrically close when the door is closed (when more limit switches are provided they may be connected in series)

(3) Limit switches electrically close when securing arrangements are in place (when more limit switches are provided they may be connected in series)

(4) Two electrical circuits (separate cables even if using multicore cable) with one for the indication of door closed/unclosed and the other for door locked/unlocked

(5) Where the limit switches malfunction, an indication to show: unclosed, unlocked, and securing arrangement not in place - as appropriate

8 "A backup power source" referred to in **23.4.7-2(3)(c), Part C** of the Rules may be regarded as a source of power, (e.g., emergency generator with automatic start or electrical batteries) which is capable of supplying power within 45 *seconds* of a failure of the main source of power, or another secure supply of power (e.g., UPS) which is capable of supplying power for 18 *hours*.

9 In order to ensure that the sensors are "protected from water" as specified in **23.4.7-2(3)(d), Part C** of the Rules, the sensors are required to have at least IP55 enclosures.

C23.4.9 Operating and Maintenance Manual

The "Operating and Maintenance Manual" specified in **23.4.9-1, Part C** of the Rules is to include the following sentences.

The following recorded inspections of the door supporting and securing devices are to be carried out by the ship's staff;

(1) Inspections at monthly intervals

(2) Inspections following incidents that could result in damage, including heavy weather or contact in the region of doors

C23.5 Side Scuttles and Rectangular Windows

C23.5.1 General Application

1 With respect to the provisions of **23.5, Part C of the Rules**, side scuttles with round or oval openings having areas exceeding $0.16m^2$ are to be treated as windows.

2 With respect to the provisions of **23.5.1-1, Part C** of the Rules, the design pressures of windows in the fore end bulkheads of superstructures and deckhouses above the third tier located above the freeboard deck and forward of $0.5L$ are not to be less than the minimum design pressures given in **Table C23.5, Part C** of the Rules. However, this requirement may be dispensed with if the height of the highest deck at the fore end is not less than $22m$ above the designed maximum load line, or if cargo, etc. is regularly loaded onto exposed decks in front of the windows (e.g., container carriers).

3 With respect to the provisions of **23.5.1-2, Part C** of the Rules, windows on the navigation bridge up to the third tier above the freeboard deck permitted to be rectangular according to the provisions of **23.5.6, Part C** of the Rules may be other than those of Class *E* or Class *F* subject to the following **(1)** and **(2)**.

(1) The navigation bridge is to be separated from spaces below the freeboard deck and spaces within enclosed superstructures by the followings

  (a) Weathertight closing devices

  (b) Two or more cabin bulkheads or doors

  The height of the doorway sill to the navigation bridge is not to be less than that required for closing devices at the position of such a doorway.

(2) The design pressure of such windows is not to be less than the value specified in **23.5.8, Part C** of the Rules. The frame of the window is to conform to Class *E* or Class *F* according to the location it is installed, and the window is to have appropriate weathertightness.

C23.5.3 Application of Side Scuttles

The side scuttles "deemed appropriate by the Society" referred to in **23.5.3-5, Part C** of the Rules are class *B* side scuttles or class *A* side scuttles without deadlights in cases where the height of superstructures and deckhouses specified in **23.5.3-5, Part C of the Rules** is greater than standard quarterdeck height specified in **V2.2.1-1**.

C23.5.5 Design Pressure and Maximum Allowable Pressure of Side Scuttles

With respect to the provisions of **23.5.5-1, Part C** of the Rules, the value of coefficient "*a*" for side scuttles for spaces below the freeboard deck or spaces within superstructures may be determined using the formula for the first tier deckhouse in the provisions of **19.2.1-1, Part C** of the Rules.

C23.5.7 Application of Rectangular Windows

The rectangular windows "deemed appropriate by the Society" referred to in **23.5.7-3, Part C** of the Rules are rectangular windows without shutters or deadlights. In such cases, deckhouses situated on the following spaces may be regarded as being in the second tier of the freeboard deck.

(1) A raised quarterdeck of a height equal to or greater than the standard quarterdeck height specified in **V2.2.1-1**.

(2) The deck of a superstructure of a height equal to or greater than the standard quarterdeck height specified in **V2.2.1-1**.

(3) The deck of a deckhouse of a height equal to or greater than the standard quarterdeck height specified in **V2.2.1-1**.

C23.6 Ventilators

C23.6.5 Closing Appliances

1 Closing appliances required in **23.6.5, Part C of the Rules** are to be of steel or other equivalent materials. Furthermore, the closing appliances of the ventilators for machinery and cargo spaces required in **23.6.5-1, Part C of the Rules** are to have inherent corrosion resistance properties or be provided with an adequate anticorrosion treatment.

2 With respect to the provisions of **23.6.5, Part C of the Rules**, mechanical ventilation systems are to be provided with warning plates stating that the closing appliances of mechanical ventilation systems are generally to be closed after the ventilation system has been shut off, unless reinforced.

3 With respect to the provisions of **23.6.5-1, Part C of the Rules**, in cases where internal checks of ventilators are impossible even if equipment installed on board is used, e.g. large ventilators that have cowls which cannot be easily removed or ventilators that have fans installed above, an inspection port at least 150*mm* in diameter is to be installed in the coaming of the ventilator. In addition, such inspection ports are to be provided with suitable covers so as not to spoil the water tightness/weather tightness and fire resistance required for the coaming of ventilators.

C23.6.7 Ventilators for Emergency Generator Room

1 Where it is not practicable for the height of ventilator coamings to comply with **23.6.7, Part C** of the Rules, they are to comply with the following requirements **(1)** or **(2)** instead.

(1) Where the emergency generator room is located in an enclosed superstructure, the ventilators are to have coamings in compliance with **23.6.1, Part C** of the Rules, and are to be fitted with weathertight closing appliances in combination with other suitable arrangements to ensure adequate ventilation.

(2) In cases other than **(1)** above, where the emergency generator room has no opening leading to a space below the freeboard deck, the height of coamings of ventilators to supply air to the emergency generator room, above the upper surface of the deck, is to be at least 900*mm* above the surface of the deck in Position I or 760*mm* above the surface of the deck in Position II specified in **20.1.2, Part C** of the Rules. In addition, these ventilator openings are to be fitted with suitable protection devices such as louvers to prevent the intrusion of sea-water. Openings on the boundaries of the emergency generator room are to be treated in a similar manner.

2 The weathertight closing appliances and louvers specified in **-1** above are also to comply with requirements specified in **1.3.5-2, Part D of the Rules**.

C23.6.8 Additional Requirement for Ventilators Fitted on Exposed Fore Deck

The strength of ventilators and their closing devices in **23.6.8, Part C** of the Rules are to comply with the following requirements.

(1) Applied Loads

Forces acting in the horizontal direction on the pipe and its closing device are to be calculated by using the pressure (p) obtained from the following formula and the largest projected area of each component.

$p = 0.5\rho V_w^2 C_a C_s C_p$ (kN/m^2)

ρ : Density of sea water (1.025 t/m^3)

V_w: Velocity of water over the fore deck given by the following:

$13.5(m/sec)$: for $h_{ed} \leq 0.5h_t$

$13.5\sqrt{2\left(1-\frac{h_{ed}}{h_t}\right)}(m/sec)$: for $0.5h_t < h_{ed} < h_t$

h_{ed}: Distance from the designed maximum load line to exposed deck (m)

h_t : $0.1L_1$ or 22 m whichever is the lesser

C_d: Shape coefficient (0.5 for pipes and 1.3 for ventilator head in general, 0.8 for ventilator head of cylindrical form with its axis in the vertical direction)

C_s: Slamming coefficient (3.2)

C_p: Protection coefficient given by the following

(0.7): for pipes and ventilator heads located immediately behind a breakwater or forecastle

(1.0): elsewhere and immediately behind a bulwark

(2) Strength Requirements

(a) Bending moments and stresses in air and ventilator pipes are to be calculated at critical positions, such as at penetration pieces, at weld or flange connections, and at toes of supporting brackets. Bending stresses in the net section are not to exceed 0.8 times σ_y, where σ_y is the specified minimum yield stress or 0.2% proof stress of steel at room temperature. Irrespective of corrosion protection, a corrosion addition to the net section of 2.0*mm* is then to be applied.

(b) For standard ventilators of 900*mm* height closed by heads of not more than the tabulated projected area, pipe thickness standards are to be according to **Table C23.6.8-1.** Where brackets are required, three or more radial brackets of a gross thickness of 8*mm* or more, of a minimum length of 100*mm*, and a height according to **TableC23.6.8-1** are to be fitted; but they need not extend over the joint flange for the head. Bracket toes at the deck are to be suitably supported.

(c) For other configurations, loads according to **(1)** are to be applied, and means of support are to be determined in order to comply with the requirements of **(a)**. Brackets, where fitted, are to be of suitable thickness and length according to their height. Pipe thickness is not to be less than as indicated in column 1of **Table C23.7, Part C** of the Rules.

(d) All component parts and connections of the air pipe or ventilator are to be capable of withstanding the loads defined in **(1)**.

(e) Rotating type mushroom ventilator heads are deemed unsuitable.

Table C23.6.8-1 900*mm* Ventilator Pipe Thickness and Bracket Standards

Nominal pipe diameter (*mm*)	Minimum fitted gross thickness (*mm*)	Maximum projected area of head (cm^2)	Height of brackets (*mm*)
80*A*	6.3	-	460
100*A*	7.0	-	380
150*A*	8.5	-	300
200*A*		550	-
250*A*		880	-
300*A*		1200	-
350*A*		2000	-
400*A*		2700	-
450*A*		3300	-
500*A*		4000	-

C23.7 Gangways

C23.7.1 General

1 In order to satisfy the provisions of **23.7.1, Part C** of the Rules that require a means of protecting crew passageways on the exposed freeboard or raised quarterdeck, a means from **Table C23.7.1-1** is to be provided according to the assigned freeboard or location onboard

2 In **Table C23.7.1-1**, "**a**" to "**f**" refer to installations and **1)** to **5)** refer to locations onboard, as specified in the following **(1)** and **(2)**.

(1) Acceptable arrangements

a: A well lighted and ventilated under-deck passageway (clear opening 0.8*m* wide, 2.0*m* high) as close as practicable to the freeboard deck, connecting and providing access to the locations in question

b: A permanent and efficiently constructed gangway fitted at or above the level of the superstructure deck on or as near as practicable to the centre line of the ship, providing a continuous platform at least 0.6*m* in width and a non-slip surface, with guard rails extending on each side throughout its length

Guard rails shall be at least 1*m* high with courses as required in **23.1.2-2** and **23.1.2-4**, **Part C** of the Rules, and supported by stanchions spaced not more than 1.5*m*, and with a foot-stop.

c: A permanent walkway at least 0.6*m* in width fitted at freeboard deck level consisting of two rows of guard rails with stanchions spaced not more than 3*m* apart

The number of courses of rails and their spacing are to be as required by **23.1.2-2** and **23.1.2-4**, **Part C** of the Rules. On Type B ships, hatch coamings not less than 0.6*m* in height may be regarded as forming one side of the walkway, provided that between the hatches two rows of guard rails are fitted.

d: A 10*mm* minimum diameter wire rope lifeline supported by stanchions not more than 10*m* apart, or a single hand rail or wire rope attached to hatch coamings, continued and adequately supported between hatches

e: A permanent and efficiently constructed gangway for tankers fitted at or above the level of the superstructure deck on or as near as practicable to the centre line of the ship:

- located so as not to hinder easy access across the working areas of the deck
- providing a continuous platform at least 1.0*m* in width
- constructed of fire resistant and non-slip material
- fitted with guard rails extending on each side throughout its length; guard rails should be at least 1.0*m* high with courses as required by **23.1.2-2** and **23.1.2-4**, **Part C** of the Rules, and supported by stanchions spaced not more than 1.5*m*
- provided with a foot stop on each side
- having openings (not more than 40*m* apart) with ladders where appropriate, to and from the deck
- having shelters of substantial construction set in way of the gangway at intervals not exceeding 45*m* if the length of the exposed deck to be traversed exceeds 70*m*
  Every such shelter should be capable of accommodating at least one person (1×1×2*m* in size as standard, and at least 0.6*m* in width of entrance), be so constructed as to afford weather protection on the forward, port and starboard sides and the strength is to be in accordance with the requirements of **Chapter 19, Part C** of the Rules.

f: A permanent and efficiently constructed walkway fitted at or above the level of the freeboard deck on or as near as practicable to the centre line of the ship having the same specifications as those for a permanent gangway listed in the arrangements "**e**" except for footstops

On type B ships (certified for the carriage of liquids in bulk), with a combined height of hatch coamings and fitted hatch covers of together not less than 1*m* in height, the hatch coamings may be regarded as forming one side of the walkway, provided that between the hatches two rows of guard rails are fitted.

(2) Alternative transverse locations for arrangements

1): At or near the centre line of the ship; or fitted on hatch covers at or near the centre line of the ship

2): Fitted on each side of the ship

3): Fitted on one side of the ship, provision being made for fitting on either side

4): Fitted on one side only

5): Fitted on each side of the hatches as near to the centre line as practicable

3 Precautions regarding arrangements specified in **-1** above

(1) Where wire ropes are fitted, turnbuckles are to be provided to ensure their tautness.

(2) Wire ropes may only be acceptable in lieu of guard rails in special circumstances and then only in limited lengths.

(3) Lengths of chain may only be acceptable in lieu of guard rails where fitted in between two fixed stanchions.

(4) Where stanchions are fitted, every third stanchion is to be supported by a bracket or stay.

(5) Removable or hinged stanchions shall be capable of being locked in the upright position.

(6) A means of passage over obstructions, if any, such as pipes or other fittings of a permanent nature, should be provided.

(7) Generally, the width of the gangway and deck-level walkway should not exceed 1.5 *m*.

4 Where a suitable passage facility is unable to be secured on or under the deck due to cargoes loaded on the exposed deck, life lines or guardrails are to be provided on the cargo on or near the centre line of the ship. Where a lumber freeboard is assigned, in addition to the above, life lines or guardrails, the height of which is at least 1.0*m* and the clearance between courses is less than 350*mm*, are to be fitted on both sides of the deck lumber.

Table C23.7.1-1 Protection of Crew on Exposed Deck or Raised Quarter Deck

<table>
<tr><th rowspan="2">Locations of access in Ship</th><th rowspan="2">Assigned Summer Freeboard</th><th colspan="4">Acceptable arrangements according to type of freeboard assigned:</th></tr>
<tr><th>Type A</th><th>Type B-100</th><th>Type B-60</th><th>Type B&B+</th></tr>
<tr><td rowspan="2">1.1 Access to Midship Quarters
1.1.1 Between poop and bridge,
1.1.2 Between poop and deckhouse containing living quarters or navigating equipment, or both.</td><td>≤ 3000mm</td><td>A
b
e</td><td>a
b
e</td><td>a
b
c 1)
e
f 1)</td><td rowspan="2">a
b
c 1)
c 2)
c 4)
d 1)
d 2)
d 3)
e
f 1)
f 2)
f 4)</td></tr>
<tr><td>> 3000mm</td><td>A
b
e</td><td>a
b
e</td><td>a
b
c 1)
c 2)
e
f 1)
f 2)</td></tr>
<tr><td rowspan="2">1.2 Access to Ends
1.2.1 Between poop and bow (if there is no bridge)
1.2.2 Between bridge and bow.
1.2.3 Between a deckhouse containing living quarters or navigating equipment, or both, and bow
1.2.4 In the case of a flush deck vessel, between crew accommodation and the forward and after ends of ship</td><td>≤ 3000mm</td><td>A
b
c 1)
e
f 1)</td><td>a
b
c 1)
c 2)
e
f 1)
f 2)</td><td>a
b
c 1)
c 2)
e
f 1)
f 2)</td><td rowspan="2"></td></tr>
<tr><td>> 3000mm</td><td>a
b
c 1)
d 1)
e
f 1)</td><td>a
b
c 1)
c 2)
d 1)
d 2)
e
f 1)
f 2)</td><td>a
b
c 1)
c 2)
c 4)
d 1)
d 2)
d 3)
e
f 1)
f 2)
f 4)</td></tr>
</table>

C23.7.2 Tankers

1 Notwithstanding C23.7.1, safe access to the bow is to be provided by at least one permanent arrangement noted in Table C23.7.2-1.

2 Notations in Table C23.7.2-1 are as specified in C23.7.1-2.

3 For tankers less than 100m in length, the minimum width of the gangway platform or deck level walkway fitted in accordance with the arrangements "**e**" or "**f**", respectively, may be reduced to 0.6m.

4 For gas carriers, where gangways are provided sufficiently high above the freeboard deck or where permanently constructed arrangements achieve an equivalent level of safety, the Society may approve modifications to the provisions of -1 above. "Sufficiently high above the freeboard deck" means a vertical height of more than 3 times the standard superstructure height specified in **Table V2.2.1-1**.

Table C23.7.2-1 Protection of Crew on Exposed Freeboard Deck or Raised Quarter Deck for Tankers

Location of access in Ship	Assigned Summer Freeboard	Acceptable arrangements according to type of freeboard assigned:
2.1 Access to Bow 2.1.1 Between poop and bow 2.1.2 Between a deckhouse containing living accommodation or navigating equipment or both, and bow 2.1.3 In the case of a flush deck vessel, between crew accommodation and the forward ends of ship	$\leq (Af + Hs)^*$	a e f 1) f 5)
	$> (Af + Hs)^*$	a e f 1) f 2)
2.2 Access to After End 2.2.1 In the case of a flush deck vessel, between crew accommodation and the after end of ship	As required in 1.2.4 of **Table C23.7.1-1** for other types of ships	

Notes:

Af: Minimum summer freeboard calculated as type A ship regardless of the type of freeboard actually assigned

Hs: Standard height of superstructure as defined in **Table V2.2.1-1.**

C23.8 Means of Embarkation and Disembarkation

C23.8.1 General

1 The wording "specially approved by the Society" specified in **23.8.1, Part C of the Rules** 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 **23.8.1, Part C of the Rules**, 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 Regulation III/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 to the ship to prevent overturning.

(6) Each accommodation ladder or gangway is to be clearly marked at each end with a plate showing the restrictions on the safe operation and loading, including the maximum and minimum permitted design angles of inclination, design load, maximum load on bottom end plate, etc. Where the maximum operational load is less than the design load, it is also to be shown on the marking plate.

(7) Gangways are not to be used at an angle of inclination greater than 30 degrees from the horizontal and accommodation ladders are not to be used at an angle greater than 55 degrees from the horizontal, unless designed and constructed for use at angles greater than these and marked as such.

(8) Gangways are not to be secured to a ship's guardrails unless they have been designed for that purpose. If positioned through an open section of bulwark or railings, any remaining gaps are to be adequately fenced.

(9) Adequate lighting is to be provided to illuminate the means of embarkation and disembarkation, the position on deck where persons embark or disembark and the controls of the arrangement.

(10) A lifebuoy equipped with a self-igniting light and a buoyant lifeline is to be available for immediate use in the vicinity of the embarkation and disembarkation arrangement when in use. This lifebuoy is not to be taken into account when determining the minimum number and distribution of lifebuoys as required by *SOLAS* Reg. III/32.1.1.

(11) A safety net is to be mounted and arrangements that enable the installation of such net are to be provided to prevent falling accident in cases where it is possible that a person may fall from the means of embarkation and disembarkation or between the ship and quayside.

C24 CEILINGS AND SPARRINGS

C24.2 Sparrings

C24.2.1 Sparrings

1 The "equivalent arrangements … for the protection of framing" prescribed in **24.2.1-1, Part C** of the Rules are to be as specified in **C1.1.3-1(3)(e)i)** and **ii)**.

2 For ships intended to carry timbers, the special protection of framing is to be as specified in **C1.1.3-1(3)**.

C25 CEMENTING AND PAINTING

C25.2 Painting

C25.2.1 General

1 Limitation of Using Aluminium Paint

Paints containing aluminium greater than 10 percent aluminium by weight in the dry film are not to be used in hazardous areas defined in **4.2.3-1** or **4.2.3-2, Part H** of the Rules in tankers and ships carrying dangerous chemicals in bulk intended to carry crude oil and petroleum products having a flashpoint not exceeding 60℃ and a Reid vapour pressure below atmospheric pressure or other liquid cargoes having similar fire hazards.

2 Special Requirements

The "special requirements (that) may be additionally made by the Society" stated in **25.2.1-1, Part C** of the Rules refer to the following.

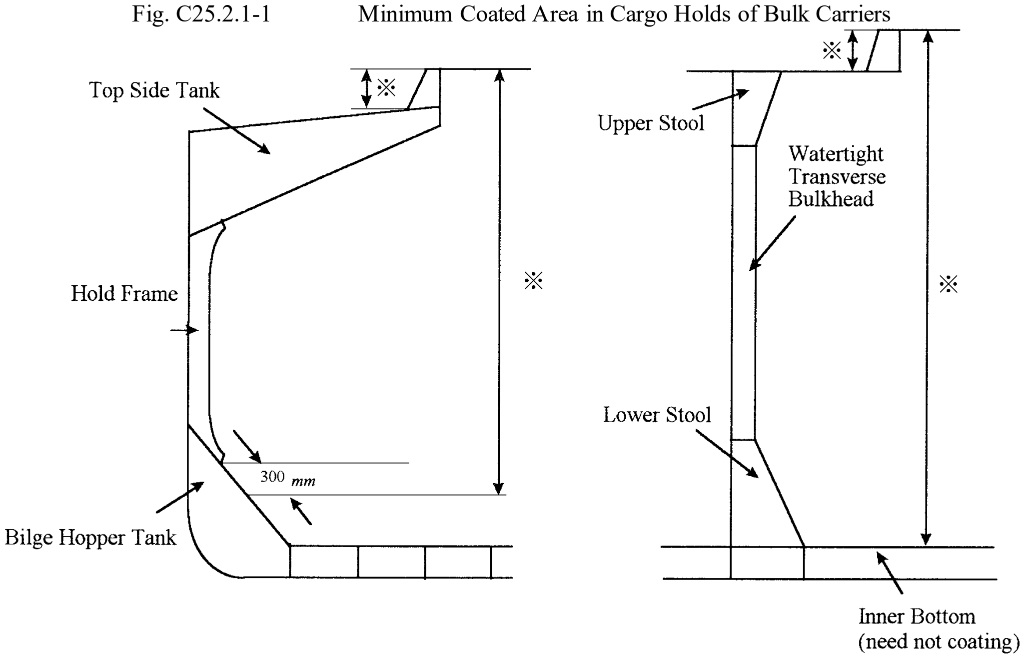
(1) Cargo hold of bulk carriers

Where ships are subject to the requirements of **Chapter 31, Part C** of the Rules, the following scope (See **Fig. C25.2.1-1**) is to have efficient protective coating (epoxy coating or equivalent) applied in accordance with the manufacturer's recommendations. In the selection of the coating, due consideration is to be given by the owner to cargo conditions expected in service.

(a) All internal surfaces of cargo holds, excluding the flat tank top areas and the sloping plating of the hopper tanks approximately 300*mm* below the side shell frame and brackets

(b) All internal and external surfaces of hatch coamings and hatch covers

Fig. C25.2.1-1 Minimum Coated Area in Cargo Holds of Bulk Carriers



※: Coated Area

3 Omission of Painting

In accordance with the requirements of **25.2.1-1, Part C** of the Rules, painting may be omitted under the following circumstances.

(1) Where ships comply with the requirements of **Chapter 31, Part C** of the Rules and their cargoes are regularly handled by grabs or similar machinery, painting for cargo holds may be omitted subject to the following **(a)** and **(b)**.

(a) Omission of painting is to be limited to those members such as inner bottom plates, slant plates of bilge hoppers and slant plates of lower stools of transverse watertight bulkheads whose thickness is increased in accordance with the requirements of **31.2.4-2**, **31.2.4-3**, **31.3.2-2** or **31.5.2-1, Part C** of the Rules. However, omission of painting is not accepted for areas within the extent of painting prescribed in **-2(1)**.

(b) The reason and area of omission of painting are to be prescribed in the plans submitted for approval (for example, “Midship Section”, specified in **Table B2.1, Part B of the Rules**).

(2) Notwithstanding the requirements of **-2(1)** above, ships specified in **Chapter 31, Part C** of the Rules that exclusively carry wood chips do not need to paint the parts where protection from corrosion can be expected due to secretions from the wood chips. However, this applies only to the parts that are in direct contact with the chips (excluding areas such as the inside of the upper deck) and the submission of documentation stipulated in **-3(1)(b)** is required.

The structural members in cargo holds that are in contact with saltwater due to their use as ballast water tanks is to be 1.0*mm* thicker than the scantlings stipulated in **Chapter 31, Part C** of the Rules. However, the structural members stated in **-3(1)(a)** and those in cargo holds used as ballast water tanks only in port need not be thicker.

(3) Where tanks are exclusively loaded with oils, they do not need to be painted in spite of the type of ship.

4 Cathodic Protection System

With respect to the provisions of **25.2, Part C** of the Rules, where a cathodic protection system is adopted as a backup for coating or the omission of painting, the cargo tanks and their adjacent tanks in tankers and ships carrying dangerous chemicals in bulk, intended to carry crude oil and petroleum products having a flash point not exceeding 60°C and Reid vapour pressure below atmospheric pressure or other liquid cargoes having similar fire hazards are to be in accordance with the following requirements.

(1) The anodes are to have steel cores and these are to be sufficiently rigid to avoid resonance in the anode support and be designed so that the anode does not come free when the surroundings become wasted.

(2) The anode is to be provided in accordance with **(a)** or **(b)**. When anode inserts and/or supports are welded to the structure, they are to be arranged so that the welds are clear of stress raisers. The supports at each end of an anode are not to be attached to separate structures which are likely to move independently.

(a) The steel inserts are to be attached to the structure by means of a continuous weld of adequate section.

(b) The steel inserts are to be attached to separate supports which are attached to the structure by means of a continuous weld of adequate section, by bolting, provided a minimum two bolts with locknuts are used or by appropriate mechanical means of clamping deemed as equivalent by the Society.

(3) Where anodes of aluminium or aluminium alloy are used, they are to meet the following requirements.

(a) Anodes are to be located such that their potential energy does not exceed 274.68*N-m*. The height of the anode is to be measured from the bottom of the tank to the centre of the anode, and its weight is to be taken as the weight of the anode as fitted, including the fitting devices and inserts. However, where anodes are located on horizontal surfaces not less than 1*m* wide and fitted with an upstanding flange or face flat projecting not less than 75*mm* above the horizontal surface, the height of the anode may be measured from this surface.

(b) Anodes are not to be located under tank hatches or butterworth openings, unless protected from any objects falling on the fitted anodes by an adjacent structure.

(4) Anodes of magnesium or magnesium alloy are not permitted.

C25.2.2 Protective Coatings in Dedicated Seawater Ballast Tanks and Double-side Skin Spaces

1 The application of **25.2.2-1, Part C** of the Rules with respect to coating system applications is to be in accordance with IACS Unified Interpretations SC223, as may be amended.

2 With respect to the provision of **25.2.2-1, Part C of the Rules,** the following tanks are not considered to be dedicated seawater ballast tanks, provided the coatings applied in the tanks described in **(2)** below are confirmed by the coating manufacturer to be resistant to the media stored in the tanks, and are applied and maintained according to the coating manufacturer’s procedures.

(1) Tanks identified as “Spaces included in Net Tonnage” in the International Convention on Tonnage Measurement of Ships, 1969

(2) Sea water ballast tanks in livestock carriers also designated for the carriage of the livestock dung

3 The “deemed appropriate by the Society” specified in **25.2.2-2, Part C** of the Rules means that full hard coatings in dedicated seawater ballast tanks (including the slop tanks) are to comply with the following **(a)** to **(f)**:

(a) Applicable paints are to be an epoxy type or a type that is as durable and effective against corrosion.

(b) The surfaces of steels are to be properly prepared before coating and the thickness of the coating is to be adequate.

(c) Painting is to be of a hard protective coating unless otherwise approved by the Society.

(d) It is recommended that cathodic protection is applied together with the coatings as a backup.

(e) For dedicated seawater ballast tanks and double-side skin spaces of ship, the coatings are preferably to be of a light colour easily distinguishable from rust.

(f) For cargo holds used as seawater ballast spaces, coating of certain parts may be dispensed with provided that alternative measures are taken for the parts in question.

C25.2.3 Corrosion Protection for Cargo Oil Tanks

1 "Crude oil tankers" in **25.2.3, Part C of the Rules** refers to ships defined in **2.1.1(19), Part 1 of the Rules for Marine Pollution Prevention Systems**, and falling under items 1.11.1 or 1.11.4 of the Supplement to the International Oil Pollution Prevention Certificate (Form B).

2 The requirements of **25.2.3, Part C of the Rules** need not be applied to "combination carrier" defined in **2.1.1(8), Part 1 of the Rules for Marine Pollution Prevention Systems** and "ships carrying dangerous chemicals in bulk" including ships certified to carry oil stipulated in **2.1.1(1), Part 1 of the Rules for Marine Pollution Prevention Systems**.

3 With respect to **25.2.3(1), Part C of the Rules**, IACS Unified Interpretation SC259 as may be amended is to be applied.

4 With respect to **25.2.3(2), Part C of the Rules**, IACS Unified Interpretation SC258 as may be amended is to be applied.

C27 EQUIPMENT

C27.1 Anchors and Chain Cables

C27.1.1 General

1 The "special consideration" referred to in **27.1.1-3, Part C of the Rules** means the evaluation of the design effectiveness of anchors, chain cables and windlasses. For ships for which L_2 is not less than 135 *m*, the following **(1)** to **(4)** may be used for the design or to assess the adequacy of the anchoring equipment. However, the application of these provisions is limited to anchoring operations in water of depths up to 120 *m*, currents up to 1.54 *m/s*, winds up to 14 *m/s* and waves with significant heights up to 3 *m*. Furthermore, the scope of chain cables, being the ratio between the paid-out length of the chain and water depth, is limited to between 3 and 4.

(1) Anchors and chain cables are to be in accordance with **Table C27.1.1-1** and based on the Equipment number EN_1 obtained from the following formula:

$$EN_1 = 0.628\left[a\left(\frac{EN}{0.628}\right)^{1/2.3} + b(1-a)\right]^{2.3}$$

a: As obtained from the following formula:

$$a = 1.83\times10^{-9}L_2^3 + 2.09\times10^{-6}L_2^2 - 6.21\times10^{-4}L_2 + 0.0866$$

b: As obtained from the following formula:

$$b = 0.156L_2 + 8.372$$

L_2: Length (*m*) of ship specified in **2.1.2, Part A** or 0.97 *times* the length of ship on the designed maximum load line, whichever is smaller. The fore end of L_2 is the perpendicular to the designed maximum load draught at the forward side of the stem, and the aft end of L_2 is the perpendicular to the designed maximum load draught at a distance L_2 aft of the fore end of L_2.

EN: Equipment number specified in **27.1.2**, **Part C of the Rules**

(2) Anchors are to be in accordance with the following **(a)** to **(d)**.

(a) Bow anchors are to be connected to their chain cables and positioned on board ready for use.

(b) Anchors are to be of a stockless high holding power (HHP) type. The mass of the head of a stockless anchor, including pins and fittings, is not to be less than 60 % of the total mass of the anchor.

(c) The mass, per anchor, of bower anchors given in **Table C27.1.1-1** is for anchors of equal mass. The mass of individual anchors may vary up to 7% of the tabular mass, but the total mass of anchors is not to be less than that required for anchors of equal mass.

(d) To hold the anchor tight in against the hull or the anchor pocket, respectively, it is recommended to fit anchor lashings appropriately (e.g., by using a "devils claw", etc.).

(3) Bower anchors are to be in accordance with the following **(a)** to **(b)**.

(a) Bower anchors are to be associated with stud link chain cables of special (Grade 2) or extra special (Grade 3) quality. The total length of chain cables, as given in **Table C27.1.1-1,** is to be reasonably divided between the two bower anchors. For the proof and breaking loads of stud link chain cables, reference is made to **Table L3.5, Part L of the Rules**.

(b) For the installation of the chain cables on board, **Chapter 27, Part C of the Rules** is to be observed.

(4) Windlass design and testing as well as chain stopper design are to be in accordance with **Chapter 16, Part D of the Rules.** In addition, windlasses and chain stoppers are to be in accordance with the following **(a)** to **(c)**.

(a) The windlass unit prime mover is to be able to supply a continuous duty pull Z_{cont} (in *N*) for at least 30 *minutes*. Z_{cont} is to be obtained as follows:

$$Z_{cont} = 35d^2 + 13.4m_A$$

d: chain diameter (*mm*) as per **Table C27.1.1-1**

m_A: HHP anchor mass (*kg*) as per **Table C27.1.1-1**

(b) As far as practicable for testing purposes, the test speed of the chain cable during hoisting of the anchor and cable is to be measured over 37.5 *m* of the chain cable and initially with at least 120 *m* of chain and the anchor submerged and hanging free. The mean speed of the chain cable during hoisting of the anchor from the depth of 120 *m* to the depth of 82.5 *m* is to be at least 4.5 *m*/*min*.

(c) For the supporting hull structures of anchor windlasses and chain stoppers, reference is made to the provisions specified in **27.1.6**, **Part C of the Rules**.

Table C27.1.1-1 Anchoring Equipment for Ships in Unsheltered Water of Depths up to 120 *m*

Equipment letter	Equipment number EN_1		High holding power stockless bower anchors		Stud link chain cable for bower anchors		
			Number	Mass per anchor	Length	Diameter	
						Grade 2	Grade 3
	Equal to or greater than	Less than		*kg*	*m*	*mm*	*mm*
-	-	1790	2	14150	1017.5	105	84
*DG*2	1790	1930	2	14400	990	105	84
*DG*3	1930	2080	2	14800	990	105	84
*DG*4	2080	2230	2	15200	990	105	84
*DG*5	2230	2380	2	15600	990	105	84
*DH*1	2380	2530	2	16000	990	105	84
*DH*2	2530	2700	2	16300	990	105	84
*DH*3	2700	2870	2	16700	990	105	84
*DH*4	2870	3040	2	17000	990	105	84
*DH*5	3040	3210	2	17600	990	105	84
*DJ*1	3210	3400	2	18000	990	105	84
*DJ*2	3400	3600	2	18300	990	106	84
*DJ*3	3600	3800	2	19000	990	107	85
*DJ*4	3800	4000	2	19700	962.5	108	87
*DJ*5	4000	4200	2	20300	962.5	111	90
*DK*1	4200	4400	2	21100	962.5	114	92
*DK*2	4400	4600	2	22000	962.5	117	95
*DK*3	4600	4800	2	22900	962.5	119	97
*DK*4	4800	5000	2	23500	962.5	122	99
*DK*5	5000	5200	2	24000	935	125	102
*DL*1	5200	5500	2	24500	907.5	130	105
*DL*2	5500	5800	2	25000	907.5	133	107
*DL*3	5800	6100	2	25500	880	137	111
*DL*4	6100	6500	2	25700	880	140	113
*DL*5	6500	6900	2	26000	852.5	143	115
*DM*1	6900	7400	2	26500	852.5	147	118
*DM*2	7400	7900	2	27000	825	152	121
*DM*3	7900	8400	2	27500	825	154	123
*DM*4	8400	8900	2	28000	797.5	158	127
*DM*5	8900	9400	2	28900	770	162	132
*DN*1	9400	10000	2	29400	770		135
*DN*2	10000	10700	2	29900	770		139
*DN*3	10700	11500	2	30600	770		143
*DN*4	11500	12400	2	31500	770		147
*DN*5	12400	13400	2	33200	770		152
*DO*1	13400	14600	2	35000	770		157
-	14600	-	2	38000	770		162

C27.1.2 Equipment Numbers

1 Significant figures are to be taken as follows:

(1) Dimensions, such as length, height, and breadth are to be in metres rounded to two decimal places.

(2) The displacement W is to be measured in tons in whole numbers.

(3) Terms in the formula ($W^{2/3}$, $2.0(hB+S_{fun}$, $0.1A$) are to be rounded to the nearest whole number.

Example

$L = 313.00\ m$ (Designed)
$L = 313.06\ m$ (Scantling)
$B = 48.20\ m$
$D = 25.50\ m$
$d = 19.00\ m$ (Designed)
$d_s = 19.8\ m$ (Scantling)
$W = 253{,}800\ t$ (Scantling)
$f = 25.50 - 19.80 = 5.70$
$h' = 2.70 \times 4 + 2.80 \times 1 = 13.60$
$h = 5.70 + 13.60 = 19.30$
$f \times L = 5.70 \times 313.06 = 1{,}784.4$
(figures below 1st place of decimals omitted)

$(h'' \times l)$
Upper deck house $= 2.70 \times 40.85 = 110.2$
(figures below 1st place of decimal omitted)
A deckhouse $= 2.70 \times 40.85 = 110.2$ (〃)
B deckhouse $= 2.70 \times 34.85 = 94.0$ (〃)
+) C deckhouse $= 2.70 \times 34.85 = 94.0$ (〃)
$\sum(h'' \times l) = 408.4$

$A = 1{,}784.4 + 408.4 = 2{,}192$ (fraction omitted)
$W^{2/3} = 253{,}800^{2/3} = 4{,}009$
(whole number rounded to nearest)
$2.0\,hB = 2.0 \times 19.30 \times 48.20 = 1{,}861$ (〃)
+) $0.1\,A = 0.1 \times 2{,}192 = 219$ (〃)
Equipment number $= 6{,}089$

2 Measurement of breadth of structures for second term of the formula in **27.1.2, Part C of the Rules**

(1) Structures are to be treated as separated above and below by a deck level. A continuous superstructure or deckhouse situated on one tier is to be treated as a single structure irrespective of the mode of variation of their breadth and height, continuous or discontinuous, and the breadth is to be the largest one as shown in **Fig. C27.1.2-1**.

(2) As for detached independent deckhouses on one tier, breadths of respective deckhouses are to be measured separately to determine whether they are to be included or not. (*See* **Fig. C27.1.2-2**)

(3) Where a deckhouse having a breadth greater than $B/4$ is above a deckhouse with a breadth of $B/4$ or less, the narrow deckhouse may be ignored. (*See* **Fig. C27.1.2-3**)

(4) When calculating h, sheer and trim are to be ignored. (*See* **Fig. C27.1.2-4**)

3 Side projected area A may be in accordance with following **(1)** and **(2)**.

(1) The area of deck camber may disregarded when determining side projected area A.

(2) Side projected area A may be calculated using following formula.

(a) A is the value obtained from the following formula:

$aL_2 + \sum h''l$

$\Sigma h''l$: Sum of the products of the height h'' (m) and length l (m) of superstructures, deckhouses, trunks or funnels which are located above the uppermost continuous deck within L_2 and also have a breadth greater than $B/4$ and a height greater than 1.5 m

(b) Structures are to be treated as separated above and below by a deck level. A continuous superstructure or deckhouse situated on one tier is to be treated as a single structure irrespective of the mode of variation of their breadth and height, continuous or discontinuous. The length of the single structure is to be the value at the largest point. However, if the height is not more than 1.5 *m*, the part of the single structure is to be ignored. (See **Fig. C27.1.2-5**)

(c) h'' is the height (m) at the centreline of each tier of deckhouses having a breadth greater than $B/4$.

Fig. C27.1.2-1

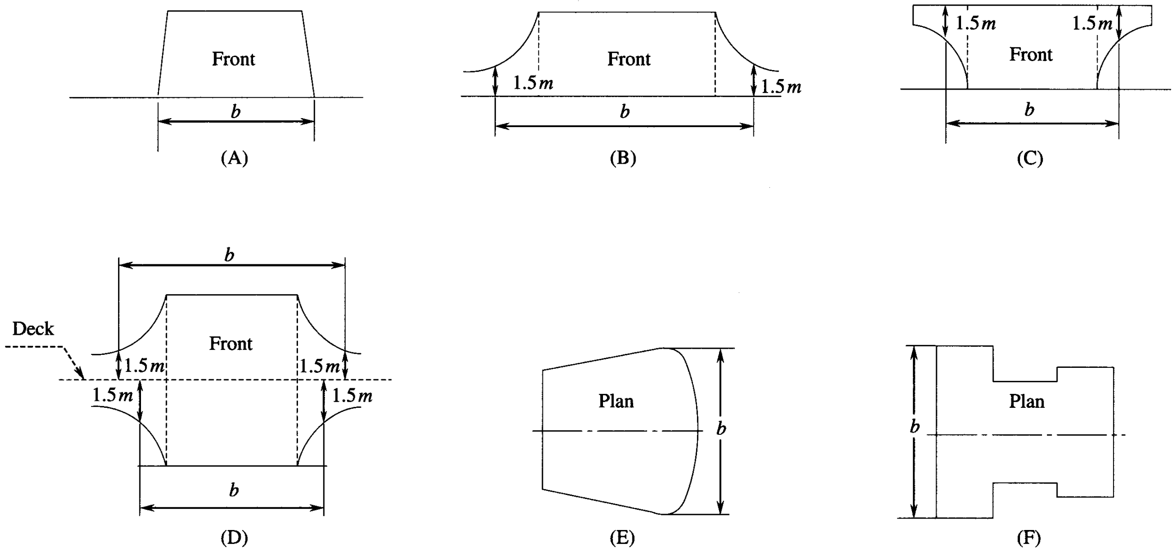
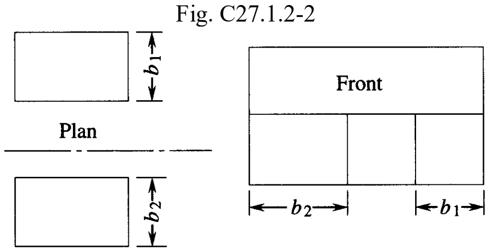


Fig. C27.1.2-2



Note:

If both b_1 and b_2 are less than $B/4$, they are not to be included (irrespective of the sum b_1+b_2)

4 Structures to be included in the third term of the formula in **27.1.2, Part C of the Rules**

(1) The following items may be excluded from ship side projected area A:

(a) portions outside the fore and aft ends of L

(b) derrick posts, ventilators, etc. in continuation with superstructures or deckhouses

(c) cargoes loaded on decks

Fig. C27.1.2-3

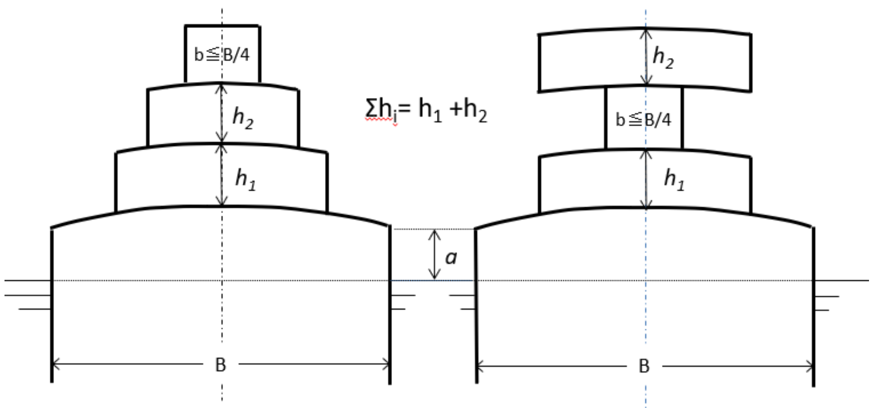


Fig. C27.1.2-4

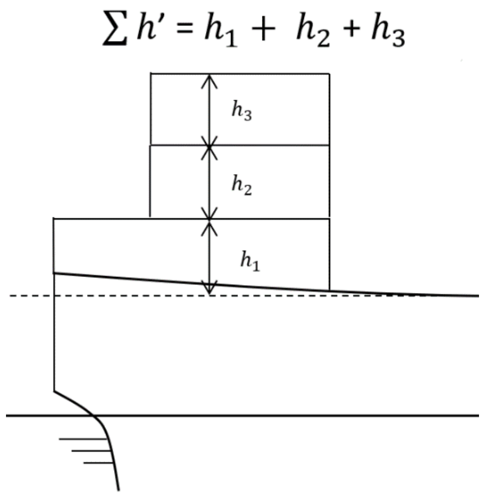
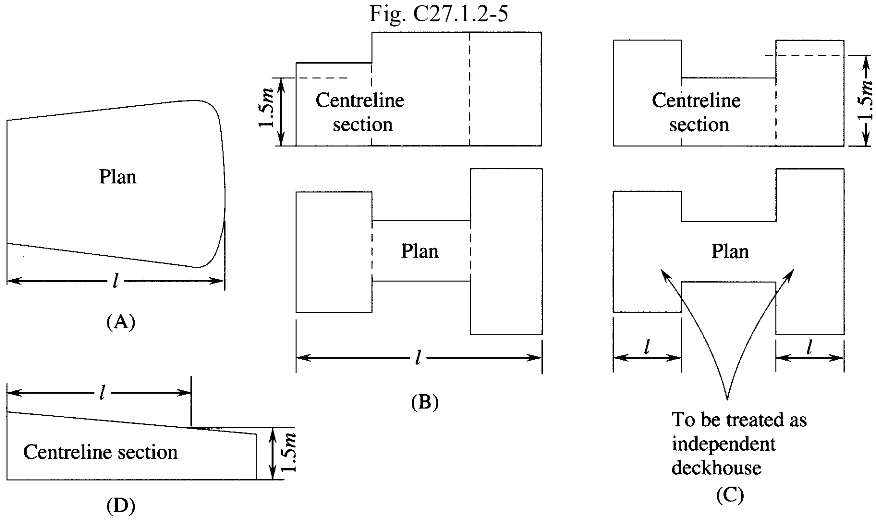


Fig. C27.1.2-5



C27.1.5 Chain Lockers

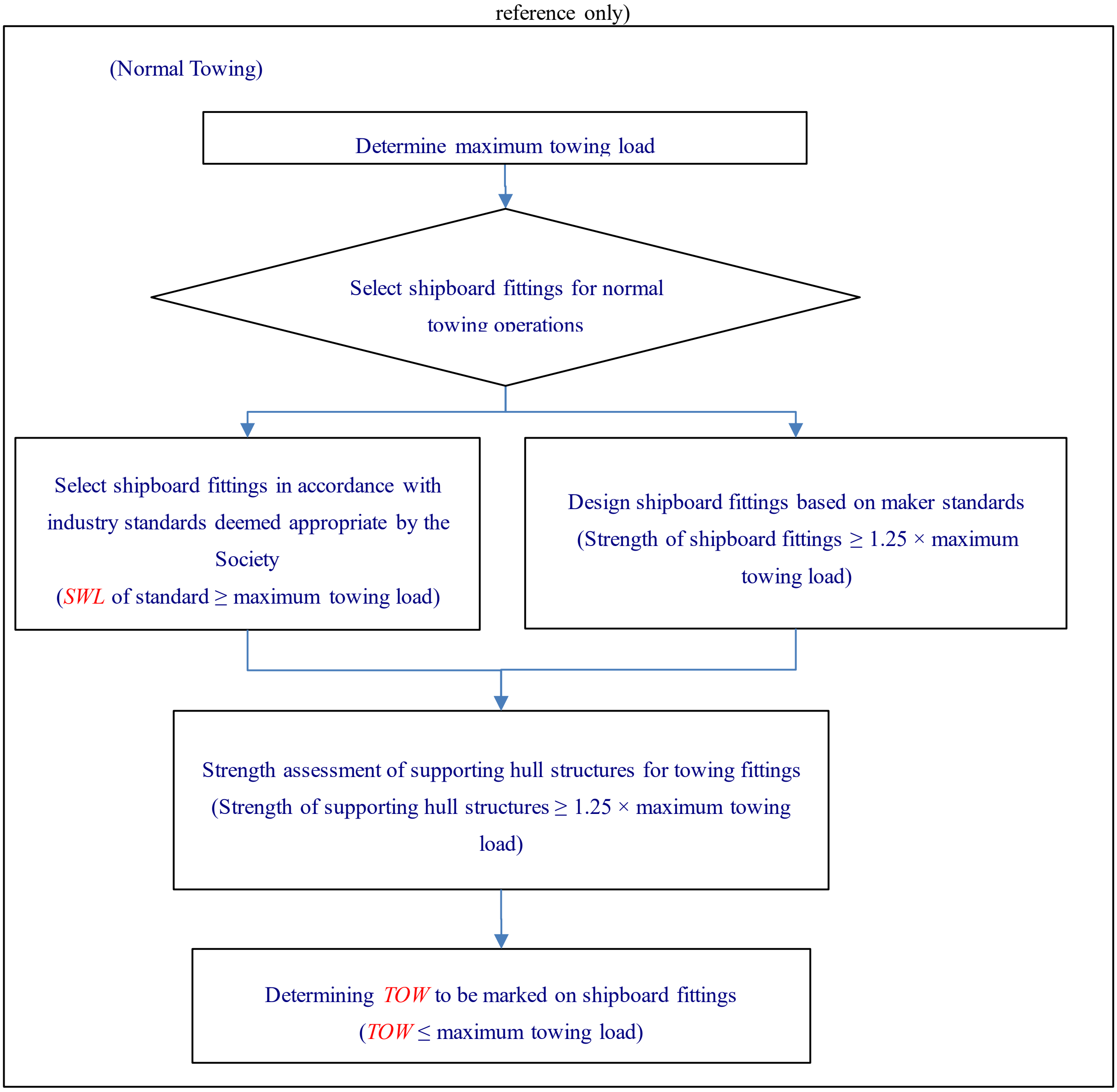
The wording "the access cover and its securing arrangements to the satisfaction of the Society" in **27.1.5-5, Part C of the Rules** means those which are in accordance with *JIS* F 2304, *JIS* F 2329, or *ISO* 5894:1999 or their equivalent.

C27.2 Towing and Mooring Fittings

C27.2.1 General

With respect to the provisions of **27.2, Part C of the Rules**, the flow charts shown in **Fig. C27.2.1-1** and **Fig. C27.2.1-2** are standard methods for the design processes of tow lines, mooring lines, shipboard fittings and their supporting hull structures.

Fig. C27.2.1-1 Standard Design and Selection Process for Tow Lines, Towing Arrangements and Supporting Hull Structures (for reference only)



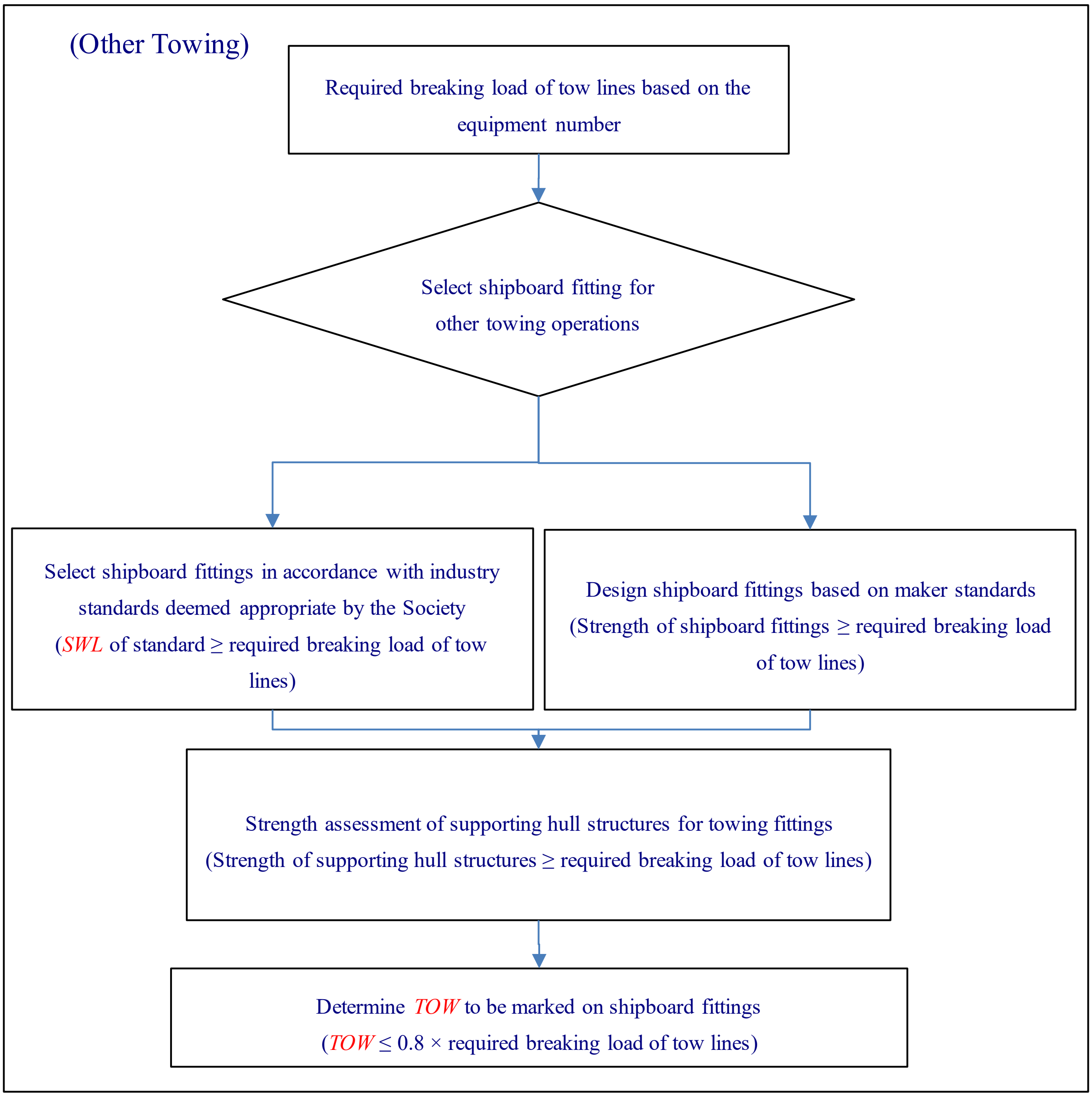
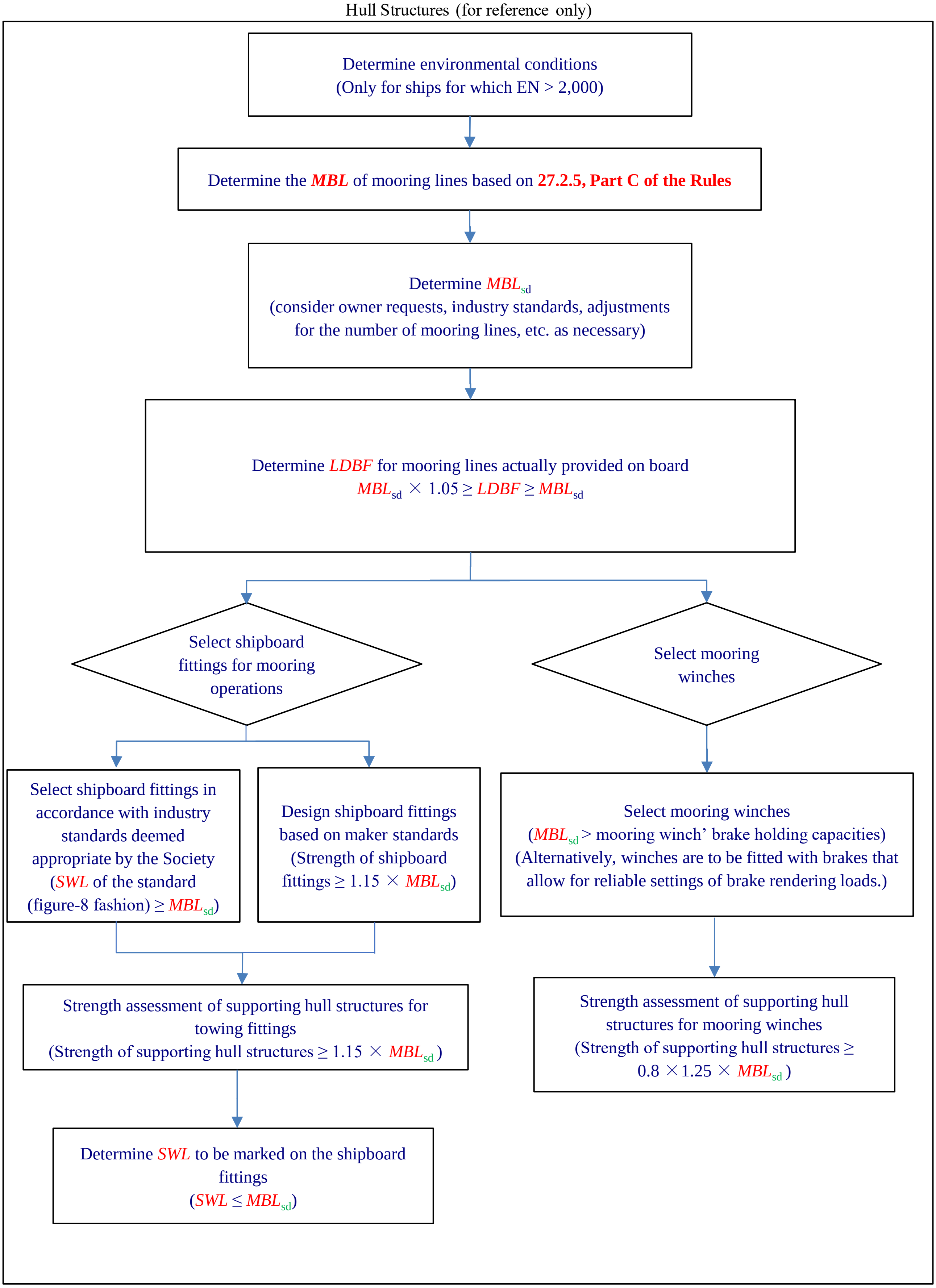

(Other Towing)
Required breaking load of tow lines based on the equipment number
Select shipboard fitting for other towing operations
Select shipboard fittings in accordance with industry standards deemed appropriate by the Society (SWL of standard ≥ required breaking load of tow lines)
Design shipboard fittings based on maker standards (Strength of shipboard fittings ≥ required breaking load of tow lines)
Strength assessment of supporting hull structures for towing fittings
(Strength of supporting hull structures ≥ required breaking load of tow lines)
Determine TOW to be marked on shipboard fittings
(TOW ≤ 0.8 × required breaking load of tow lines)

Fig. C27.2.1-2 Standard Design and Selection Process for Mooring Lines, Mooring Arrangements, Mooring winches and Supporting Hull Structures (for reference only)



C27.2.3 Towing Fittings

1 "Industry standards deemed appropriate by the Society" as prescribed in **27.2.3-3(1), Part C of the Rules**, means international standards or national standards such as *ISO*, *JIS F*, etc.

2 The provisions for the *TOW* specified in **27.2.3-6, Part C of the Rules** are applied for the use of no more than one line. If not otherwise specified the *TOW* for towing bitts (double bollards) is the load limit for tow lines attached with eye splices.

3 Towing arrangements are recommended as follows.

(1) Tow lines are to be led through a closed chock. The use of open fairleads with rollers or closed roller fairleads is to be avoided.

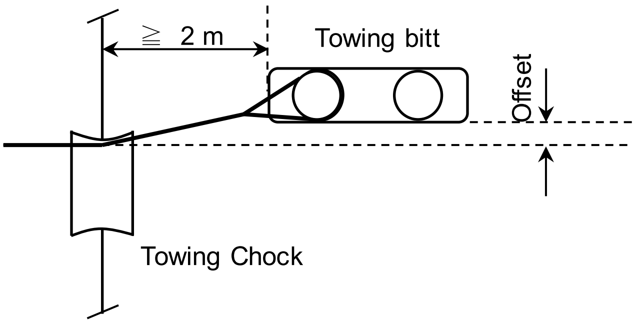
(2) It is recommended to provide at least one chock close to centreline of the ship forward and aft. It is beneficial to provide additional chocks on the port and starboard sides at the transom and at the bow.

(3) Tow lines are to have a straight lead from the towing bitt or bollard to the chock. Bitts or bollards serving chocks are to be located slightly offset and at a distance of at least 2 *m* away from the chock. (See **Fig. C27.2.3-1**)

(4) Warping drums are to be positioned not more than 20 *m* away from chocks measured along the path of the line as far as practicable.

(5) Attention is to be given to the arrangement of the equipment for towing and mooring operations in order to prevent interference of mooring and tow lines as far as practicable.

Fig. C27.2.3-1 Sample Arrangement of Towing Fittings



C27.2.6 Mooring Fittings

1 The requirements in **27.2, Part C of the Rules** also apply to additional mooring fittings as well as their supporting hull structures. However, MBL_{sd} specified in **27.2.6-3(1), Part C of the Rules** and MBL_{sd} specified in **27.2.6-4, Part C of the Rules** may be read as assumed values in consideration of the intended use. This information is to be incorporated into the towing and mooring arrangement plan specified in **27.2.9, Part C of the Rules.**

2 The "industry standards deemed appropriate by the Society" referred to in **27.2.6-3(1), Part C of the Rules** means international standards or national standards such as *ISO*, *JIS F*, etc.

3 The provisions for *SWL* specified in **27.2.6-6, Part C of the Rules** apply only in cases where no more than one line is used.

4 Attention is to be given to the arrangement of the equipment for mooring operations in order to prevent interference of the mooring lines as far as practicable.

C27.2.9 Towing and Mooring Arrangements Plan

1 It is recommended that the information related to safe towing and mooring operation in the towing and mooring arrangement plan specified in **27.2.9, Part C of the Rules** is incorporated into the pilot card in order to provide pilots with relevant information on harbour or escort operations.

2 With respect to the provisions specified in **27.2.9-2(6), Part C of the Rules**, the design condition related to **27.2.5-3(2), Part C of the Rules** is to be described in this plan as a note.

C27.2.11 Inspection and Maintenance of Mooring Equipment Including Mooring Lines

The wording "deemed appropriate by the Society" in **27.2.11, Part C of the Rules** means those which are in accordance with **B2.1.6-10, Part B of the Guidance**.

C27.3 Emergency Towing Arrangements

C27.3.2 General

1 "Emergency towing arrangements approved by the Society" specified in **27.3.2-1, Part C** of the Rules refer to emergency towing arrangements that comply with the requirements in **C27.3.2-2** to **-13** and the requirements specified in the following **(1)** or **(2)**.

(1) Where a prototype of the emergency towing arrangement is arranged in the same manner as it is to be installed on board the ship, the prototype test is to be carried out in accordance with the requirements specified in **Chapter 6, Part 2 of** "**Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**" and a production test of individual components is to be carried out in accordance with the same requirements.

(2) Emergency towing arrangements are to comply with the requirements specified in the following **(a)** to **(c)**.

(a) Loose gear such as chafing gear or towing pennants among the components listed in **Table C27.3.2-1 and Table C27.3.2-2** are to be tested according to the requirements of **Part K or Part L** of the Rules or other standards deemed appropriate by the Society.

(b) Fixed gear such as strong points and fairleads among the components listed in **Table C27.3.2-1** are to be tested according to the requirements of **Part K or Part L** of the Rules or other standards deemed appropriate by the Society. A strength analysis of the foundations of these components and associated supporting structures including reinforced members is to be carried out according to the conditions specified in **C27.3.2-3** and confirmation that these components have adequate strength corresponding to the type of emergency towing arrangements is to be made. Where the structural configuration of the arrangement is of a particularly complex or novel nature that a strength analysis cannot be satisfactorily carried out, a suitable load test deemed appropriate by the Society is to be carried out.

(c) After the emergency towing arrangements are installed on board, it is to be demonstrated that the requirements specified in **C27.3.2-11, C27.3.2-12 and C27.3.2-13** are satisfied.

Table C27.3.2-1 The Major Components of an Emergency Towing Arrangement

Components	Non pre-rigged emergency towing arrangement	Pre-rigged emergency towing arrangement
Pick-up gear	Optional	Yes
Towing pennant	Optional	Yes
Fairlead	Yes	Yes
Strongpoint	Yes	Yes
Roller pedestal	Yes	Depending on design

Table C27.3.2-2 Chafing Gear

Components	Emergency towing arrangements fitted at forward of ship	Emergency towing arrangements fitted at aft of ship
Chafing gear	Yes	Depending on design

2 The major components of an emergency towing arrangement are listed in **Table C27.3.2-1 and Table C27.3.2-2**.

3 The major components of an emergency towing arrangement are to comply with the following **(1)** and **(2)**.

(1) Towing pennants, chafing gear, fairleads and strongpoints are to have at least the following working strength corresponding to the type of emergency towing arrangement.

(a) For 1,000 kN type emergency towing arrangement: 1,000 kN

(b) For 2,000 kN type emergency towing arrangement: 2,000 kN

Where working strength is defined as one half the ultimate strength

The strength is to be sufficient for all relevant angles of the towline, *i.e.* up to 90° from the ship's centreline to port and starboard and 30° downwards.

(2) Other components are to have a working strength sufficient to withstand the load to which such components may be subjected during the towing operation.

4 The towing pennant is to comply with the following **(1)** and **(2)**.

(1) The towing pennant is to have a length of at least twice the lightest seagoing ballast freeboard at the fairlead plus 50 *m*.

(2) The towing pennant is to have a hard eye-formed termination allowing connection to a standard bow shackle.

5 The strongpoint and fairlead is to be located so as to facilitate towing from either side of the bow or stern and minimize the stress on the towing system.

6 For strongpoints, the inboard end fastening is to be a stopper or bracket or other fitting of equivalent strength. The strongpoint can be integrated with the fairlead.

7 Fairleads are to comply with the following **(1)** to **(4)**.

(1) Fairleads are to have an opening large enough to pass the largest portion of the chafing gear, towing pennant or towing line.

(2) The fairlead is to give adequate support for the towing pennant during towing operation which means bending 90° to port and to starboard side and 30° downwards.

(3) The bending ratio (towing pennant bearing surface diameter to towing pennant diameter) is to be not less than 7 to 1.

(4) The fairlead is to be located as close as possible to the deck and, in any case, in such a position that the chafing chain is approximately parallel to the deck when it is under strain between the strongpoint and the fairlead.

8 If a chafing chain may be used, the chafing chain is to comply with the following **(1)** to **(4)**.

(1) The chafing chain is to be a Grade 2 chain or Grade 3 chain specified in **Chapter 3, Part L** of the Rules. For each type of emergency towing arrangement, the nominal diameter of chafing chains is to comply with the value indicated in **Table C27.3.2-3**.

(2) The chafing chain should be long enough to ensure that the towing pennant remains outside the fairlead during the towing operation. A chain extending from the strongpoint to a point at least 3 *m* beyond the fairlead may meet this requirement.

(3) One end of the chafing chain is to be suitable for connection to the strongpoint. The other end is to be fitted with a pear-shaped open link allowing connection to a standard bow shackle.

(4) The chafing chain is to be stowed in such a way that it can be rapidly connected to the strongpoint.

Table C27.3.2-3 Nominal Diameter of Chafing Chains

Type of emergency towing arrangements	Nominal diameter of chains (*mm*)	
	Grade 2 chain	Grade 3 chain
1,000 *kN* type	62 min	52 min
2,000 *kN* type	90 min	76 min

9 The pick-up gear is to comply with the following **(1)** to **(3)**.

(1) The pick-up gear is to be protected against the weather and other adverse conditions that may prevail.

(2) The pick-up gear is to be floatable.

(3) A marker buoy with aself-ignition light is to be provided.

10 All emergency towing arrangements are to be clearly marked to facilitate safe and effective use even in darkness and poor visibility.

11 The pre-rigged emergency towing arrangement is to comply with the following **(1)** to **(2)**.

(1) The emergency towing arrangement is to be capable of being deployed according to its operation manual in harbour conditions in not more than 15 minutes.

(2) The pick-up gear for the aft towing pennant is to be designed at least for manual operation by one person taking into account both of the following conditions.

(a) Absence of power

(b) The potential for adverse environmental conditions that may prevail during such emergency towing operations

12 The non pre-rigged emergency towing arrangement is to be capable of being deployed according to its operation manual in harbour conditions in not more than 1 hour.

13 The forward emergency towing arrangement is to be designed at least with a means of securing a towline to the chafing gear using a suitably positioned pedestal roller to facilitate connection of the towing pennant.

C29 TANKERS

C29.1 General

C29.1.1 Application

1 With respect to the provisions of **29.1.1-2**, **Part C** of the Rules, ships intended for the carriage of liquid cargoes having a vapour pressure less than 0.28 *MPa* at 37.8°C other than crude oil and oil petroleum products, are to be in accordance with the following.

(1) For tankers carrying liquid cargoes with a specific gravity ρ exceeding 1, the scantlings of structural members composing the cargo oil tank are to be the greater of the values obtained by the following two procedures.

(a) All scantlings calculated in accordance with the relevant requirements of the Rules

(b) Scantlings calculated by structural member type as follows

i) The scantlings of bulkhead plates, stiffeners attached to bulkhead plating, and girders attached to bulkhead plating are to be calculated by multiplying h by ρ before using the formulae specified in **29.4**, **29.5** and **29.6, Part C** of the Rules.

ii) The scantlings of girders and floors in the double bottom and girders and transverses in the double side hull are to be calculated by multiplying h' by ρ before using the formulae specified in **29.6.3** and **29.6.4, Part C** of the Rules. Where the load from the cargo oil tank is considered in determining h_i specified in **C29.5.1(1)**, the load is to be multiplied by ρ.

iii) The values of ρ are to be determined for respective cases unless shown in **Table C29.1.1-1**.

(2) For tankers carrying dangerous chemicals in bulk, the requirements in **Part S** of the Rules are also to be applied.

Table C29.1.1-1 Values of ρ

Cargo	ρ
Molasses	1.4
Asphalt	1.1
Concentrated sulphuric acid	1.85

2 Proposal of novel construction type

In the event that a novel construction type is proposed, scantlings are to be determined by carrying out comparative calculations with the standard structural model conforming to the requirements of the Rules. Submission of data covering the results of model experiments or real ship experiments may be requested by the Society as necessary.

C29.1.2 Location and Separation of Spaces

1 Size and arrangement of cargo oil tanks and segregated ballast tanks.

The size and arrangement of cargo oil tanks and segregated ballast tanks are to comply with the requirements of **3.2.1**, **3.2.3**, **3.3.1-3** and **3.3.1-4, Part 3 of the Rules for Marine Pollution Prevention Systems**.

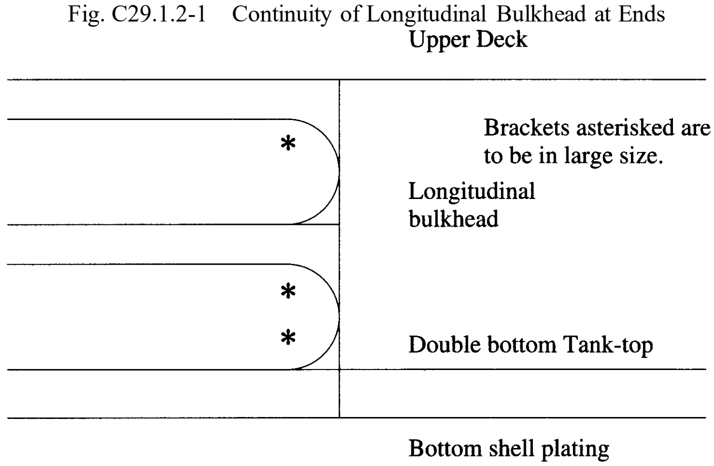
2 Restriction on arrangements of double hull structures and double bottom structures

Arrangements of double side hulls and double bottoms are to comply with the requirements of **3.2.4, Part 3 of the Rules for Marine Pollution Prevention Systems**.

3 Continuity of longitudinal bulkhead

At the forward and afterward ends of cargo oil tanks, precautions are to be taken to keep continuity between the ends of longitudinal bulkheads and the longitudinal members of the deck. (*See* **Fig. C29.1.2-1**)

Fig. C29.1.2-1 Continuity of Longitudinal Bulkhead at Ends



4 Cofferdams and bulkheads bounding cargo oil tanks

(1) "Cofferdam" referred to in **29.1.2-2, Part C** of the Rules means an isolating void space between two adjacent steel bulkheads or decks. In case of the cofferdam between bulkheads, it is to be arranged to keep the minimum distance of 600 *mm* between bulkheads.

(2) Where a cargo oil tank is adjacent to the fore peak (fore peak tank), the collision bulkhead is to be free from openings. (*See* **14.3.2** and **14.3.3, Part D** of the Rules)

(3) Divisions between compartments defined as cofferdams and other compartments (except cargo oil tanks and fuel oil tanks) are not to have any openings with the exception of bolted watertight manholes provided in chain locker bulkheads, etc. (no watertight door is permitted).

(4) Electrical equipment is to be dealt with referring to the relevant requirements in **Chapter 4, Part H** of the Rules.

5 Airtight bulkheads

(1) Cofferdams which are not utilized as main or auxiliary pump rooms and compartments utilized as cofferdams under the freeboard deck are to meet the requirements for the strength of deep tanks. The bulkhead between the main pump room and engine room is to have structural scantlings of a watertight bulkhead in ships of not less than 100 *m* in length and of an airtight bulkhead in ships of less than 100 *m* in length.

(2) The following values are standard for scantlings of airtight bulkheads for which no hydrostatic tests are required. Airtightness tests may be replaced by hose tests. The plate thickness is not to be less than 6 *mm*, which may, however, be reduced to 4.5 *mm* in ships of less than 100 *m* in length. The section modulus of stiffeners and girders is to be 50% of the Rule requirements for watertight bulkheads. Where connected to the shell and decks, however, these stiffening members are to have the same effectiveness as frames and beams.

6 Superstructures and deckhouses

The deckhouse protecting the entrance to pump rooms is to be in accordance with the following requirements.

(1) The strength of the front wall is to be equivalent to that of the wall of the bridge.

(2) The strength of side walls and after wall are to be equivalent to that of the front wall of the poop.

(3) The height of doorway coamings is not to be less than 600 *mm* above the freeboard deck. However, the height may be reduced to not less than 450 *mm* for ships with a class notation of *Coasting Service*.

C29.4 Bulkhead Plating

C29.4.1 Bulkhead Plating in Cargo Oil Tanks and Deep Tanks

1 "Bulkhead plating" referred to in this Chapter means those plate members used in the boundaries of cargo oil tanks and deep tanks which include longitudinal bulkheads, transverse bulkheads, decks plates, side shell and inner bottom plates.

2 Distribution of Δh in double hull structures and the measurement of b are to be in accordance with **Fig. C29.4.1-1** or **Fig. C29.4.1-2**.

Fig. C29.4.1-1 Case of L-type of Tanks

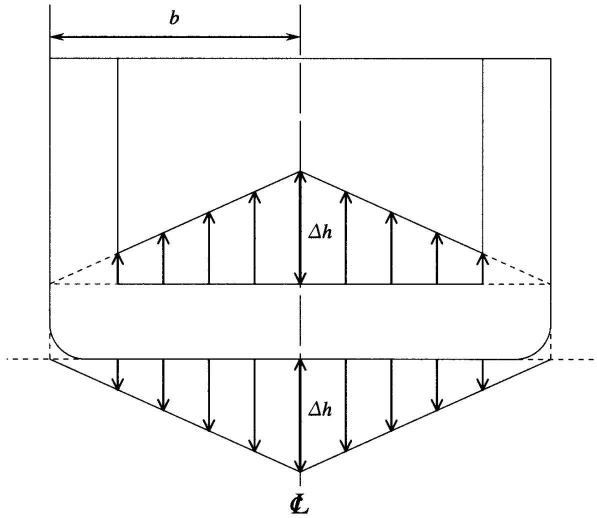
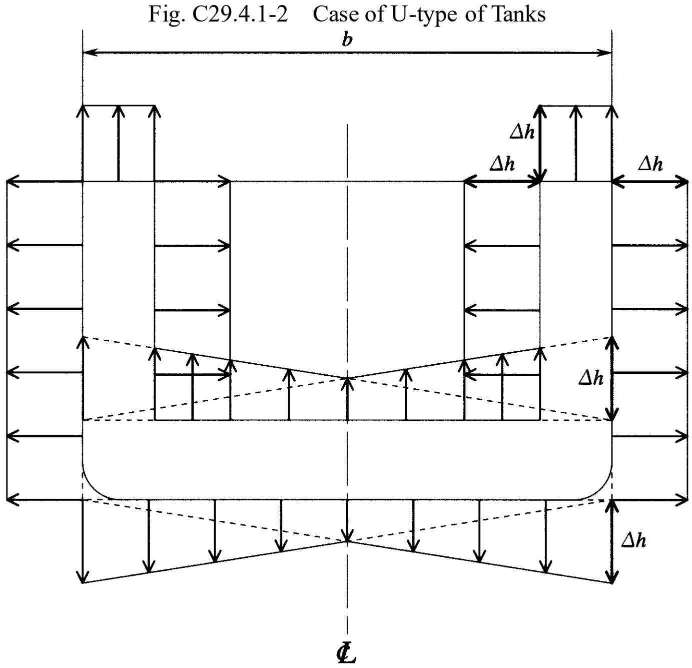


Fig. C29.4.1-2 Case of U-type of Tanks



C29.4.2 Swash Bulkheads

1 Arrangements of swash bulkheads

Where the length or breadth of a cargo oil tank exceeds, 15 m or $0.1L$ (m), whichever is greater, swash bulkheads are to be provided in cargo oil tanks. However, this requirement may be dispensed with if special consideration is given to sloshing.

(1) The breadth and thickness of the uppermost and lowest strakes of the centreline swash bulkhead may be 90% of those required by the Rules for the uppermost and lowest strakes (respectively) of the longitudinal oiltight bulkhead.

(2) The “opening ratio” means the ratio of the sum of areas of openings (except slots and scallops) to the area of the bulkhead.

(3) The section modulus of stiffeners is to be obtained from the following formula.

It is not to be less than 2.0.

$CSh_s l^2$ (cm^3)

Where:

S: Spacing (m) of stiffeners

l: Span (m) of stiffener between supports

C: Coefficients given below:

Both ends effectively bracketed: 7.1

One end effectively bracketed and the other end supported by girder: 8.4

Both ends supported by girders: 10.0

h_s: Value obtained from the following formula

It is not to be less than 2.0.

$$\left(0.176 - \frac{0.025}{100}L\right)(1-\alpha)l_t$$

Where:

L: Length (m) of ship

α: Opening ratio of bulkhead plating

l_t: Length (m) of tank

(4) In applying the requirements of **29.6.5-1** to **29.6.5-3, Part C** of the Rules, the scantlings of girders supporting stiffeners are to be obtained in such a way that values of h specified in the requirements under consideration referred to are not less than that obtained by substituting h with h_s specified in **(3)**.

C29.5 Longitudinals and Stiffeners

C29.5.1 Longitudinals

Where section struts are provided in an intermediate space between floors in the double bottom, the following requirements **(1)** and **(2)** are to be complied with.

(1) Section struts, where provided, are to be sections other than flat bars or bulb plates, and are to be arranged so that they are sufficiently overlapped with webs of the bottom and inner bottom longitudinals (*See* **C6.4.4**). The sectional area A of the section struts is not to be less than the value obtained from the following formula:

$$A = 1.8CSbh \ \ (cm^2)$$

Where:

S: Spacing (m) of frames

b: Breadth (m) of part supported by section strut

h: Value obtained from the following formula (m)

It is not to be less than d.

$$h = \frac{d + 0.026L' + h_i}{2} \ (m)$$

L': Length (m) of ship

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

h_i: h specified in **29.4.1-1, Part C** of the Rules, applies to inner bottom longitudinals. In this case, h is that of the inner bottom plating of cargo oil tanks or deep tanks immediately above the inner bottom longitudinals under consideration.

C: Coefficient obtained from the following formula

However, it is not to be less than 1.43.

$$C = \frac{1}{1 - 0.5\frac{l_s}{K}}$$

l_s: Length (m) of section strut

k: The minimum radius of gyration of section strut obtained from the following formula:

$$k = \sqrt{\frac{I}{A}} \ (cm)$$

I: The least moment (cm^4) of inertia of section strut

A: Sectional area (cm^2) of section strut

(2) Where section struts specified in **(1)** above are provided at the centre between floors, the section module of bottom longitudinals and inner bottom longitudinals may be obtained by multiplying 0.625 by the value obtained in accordance with **29.5.1-1** and **29.5.2-1, Part C** of the Rules.

C29.6 Girders

C29.6.1 General

1 If the spacing of girders and floors in the double bottom and stringers and transverses in the double side hull according to **29.6.1-2, Part C** of the Rules are smaller than the values shown in **(1)** and **(2)** in tankers without partial loading conditions (such as half-loading or alternate loading), the spacing may be increased to the values given in **(1)** and **(2)**.

(1) Girders in the double bottom and stringers in the double side hull: 4.1 (m)

(2) Floors in the double bottom and transverses in the double side hull: 2.8 (m)

2 For tankers specified in **29.6.1-3, Part C** of the Rules, the arrangement and scantlings of girders in the double bottom and double side hull of these tankers are to be determined by an appropriate design procedure taking account for their structure, loading conditions, etc. Necessary plans and documents which show the propriety of the design procedure are to be submitted for approval beforehand.

C29.6.2 Direct Strength Calculations for Girders

1 General

(1) Where scantlings of girders (including plate members connected thereto) are determined by direct strength calculation, the necessary documents and data on the calculation method are to be submitted beforehand to the Society for approval.

(2) Except where specifically provided for in this part, strength calculations are to be in accordance with **Annex C1.1.22-1 Guidance for Direct Strength Calculation**.

2 Structural modelling

(1) Range of analysis

The range of structure to be analyzed is one side of the two adjacent cargo oil tanks in the parallel body part, including the whole length or half length of each cargo oil tank and transverse bulkhead between these two tanks. However, this range is to be extended if necessary so that every condition can be reproduced considering the arrangement of ballast tanks in double hull structures, loading patterns of cargo oil and ballast, and longitudinal and transverse symmetries of the bulkheads and girders attached thereto.

(2) Structural modelling

Structural modelling is, in principle, to be of shell elements, and the following standards **(a)** to **(c)** apply to divisions in meshing.

(a) In meshing, proper sizes of meshes are to be selected by predicting the stress distribution in the model, and meshes with abnormally large aspect ratios are to be avoided.

(b) Girders and similar members having stress gradients along their depth are to be so meshed as to enable their discrimination.

(c) The length of the short side of each mesh is to be restricted to frame spacing or thereabouts.

3 Load

Load to be applied to structural models are to be a combination of internal loads and external loads specified below. Where, however, another combination of loads is clearly severer than that specified, the latter may be omitted.

(1) Internal loads

(a) Hydrostatic test condition

The water head is to be the vertical distance (m) from each point to 2.4 m above the top of the tank. Examples are shown in **Table C29.6.2-1** to **Table C29.6.2-3**.

(b) Navigating condition

The loading conditions for consideration are, in principle, to be the full load condition and ballast condition. Where special loading conditions such as two-ports loading is predicted, such cases are to be included. Examples are shown in **Table C29.6.2-1** to **Table C29.6.2-3**.

i) Water head h' at each position in cargo oil tanks is to be obtained from the following formula:

$$h' = \rho(h + \Delta h)\ (m)$$

Where:

ρ: Maximum designed specific gravity of cargo as given in the Loading Manual

h: Vertical distance (m) measured from the position under consideration to the top of hatch However, for lower cargo oil tanks in tankers having mid-decks, it is to be the vertical distance (m) measured from the position under consideration on the level of mid-deck.

Δh: As specified in the provisions of **29.4.1, Part C of the Rules**

ii) Water head h' at each position in ballast tanks is to be obtained from the following formula:

$h' = \rho h$ (m)

Where:

ρ: 1.025

h: Vertical distance (m) measured from the position under consideration to the mid-point of the distance between the tops of the tanks and the tops of the overflow pipes

iii) Requirements prescribed in **ii)** also apply to cargo oil tanks which may be utilized as ballast tanks at sea.

iv) For water head in ships in harbour or similar quiet waters, Δh does not need to be considered.

Table C29.6.2-1 Case of Two Rows of Longitudinal Bulkheads

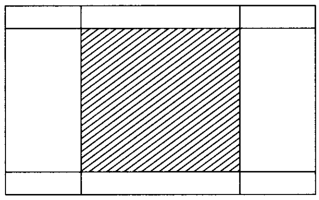
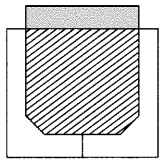
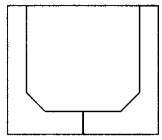
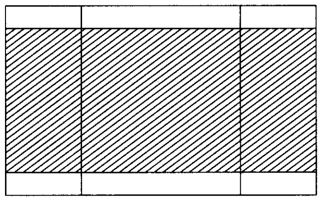
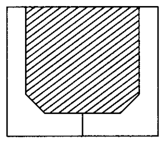
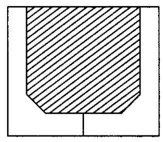
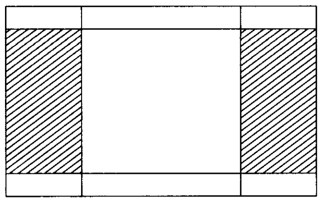
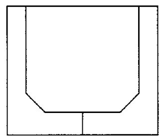
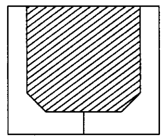
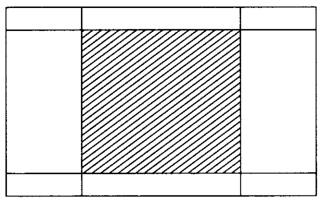
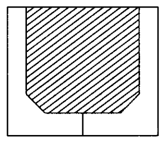
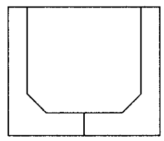
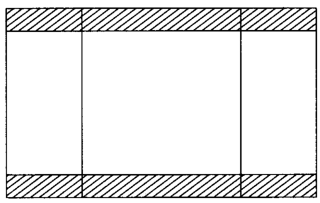
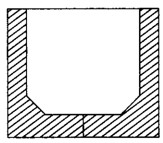
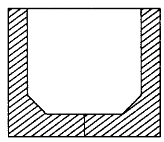
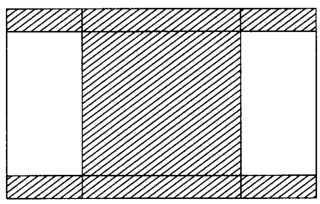
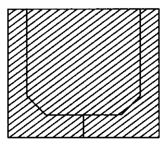
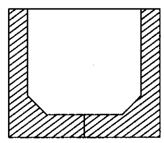
	Case	Loading pattern	Centre tank	Fore and aft tanks
Hydrostatic test condition	*T*-1			
Full load and special loading conditions	*F*-1			
	F-2			
	F-3			
Ballast condition	*B*-1			
	B-2			

Table C29.6.2-2 Case of Three Rows of Longitudinal Bulkheads

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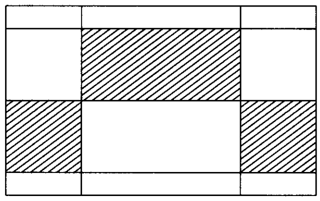
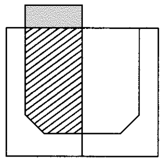
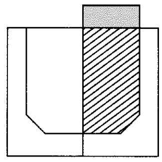
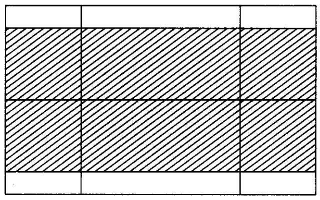
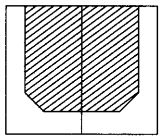
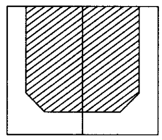
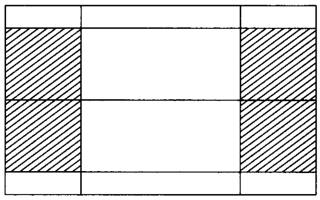
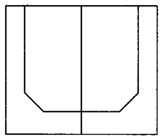
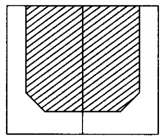
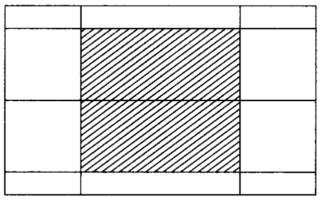
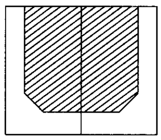
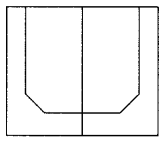
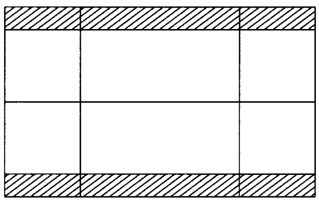
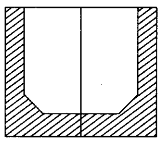
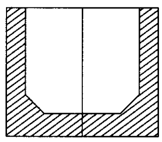
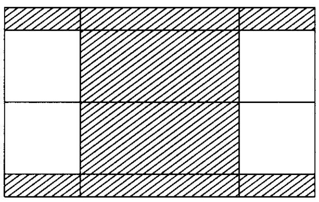
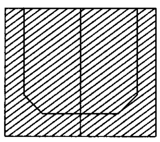
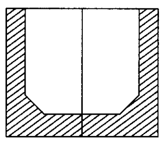
Hydrostatic test condition	*T*-1			
Full load and special loading conditions	*F*-1			
	F-2			
	F-3			
Ballast condition	*B*-1			
	B-2			

Table C29.6.2-3 Case of Four Rows of Longitudinal Bulkheads

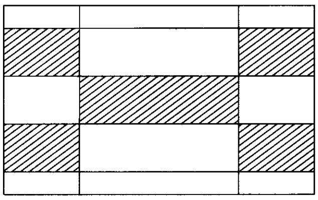
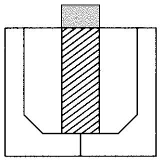
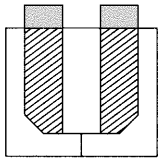
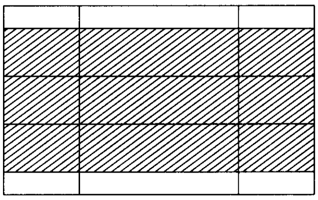
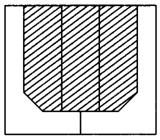
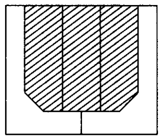
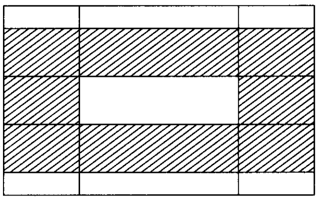
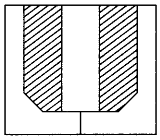
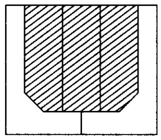
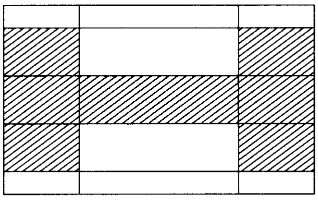
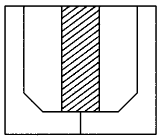
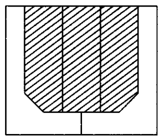
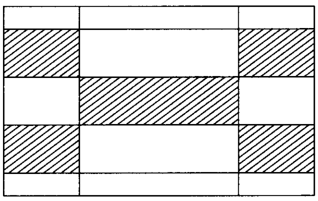
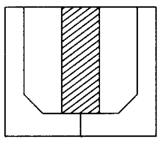
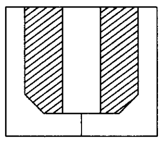
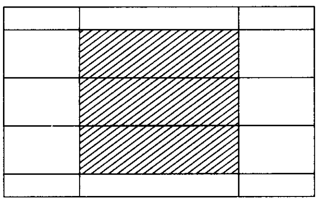
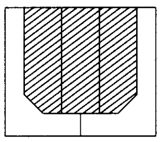
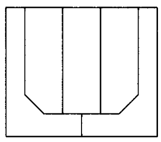
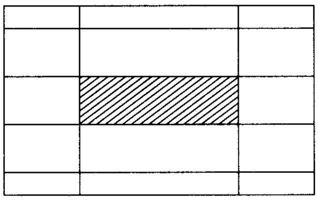
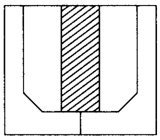
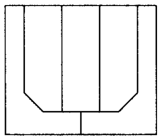
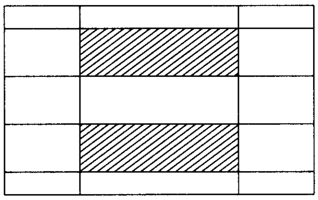
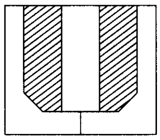
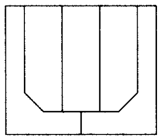
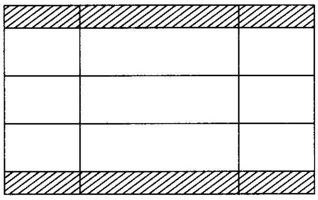
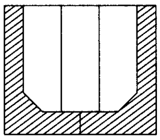
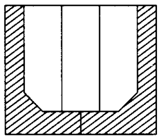
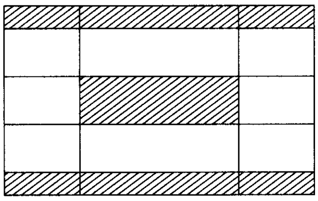
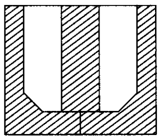
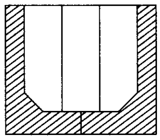
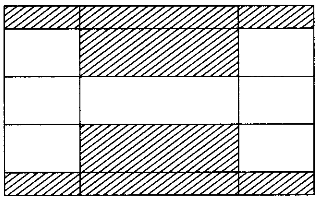
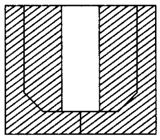
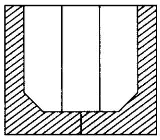
	Case	Loading pattern	Centre tank	Fore and aft tanks
Hydrostatic test condition	*T*-1			
Full load and special loading conditions	*F*-1			
	F-2			
	F-3			
	F-4			
	F-5			

Table C29.6.2-3 Case of Four Rows of Longitudinal Bulkheads (Continued)

	Case	Loading pattern	Centre tank	Fore and aft tanks
Full load and special loading conditions	*F*-6			
	F-7			
Ballast condition	*B*-1			
	B-2			
	B-3			

(2) External loads

(a) Hydrostatic test condition

The water pressure at the bottom and sides when under hydraulic pressure test conditions is to be equal to the hydrostatic pressure corresponding to a draught 1/3 the designed maximum load draught.

(b) Navigation condition

i) The water pressure at the side and bottom when under navigation conditions is to take into account the following wave induced loads in addition to the draught in still water.

1) The wave induced loads corresponding to the wave crests and troughs take into consideration the water heads (m) corresponding to the variations H_0, H_1 and H_2 from the hydrostatic pressure at the still water draught, according to the following formulae.(*See* **Fig. C29.6.2-1**):

$H_0 = 0.5 \times H_w$

$H_1 = 0.9 \times H_w$

$H_2 = 0.25 \times H_w$

Where:

H_w: Value obtained from the following formulae:

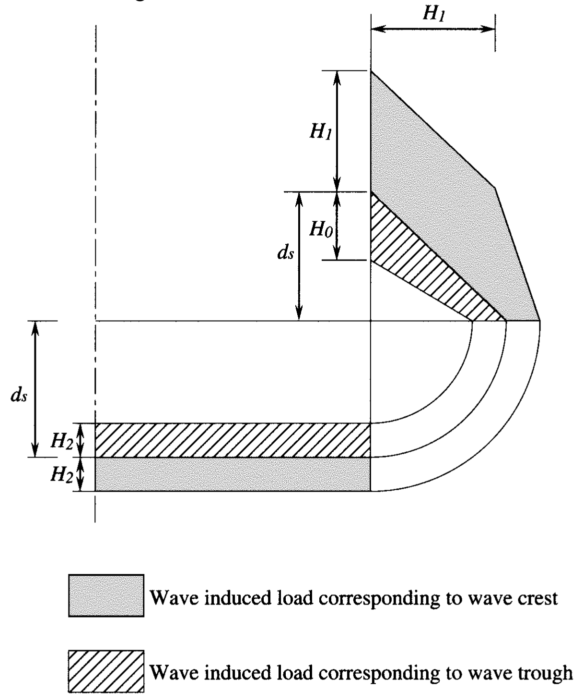
$H_w = 0.61L^{1/2}$: $L \leq 150$ (m)
$H_w = 1.41L^{1/3}$: $150 < L \leq 250$ (m)
$H_w = 2.23L^{1/4}$: $250 < L \leq 300$ (m)
$H_w = 9.28$: $300 < L$ (m)

2) The wave induced loads in harbours and similar quiet waters may be taken as equal to 1/3 of the values of H_0, H_1 and H_2 specified in **1)** above.

3) The wave induced loads may be assumed to be equally distributed throughout the ship's length.

ii) Where cargo oil tanks are empty when under navigation conditions and the wave induced load is that of a wave crest, deck loads are to be taken into account. Deck loads in this case are to be the values specified for deck girders in **10.2.1, Part C of the Rules**.

Fig. C29.6.2-1 Wave Induced Load



4 Allowable stress

Allowable stress for the modelling by using shell elements is shown in **Table C29.6.2-4**.

5 Deflection of girders and transverses

Where the results of direct strength calculations show that relative deformations on transverses and vertical webs supporting longitudinals, longitudinal beams, bulkhead stiffeners, or between bulkheads are large, the added stress due to their effects is to be considered.

6 Fatigue strength

Detailed assessment of fatigue strength may be required as deemed necessary by the Society.

Table C29.6.2-4 Allowable Stress for Modelling by Using Shell Elements

	Structural members considered		σ_l	σ_t, σ_v	σ_e
Primary members in double hull structure	Longitudinal strength members	Shell plating, longitudinal bulkhead plates including inner bottom plates	$145/K$-$35f'$ but, max. $125/K$	$145/K$	$145/K$
		Girder, stringers		-	$175/K$
	Others	Floors, Transverses		-	$175/K$

Notes:

1. Unit: N/mm^2
2. σ_e

   : $\sqrt{(\sigma_l^2 - \sigma_l \cdot \sigma_t + \sigma_t^2 + 3\tau^2)}$ (for horizontal longitudinal strength member)

   : $\sqrt{(\sigma_l^2 - \sigma_l \cdot \sigma_v + \sigma_v^2 + 3\tau^2)}$ (for vertical longitudinal strength member)

   : $\sqrt{(\sigma_v^2 - \sigma_v \cdot \sigma_t + \sigma_t^2 + 3\tau^2)}$ (for transverse strength member)

   σ_l : Normal stress in lengthwise direction

   σ_t : Normal stress in breadthwise direction

   σ_v : Normal stress in depthwise direction

   τ : Shearing stress
3. Openings in floors and girders, if any, are to be taken into consideration in evaluating the stresses.
4. The point of detecting stress is to be the centre of the element.
5. Value of K is to be as specified in **29.4.1-1, Part C** of the Rules.
6. f' is to be 0 at the position of the horizontal neutral axis of the cross sectional area of hull; f_D on upper deck, and f_B on bottom shell plating, f_D and f_B are to be as specified in **29.4.1-1, Part C** of the Rules.

Table C29.6.2-4 Allowable Stress for Modelling by Using Shell Elements (Continued)

Structural members considered			σ_a	σ_e
Primary members outside double hull structure	Face plate	Parallel part	$175/K$	-
		Corners	$195/K$	-
	Web plate	Parallel part	-	$175/K$
		Corners	-	$195/K$

Notes:

1. Unit: N/mm^2
2. σ_a: Normal stress of face plate
3. σ_e: $\sqrt{(\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2 + 3\tau^2)}$

   (The element coordinate system is to be X-Y rectangular coordinate system)

   Where

   σ_x: Normal stress in X-direction of element coordinate system

   σ_y: Normal stress in Y-direction of element coordinate system

   τ : Shearing stress in X-Y plane
4. The point of detecting stress is to be the centre of the element.
5. Value of K is to be as specified in **29.4.1-1, Part C** of the Rules.

C29.6.3 Scantlings of Girders and Floors in Double Bottom

1 When the thickness of girders and floors in the double bottom is calculated according to **29.6.3-1(1)** and **-2(1), Part C** of the Rules, the inner ends of brackets at d_1, x and y in the formulae are the points measured by the method shown in **Fig. C29.6.3-1**.

2 When calculating the thickness of the side girder just under the hopper plate of the bilge hopper tank, the standard method for measuring S from the formulae in **29.6.3-1(1)(b)** and **(c), Part C** of the Rules, is as shown in **Fig. C29.6.3-2**. For the hopper plate within the range of l in the figure, the sectional area obtained from the following formula may be included into the effective sectional area of the side girder under consideration. However, if l exceeds the breadth of the hopper plate (b_H), l is to be taken as b_H.

Fig. C29.6.3-1

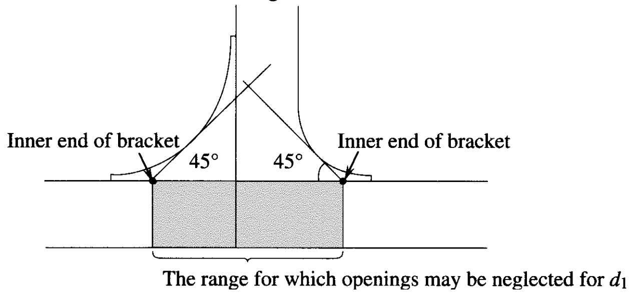
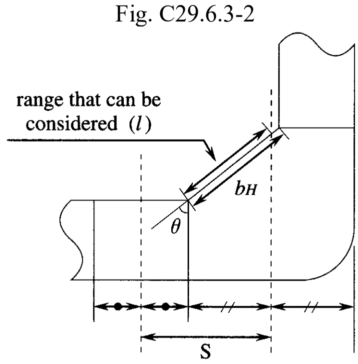


Fig. C29.6.3-2



Notes:

$10\Sigma h_i t_i(1-\theta/90)$ (cm^2)

Where:

h_i: Breadth (mm) of hopper plate within l

t_i: Thickness (mm) of hopper plate - 2.5 (mm)

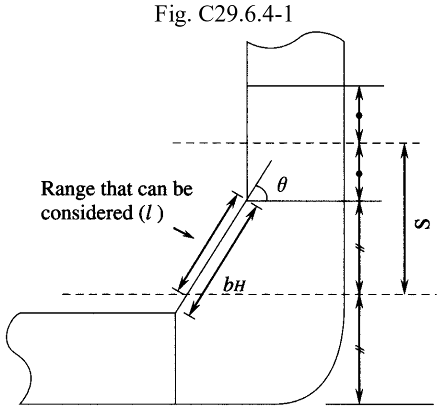
θ : Angle (degrees) between side girder plate and hopper plate

C29.6.4 Scantlings of Stringers and Transverses in Double Side Hull

1 When the thickness of stringers and transverses in the double side hull is calculated according to **29.6.4-1(1)** and **-2(1), Part C** of the Rules, the inner ends of brackets at d_1, x and z in the formulae are the points measured by the method shown in **Fig. C29.6.3-1**.

2 When calculating the thickness of stringer just above the hopper plate of the bilge hopper tank, the standard method for measuring S from the formulae in **29.6.4-1(1)(a)** and **(b), Part C** of the Rules, is as shown in **Fig. C29.6.4-1**. For the hopper plate within the range of l in the figure, the sectional area obtained from the following formula may be included into the effective sectional area of the stringer under consideration. However, if l exceeds the breadth of the hopper plate (b_H), l is to be taken as b_H.

Fig. C29.6.4-1



Notes:

$10\Sigma h_i t_i(1-\theta/90)$ (cm^2)

Where:

h_i: Breadth (mm) of hopper plate within l

t_i: Thickness (mm) of hopper plate - 2.5 (mm)

θ : Angle (degrees) between side longitudinal girder plate and hopper plate

C29.6.5 Girders and Transverses in Cargo Oil Tanks and Deep Tanks

1 Measurement of span l

Where the web under consideration and the adjacent web do not cross at a right angle to each other, l is to be as specified in **Fig. C29.6.5-1**.

2 Transverses on longitudinal bulkhead

(1) Even when large brackets are provided on the opposite side of a longitudinal bulkhead, span l_0 and radius R of transverses are to be measured on the wing tank side in the same manner as in **-1**. The size of bracket b may be $(b' + b'')/2$, except when b is to be taken as b' if b'' is smaller than b'. (*See* **Fig. C29.6.5-2**)

(2) In calculating the thickness of web plates in regard to shearing force, the brackets on the opposite side of longitudinal bulkheads may be taken into account.

(3) Girders on corrugated bulkheads are to be balanced girders. Where balanced girders are not adaptable, the neutral axis is to be brought as close to the bulkhead plating as possible.

Fig. C29.6.5-1 Measurement of l

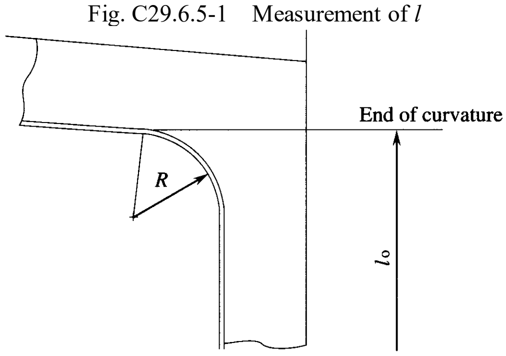
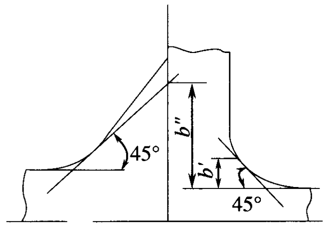


Fig. C29.6.5-2 Measurement of b' and b''



C29.7 Structural Details

C29.7.1 General

1 Frames and stringers

Areas marked with ○ in **Table C29.7.1-1** are required to penetrate longitudinal beams and longitudinals.

Table C29.7.1-1 Required Areas of Longitudinal Beam and Longitudinals

L (m)	$90 \leq L < 120$	$120 \leq L$
Longitudinal beams and side longitudinals attached to sheer strake	○	○
Side longitudinals and longitudinals on longitudinal bulkhead (except those specified above)	-	○
Bottom longitudinals, inner bottom longitudinals and longitudinals on bilge strake	○	○

C29.7.3 Girders and Cross Ties

1 General

(1) The dimensions and locations of lightening holes, where provided, are to be as shown in **Fig. C29.7.3-1**.

(2) Slots are to be reinforced with collars where flanges of longitudinals are facing each other or where slots are provided at small intervals as is often the case with the bilge part.

(3) Where the depth of the girder is smaller than the required depth, the section modulus of the girder is to be decreased by the same ratio.

(4) In pump rooms or void spaces, the thickness of webs may be reduced by 1 mm from the required thickness of webs in cargo oil tanks.

(5) The scantlings of members in segregated ballast tanks in the midship part are to be the same as those of members in cargo oil tanks.

(6) The connection of web plates is to be of butt-welding or a type of connection deemed appropriate by the Society.

(7) Additional stiffeners are to be fitted at end bracket parts, connections with cross ties of transverses, and parts where shearing stress and/or compressive stress are expected to be high. These parts are not to have lightening holes. If considered necessary, slots for penetration of longitudinals in these parts are to be reinforced with collars.

(8) No scallops are to be permitted in web plates at the connection of face plates on transverses and those of girder plates. Scallops cut out for work convenience are to be filled up by welding. Abrupt changes in dimensions are to be avoided. (*See* **Fig. C29.7.3-2**)

(9) The radius of the rounded corner of longitudinals and transverses is to be as large as practicable.

(10) Where angle bars are used instead of flat bars as stiffeners of transverses and girders, their moments of inertia with effective plates is to be approximately equivalent to the required ones.

(11) Where longitudinal frames or stiffeners penetrate bottom transverses, side transverses and vertical webs on the longitudinal bulkhead, proper reinforcement is to be made in the extents stipulated in **Table C29.7.3-1**, by fitting brackets on the opposite side of the stiffeners to secure the transverse to the longitudinals, by fitting collars on slots, or by other suitable means. In ships not exceeding 230 m in length, however, the extents of application of such reinforcement may be properly reduced.

Table C29.7.3-1 Reinforcing Range

Member	Reinforcing range
Floor	All connections
Transverses in bilge hopper tank	All connections
Side transverses	All connections below the upper end of curvature of upper cross tie, or the designed maximum load line, whichever is higher. In ships of not less than 300 *m* in length, it is recommended that similar reinforcement be applied upward beyond the limit stipulated above.
Transverses on longitudinal bulkhead	All connections below the upper end of curvature of upper cross tie.

Note:
The requirement for this reinforcement is also to apply to slots with a similar condition as the transverses shown above (for example, slots for transverse swash bulkheads).

2 The intersections of inner bottom plating and bilge hopper

Where double hull structures include bilge hoppers (*See* asterisks (*) in **Fig. C29.7.3-7**), the construction at the intersections of the inner bottom plating and hopper plates is to be as follows.

(1) Where the construction at the intersection of the inner bottom plating and hopper plates forms a built up construction as specified in **Fig. C29.7.3-3**:

(a) The construction at the above mentioned intersection is to comply with following:

i) Scallops at the above-mentioned intersections in bilge hopper transverses are to be filled up by welding or closed with collar plates. (*See* **Fig. C29.7.3-3**)

ii) Bilge hopper transverses on the extended line of the inner bottom plating are to be fitted with gusset plates. (*See* **Fig. C29.7.3-3**)

(b) Where the spacing of floor plates is not less than 2 *m*, a bracket is to be provided at the mid-point between floor plates. This bracket is to reach the inner bottom longitudinal and the hopper plate longitudinal next to the side girder located at the intersection.

The weld length of stiffeners under consideration is not to be less than $F1$. (*See* **Fig. C29.7.3-4**)

(2) Where the construction at the intersection of the inner bottom plating and hopper plates forms a knuckle as specified in **Fig. C29.7.3-5,** the construction is to comply with the following **(a)** and/or **(b)**, and **(c)** in addition to **(1)(b)** above.

(a) In areas where brackets are provided, gusset plates are to be attached to the transverses of bilge hoppers along the line extending from the inner bottom plating. Where the radius of curvature at the knuckle is large, the number of gusset plates is to be suitably increased. (*See* **Fig. C29.7.3-5**)

(b) Stiffeners as shown in **Fig. C29.7.3-4** are to be fitted within 300 *mm* afore and abaft the bracket.

(c) The knuckled part is to be bevelled and welded as far as possible.

3 The intersections of longitudinal bulkhead and bilge hopper

The construction at the intersections of longitudinal bulkheads in double side hull structures and hopper plates is to comply with the requirements prescribed in **-2**.

4 Details of end structure of strong brackets

The following recommendations are for averting the risk of stress concentration in detailed end structures of end brackets of girders and of brackets and struts provided on the rear side of web plates (*See* asterisked areas in **Fig. C29.7.3-7** to **Fig. C29.7.3-9**).

(*See* **Fig. C29.7.3-6**)

(1) Bracket ends are to be connected as smooth as possible.

(2) Face plates are to have soft snip ends as far as possible.

(3) Where thick plates are used for face plates, the thickness at the ends is not to be more than 15 *mm*, and this is to be achieved either by inserting plates or by tapering to reduce the thickness smoothly.

(4) Bracket ends and corners are to be fitted with ribs with no scallop.

(5) Bracket ends are to be bevelled and welded.

(6) Bracket ends are to be as thick as possible.

(7) Slots in plating, girders on the rear side of strong bracket end connections are to be closed.

5 Connection of struts

In constructions as shown in **Fig. C29.7.3-10**, asterisked brackets are to be fitted.

Fig. C29.7.3-1 Locations and Dimensions of Lightening Holes

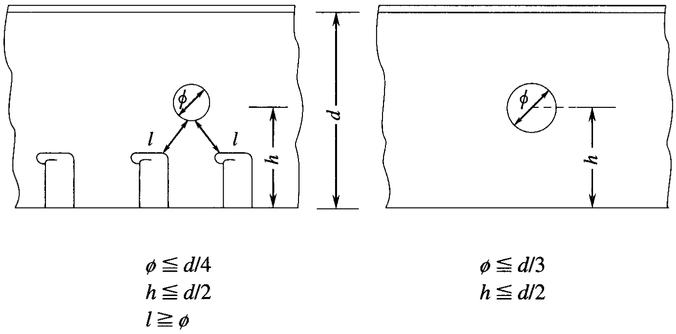


Fig. C29.7.3-2

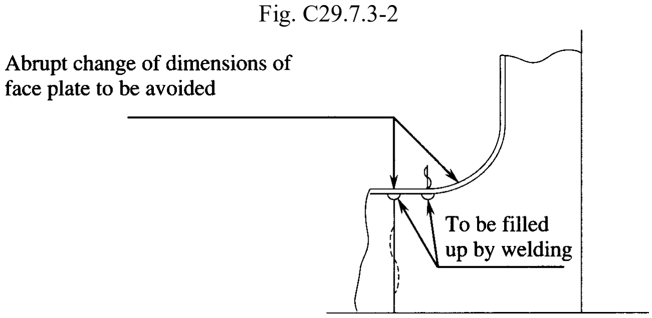


Fig. C29.7.3-3

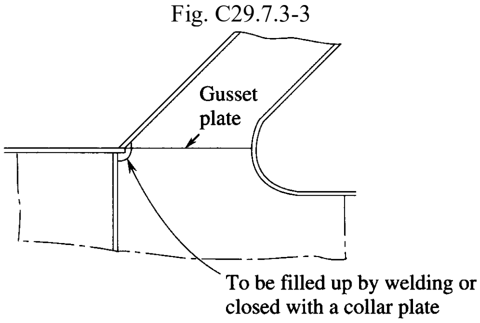


Fig. C29.7.3-4

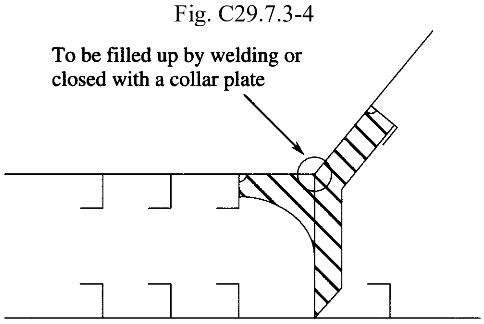


Fig. C29.7.3-5

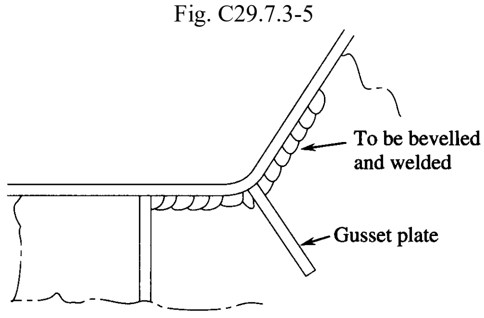


Fig. C29.7.3-6 Structural Details of Bracket Toe

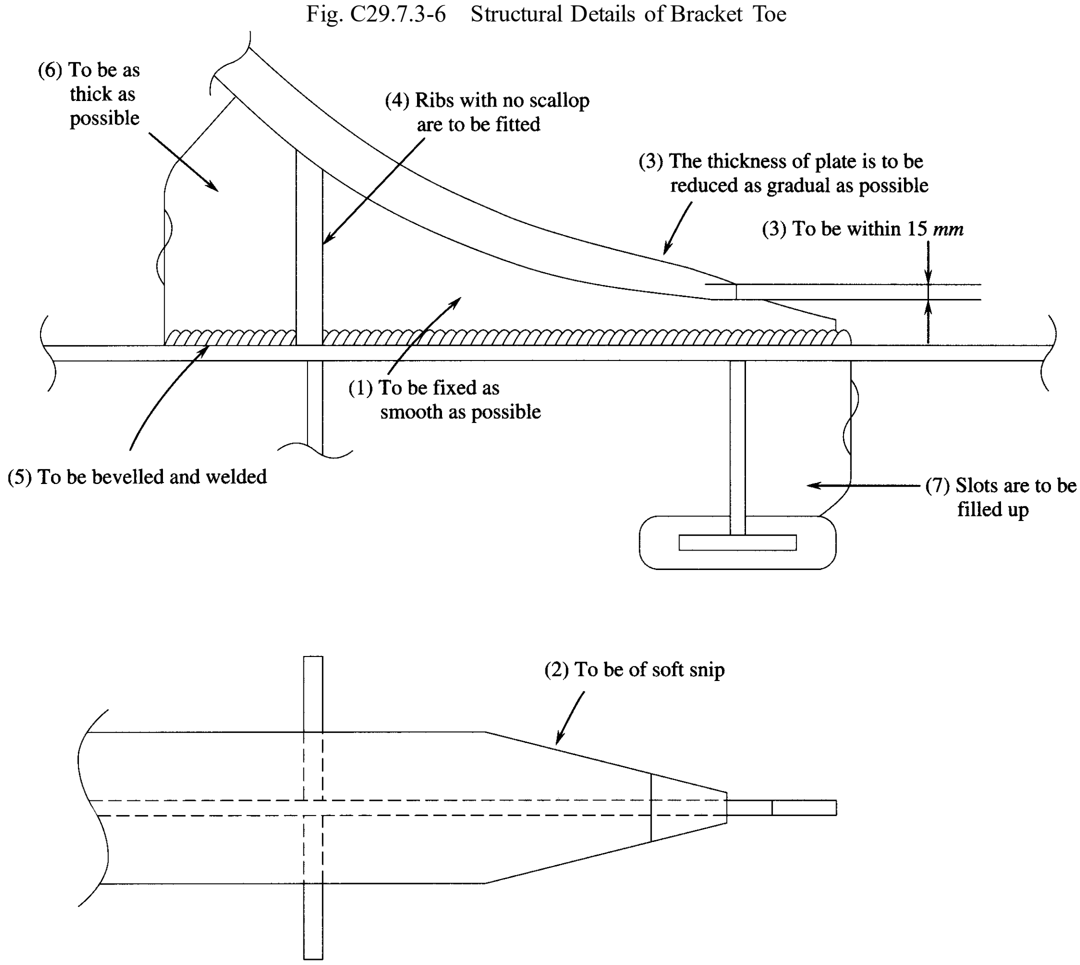


Fig. C29.7.3-7 Intersections of Transverses and Struts (Where Bilge Hoppers are Provided)

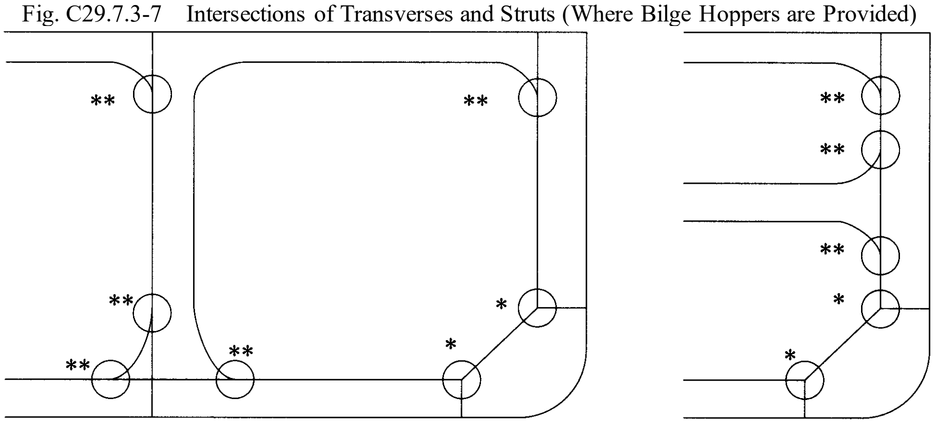


Fig. C29.7.3-8 Intersections of Transverses and Struts (Where Bilge Hoppers are Not Provided)

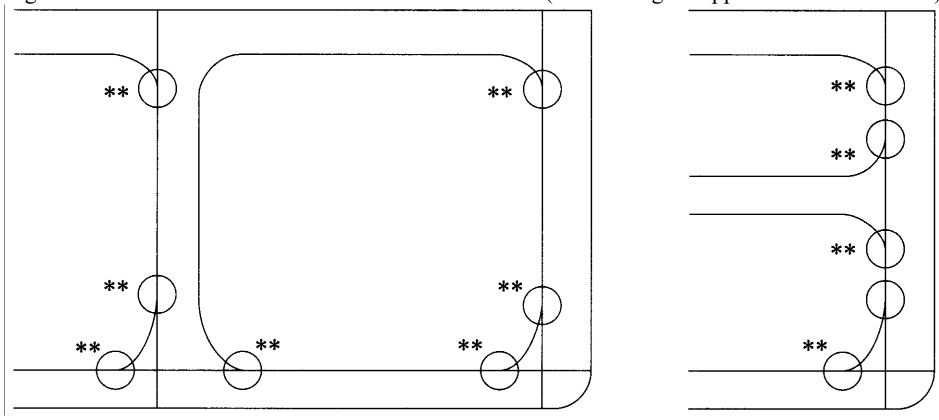


Fig. C29.7.3-9 Intersections of Horizontal Girders

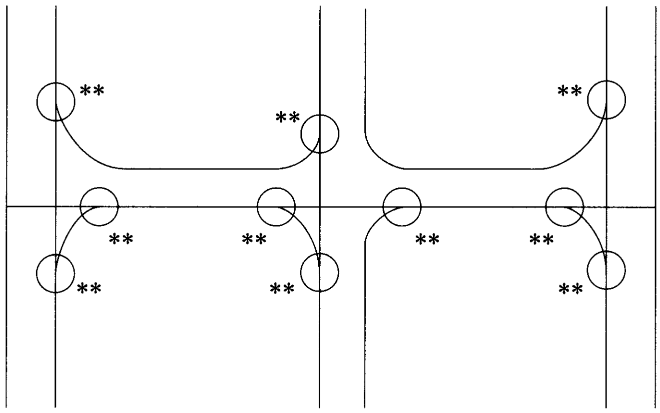
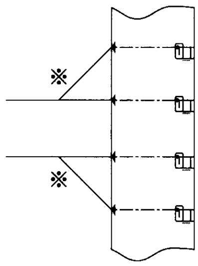


Fig. C29.7.3-10 Connections of Struts



C29.7.4 Supporting Structures of Independent Prismatic Tanks

1 General

With respect to the provisions of **29.7.4, Part C of the Rules,** the arrangement and scantlings of the supporting structures of the independent prismatic tanks are to comply with the requirements of this paragraph. However, other methods approved by the Society may be acceptable.

2 Strength Criteria

Compressive stress σ_a (N/mm^2) acting on each plate which composes the supporting structures, excluding top plate, is to comply with the following criteria:

$$\sigma_a < \sigma_{cr}$$

σ_a : The compressive stress acting on each plate which composes the supporting structures, excluding top plate, as given by the following:

$$\sigma_a = \frac{F_a}{A_{\min}} \quad (N/mm^2)$$

F_a : Load acting on the supporting structures as given by the following:

$$F_a = 1000\rho V_t (1 + a_z) g \quad (N)$$

ρ : Cargo density (*ton/m*^{3})

V_t : Tank volume (m^3) supported by the supporting structure under consideration

a_z: Maximum dimensionless vertical acceleration (i.e. relative to the acceleration of gravity) acting on the centre of the cargo tank under consideration obtained from the following formula. a_z does not include the component due to the static weight.

$$a_z = \pm a_0 \sqrt{1 + \left(5.3 - \frac{45}{L}\right)^2 \left(\frac{x}{L} + 0.05\right)^2 \left(\frac{0.6}{C_b}\right)^{1.5}}$$

a_0: As obtained from the following formula:

$$a_0 = 0.2\frac{V}{\sqrt{L}} + \frac{34 - \frac{600}{L}}{L}$$

V : Ship speed (*kt*) as define in **2.1.8, Part A of the Rules**

x : Longitudinal distance (*m*) from amidships to the centre of gravity of the cargo tank; x is positive forward of amidships, negative aft of amidships

g: Acceleration due to gravity to be taken as 9.81 (*m/s*^{2})

$A_{\min}$: Minimum horizontal sectional area (*mm*^{2}) which is obtained by subtracting 0.5 *mm* from all side of the plates (*See* **Fig.C29.7.4-1**)

σ_{cr}: Allowable stress obtained by the following value, whichever is the lesser:

$\dfrac{\sigma_{yd}}{1.33}$ (*N/mm*^{2})

$C_x \sigma_{yd}$ (*N/mm*^{2})

σ_{yd}: Yield stress (*N/mm*^{2}) of the material used for the supporting structures

C_x : Reduction factor for each plate which composes the supporting structures, excluding top plate, as obtained by **Table C29.7.4-1**. Assessed plate which is not rectangular may be approximated using **Table C29.7.4-2**.

Fig. C29.7.4-1 Example of Supporting Structure (Excluding Top Plate) and the Relevant Minimum Horizontal Sectional Area

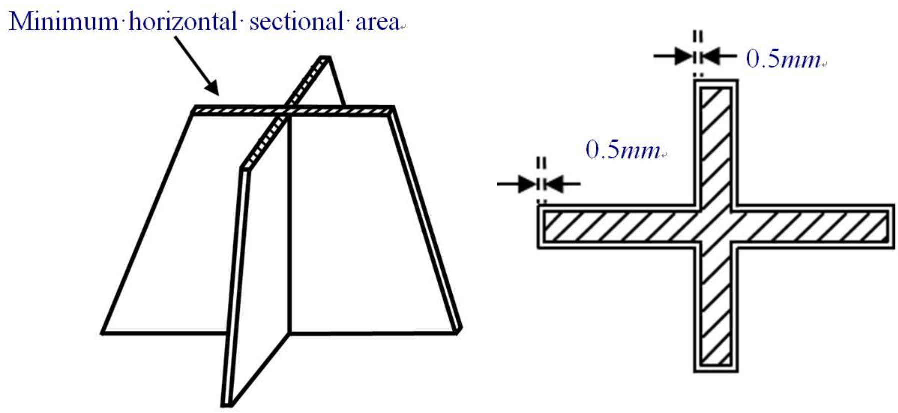
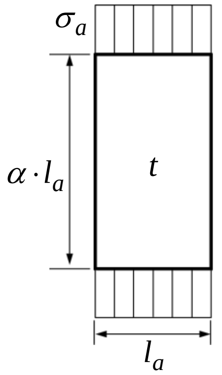
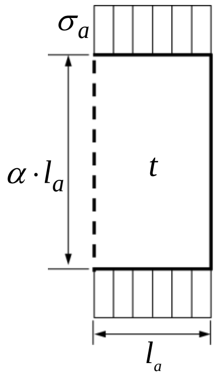


Table C29.7.4-1 Reduction Factor for Plane Plate Panels

	Aspect ratio α	Buckling factor K	Reduction factor C_x
1 	$\alpha \geq 1$	$K = 4$	$C_x = 1$ for $\lambda \leq 0.8$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.8$
2 	$\alpha > 0$	$K = 0.425 + \frac{1}{\alpha^2}$	$C_x = 1$ for $\lambda \leq 0.7$ $C_x = \frac{1}{\lambda^2 + 0.51}$ for $\lambda > 0.7$

Explanations for boundary conditions:

- - - - - plate edge free

——— plate edge simply supported

λ: Reference degree of slenderness, to be taken as:

$$\lambda = \sqrt{\frac{\sigma_{yd}}{K\sigma_E}}$$

σ_E: Reference stress (N/mm^2), to be taken as:

$$\sigma_E = 0.9E\left(\frac{t}{l_a}\right)^2$$

E: Modulus of elasticity, 206,000 (N/mm^2)

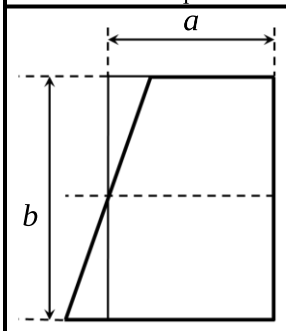
t : As obtained from the following formula

$$t = t_{as-built} - 1.0 \ (mm)$$

$t_{as-built}$: As-built thickness (mm)

l_a: Length of the side of the plate panel (mm)

Table C29.7.4-2 Trapezoidal Panel Approximation

Shape	Approximation
	A rectangle is derived with a being the mean value of the bases and b being the height of the original panel.

C29.8 Special Requirements for Corrosion

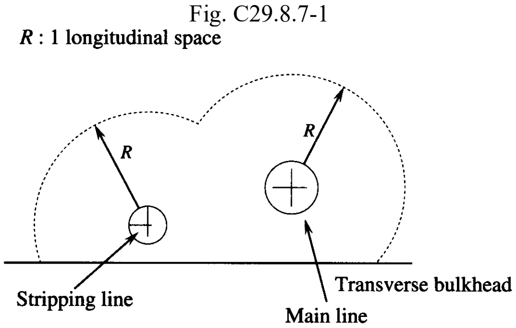
C29.8.7 Thickness of Inner Bottom Plating in Cargo Oil Tanks

1 The thickness of inner bottom plating specified in **29.8.7-1, Part C** of the Rules is to comply with the following requirement. In ships engaged mainly in the carriage of crude oil, the thickness t of inner bottom plating is not to be less than that obtained from the following formula, except where the inner bottom is inclined appropriately.

$$t = 0.026L + 10.0 \ \ (mm)$$

2 The “appropriate area” specified in **29.8.7-2, Part C** of the Rules means the area one longitudinal spacing radius from the outer periphery of a suction bellmouth. (*See* **Fig. C29.8.7-1** and **Fig. C29.8.7-2**)

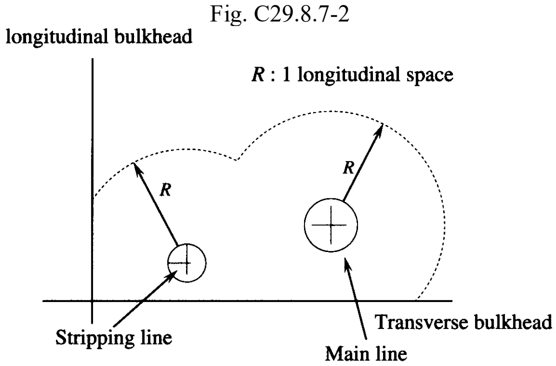
Fig. C29.8.7-1



Note:

Thickness Increasing Range (Where there is no longitudinal bulkhead in the vicinity of the suction bellmouth)

Fig. C29.8.7-2



Note:

Thickness Increasing Range (Where there are longitudinal bulkheads in the vicinity of the suction bellmouth)

C29.12 Special Requirements for Hatchways and Freeing Arrangements

C29.12.2 Hatchways to Cargo Oil Tanks

1 Hatchway covers of glass-fibre reinforced plastics

Where hatchway covers of glass-fibre reinforced plastics are provided for cargo oil tanks, they are to comply with the following requirements.

(1) The basic material is to be of a fire-resistant nature.

(2) Model tests are to be carried out according to the standard fire test method specified in **3.2.47, Part R** of the Rules, through exposing the inside face to fire. This standard fire test is to be carried out for a duration of not less than 20 *minutes* at a highest temperature of 790°C to confirm that there is no passage of flame until the end of the first 20 *minutes* of the test.

(3) Steaming tests are to be carried out to confirm that no deformations causing leakage occur.

(4) Each model of different dimensions is to be subject to a hydraulic test with a pressure not less than 27.5 *kPa* to confirm its strength.

(5) The cover is to be designed to be set either at a full-open position or full-close position only. A notice indicating this manner of handling is to be fitted to the upper surface of the cover.

2 Materials of tank cleaning hatch covers

(1) Covers may be of brass, bronze or steel, but are not to be of aluminium.

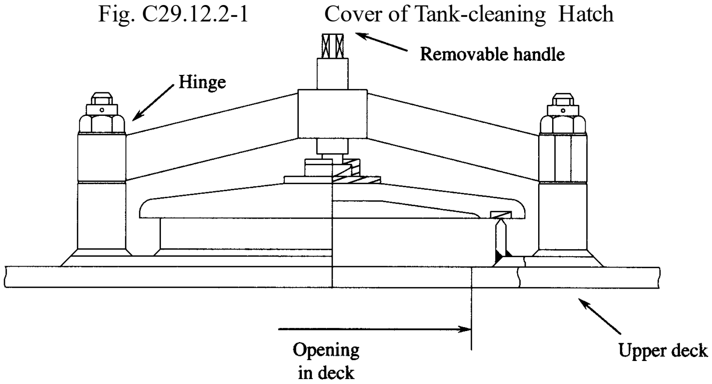
(2) Synthetic materials such as glass-fibre reinforced plastics materials may be used only when all the requirements under **-1** above can be met.

3 The tightening devices of covers of tank-cleaning hatches are to be capable of keeping ample tightness under pressure corresponding to a water head of 2.4 *m* above the tank top. If the devices are constructed as mentioned below or equivalent, the height of hatch coamings required by the provisions of **20.2.2-1, Part C** of the Rules may be reduced in accordance with the provisions of **20.2.2-2** and **20.2.5-4(2), Part C** of the Rules.

(1) Where a liner is placed on the tank top and the cover is tightened by means of bolts, the pitch between these bolts is not to exceed 150 *mm*, and the number of bolts is not to be less than 10. The use of parts such as butterfly-nuts that allow the hatches to be opened by simple manipulations is not permitted. The liners are to be of the same material as the upper deck.

(2) Hatches having a hinged cover with arm are to have a coaming. The construction is to be such that the hatch cannot be opened simply by hand. (*See* **Fig. C29.12.2-1**)

Fig. C29.12.2-1 Cover of Tank-cleaning Hatch



C29.12.4 Freeing Arrangement

1 Effective freeing arrangement

Open guardrails installed on more than half the length of the exposed parts of the freeboard deck may be replaced by freeing ports in the lower parts of the bulwarks, for at least 33% of the total area of bulwarks.

C29.13 Welding

C29.13.2 Fillet Welding

In areas where bending, shearing or axial force is particularly significant, the leg length of fillet welds is to be suitably increased or to be bevelled and welded.

C30 ORE CARRIERS

C30.1 General

C30.1.2 Direct Calculations

The direct calculations for determination of structural scantlings of ore carriers are to comply with the following conditions **(1)** to **(4)**:

(1) Structural members to be calculated

The direct calculations can be applied for determining the scantlings of the following members:

Bottom transverses, deck transverses, side transverses, vertical webs on longitudinal bulkhead, struts, floors, inner bottoms, bottom shell plating, cross decks and girders

(2) Loads, boundary conditions, and supporting condition and modelling of structure

Assumed loads, structural models, boundary conditions and supporting condition for the calculation are to be as follows:

(a) Loads

The loads are to be as shown in the Load column in **Table C30.1.2-1**. Among these, the hydraulic test condition **(b)**, the oil loading condition and the ballasted condition **(a)** apply to ore/oil carriers only.

(b) The procedure of structural modelling is to be as follows:

i) Range of analysis

The range of structure to be analyzed is one side of the adjacent cargo hold (or tank) in the parallel part of the hull, including the whole length or half length of each cargo hold (or tank) and transverse bulkhead between these cargo holds (or tanks). However, this range is to be determined considering the loading patterns of cargo and ballast, and longitudinal and transverse symmetries of the bulkheads and girders attached thereto.

ii) Structural modelling

The following standards **1)** to **3)** apply to divisions in meshing for structural modelling. An example of meshing is shown in **Fig. C30.1.2-1**.

1) In meshing, proper sizes of meshes are to be selected by predicting the stress distribution in the model, and meshes with abnormally large aspect ratios are to be avoided.

2) Girders and similar members having stress gradients along their depth are to be so meshed as to enable their discrimination.

3) The length of the short side of each mesh is to be restricted to longitudinal spacing or thereabouts.

(c) Boundary condition and supporting condition of structural modelling

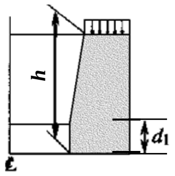
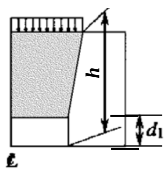
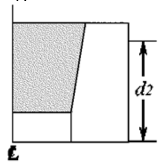
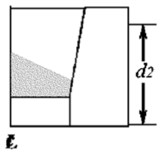
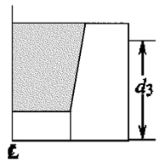
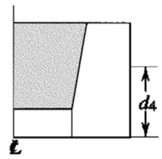
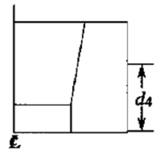
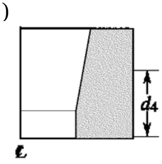
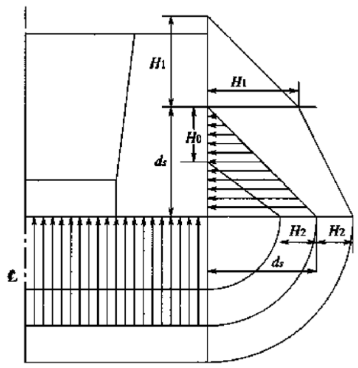
The boundary condition and supporting condition are to allow the effective reproduction of the behaviour of the structural model in accordance with the range of structural modelling.

(3) Permissible stress

The standard values of permissible stress obtained by the direct calculations using the initial scantlings of members including corrosion margins are shown in **Table C30.1.2-2**.

(4) For cargo spaces, direct calculations for a range of analysis other than that specified in **(2)(b)i)** above are to be as deemed appropriate by the Society.

Table C30.1.2-1

<table>
<tr><th colspan="2"></th><th>Hydraulic test</th><th>Ore loading</th><th>Oil loading</th><th>Ballasted</th></tr>
<tr><td rowspan="2">Load</td><td>In still water</td>
<td>(a)

(b)

d_1 = 1/3 × Designed maximum load draught
h = vertical distance from the top of the keel to the top of the tank + 2.4 (m)</td>
<td>(a) In case the density of ore is light

(b) In case the density of ore is heavy

d_2 = Designed maximum load draught</td>
<td>(a)

d_3 = Designed maximum load draught</td>
<td>(a)

(c)

(b)

d_4 = Ballasted draught</td></tr>
<tr><td>In waves</td><td></td>
<td colspan="3">
d_s ; Draught in still water
H_w ; $0.61L^{\frac{1}{2}}$ ・・・ $L \leq 150m$
$1.41L^{\frac{1}{3}}$ ・・・ $150m < L \leq 250m$
$2.23L^{\frac{1}{4}}$ ・・・ $250m < L \leq 300m$
$9.28m$ ・・・ $300m < L$
$H_0 = H_w/2$
$H_1 = h_1 \times H_0$
$H_2 = h_2 \times H_0$
$h_1 = 1.8$
$h_2 = 0.5$
H_0, H_1 and H_2 are to be added to or subtracted from d_s as shown in the above figure.</td></tr>
<tr><td colspan="2">Range of strength calcul.</td><td>All transverses</td><td colspan="3">In the range where load (a) to (c) are present</td></tr>
</table>

Notes:

1. The density, loading height and angle of repose under ore loading, oil loading and ballasted conditions are to be selected in reference to the loading manual. The angle of repose is to be taken at 35° unless specified otherwise.
2. The ballasted draught is to be the mean of the draughts at A.P. and F.P.
3. When the density of cargoes is not specified (e.g. in the loading manual), it is to be taken as 3.0 t/m^3 and the apparent density of cargoes as W/V.

   W: Maximum mass of cargoes for the hold (t)

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

Table C30.1.2-2 Allowable Stress for Modelling by Using Shell Elements

	Structural members considered		σ_l	σ_t	σ_a	σ_e
Longitudinal strength members	Bottom shell plating Inner bottom plating		145/*K* – 35*f'* but, max 125/*K*	145/*K*	-	145/*K*
	Girder		-	-	-	175/*K*
Transverse strength members	Bottom transverse, Deck transverse, Side transverse, Longitudinal bulkhead transverse, Cross tie	Face plate (Parallel part)	-	-	175/*K*	-
		Face plate (Corners)	-	-	195/*K*	-
		Web plate (Parallel part)	-	-	-	175/*K*
		Web plate (Corners)		-	-	195/*K*
	Floor, Cross deck		-	-	-	175/*K*

Notes:

1. Unit: N/mm^2
2. σ_e : $\sqrt{(\sigma_l^2 - \sigma_l \cdot \sigma_t + \sigma_t^2 + 3\tau^2)}$ (for longitudinal strength members)

   : $\sqrt{(\sigma_x^2 - \sigma_x \cdot \sigma_y + \sigma_y^2 + 3\tau^2)}$ (for transverse strength members)

   σ_l: Normal stress in lengthwise direction

   σ_t: Normal stress in breadthwise direction

   τ : Shearing stress on the lengthwise face in the breadthwise-direction for longitudinal strength member
   Shearing stress in the *X*-*Y* plane for transverse strength member

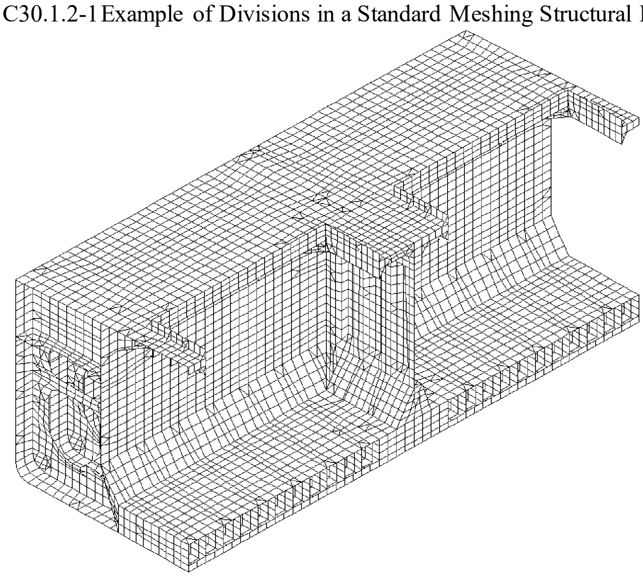
   σ_x: Normal stress in *X*-direction of element coordinate system

   σ_y: Normal stress in *Y*-direction of element coordinate system

   σ_a: Normal stress of face plate
3. Openings in floors and girders, if any, are to be taken into consideration in evaluating the stresses.
4. The point of detecting stress is to be the centre of the element.
5. Value of ***K*** is to be as specified in **30.2.2-1**, **Part C** of the Rules.
6. f': 0 at the position of the horizontal neutral axis of the cross sectional area of hull, f_B on bottom shell plating. For intermediate values between 0 and f_B, f' is to be determined by linear interpolation in accordance with the vertical distance from the baseline.

   f_B: Ratio of section moduli of athwartship section on the basis of mild steel in accordance with the requirements of **Chapter 15** in **Part C** to actual section moduli of athwartship section concerning the strength bottom.

Fig. C30.1.2-1 Example of Divisions in a Standard Meshing Structural Model



C30.2 Double Bottoms

C30.2.3 Longitudinals

The scantlings of inner bottom longitudinals are to comply with the requirements in **C31A.6.2-4**.

C30.3 Wing Tanks or Void Spaces

C30.3.2 Bulkhead Plating

The extent of application "deemed appropriate by the Society" referred to in **30.3.2-3**, **Part C of the Rules** is generally to be up to a height of 3.0 *m* above the lowest point of the inner bottom excluding bilge wells.

C30.3.3 Longitudinals and Stiffeners

The scantlings of longitudinal stiffeners attached to longitudinal bulkheads are to comply with the requirements in **C31A.6.2-4**.

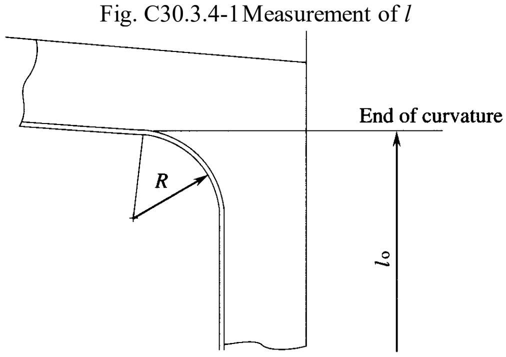
C30.3.4 Girders

1 In tanks and spaces other than water ballast tanks, the thickness of transverses and swash bulkheads may be reduced by 1.0 *mm*, except where the provisions of **30.3.1**, **Part C of the Rules**, are to be applied.

2 Measurement of span l (l_0, l_1 and l_2) of transverses in wing tanks and void spaces

Where the web under consideration and the adjacent web do not cross at a right angle to each other, l is to be as specified in **Fig. C30.3.4-1**.

Fig. C30.3.4-1 Measurement of l



3 The structural details of transverses and struts are to be in accordance with the following **(1)** to **(3)**:

(1) General

(a) The dimensions and locations of lightening holes, where provided, are to be as shown in Fig. C30.3.4-2.

(b) Slots are to be reinforced with collars where flanges of longitudinals are facing each other or where slots are provided at small intervals as is often the case with the bilge part.

(c) Where the depth of the girder is smaller than the required depth, the section modulus of the girder is to be decreased by the same ratio.

(d) In pump rooms or void spaces, the thickness of webs may be reduced by 1.0 *mm* from the required thickness of webs in deep tanks.

(e) The connection of web plates is to be of butt-welding or a type of connection deemed appropriate by the Society.

(f) Additional stiffeners are to be fitted at end bracket parts, connections with cross ties of transverses, and parts where shearing stress and/or compressive stress are expected to be high. These parts are not to have lightening holes. However, parts that are provided with adequate reinforcements (for example, horizontal girders are to be fitted at struts) in order to release stress do not need to be in accordance with these requirements. If considered necessary, slots for penetration of longitudinals in these parts are to be reinforced with collars. Sufficient consideration is to be taken for the continuity of strength at the connection between struts and longitudinals (for example, soft brackets are to be provided on the both sides of a transverse).

(g) No scallops are to be permitted in web plates at the connection of face plates on transverses and those of girder plates. Scallops cut out for work convenience are to be filled up by welding. Abrupt changes in dimensions are to be avoided. (*See* Fig. C30.3.4-3)

(h) The radius of the rounded corner of longitudinals and transverses is to be as large as practicable.

(i) Where angle bars are used instead of flat bars as stiffeners of transverses and girders, their moments of inertia with effective plates is to be approximately equivalent to the required ones.

(j) Where longitudinal frames or stiffeners penetrate bottom transverses, side transverses and vertical webs on the longitudinal bulkhead, proper reinforcement is to be made in the extents stipulated in Table C30.3.4-1, by fitting brackets on the opposite side of the stiffeners to secure the transverse to the longitudinals, by fitting collars on slots, or by other suitable means. In ships not exceeding 230 *m* in length, however, the extents of application of such reinforcement may be properly reduced. This reinforcement is to apply to slots under conditions similar to those in the above-mentioned girders or transverses (for example, slots in transverse swash bulkheads, etc.).

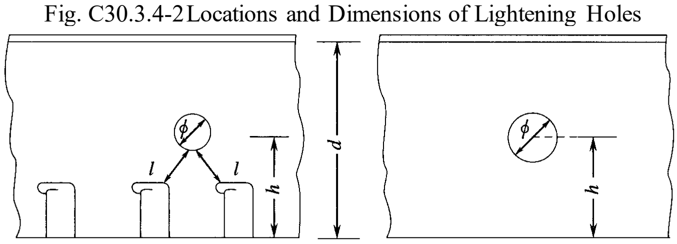
(2) The construction at the position of floors within the intersection of the inner bottom plating and longitudinal bulkhead is to comply with the following **(a)** and **(b)**:

(a) Scallops at the above-mentioned intersections in transverses of wing tanks are to be filled up by welding or closed with collar plates. (*See* Fig. C30.3.4-4)

(b) Transverses of wing tanks on the extended line of the inner bottom plating are to be fitted with gusset plates. (*See* Fig. C30.3.4-4)

(3) Where the construction at the intersection of the slant and vertical plates of longitudinal bulkhead forms a built up construction, scallops at the above-mentioned intersections in transverses of wing tanks are to be filled up by welding or closed with collar plates.

Fig. C30.3.4-2 Locations and Dimensions of Lightening Holes



$\phi \leqq d/4$
$h \leqq d/2$
$l \geqq \phi$

$\phi \leqq d/3$
$h \leqq d/2$

Fig. C30.3.4-3

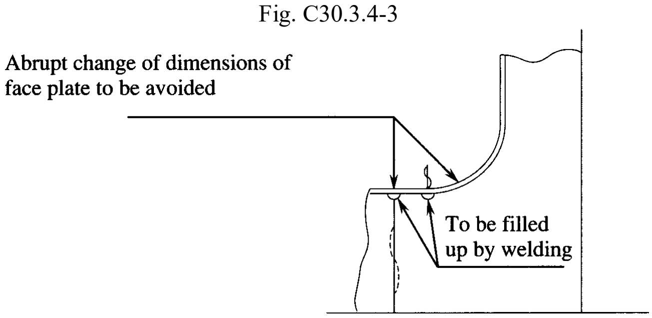
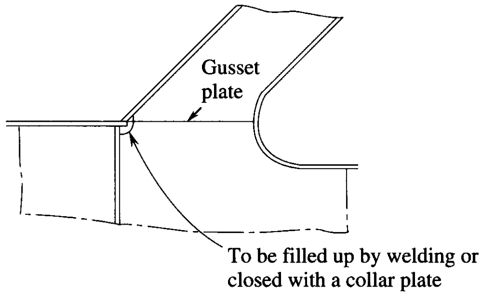


Table C30.3.4-1 Reinforcing Range

Member	Reinforcing range
Bottom transverses	All connections
Side transverses	All connections below the upper end of curvature of upper cross tie, or the designed maximum load line, whichever is higher. In ships of not less than 300 m in length, it is recommended that similar reinforcement be applied upward beyond the limit stipulated above.
Transverses on longitudinal bulkhead	All connections below the upper end of curvature of upper cross tie.

Fig. C30.3.4-4



C30.4 Transverse Bulkheads and Stools in Ore Holds

C30.4.1 Transverse Bulkheads in Ore Holds

Where the vertical stiffeners are provided on transverse bulkheads (excluding corrugated bulkheads), the scantlings of the vertical stiffeners are to comply with the requirements in **C31A.6.2-4**.

C30.4.2 Lower and Upper Stools at Transverse Bulkheads in Ore Holds

1 The extent of application "deemed appropriate by the Society" referred to in **30.4.2-2**, **Part C of the Rules** is to be in accordance with the requirements in **C30.3.2**.

2 Where the vertical stiffeners are provided on side plates of upper and lower stools at transverse bulkheads, the scantlings of the vertical stiffeners are to comply with the requirements in **C31A.6.2-4**.

C30.5 Relative Deformation of Wing Tanks

C30.5.1 Relative Deformation of Wing Tanks

1 Where the longitudinal bulkheads are inclined, a and b are to be such that the hatched parts are equal in area as shown in **Fig.**

C30.5.1-1.

2 What to do when the relative deformation exceeds limit values and how to measure the mean thickness of transverse bulkhead plating are given in the following **(1)** and **(2)**:

(1) Data demonstrating that the proposed construction has effectiveness equivalent to that required in the Rules is to be submitted.

(2) The mean thickness t of plating used in the formulae in **30.5.1, Part C of the Rules** is to be obtained from the following formula:

$$t = \frac{\Sigma l_i t_i}{\Sigma l_i} \ (mm)$$

l_i and t_i: To be taken as follows:

(a) For transverse bulkheads and perforated swash bulkheads:
The thickness and breadth of each strake of the bulkhead are to be taken at the middle of the breadth of the tank as shown in **Fig. C30.5.1-2**.

(b) For transverse rings and swash bulkheads of transverse ring type:
The thickness and vertical extent of the deck transverse, transverse on longitudinal bulkhead between the face plate of the deck transverse and the upper face plate of the uppermost strut, and other parts from the uppermost strut to the bottom transverse are to be taken at the middle of the breadth of the tank (at the bulkhead side if no plating is present at the middle of the breadth of the tank) as shown in **Fig. C30.5.1-3**.

Fig. C30.5.1-1

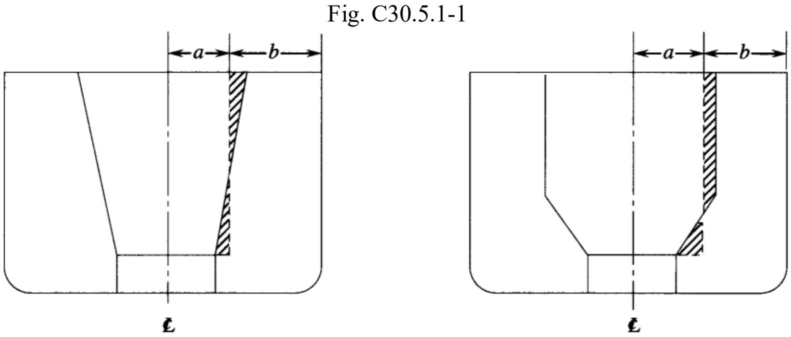


Fig. C30.5.1-2

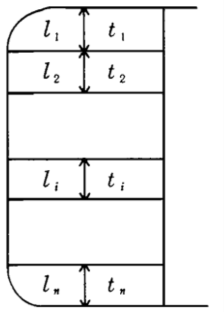
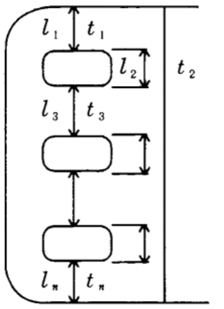


Fig. C30.5.1-3



C30.6 Decks and Miscellaneous

C30.6.1 Decks, etc.

1 The scantlings of deck plating inside the line of openings are to be determined by direct calculations using 1/2 + 1 + 1 + 1/2 hold models in accordance with the requirements in **C30.1.2**.

2 Hatchways and coamings are to comply with the requirements in **C31A.6.2-1(2)**.

C30.7 Ore/Oil Carriers

C30.7.1 General

1 General

The construction, arrangement and equipment of ore/oil carriers are to be in accordance with the following **(1)** to **(6)** in addition to the requirements in **30.7.1-2**, **Part C of the Rules**.

(1) The piping arrangement is to comply with **14.5**, **Part D of the Rules**.

(2) The length of combined ore holds / cargo oil tanks is to comply with **C14.1.3-1**.

(3) No openings for cargo operations are to be provided in bulkheads and decks separating cargo oil tanks (including combined ore holds/cargo oil tanks) designed and equipped to carry oil having a flash point below 60°C (closed cup test) from other spaces that are not designed and equipped for its carriage.

(4) When the ship is operated as an ore carrier, all compartments except for slop tanks are to be gas-freed.

(5) Documents stipulating the details regarding cleaning and gas-freeing of cargo oil tanks (e.g. the equipment and required time) are to be submitted to the Society for reference.

(6) Precautions regarding the work that is required to convert ore/oil carriers from carrying ore to oil or vice versa are to be submitted to the owner and their copies submitted to the Society (including the precautions in relation to **14.5**, **Part D of the Rules** during the document approval phase.

2 Construction of Pump Rooms

The bottom of the pump room of ore/oil carriers is to be constructed with particular care taken regarding the continuity of structural members.

(1) The longitudinal bulkheads in the hold space are to be extended aft as far as is practicable.

Deep horizontal girders are to be provided on the longitudinal bulkheads at the level of the inner bottom in the hold space. The webs of these girders are to be of approximately the same thickness as the inner bottom.

(2) Centre girder

Height: same as double bottom in the hold space

Thickness: same as centre girder in the hold space

(3) Side girders

Number: 2 lines each side, if $b \leq 15\ m$

3 lines each side, if $b > 15\ m$

Thickness: same as centre girder

Height: not less than the height of the double bottom in the engine room

It is recommended that the side girders be as high as possible.

(4) Sectional area of face plates of girders

The total sectional area of face plates of girders (including total sectional areas of horizontal girders on longitudinal bulkheads, if any) is not to be less than 35% of the sectional area of the inner bottom in the hold space.

(5) Bottom longitudinals

The section modulus Z of bottom longitudinals is to be 1.21 *times* the value obtained from the formula in **30.2.3-1**, **Part C of the Rules** and further, it is not to be less than the value obtained from the following formula:

$Z = 290dS\ (cm^3)$

d: Draught (m)

S: Spacing (m) of longitudinals

(6) Omission of side girders

One of the side girders as per **(3)** above may be omitted, provided that the thickness of the bottom shell plating under the pump room is increased by 2.0 *mm* in excess of the required thickness (including tapering).

(7) If high tensile steel is used for strength deck plating over the pump room, the sectional area of the deck in this part is to be suitably increased in excess of the required area.

C31 BULK CARRIERS

C31.1 General

C31.1.1 Application

1 With respect to the provisions of **31.1.1-3, Part C** of the Rules, to register ships other than ordinary bulk carriers with a single deck, and bilge hopper tanks, topside tanks and a double bottom for the length of the cargo area as "*Bulk Carrier(s)*", the requirements of **Chapter 31, Part C** of the Rules are generally to be applied to such ships in accordance with **Table C31.1.1-1**. Structural peculiarities of such ships are to be registered in the Classification Register as a descriptive note (*e.g. Double hull construction applied to cargo holds Nos.2-4*).

Table C31.1.1-1 Application of the Requirements to Ships other than Ordinary Bulk Carriers

The requirements of **Chapter 31, Part C** of the Rules	For box shaped ships	Ships of unconventional shape
Double Bottoms (**31.2**)	*A* (See **C31.2.1-1**)	*A*
Bilge Hopper Tanks (**31.3**)	*NA*	*AI*
Topside Tanks (**31.4**)	*AI*	*AI*
Transverse Bulkheads and Stools (**31.5**)	*A*	*A*
Hold Frames (**31.6**)	*NA*	*AI*
Deck Plating outside the Line of Openings (**31.7.1**)	*AI*	*AI*
Deck Plating inside the Line of Openings (**31.7.2**)	*A*	*A*
Bottom Shell Plating (**31.7.3**)	*A*	*A*
Scuppers (**31.7.4**)	*A*	*A*
Coal Transportation (**31.7.5**)	*A*	*A*
Supplementary Provisions for Carriage of Liquid in Holds (**31.8**)	*A*	*A*

Notes:
A : The requirements are applicable.
NA: The requirements are not applicable.
AI : The requirements are applicable if relevant.

2 Ships having a construction similar to bulk carriers

The provisions of **Chapter 31, Part C** of the Rules apply to ships other than bulk carriers having a construction similar to that of bulk carriers, such as chip carriers and timber carriers.

3 Where cargo holds of bulk carriers and chip carriers applicable to **Chapter 31, Part C** of the Rules are exempt from coating, the requirements in **C25.2.1-3** apply.

C31.1.2 Ship Types and Applicable Requirements

1 For bulk carriers specified in **31.1.2-1(1), Part C** of the Rules, the combination of specified empty holds may be limited. In such cases, the applicable combinations are to be registered in the Classification Register as a descriptive note.

2 For bulk carriers specified in **31.1.2-1(1)** or **(2), Part C** of the Rules, the design bulk cargo density is to be 3.0 t/m^3. However, a maximum bulk cargo density of less than 3.0 t/m^3 may be applied on the basis that it is registered in the Classification Register as a descriptive note.

3 Ships registered as "*Bulk Carrier(s)*" in accordance with the provisions of **C31.1.1-1** and ships of less than 150 *m* in length L_1 specified in **31.1.2-2, Part C** of the Rules need not comply with the requirements of **31.1.2-1, Part C** of the Rules. The specific gravity of cargoes specified in **31.2.1-3, Part C** of the Rules and the coefficients "*n*" and "*a*" specified in **31.2.2-3, Part C** of the Rules may be determined by using actual design conditions (See **C31.2.2-2**), provided that the value of γ for the inner bottom and bilge hopper plate in 31.2.4-1 and 31.3.2-1, Part C of the Rules respectively is not to be less than 1.2 *times* the ratio of the designed total cargo mass (t) to the total volume (m^3) of all cargo holds including the hatchway part.

4 With respect to the provisions of 31.1.2-1, Part C of the Rules, loading conditions specified in 31.1.2-1, Part C of the Rules corresponding to the type of ship, are to be included in loading manuals as a condition required by the provisions of 34.2.2-2, Part C of the Rules. In this context, "homogeneously loaded condition" means that all cargo holds are loaded with the same filling rate and "alternately loaded condition" means that specific hold(s) are empty and the other cargo holds are loaded with the same filling rate. The mass of consumables at arrival and departure is to be in accordance with the provisions of C31.1.3-3. "Filling rate" means the ratio of the loaded cargo mass to the volume of the hold including the hatchway part.

C31.1.3 Capacity of Ballast Tanks

1 With respect to the provisions of 31.1.3-1, Part C of the Rules, ballast conditions specified in 31.1.3-1, Part C of the Rules are to be included in the loading manual as a condition required by the provisions of 34.2.2-2, Part C of the Rules. Ballast conditions involving partially filled ballast tank(s) are not permitted except where both of the following apply.

(1) Such ballast tanks meet the requirements of 14.1.3-2 or -3, Part C of the Rules

(2) The longitudinal strength complies with C15.2.1(4)

2 With respect to the provisions of 31.1.3-1, Part C of the Rules, the draught at the forward and after perpendiculars may be used in the assessment of the propeller immersion and trim.

3 The ballast conditions specified in 31.1.3-1, Part C of the Rules are to be investigated for the arrival and departure conditions defined below.

(1) Departure condition: with bunker tanks not less than 95% full and other consumables 100%

(2) Arrival condition: with 10% of consumables

4 With respect to the provisions of 31.1.3-2, Part C of the Rules, where more than one hold is adapted and designed for the carriage of water ballast at sea, two or more holds do not need to be assumed 100% full simultaneously in the longitudinal strength assessment, unless such conditions are expected in the heavy ballast condition. All restrictions for the use of ballast holds are to be indicated in the loading manual.

5 With respect to the provisions of 31.1.3-2, Part C of the Rules, in application of the requirements of 6.8 and 16.4.4, Part C of the Rules to the bottom forward in normal ballast conditions, the slamming impact pressure may be 0.75 *times* the pressure "P" specified in 6.8.4-1, Part C of the Rules. The bow draught in heavy ballast condition is to be used as the minimum bow draught required for the structural strength of the strengthened bottom forward in the ship's loading manual.

6 Ships specified in C31.1.2-3 need not apply to the provisions of 31.1.3, Part C of the Rules.

C31.1.5 Direct Strength Calculations

When determining the scantlings of structural members of cargo holds of a bulk carrier by direct strength calculations, the necessary documents and data on the calculation procedure are to be submitted beforehand to the Society for approval. The procedure is to comply with the following **(1)** to **(4)**.

(1) Structural Modelling

(a) The range of structure to be analyzed is the port side of two adjacent cargo holds in the parallel body part, including the whole length or half length of each cargo hold and the transverse bulkhead between these two holds.

(b) The procedure of modelling by using shell elements is to comply with 1.3.1-2 **of** Annex C1.1.22-1 "**GUIDANCE FOR DIRECT CALCULATIONS**." An example of a standard meshing model is shown in Fig. C31.1.5-1. The standard method of meshing is to mesh the structure lengthwise, at each side frame station, breadthwise, into 2 or 3 sections between two adjacent girders, and depthwise, into 3 sections in the double bottom.

(c) For remeshing with fine meshes according to 1.3.1-1(4) **of** Annex C1.1.22-1 "**GUIDANCE FOR DIRECT CALCULATIONS**", an example of meshing is shown in Fig. C31.1.5-2. The standard method of meshing the depth of a girder is to mesh into 3 sections.

(d) Support and boundary conditions of the model are to be given to reproduce the structural behaviour with sufficient fidelity according to the extent of the model.

(2) Loads

(a) The loading conditions to be taken into consideration are, as a rule, to be the conditions specified in the following. When there are special loading conditions or cargoes of especially high density are to be loaded, such conditions are to be included in the calculations. **Table C31.1.5-1** gives an example.

i) Definitions

1) M_D: The maximum cargo mass (t) given for each cargo hold

2) 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.

3) M_H: The cargo mass (t) in the cargo hold corresponding to a homogeneously loaded condition at designed maximum load draught

4) M_{HD}: The maximum cargo mass (t) allowed to be carried in a cargo hold according to design alternately loaded condition

5) M_{Block}: The cargo mass (t) in two adjacent cargo holds carrying high density cargo

ii) Load conditions applicable to all cargo holds in *BC-A*, *BC-B*, and *BC-C* ships specified in **31.1.2-1, Part C** of the Rules

1) Homogeneously loaded condition

The cargo hold is to be carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at designed maximum load draught.

2) Condition with slacked loaded hold

The cargo hold is to be carrying 50% of M_H, with all double bottom tanks in way of the cargo hold being empty, at designed maximum load draught. In this context, adjacent cargo holds are generally to be carrying M_{Full}.

3) Normal ballast condition

The cargo hold is to be empty, with all double bottom tanks in way of the cargo hold being empty, at the deepest ballast draught.

iii) Load conditions applicable to all cargo holds in *BC-A*, *BC-B*, and *BC-C* ships specified in **31.1.2-1, Part C** of the Rules (except ships not designed for loading and/or unloading in multiple ports)

1) Loaded hold in a ship loaded or unloaded at multiple ports

The cargo hold is to be carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of designed maximum load draught. In this context, adjacent cargo holds are generally to be empty.

2) Empty hold in a ship loaded or unloaded at multiple ports

The cargo hold is to be empty with all double bottom tanks in way of the cargo hold being empty, at 83% of designed maximum load draught. In this context, adjacent cargo holds are generally to be carrying M_{Full}.

3) Loaded hold in a ship with two adjacent holds loaded

The two adjacent cargo holds are to be carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of designed maximum load draught. In this context, forward and after cargo holds next to these holds are generally to be empty.

4) Empty hold in a ship with two adjacent holds empty

The two adjacent cargo holds are to be empty, with all double bottom tanks in way of the cargo hold being empty, at 75% of designed maximum load draught. In this context, in general, forward and after cargo holds next to these holds are generally to be carrying M_{Full}.

5) Loaded cargo hold adjacent to a cargo hold filled with ballast water

This load condition is applicable to specific cargo hold(s) only where the condition is included in the loading manual. The draught and the mass of cargo and fuel oil in double bottom tanks in way of the cargo hold apply to the condition specified in **3)** above.

iv) Load conditions applicable for *BC-A* ships specified in **31.1.2-1(1), Part C** of the Rules

1) Empty hold in an alternately loaded condition

Cargo holds, which are intended to be empty at designed maximum load draught, are to be empty with all double bottom tanks in way of the cargo hold also being empty. In this context, adjacent cargo holds are generally to be carrying M_{HD}.

2) Loaded hold in an alternately loaded condition

Cargo holds, which are intended to be loaded with high density cargo, are to be carrying M_{HD} plus 10% of M_H, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom being empty in way of the cargo hold, at designed maximum load draught. In this context, adjacent cargo holds are generally to be empty.

3) Loaded hold in a ship with high density cargoes loaded in two adjacent cargo holds

This load condition is applicable to specific cargo hold(s) only where the condition is included in the loading manual. The two adjacent cargo holds are to be carrying M_{Block} plus 10% of M_H, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at designed maximum load draught. In this context, forward and after cargo holds next to these cargo holds are generally to be empty.

v) Load condition applicable to hold(s) adapted for carriage of water ballast at sea

Hold ballast condition

Cargo holds are to be 100% full of ballast water including hatchways, with all double bottom tanks in way of the cargo hold being 100% full, at minimum draught for conditions with ballast hold(s) 100% full. In this context, adjacent cargo holds are to be empty except where ships are designed for carriage of ballast in two or more adjacent cargo holds.

vi) Load conditions during loading and unloading in harbour (applicable to all cargo holds in *BC-A*, *BC-B* and *BC-C* ships specified in **31.1.2-1, Part C** of the Rules)

In the assessment for these conditions, wave induced loads specified in **1.2.4-1(2) of Annex C1.1.22-1** "**GUIDANCE FOR DIRECT CALCULATIONS**" may be taken as 0.

1) The cargo hold is to be carrying M_D, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of designed maximum load draught. In this context, adjacent cargo holds are to be empty.

2) The two adjacent cargo holds are to be carrying M_{Full}, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of designed maximum load draught. In this context, forward and after cargo holds next to these cargo holds are to be empty.

(b) Loads due to ore cargo, grain cargo, etc.

i) The standard method for determining the height and surface of the cargo is as shown in 1) through 4) below. (*See* **Fig. C31.1.5-3**)

1) The shape of the cargo surface is assumed to be horizontal longitudinally and transversely in the part near the ship's centreline and sloped down straight to the ship's sides with the angle of repose ϕ.

2) The width of the horizontal part b is assumed to be equal to 1/4 of the breadth of the hold.

3) The loading height h_{C1} is determined in accordance with the mass, angle of repose and density of the cargo to be loaded. The shape of the cargo surface may be assumed to be unchanged for the whole length of the hold.

4) When the density and angle of repose of the cargo are not specified, they are to be taken as 3.0 (t/m^3) and 30° respectively.

ii) The loads on the vertical walls of the hold are, in principle, to be determined by the following formula. The cargo load is not to be applied to the side plating.

$9.81\rho h k^2$ (N/m)

ρ: Density of cargo (kg/m^3)

h: Vertical height (m) from the panel in question to the surface of cargo right above the panel

k: Value of C_2 in **31.3.2, Part C** of the Rules

(c) Loads due to liquid cargo, water ballast, etc.

In a cargo hold commonly used as a water ballast tank, the water head (m) at a certain position is to be taken equal to the greater of the values obtained from the following formula and the value of h in the same formula.

$0.85(h + \Delta h)$ (m)

h : Height (m) from the position in question to the top of hatch coaming

Δh: A value obtained from the following formula

$$\Delta h = \frac{16}{L}(l_t - 10) + 0.25\left(\frac{2}{3}B - 10\right)$$

l_t: Length of tank (m), however, where it is less than 10 (m), it is to be taken as 10

B is to be taken as 15 where B is less than 15 (m).

(3) Allowable Stress

(a) Allowable stress for kind of structural model

i) Allowable stress when modelling by using shell elements

The permissible values of normal stress σ and equivalent stress σ_e of each member are to be as given in **Table C31.1.5-2**. The allowable stresses in the transverse rings and side frames which correspond to the values obtained as a result of the calculations by remeshing with fine meshes according to the requirements in **1.3.1-1(4) of Annex C1.1.22-1** "**GUIDANCE FOR DIRECT CALCULATIONS**" are to be as given in **Table C31.1.5-3**.

ii) Allowable stress when modelling by using beam elements

The permissible values for each member are to be approximately the same as those given in **Table C31.1.5-2** and **Table C31.1.5-3**, but they are to be determined for respective cases after the submission of necessary materials and data to the Society in accordance with **1.3.1-3 of the Annex C1.1.22-1** "**GUIDANCE FOR DIRECT CALCULATIONS**." The standard values for the members of double bottoms are given in **Table C31.1.5-4**.

iii) Allowable stress for double bottom modelled into sandwich structure

The allowable values of normal stress σ, mean shearing stress τ and equivalent stress σ_e in members forming the double bottom are to be as specified in **Table C31.1.5-5**.

(b) Allowable Stress where hull girder section modulus has fair allowances.

The allowable values of normal stress in the lengthwise direction in the bottom shell and inner bottom plating may be as determined from the following formula (N/mm^2).

For structural model using shell elements

$145/K - 35f$

For structural model using beam elements

$135/K - 35f$

For sandwich structure model

$135/K - 35f$

K: Coefficient corresponding to the kind of steel

e.g. 1.0 for mild steel, the values specified in **1.1.7-2(1) of the Rules** for high tensile steel

f: The ratio of the required hull girder section modulus obtained assuming that mild steel is used according to **15.2.1, Part C** of the Rules to the section modulus for the bottom of the ship in question.

(c) Allowable Stress for loading/unloading conditions in the harbour

The allowable stress for loading/unloading conditions in the harbour may be 110% of the values given in **Tables C31.1.5-2** to **C31.1.5-5**.

(4) Buckling Strength

Longitudinal still water bending moment for Group B in **Table 2.1** in **Annex C1.1.22-2 "GUIDANCE FOR BUCKLING STRENGTH CALCULATION"** is generally to be taken as the allowable still water bending moment at sea for the ship. Notwithstanding the above, an allowable still water bending moment for alternately loaded conditions, if established separately, may be used for the buckling strength calculation. For loading/unloading conditions at harbour, the allowable still water bending moment in port may be used and the buckling criterion may be taken as 1.0 in the buckling strength calculation.

Fig. C31.1.5-1 Example of Model by Using Shell Elements

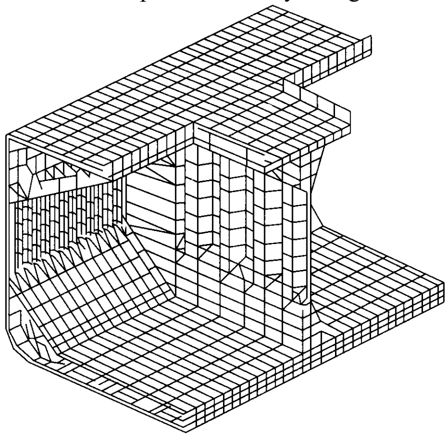


Fig. C31.1.5-2 Example of Model by Remeshing with Fine Meshes

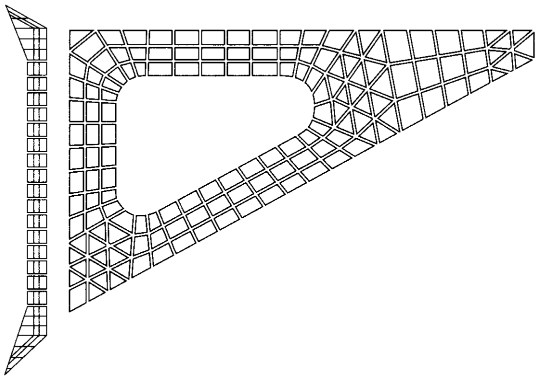
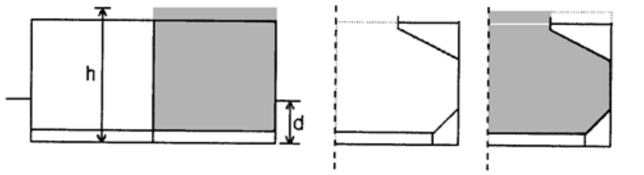
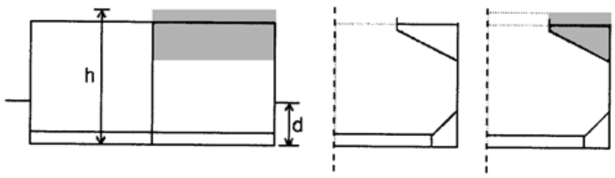


Table C31.1.5-1 Loading Conditions (Example)

	Loading Condition	Illustration for reference	Application
1	Hydrostatic Test Condition (a) (Centre Tank Test)	 Hydrostatic test with a head of water to the level of 2.4 *m* above the top of the tank. *h* = vertical distance from the top of the keel to the top of the tank + 2.4(*m*) *d* = 1/3 × design maximum load draught	Transverse bulkhead, Sloping plate of stool, Double bottom structure, Topside tank, Bilge hopper tank, Hold frame
2	Hydrostatic Test Condition (b) (Side Tank Test)	 Hydrostatic test with a head of water to the level of 2.4 *m* above the top of the tank. *h* = vertical distance from the top of the keel to the top of the tank + 2.4(*m*) *d* = 1/3 × design maximum load draught	Topside tank

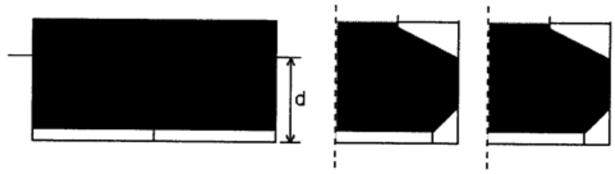
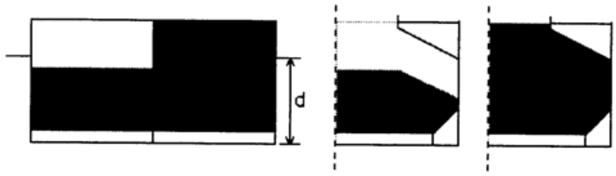
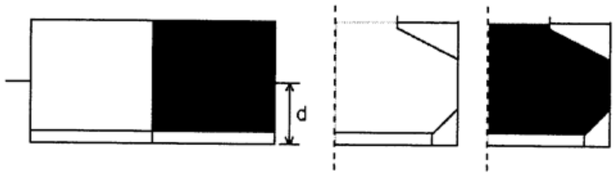
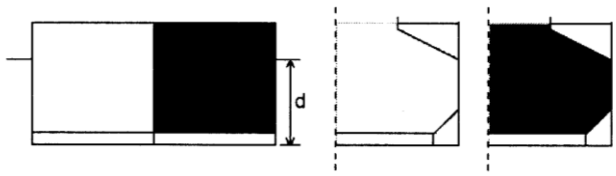
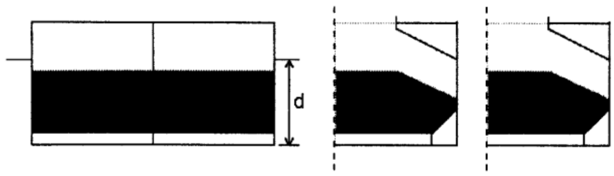
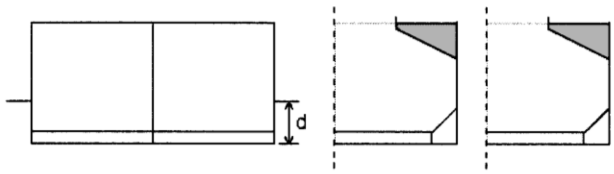
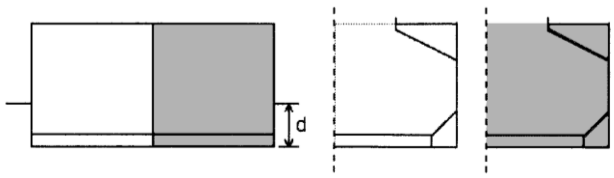
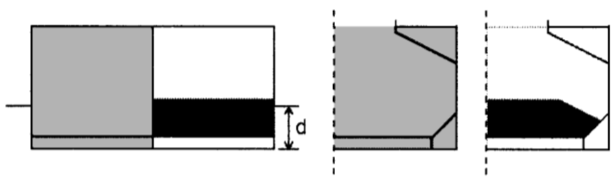
3	Homogeneously cargo loaded condition (Homogeneous Loading)	 *d* = designed maximum load draught	Double bottom structure, Bilge hopper tank
4	Condition with slacked cargo hold (Slack Loading)	 *d* = designed maximum load draught	Double bottom structure, Bilge hopper tank
5	Condition loaded and/or unloaded in multiple ports (Multi-port Loading/Unloading)	 *d* = 0.67 × design maximum load draught / 0.83 × design maximum load draught	Transverse bulkhead, Sloping plate of stool, Double bottom structure, Bilge hopper tank, Hold frame
6	Alternately cargo loaded condition (Alternate Loading)	 *d* = designed maximum load draught	Transverse bulkhead, Sloping plate of stool, Double bottom structure, Bilge hopper tank, Hold frame
7	Condition with heavy density cargoes in adjacent two cargo holds (Block Loading)	 *d* = draught of the block loading condition	Cross deck, Double bottom structure, Transverse bulkhead, Bilge hopper tank, Hold frame
8	Normal Ballast	 *d* = draught of the normal ballast condition	Double bottom structure, Bilge hopper tanks, Topside tank
9	Hold Ballast	 *d* = draught of the hold ballast condition	Transverse bulkhead, Sloping plate of stool, Double bottom structure, Bilge hopper tank
10	Hold Ballast and High Density Cargo Loading (Port Condition)	 *d* = draught of the ballast condition in port	Cross deck, Double bottom structure, Transverse bulkhead, Bilge hopper tank

Fig. C31.1.5-3 Assumed Cargo Surface

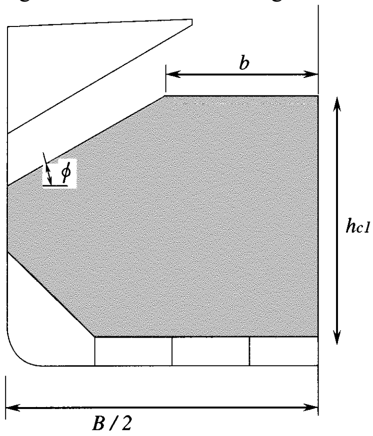


Table C31.1.5-2 Allowable Stress for Modelling by Using Shell Elements

Structural members considered		σ_l	σ_t, σ_v	σ_e
Longitudinal strength members	Bottom shell plating; inner bottom plating; sloping plate of bilge hopper tanks or topside tanks	110/K	145/K	145/K
	Girder		-	175/K
Transverse strength members	Sloping plate of stools; transverse bulkhead		145/K	175/K
	Floor ; Cross Deck		-	175/K

Notes:

1. Unit: N/mm^2
2. σ_e : $\sqrt{(\sigma_l^2 - \sigma_l \cdot \sigma_t + \sigma_t^2 + 3\tau^2)}$ (for longitudinal strength members)

   : $\sqrt{(\sigma_v^2 - \sigma_v \cdot \sigma_t + \sigma_t^2 + 3\tau^2)}$ (for transverse strength members)

   σ_l: Normal stress in lengthwise direction

   σ_t: Normal stress in breadthwise direction

   σ_v: Normal stress in depthwise direction

   τ : Shearing stress on the lengthwise face in the breadthwise direction
3. Openings in floors and girders, if any, are to be taken into consideration in evaluating the stresses.
4. The point of detecting stress is to be the centre of the element.
5. The cross deck is to be included in the direct strength calculation when loading high-density cargoes.
6. Coefficient corresponding to the kind of steel

   e.g. 1.0 for mild steel, the values specified in **1.1.7-2(1) of the Rules** for high tensile steel

Table C31.1.5-3 Allowable Stress for Modelling by using Shell Elements
(For Results of the Calculations by Remeshing with Fine Meshes)

Structural members considered		σ_a	τ	σ_e
Transverse rings	Parallel part	-	-	175/K
	Corners	195/K	-	195/K
Side frames	Middle of parallel part	175/K	-	175/K
	Upper and lower ends of parallel part	215/K	70/K	195/K

Notes:

1. Unit: N/mm^2
2. σ_a: Normal stress of face plate
3. σ_e : $\sqrt{\sigma_x^2 - \sigma_x \cdot \sigma_y + \sigma_y^2 + 3\tau^2}$ (The element coordinate system is to be *X*-*Y* rectangular coordinate system.)

   σ_x: Normal stress in *X*-direction of element coordinate system

   σ_y: Normal stress in *Y*-direction of element coordinate system

τ : Shearing stress in the *X*-*Y* plane

4. The point of detecting stress is to be the centre of the element.
5. Coefficient corresponding to the kind of steel

   e.g. 1.0 for mild steel, the values specified in **1.1.7-2(1) of the Rules** for high tensile steel

Table C31.1.5-4 Allowable Stress for Modelling by Using Beam Elements

Structural members considered	σ_l	σ_t	τ	σ_e
Girders; floors	-	-	100/*K*	175/*K*
Inner bottom plating; bottom shell plating	100/*K*	145/*K*	-	-

Notes:

1. Unit: *N/mm*^{2}
2. σ_e: $\sqrt{\sigma^2 + 3\tau^2}$ (Equivalent stress)

   σ : $\sigma_a + \sigma_b$ (Normal stress)

   σ_a: Axial stress

   σ_b: Bending stress

   σ_l : Normal stress in lengthwise direction

   σ_t : Normal stress in breadthwise direction

   τ : Mean shearing stress
3. Openings in floors and girders, if any, are to be taken into consideration in evaluating the stress.
4. Coefficient corresponding to the kind of steel

   e.g. 1.0 for mild steel, the values specified in **1.1.7-2(1) of the Rules** for high tensile steel

Table C31.1.5-5 Allowable Stress for Double Bottom Modelled into Sandwich Structure

Structural members considered	σ_l	σ_t	τ	σ_e
Girders; floors	-	-	100/*K*	175/*K*
Inner bottom plating; bottom shell plating	100/*K*	145/*K*	-	145/*K*

Notes:

1. Unit; *N/mm*^{2}
2. σ_e: As per notes to **Table C31.1.5-4** (Girders, floors)

   σ_e: $\sqrt{(\sigma_l^2 - \sigma_l \cdot \sigma_t + \sigma_t^2 + 3\tau^2)}$ (Inner bottom plating, bottom shell plating)

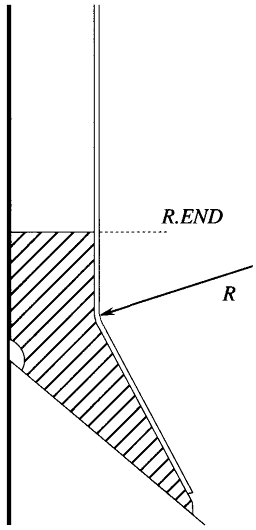
   σ_l, σ_t and τ: As per notes to **Table C31.1.5-4**
3. Openings in floors and girders, if any, are to be taken into consideration in evaluating the stress.
4. Coefficient corresponding to the kind of steel

   e.g. 1.0 for mild steel, the values specified in **1.1.7-2(1) of the Rules** for high tensile steel

C31.1.6 Minimum Thickness

For built-up type hold frames, "the lower end brackets of hold frames" stated in **31.1.6-2, Part C** of the Rules mean the shaded portion of **Fig. C31.1.6-1**.

Fig. C31.1.6-1 Lower End Brackets of Hold Frames



C31.2 Double Bottoms

C31.2.1 General

1 The value of k for double-hull construction or bilge hoppers with a large slope angle

Where the angle to the horizontal of the slope of bilge hoppers exceeds 60°, the value of k is to be obtained from the formula in **31.2.1-4, Part C** of the Rules, assuming $\beta = 60°$. In ships with double-hull construction, the value of k may be 70% of the value obtained from the same formula.

2 Measurement of hold length l_H

Where the angle of the slope of the lower stool of the transverse bulkhead is smaller than 60°, the hold length l_H in the formula in **31.2.1-4, Part C** of the Rules, is to be the distance (m) between the intersections of the inner bottom and straight lines having a slope of 60° and passing through the top of the lower stool of the transverse bulkhead.

C31.2.2 Centre Girders and Side Girders

1 Height of centre girders in ships having unusually large freeboards

In ships having unusually large freeboards, the height of centre girders may be reduced to the values obtained from the formula in **31.2.2-2, Part C** of the Rules in which D is to be replaced by D', the depth to the assumed freeboard deck. However, this height is not to be less than $B/20$.

2 Special Loading Conditions

"Special loading conditions" in **31.2.2-3(1), Part C** of the Rules refer to conditions such as when the ship is loaded with slacked cargo holds of less than $0.5\gamma_H$ in mass; loaded and/or unloaded in multiple ports at a draught greater than 83% or less than 67% of the designed maximum load draught; or loaded with high density cargoes in two adjacent cargo holds. The values of coefficients "n" and "a" may be determined based on actual design loading conditions in the following manner.

(1) The designed maximum load draught (d) is replaced with the draught of the loading condition under consideration (d_{act}).

(2) The value of coefficient "a" in the formulae is to be equal to $0.45 + 0.026L'/d$ or the larger of the values obtained from either of the following two formulae depending on whether the hold is loaded or empty.

For loaded holds: $h\gamma/d_{act} - (1 - 0.026L'/d_{act})$

For slacked holds, etc.: $1 + 0.026L'/d_{act} - h\gamma/d_{act}$

For holds which may be empty during navigation: $1 + 0.026L'/d_{act}$

γ : The ratio of the loaded cargo mass (t) and the volume (m^3) of the cargo hold excluding the volume (m^3) of hatchway part

However, when high density cargoes are in two adjacent cargo holds, this value is to be modified in the same manner as γ_{HD} specified in **31.2.1-3, Part C** of the Rules.

L': As specified in **31.2.2-3, Part C** of the Rules

(3) The value of the coefficient "n" used in the formulae prescribed in **31.2.2-3, Part C** of the Rules is to be obtained from the following formula. For the value of B/l_H in this formula, 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

$$n = \frac{1}{3}\left(\alpha\left(2 - \frac{B}{l_H}\right) + 5 - \frac{B}{l_H}\right)$$

l_H: As specified in **31.2.1-4, Part C** of the Rules

α : As specified in **31.2.2-3, Part C** of the Rules

3 Load conditions for adjacent cargo holds

For the calculation of the coefficient "a" in **31.2.2-3, Part C** of the Rules, load conditions for adjacent cargo holds are generally to be in accordance with the provisions of **C31.1.5(2)**.

4 Thickness of partial intermediate side girders

The thickness of partial intermediate side girders prescribed in **31.2.2-4, Part C** of the Rules is not to be less than the greater of that obtained from the following **(1)** or **(2)**.

(1) Minimum thickness as per **31.1.4, Part C** of the Rules

(2) $C_1''d_0 + 2.5$ (mm)

d_0: As per **31.2.2-3(2), Part C** of the Rules

C_1'': Coefficient obtained from **Table C31.2.2-1**, depending upon the value of S_1/d_0

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

S_1: As per **31.2.2-3(2), Part C** of the Rules

Table C31.2.2-1

S_1/d_0	Up to 0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6 upward
C_1''	3.0	3.5	4.3	5.1	5.8	6.5	7.0	7.4	8.0	8.4	8.6

5 Spacing of side girders just under hopper plates of bilge hopper tanks

For calculating the thickness of the side girder just under the hopper plate of the bilge hopper tank, the standard method for measuring S for the formula in **31.2.2-3, Part C** of the Rules is shown in **Fig. C31.2.2-1**.

Furthermore, when calculating the effective sectional area of the above-mentioned side girder, the sectional area obtained from the following formula of the hopper plate in the extent shown in **Fig. C31.2.2-1** may be included into the effective sectional area of the same side girder.

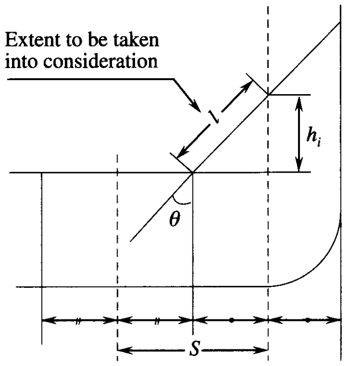
$$10\sum h_i(t_i - 2.5)\left(1 - \frac{\theta}{90}\right)$$

h_i: Height (m) in the extent of l

t_i: Thickness (mm) of the hopper plate

θ : Angle (degrees) between the side girder and the hopper plate

Fig. C31.2.2-1



C31.2.3 Floor Plates

Thickness of partial intermediate floors

The thickness of partial intermediate floors prescribed in **31.2.3-3, Part C** of the Rules is not to be less than the greater of that obtained from the following **(1)** or **(2)**.

(1) Minimum thickness as per **31.1.4, Part C** of the Rules

(2) The thickness of neighbouring floors obtained from the formulae in **31.2.3-2(1)** and **(2), Part C** of the Rules with the value of S reduced by 60%

C31.3 Bilge Hopper Tanks

C31.3.1 General

Continuity of bilge hopper tanks at ends

Floor plates are to be provided at the forward and after ends of bilge hopper tanks, and the tank top plating in the engine room is to be extended into the bilge hopper tanks by about 2 frame spaces.

C31.3.2 Thickness of Hopper Plates

1 Thickness of hopper plates having transverse stiffeners

Where the hopper plate of the bilge hopper has transverse stiffeners, the thickness of the hopper plate is not to be less than that obtained from the following formula.

$9.6S + 2.5 \ (mm)$

S : Spacing of transverse stiffeners (m)

The thickness of hopper plates to be included into the calculation of the section modulus of the hull girder is to be the actual thickness multiplied by 0.5 (when the ratio of the actual thickness to the thickness derived from the above formula is 1.0) or 1.0 (when the same ratio is 2.0 and above) or by a factor obtained by linear interpolation for an intermediate value of the ratio.

2 Construction at the intersection of inner bottom plating and hopper plates

The construction at the intersection of inner bottom plating and hopper plates is to be as follows.

(1) The construction at the above-mentioned intersections is to be either of the following two types.

(a) The scallop in the bilge hopper transverse at the above-mentioned intersection is to be filled up or closed by a collar plate. (*See* **Fig. C31.3.2-1**)

(b) Gusset plates are to be fitted onto the bilge hopper transverse in the extension of the inner bottom plating. (*See* **Fig. C31.3.2-2**)

(2) Where the spacing of floor plates is 2 m or more, a bracket is to be provided at the mid-length between floor plates. This bracket is to reach the inner bottom longitudinal and the hopper plate longitudinal next to the side girder located at the intersection. (*See* **Fig. C31.3.2-3**)

Fig. C31.3.2-1

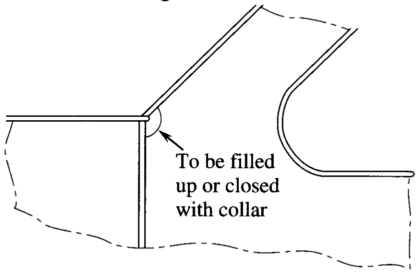


Fig. C31.3.2-2

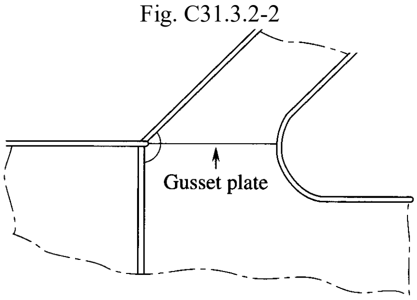
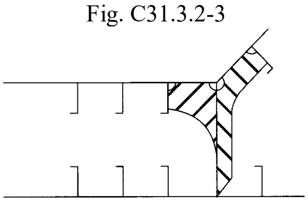


Fig. C31.3.2-3



C31.4 Topside Tanks

C31.4.2 Thickness of Sloping Plates

Thickness of sloping plates having transverse stiffeners

Where the sloping plate of topside tank has transverse stiffeners, the thickness of the sloping plate is not to be less than that obtained from the following formula:

$12S + 2.5 \ (mm)$

S : Spacing (m) of transverse stiffeners

The thickness of sloping plates to be included into the calculation of the section modulus of the hull girder is to be the actual thickness multiplied by 0.5 (when the ratio of the actual thickness to the thickness derived from the above formula is 1.0) or 1.0 (when the same ratio is 2.0 and above) or by a factor obtained by linear interpolation for an intermediate value of the ratio.

C31.4.7 Large Topside Tanks

Thickness of longitudinal diaphragms having transverse stiffeners

Where the longitudinal diaphragm has transverse stiffeners, the thickness of the diaphragm is not to be less than that obtained from the following formula:

$12.8S + 2.5 \ (mm)$

S : Spacing (m) of transverse stiffeners

The thickness of diaphragms to be included into the calculation of the section modulus of the hull girder is to be the actual thickness multiplied by 0.5 (when the ratio of actual thickness to the thickness derived from the above formula is 1.0) or by 1.0 (when the same ratio is 2.0 and above) or by a factor obtained by linear interpolation for an intermediate value of the ratio.

C31.5 Transverse Bulkheads and Stools

C31.5.1 Transverse Bulkheads

With respect to the provisions of 31.5.1-3, Part C of the Rules, the thickness of single strakes of transverse bulkheads adjacent to the side shell plating is not to be less than the value (t) given by the following formula, unless the structure is of trunk construction with adequate supports at the top and bottom of the trunk or it has been examined by an adequate way such as direct calculation using $1/2+1+1+1/2$ holds models.

$$t=\frac{0.0034KF}{h_{sh}}+2.5\ \ (mm)$$

K : As specified in **1.2.1-2(2) of Annex C1.1.7 "GUIDANCE FOR HULL CONSTRUCTION CONTAINING HIGH TENSILE STEEL MEMBERS"**

h_{sh}: Vertical distance (m) from the intersection of sloping plate of topside tank and side shell plating to the intersection of hopper plate of bilge hopper tank and side shell plating

However, where a lower stool is provided or a bulkhead, a solid floor or a similar construction is provided in the same plane as the transverse bulkhead within the bilge hopper tank, the height of the bilge hopper tank may be included in the vertical distance. Where a bulkhead, a solid floor or a similar construction is provided in the same plane as the transverse bulkhead within the topside tank, the height of the topside tank also may be included in this distance.

F : Total loads acting on the girders in the double bottom (including the outermost girders) which is to be obtained by the following formula

Notwithstanding the above provisions, this value is to be further examined for special loading conditions such as those with heavy density cargoes in adjacent cargo holds, etc.

$F=F_a+F_f\ \ (kN)$

F_a and F_f: Total loads acting on the girders in the double bottom in the after cargo hold and the forward cargo hold of the considered transverse bulkhead which are obtained by the following formula

$$\sum\left\{135C_1SBd\left(1-4\left(\frac{y}{B}\right)^2\right)\right\}$$

C_1, S, y: As specified in 31.2.2-3(1), Part C of the Rules

For the calculation of coefficient "C_1", the value of coefficient "a" is to be the greater of the values obtained by the following formulae, and the value of coefficient "n" may be taken as 1.0. Notwithstanding the above provisions, for ships not designed for loading and/or unloading in multiple ports, the value of coefficient "a" may be obtained by the formula $h\gamma_{Full}/d$.

(1) $h\gamma_{Full}/d-0.67+0.026L'/d$

(2) $0.75+0.026L'/d$

γ_{Full}: As specified in 31.2.1-3, Part C of the Rules

L': As specified in 31.2.2-3, Part C of the Rules

C31.5.2 Lower and Upper Stools at Transverse Bulkheads

With respect to the provisions of 31.5.2-5, Part C of the Rules, construction of the upper stools is to meet the following, unless the construction is examined by an adequate way such as direct calculation using $1/2+1+1+1/2$ holds models.

$$\sigma=\left|\left(\frac{wB_{CD}^2}{8}-M\right)\frac{10^3}{Z_{DK}}+\frac{F_{IB}-F_{SS}}{l_{DK}t_{DK}}\right|\le\frac{145}{K}\ \ (N/mm^2)$$

$$\tau=\left|\frac{wB_{CD}}{4\left(h_{ST}\left(t_{ST}-2.5\right)\right)}\right|\le\frac{70}{K}\ \ (N/mm^2)$$

$$w=\frac{(a_1-a_3)a_5}{a_1a_4-a_2a_3}w_1\ \ (kN/m)$$

$$w_1=\frac{\left(\alpha_{IB}{}^3-4\alpha_{IB}{}^2+8\right)}{5}\frac{F}{B}\ \ (kN/m)$$

$$w_2 = \frac{(a_2 - a_4)a_5}{a_2 a_3 - a_1 a_4} w_1 \ (kN/m)$$

$$a_1 = \frac{(1-\alpha_{CD})^2}{(1+\alpha_{CD})(5-\alpha_{CD}{}^2)}\left((5+7\alpha_{CD}) + 2(1-\alpha_{CD})\frac{(1-\alpha_{CD})(4\beta_1 - 3\beta_2) + 4\alpha_{CD}\beta_1\left(\frac{I_{TST}}{I_{CD}}\right)}{(1-\alpha_{CD}) + \alpha_{CD}\left(\frac{I_{TST}}{I_{CD}}\right)}\left(\frac{I_{IB}}{I_{TST}}\right)\right)$$

$$a_2 = \frac{2\alpha_{CD}}{(1+\alpha_{CD})(5-\alpha_{CD}{}^2)}\left(4(1+\alpha_{CD} - \alpha_{CD}{}^2) + (1-\alpha_{CD})\frac{(1-\alpha_{CD})^2 + 2\alpha_{CD}(2-3\alpha_{CD})\left(\frac{I_{TST}}{I_{CD}}\right)}{(1-\alpha_{CD}) + \alpha_{CD}\left(\frac{I_{TST}}{I_{CD}}\right)}\left(\frac{I_{IB}}{I_{TST}}\right)\right)$$

$$a_3 = \frac{6(1-\alpha_{CD})^2}{(6-\alpha_{CD}^2)}\left(1 + \frac{4\alpha_{CD}\beta_2}{(1-\alpha_{CD}) + \alpha_{CD}\left(\frac{I_{TST}}{I_{CD}}\right)}\left(\frac{I_{IB}}{I_{CD}}\right)\right)$$

$$a_4 = \frac{\alpha_{CD}}{(6-\alpha_{CD}{}^2)}\left(12 - 7\alpha_{CD} + \frac{(1-\alpha_{CD})(6-\alpha_{CD}) + \alpha_{CD}{}^2\left(\frac{I_{TST}}{I_{CD}}\right)}{(1-\alpha_{CD}) + \alpha_{CD}\left(\frac{I_{TST}}{I_{CD}}\right)}\left(\frac{I_{IB}}{I_{CD}}\right)\right)$$

$a_5 = \sqrt{\frac{I_{CD}}{I_{IB}}}$, however, a_5 does not need to be greater than 1.

$$M = \frac{B^2}{24}\frac{-3(1-\alpha_{CD})^3\beta_2 w_2 + \alpha_{CD}\left(2\alpha_{CD}{}^2\left(\frac{I_{TST}}{I_{CD}}\right) - 3(1-\alpha_{CD})^2\right)w}{(1-\alpha_{CD}) + \alpha_{CD}\left(\frac{I_{TST}}{I_{CD}}\right)} \ (kN\text{-}m)$$

$$F_{IB} = \frac{B^3}{8h_{SH}{}^2}\frac{I_{SH}}{I_{IB}}\left(2w_1 - \left(2 - \alpha_{CD}(3-\alpha_{CD}{}^2)\right)w_2 - \alpha_{CD}(3-\alpha_{CD}{}^2)w\right) \ (kN)$$

However, F_{IB} is not to be less than 0.

$F_{SS} = 5l_{Hold}(d + 0.026L' - h_{SS})^2$ (kN)

However, F_{SS} is to be 0 in loaded condition.

β_1 and β_2 are to be as follows.

(1) Where a bulkhead, a solid floor or a similar structure is provided in the same plane as the transverse bulkhead within the topside tank, β_1 is to be taken as $3/8$ and β_2 is to be taken as $1/3$.

(2) Where a bulkhead, a solid floor or a similar structure is not provided in the same plane as the transverse bulkhead within the topside tank, β_1 and β_2 are to be the ratio of the horizontal distance between the inner end of the topside tank and the centre of the opening in the transverse ring within the topside tank, to the breadth of the topside tank.

Z_{DK}: Section modulus (cm^3) of the upper stool structure about the ship longitudinal axis at deck side

t_{DK} : The thickness (mm) of deck plating inside the line of openings

l_{DK} : The length (m) of the deck inside the line of openings

t_{ST} : The thickness (mm) of the sloping plating of upper stool

h_{ST}: The height (m) of upper stool

h_{SH}: The vertical distance (m) between the bottom of topside tank and the top of bilge hopper tank

h_{SS} : The vertical distance (m) from the base line to the centre of the side structure between the topside tank and the bilge hopper tank

l_{Hold}: The average length (m) of after and forward cargo holds of the transverse bulkhead

F : As specified in C31.5.1 (kN)

However, where bottom pressure is greater than internal pressure such as those acting on the double bottoms of empty holds, F is to be corrected to a negative value.

$\alpha_{IB} = {}^{B_{IB}}/_{B}$

$\alpha_{CD} = {}^{B_{CD}}/_{B}$

B_{IB}: The horizontal distance (m) between the inner end of bilge hopper tanks

B_{CD}: The breadth (m) of the deck inside the line of openings

I_{IB} : The moment of inertia (cm^4) of the double bottom structure and lower stool structure about the ship's longitudinal axis

Only the part of the double bottom just under the lower stool needs to be taken into consideration.

I_{TST}: The moment of inertia (cm^4) of the topside tank structure about the ship's longitudinal axis at the midpoint of the breadth of the topside tanks

The deck plating and the sloping plating within the area 0.1 *times* the breadth of the topside tank forward and after the transverse bulkhead may be taken into consideration.

I_{CD} : The moment of inertia (cm^4) of upper stool structure about the ship's longitudinal axis at the ship's centre line

The deck plating within the area 0.1 *times* B_{CD} forward and after the transverse bulkhead may be taken into consideration.

I_{SH} : The moment of inertia (cm^4) of side structure around the transverse bulkhead about the ship's longitudinal axis

The side shell plating within the area 0.1 *times* h_{SH} forward and after the transverse bulkhead, a single strake of the bulkhead plating including plating deemed as its face plate, and the trunk construction may be taken into consideration.

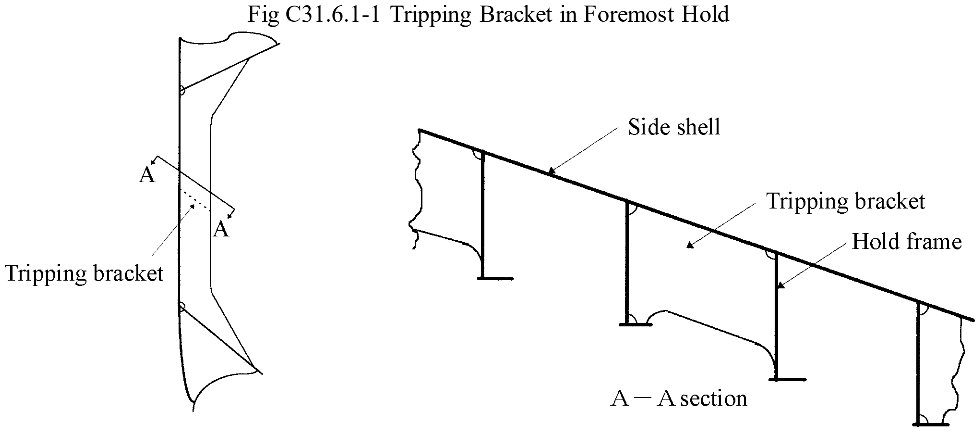
K : As specified in **1.2.1-2(2) of Annex C1.1.7 "GUIDANCE FOR HULL CONSTRUCTION CONTAINING HIGH TENSILE STEEL MEMBERS"**

C31.6 Hold Frames

C31.6.1 Hold Frames

The standard arrangement of tripping brackets specified in **31.6.1-5, Part C** of the Rules is as shown in **Fig C31.6.1-1**.

Fig C31.6.1-1 Tripping Bracket in Foremost Hold



C31.6.2 Upper and Lower End Connections of Hold Frames

Figs. C31.6.2-1 and **C31.6.2-2** show examples of connections of the upper and lower ends of the hold frame to the topside tank and the bilge hopper tank respectively.

Fig. C31.6.2-1

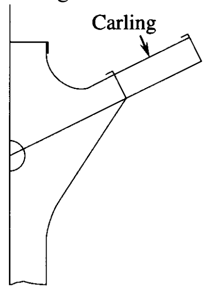
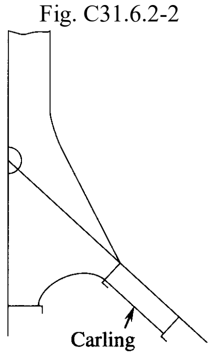


Fig. C31.6.2-2



C31.7 Decks, Shell Plating and Miscellaneous

C31.7.1 Deck Plating outside the Line of Openings

Sectional area of the deck at the ends of topside tanks

The effective sectional area of the deck outside the line of openings at the ends of the topside tank is to be determined by tapering from the value obtained from the following formula:

$$\left(1+0.5\frac{A_t}{A_d}\right)A_d$$

A_t: Effective sectional area of sloping plate of topside tank in the midship part

A_d: Effective sectional area required by the Rules of the strength deck in the midship part

C31.7.2 Deck Plating inside the Line of Openings

1 Thickness of deck plating with longitudinal beams inside the line of openings

Where the deck inside the line of openings is constructed on the longitudinal framing system, the thickness of the deck plating is not to be less than that obtained from the following formula:

$$1.69\sqrt[3]{\frac{F}{l}S^2}+2.5\ \ (mm)$$

S: Spacing (m) of longitudinal beams

l: Length (m) of deck inside the line of openings

F: F_1+F_2 (*kN*)

$F_1=0.49h_t^2(\alpha+1)^2(l_1+l_2)$ (*kN*)

$F_2=0.26LBC_b$ (*kN*)

$\alpha=h_s/h_t$

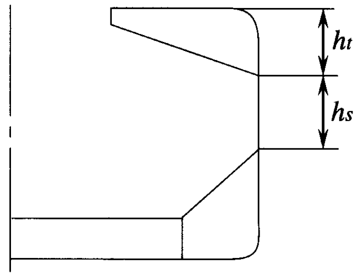
h_t: Vertical distance (m) from the intersection of sloping plate of topside tank and side shell plating to the upper end of D

h_s: Vertical distance (m) from the intersection of sloping plate of topside tank and side shell plating to the intersection of hopper plate of bilge hopper tank and side shell plating (*See* **Fig. C31.7.2-1**)

l_1 and l_2: Lengths (m) of holds forward of and abaft the deck inside the line of openings concerned

"The lengths of holds" are defined as the distances between bulkheads.

Fig. C31.7.2-1



2 Thickness of deck plating with transverse beams inside the line of openings

Where the deck inside the line of openings is stiffened in the transverse framing system and the transverse bulkhead is stiffened in a vertically corrugated system, the thickness of the deck plating is not to be less than that obtained from the following formula for *BC-A*, *BC-B*, and *BC-C* ships; ships loading and/or unloading at multiple ports; and ships carrying dense cargoes such as ore. However, this requirement does not apply if the scantlings are determined by direct calculation using $1/2+1+1+1/2$ holds models in accordance with **C31.1.3**.

$$t_{DK} = 12.5\beta S + t_0 \ (mm)$$

$$\beta = \sqrt{\frac{\sigma}{118}}$$

However, β is not to be less than 1.

σ : Stress given by the provisions **C31.5.2** for a loaded condition
However, for deck plating outside the area within 0.2 *times* the breadth of the deck inside the line of openings measured from the centreline, σ may be taken as 118.

S : Spacing of stiffeners (m)

t_0: 2.5 (mm) for cargo holds, 3.0 (mm) for cargo hold(s) adapted for the carriage of water ballast

C31.8 Supplementary Provisions for Carriage of Liquid in Holds

C31.8.1 General

1 Any openings which may be used for cargo operations are not to be fitted to bulkheads and decks separating the cargo oil tanks (including combined ore holds/cargo oil tanks) designed and equipped for the carriage of oil having a flash point below 60°C (closed cup test) from other spaces that are not designed and equipped for its carriage.

2 Cargo holds utilized for ballasting

When cargo holds are utilized as ballast tanks, they are to be kept empty or full throughout the duration of the voyage in order to avoid impact due to the dynamical load of the ballast water.

C31.8.2 Holds Half-loaded with Cargo Oil

Reinforcement for half-loading of cargo oils

Where synchronism between pitching and/or rolling and the natural oscillations of cargo oil half-loaded in a hold is unavoidable, the scantlings of plating, stiffeners and girders, near the synchronizing oil level, of the transverse bulkheads (in case of pitching) or of the sloping plates of topside tanks (in case of rolling) are not to be less than that obtained from the respective formulae in which *h* is to be determined by the following formulae:

(1) Pitching

$$h_1 + 0.1l + 0.77\frac{h_1}{h_2}\left(1 - \frac{h_1}{h_2}\right)l \ (m)$$

h_1: Height (m) of cargo oil level measured from the top of inner bottom

l : Length (m) of hold (distance between transverse bulkheads)

h_2: Height (m) of upper deck, at centreline, above the top of inner bottom

(2) Rolling

$$0.4B\left[\left\{\frac{3\times\frac{h_1}{h_2}+0.6}{\sqrt{\left\{1-\left(\frac{x}{l_s}\right)^2\right\}^2+\left\{17\left(\frac{h_1}{h_2}-0.45\right)^2+0.12\right\}\left(\frac{x}{l_s}\right)^2}}\right\}-9.69\left(0.7-\frac{h_1}{h_2}\right)\left(0.3-\frac{h_1}{h_2}\right)\right]\ (m)$$

x : Vertical distance (m) from the intersection of the side shell with hopper plate of bilge hopper tank to the member under consideration

h_1 and h_2 : As specified in **(1)** above

l_s : Vertical distance (m) from the intersection of the side shell with hopper plate of bilge hopper tank to the intersection of the side shell with the sloping plate of the topside tank

C31A ADDITIONAL REQUIREMENTS FOR NEW BULK CARRIERS

C31A.1 General

C31A.1.1 Application

1 For the application of the provisions of **31A.2**, **31A.3**, **31A.4** and **31A.5, Part C** of the Rules, for bulk carriers of double-side skin construction which have a longitudinal bulkhead located within *B*/5 or 11.5 *m*, whichever is less, inboard from the ship's side at right angled to the centreline at the assigned summer load line, cargo holds where the longitudinal bulkhead is closer to the ship's side than the required distance may be considered flooded.

C31A.1.2 Definitions

"A ship which is intended primarily to carry dry cargo in bulk" stipulated in **31A.1.2(1), Part C** of the Rules refers to ships which have loading conditions for carrying dry cargoes in bulk included in their loading manual.

C31A.2 Damage Stability

C31A.2.1 Survivability

1 With respect to the requirements of **31A.2.1-1, Part C** of the Rules, if the following load conditions satisfy the requirements regarding the final water line specified in **31A.2.1-2, Part C** of the Rules, there is no need to confirm the survivability of each load condition separately.

(1) The ship is to be loaded to its summer load water line on an even keel.

(2) Where the vertical centre of gravity is calculated, the following conditions are to be satisfied.

(a) Homogeneous cargo loading condition

(b) All cargo compartments including those to be partly loaded are considered fully loaded.

(c) If the ship is intended to operate at its summer load line with empty compartments, such compartments are to be considered empty only when the height of the centre of gravity so calculated is not less than as calculated in **(b)** above.

(d) 50% of the individual total capacity of all tanks and spaces fitted to contain consumable liquids and stores is allowed for. It is assumed that for each type of liquid, at least one transverse pair or single centre line tank has maximum free surface, and that the effect of the free surface on the tank or combination of tanks to be taken into account is the greatest. The remaining tanks are assumed either completely empty or completely filled, and the distribution of consumable liquids between these tanks is to be effected so as to obtain the greatest possible height above the keel for the centre of gravity.

(e) The specific gravity of the liquid weight is to be obtained from **Table C31A.2.1**.

2 In applying the requirements of **31A.2.1-2(4), Part C of the Rules**, "unprotected openings" include ventilators provided with weathertight closing appliances in accordance with the requirements of **23.6.5-2, Part C of the Rules** that for operational reasons have to remain open to supply air to the engine room or emergency generator room (if the same is considered buoyant in the stability calculation or protecting openings leading below) for the effective operation of the ship.

Table C31A.2.1 Specific Gravity

Liquid	Specific gravity
Sea water	1.025
Fresh water	1.000
Heavy oil C	0.950
Heavy oil A	0.900
Lubricating oil	0.900

C31A.2.2 Permeability

1 The permeability of the compartment assumed to be damaged is to be obtained from **Table C31A.2.2**. However, the permeability may be different where deemed appropriate by the Society.

Table C31A.2.2 Permeability

Compartment	Permeability
Loaded hold	0.9
Empty hold	0.95

C31A.4 Allowable Hold Loading on Double Bottom

C31A.4.1 General

1 The provisions of **31A.4, Part C** of the Rules are to apply to ships without bilge hopper tanks in accordance with the following.

(1) For ships having double side construction from the tank top to the upper deck, e.g., box shape ships, the parts of double side construction are to be treated as bilge hoppers.

(2) For ships having single side construction from the tank top to the upper deck or top side tanks, ends of the lower brackets of the web frames are to be treated as the lower ends of hoppers.

C31A.4.3 Strength Criteria

1 "Appropriate reinforcements …fitted to the Society's satisfaction" specified in **31A.4.3-2, Part C** of the Rules refer to the following.

(1) Two horizontal stiffeners are fitted on the floor and/or girder above and below the opening.

(2) A doubling plate is fitted in the circumference of the opening.

2 It is stipulated in **31A.4.3-3, Part C** of the Rules that "the density for steel is to be used for steel mill products" and the "permeability of cargo … is to be taken as 0 for steel mill products." Therefore, the loads acting on the double bottom when steel mill products are loaded in a flooded cargo hold are obtained by combining the weight of the loaded steel products and the flood water in the following way.

(1) Calculate the volume occupied by the steel mill products using their density.

(2) Take the permeability of the space obtained from **(1)** above as 0.

(3) Take the permeability of the volume left in the cargo hold as 0.95.

C31A.5 Longitudinal Strength in Flooded Condition

C31A.5.1 General

1 The weight of the water in a flooded hold is to be calculated in accordance with **C31A.5.2-2, Part C**, at the water level of the equilibrium water line with the assumption that each cargo hold is individually flooded. In this case, the loaded cargo may be taken to be level. The equilibrium water line is the water level that is below the lower edge of any opening through which progressive flooding may take place, after taking into account sinkage, heel, and trim.

2 The loading condition prescribed in **31A5.1-2(2)** through **(4)**, **Part C** of the Rules refers to cases where the ship carries bulk cargoes having a density of not less than 1.0 (ton/m^3).

3 For bulk carriers as defined in **1.3.1(13), Part B** of the Rules which are contracted for construction on or after 1 January 2004, the ballast conditions specified in **31.1.3-3, Part C** of the Rules are to be included in the ballast conditions specified in **31A.5.1-2(1), Part C** of the Rules. Where the provisions of **1.3.1-2** and **-3** in **Annex C34.1.2** apply to such ships, intermediate conditions specified in **1.3.1-2** and **-3** are to be included with the conditions at departure and arrival. Where ballast conditions and/or cargo loaded conditions involve partially filled ballast tanks at departure, arrival or during intermediate conditions, these ballast tanks are to be added as either full or empty according to the provisions of **C15.2.1(4)** and **(5)**.

4 Where ships are assumed to have sufficient longitudinal strength in flooded conditions, the longitudinal strength evaluation may be omitted at the Society's discretion. In this case, the reason of the omission is to be clarified.

C31A.5.2 Loads in Flooded Holds

1 With respect to the provisions of **31A.5.1-2, Part C** of the Rules, the requirements of **31A.5, Part C** of the Rules do not need to apply to harbour conditions, conditions for entering drydock, loading and unloading transitory conditions in port, and loading conditions encountered during ballast water exchange.

2 The requirements prescribed in **31A.5.2-2(2), Part C** of the Rules regarding the permeability of steel mill products being 0 are to be in accordance with **C31A.4.3-2**.

C31A.5.3 Strength Criteria

Where the cargo in two adjacent holds divided by a transverse bulkhead becomes similar to an alternate loading condition as a result of flooding, the shear force F_{sf} in still water after flooding may be corrected according to the provisions of **C15.3.1-2**.

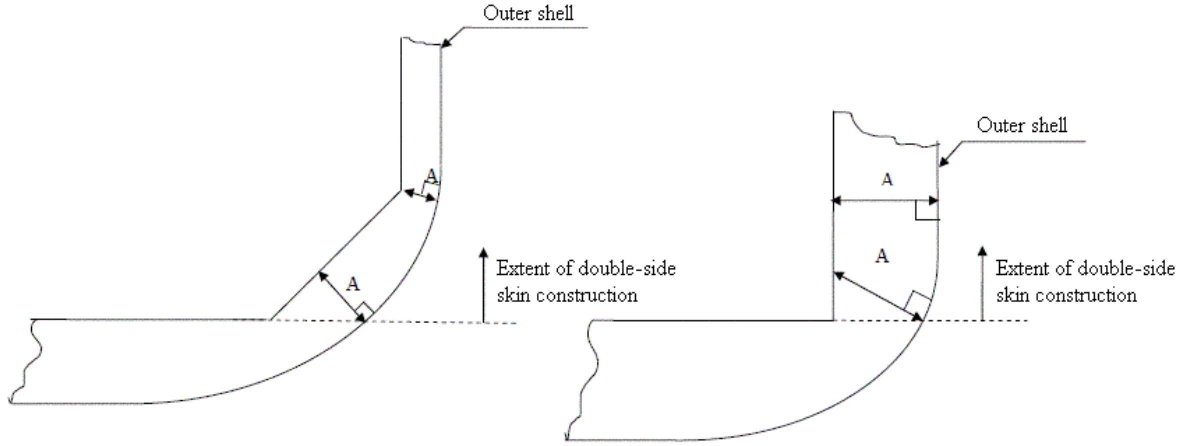
C31A.6 Double-side Skin Construction and Cargo Hold Construction

C31A.6.1 Double-side Skin Construction

1 The distance between the outer shell and the inner shell as specified in **31A.6.1-1(2), Part C** of the Rules is to be measured in accordance with **Fig. C31A.6.1-1**.

2 "Corrosion prevention systems deemed appropriate by the Society" specified in **31A.6.1-2, Part C** of the Rules refers to those specified in **C25.2.1-2(2)**.

Fig. C31A.6.1-1 Width of Double-side Skin Construction



C31A.6.2 Cargo Hold Construction

1 With respect to the provisions of **31A.6.2-1(1), Part C** of the Rules, cargo hold construction is to be in accordance with the following.

(1) Inner bottom and bilge hopper plating is to be increased to cater for grab operations in accordance with the provisions of **31.2.4-3** and **31.3.2-2, Part C** of the Rules. In this case, the notation "*GRAB*" is affixed to the Classification Characters.

(2) Appropriate means for the protection of hatchways and coamings from grab wire damage are to be taken.

2 With respect to the provisions of **31A.6.2-1(2), Part C** of the Rules, continuity between the side shell structure and the rest of the hull structure is to be in accordance with the provisions of **C31.6.2**. For double-side skin construction, appropriate attention is to be paid for the continuity of primary transverse structural members.

3 With respect to the provisions of **31A.6.2-1, Part C** of the Rules, steel materials in the following structural members in bulk carriers of single-side skin construction are not to be less than grade *KD*, *KD*32 or *KD*36 as defined in **Part K of the Rules**.

(1) Side shell strakes included totally or partially between the two points located 0.125*l* above and below the intersection of the side shell and bilge hopper sloping plate or inner bottom plate, where *l* is the span of the ordinary frame.

(2) Web of ordinary frames, including end bracket, of single-side skin construction within 0.125*l* above the intersection of the side shell and bilge hopper sloping plate or inner bottom plate.

4 With respect to the provisions of **31A.6.2-1(3), Part C** of the Rules, the stiffeners used in cargo hold areas are to be in accordance with the buckling strength criteria as specified in the following **(1)** to **(5)**. The buckling strength can be examined by the provisions of **2.3.4, Section 5, Chapter 8, Part 1. Part CSR-B&T** of the Rules, in lieu of that specified in this section. When calculating the buckling strength, typical loading conditions are to be considered.

(1) Structural members to be considered

"Stiffeners used in cargo hold areas" are those complying with the following **(a)** to **(h)**. Stiffeners outside of $0.4L$ of the midship part are deemed to satisfy the requirements here if they comply with all the requirements which apply to stiffeners, unless deemed otherwise by the Society.

(a) Longitudinal stiffeners provided on inner bottom plates

(b) Longitudinal stiffeners provided on hopper plates and sloping plates of topside tanks

(c) Longitudinal stiffeners provided on longitudinal bulkheads (excluding corrugated bulkheads)

(d) Horizontal stiffeners provided on hatch side coamings over $0.15L$ in length

(e) Vertical stiffeners provided on transverse bulkheads (excluding corrugated bulkheads)

(f) Vertical stiffeners provided on sloping plates and vertical plates of lower stool and upper stool of transverse bulkheads

(g) Hold frames (single side skin construction only)

(h) Other stiffeners that have high pressure and high axial compressive stress acting on them simultaneously

(2) Pressure acting on stiffeners

The pressure p (kN/m^2) acting on stiffeners is given by the following **(a)** to **(c)** depending on the stiffener considered. When pressure is applied from the stiffener side, p is to be taken as a negative value and when pressure is applied from the side opposite to the stiffener, p is to be taken as a positive value.

(a) Pressure p (kN/m^2) due to dry bulk cargo is given by the following formula:

$$p = \gamma(1 + C_1)gK_C h_1$$

γ : Specific gravity of cargo given by the following formula:

$$\gamma = \frac{M}{V} \ (t/m^3)$$

M: Maximum cargo mass (t) given for each cargo hold

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

C_1: Coefficient obtained from **Table C31A.6.2-1** depending on L

For intermediate values of L, C_1 is to be obtained by linear interpolation.

g : Gravity acceleration, taken as 9.81 (m/s^2)

K_C: Coefficient given by the following:

For stiffeners provided on hatch side coamings, sloping plates of topside tanks, sloping plates of upper stools (excluding vertical plates, see **Fig. C31A.6.2-1**) and hold frames: $K_C = 0$

For stiffeners other than above: $K_C = \cos^2\alpha + (1 - \sin\psi)\sin^2\alpha$

α : Angle of inclination (*degrees*) of the panel considered on the side not facing the cargo hold with respect to the horizontal plane

ψ : Angle of repose (*degrees*) of cargo

The value given in **Table C31A.6.2-2** may be used as the standard value corresponding to the type of cargo.

h_1: Vertical distance (m) from the mid-point of the stiffener under consideration to the upper deck at centre line

(b) Pressure p (kN/m^2) due to ballast water is given by the following formulae.

For ballast tanks excluding ballast hold: $p = 1.025(1 + C_2)gh_2$

For ballast hold: $p = 1.025(1 + C_2)gh_3$

C_2: Coefficient obtained from **Table C31A.6.2-3** depending on L

For intermediate values of L, C_2 is to be obtained by linear interpolation.

g : Gravity acceleration, taken as 9.81 (m/s^2)

h_2: Vertical distance (m) from the mid-point of the stiffener under consideration to the middle point of the distance from the tank top to the upper end of overflow pipe

h_3: Vertical distance (m) from the mid-point of the stiffener under consideration to the top of the hatch coaming

(c) Total external sea pressure p (kN/m^2) is given by the following formula.

$p = 1.025gh_4$

h_4: Vertical distance (m) from the mid-point of the hold frame or horizontal stiffener of hatch side coaming under consideration to the point $d + 0.05L'$ above the top of keel

Where the position of the hatch side coaming is higher than $d + 0.05L'$ above the top of keel, h_4 is to be taken equal to zero.

L' : Length of ship (m)

Where, L exceeds $230m$, L' is to be taken as $230m$.

(3) Reference Stress

Reference stress σ_{ref} (N/mm^2) of the stiffener is given by the following **(a)** to **(e)** depending on the type of stiffeners under consideration.

(a) In case of longitudinal stiffeners, reference stress is to be obtained from the following **i)** or **ii)**, whichever is greater.

i) Compressive stress due to longitudinal hull girder bending moment, obtained from the following formula, but not less than $30/K$

For members located above the horizontal neutral axis, sagging condition is to be considered and for members located below the horizontal neutral axis, hogging condition is to be considered.

$$\sigma_V = \frac{M_S + M_W}{I} z \times 10^5 \ (N/mm^2)$$

M_S: Allowable still water bending moment (kN-m)

However, in ballast condition, M_S may be taken as the greater of the values specified in the following **1)** or **2)**. M_S is to be calculated for hogging and sagging conditions respectively.

1) 120% of the actual hull girder bending moment in the ballast condition specified in the Loading Manual but not in excess of the allowable still water bending moment

Where the ballast condition includes intermediate conditions specified in **1.3.1-2** and **-3** in **Annex C34.1.2**, the partially filled ballast tanks do not need to be considered as being full or empty.

2) Half of the allowable still water bending moment

M_W: Wave induced longitudinal bending moments (kN-m) as specified in **15.2.1, Part C** of the Rules

z : Vertical distance (m) from the horizontal neutral axis to the location of the member considered in the athwartship section under consideration

I : Gross moment of inertia (cm^4) at the athwartship section considered

ii) Compressive stress due to horizontal hull girder bending moment, given by the following formula:

$$\sigma_H = C_3 \frac{2y}{B} \ (N/mm^2)$$

C_3: Coefficient given by the following formulae

For the intermediate values of L, C_3 is to be obtained by linear interpolation.

$C_3 = \frac{6}{a} g$ where L is 230 m and below

$C_3 = \frac{10.5}{a} g$ where L is 400 m and over

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.

K : Coefficient corresponding to the kinds of steels of side shell plating

e.g.1.0 for mild steel and the values specified in **1.1.7-2, Part C** of the Rules for high tensile steel

y : Athwartship distance (m) from centreline of the hull to the point under consideration

(b) Reference stress for horizontal stiffeners of hatch side coamings is given by the following **i)** or **ii)**.

i) When the stiffener is fitted on a continuous hatch side coaming, **(a)** above is to be applied treating the stiffener as a longitudinal stiffener.

ii) When the stiffener is fitted on a discontinuous hatch side coaming, **(a)** above is to be applied treating the stress as bending stress at deck.

(c) The reference stress of vertical stiffeners of slant and vertical plating of upper and lower stools of transverse bulkheads and transverse bulkheads (excluding corrugated bulkheads) is given by the following **i)** or **ii)**, depending on the loading condition and loading pattern. When the axial compressive stress at the mid-point of the stiffener is calculated by direct strength analysis, the value may be used as the reference stress, but it is not to be less than $30/K$ (See **Fig. C31A.6.2-2**).

i) When relatively high axial compressive stress is acting on the stiffener (e.g. vertical stiffeners of the stool facing an empty hold in alternately cargo-loaded condition or those facing a hold adjacent to a heavy ballast hold in heavy ballast condition), reference stress is given by the following formula:

$\sigma_{ref} = 145/K$ (N/mm^2)

ii) In other cases, given by the following formula:

$\sigma_{ref} = 30/K$ (N/mm^2)

K : Coefficient corresponding to the kinds of steels of attached plating

e.g. 1.0 for mild steel and the values specified in **1.1.7-2, Part C** of the Rules for high tensile steel

(d) In case of hold frames, reference stress is obtained from the following formula:

$\sigma_{ref} = 30/K$ (N/mm^2)

K : As specified in **(c)** above

(e) The reference stress of members other than those above is to be in accordance with the discretion of the Society.

(4) Buckling Stress

Buckling stress σ_{Uxp} (N/mm^2) of the stiffener considered is given by the following **(a)** or **(b)** corresponding to the pressure acting on the stiffener. When calculating the buckling stress, thickness standard deductions equal to the values given in **Table C31A.6.2-4** are to be considered for t_b, t_w and t_f.

(a) Where $0 \le p \le p_{cr}$ or $-p_{cr} \le p \le 0$:

$$\sigma_{Uxp} = \min[\sigma_{PI}, \sigma_{SI}]$$

$$\sigma_{PI} = \frac{A_e}{2A}\left\{P_C\left(\frac{1}{A_e} + \frac{y_p}{I_e}\left(w_s + \frac{5\ell^4 s|p|}{384 \times 10^3 E I_e}\right)\right) + \sigma_Y - \frac{p\ell^2 s}{8 \times 10^3}\frac{y_p}{I_e}\right.$$
$$\left. - \sqrt{\left(P_C\left(\frac{1}{A_e} + \frac{y_p}{I_e}\left(w_s + \frac{5\ell^4 s|p|}{384 \times 10^3 E I_e}\right)\right) + \sigma_Y - \frac{p\ell^2 s}{8 \times 10^3}\frac{y_p}{I_e}\right)^2 - 4\left(\sigma_Y - \frac{p\ell^2 s}{8 \times 10^3}\frac{y_p}{I_e}\right)\frac{P_C}{A_e}}\right\}$$

$$\sigma_{SI} = \frac{A_e}{2A}\left\{P_C\left(\frac{1}{A_e} + \frac{y_s}{I_e}\left(w_s + \frac{\ell^4 s|p|}{384 \times 10^3 E I_e}\right)\right) + \sigma_Y + \frac{p\ell^2 s}{24 \times 10^3}\frac{y_s}{I_e}\right.$$
$$\left. - \sqrt{\left(P_C\left(\frac{1}{A_e} + \frac{y_s}{I_e}\left(w_s + \frac{\ell^4 s|p|}{384 \times 10^3 E I_e}\right)\right) + \sigma_Y + \frac{p\ell^2 s}{24 \times 10^3}\frac{y_s}{I_e}\right)^2 - 4\left(\sigma_Y + \frac{p\ell^2 s}{24 \times 10^3}\frac{y_s}{I_e}\right)\frac{P_C}{A_e}}\right\}$$

(b) Where $p \ge p_{cr}$ or $p \le -p_{cr}$:

$$\sigma_{Uxp} = \sigma_{HI}$$

$$\sigma_{HI} = -\frac{\sigma *_{HI}}{p_{st} - p_{cr}}(|p| - p_{cr}) + \sigma *_{HI}$$

$$\sigma *_{HI} = \min[\sigma_{PI(p=pcr)}, \sigma_{SI(p=pcr)}]$$

The following definitions apply to **(a)** and **(b)** above.

p : Pressure acting on the stiffener considered, as specified in **(2)** above

p_{cr}: Plastic collapse load of attached plating considered, which is obtained from the following formula:

$$p_{cr} = \frac{12}{\ell^2 s}\frac{I}{y_{s0}}\sigma_Y \times 10^3 \quad (kN/m^2)$$

p_{st}: Plastic collapse load of stiffener considered, which is obtained from the following formula:

$$p_{st} = \frac{16}{\ell^2 s} Z_p \sigma_Y \times 10^3 \quad (kN/m^2)$$

P_C : Euler's buckling load, as obtained from following formula:

$$P_C = \frac{\pi^2 E I_e}{\ell^2} \ (N)$$

I : Moment of inertia (mm^4) of stiffener including attached plating with full width

I_e : Moment of inertia (mm^4) of stiffener including attached plating with effective width

Z_p : Plastic section modulus (mm^3) of stiffener including attached plating

y_p : Vertical distance (mm) from neutral axis of stiffener including attached plating to the mid point of thickness of attached plating

y_s : Vertical distance (mm) from neutral axis of stiffener including attached plating with effective width to the outer surface of the face plate

y_{s0} : Vertical distance (mm) from neutral axis of stiffener including attached plating with full width to the outer surface of the face plate

σ_Y : Yield stress of stiffener including attached plating, obtained from following formula:

$$\sigma_Y = \left\{ s t_p \sigma_{Yp} + \left((h_w - t_f) t_w + b_f t_f \right) \sigma_{Ys} \right\} / A \ (N/mm^2)$$

σ_{Yp}: Yield stress (N/mm^2) of material of attached plating under consideration

σ_{Ys}: Yield stress (N/mm^2) of material of stiffener under consideration

ℓ : Span of stiffener (mm)

However, where suitable end brackets are fitted, the span of the stiffener which is used in the formulae except α_p, m_1 and P_C may be corrected as specified in the following **i)** or **ii)** depending on the type of end bracket (See **Fig. C31A.6.2-3**).

i) The span is taken between points where the depth of the bracket is equal to half the depth of the stiffener web

ii) Where the face plate of the stiffener is continuous along the face of the bracket, the span is taken between points where the depth of the bracket is equal to one quarter the depth of the web

A: Cross sectional area (mm^2) of stiffeners including attached plating with full width, which is given by the following formula:

$$A = s t_p + (h_w - t_f) t_w + b_f t_f$$

A_e: Cross sectional area (mm^2) of stiffeners including attached plating with effective width, which is given by the following formulae:

$A_e = s_e t_p + (h_w - t_f) t_w + b_f t_f$ for angles and T-sections

$A_e = s_e t_p + (h_w - t_f) t_e$ for flat bars

s : Spacing of stiffeners (mm)

t_p : Plate thickness (mm) of attached plating

h_w: Web height (mm)

t_w: Web thickness (mm)

b_f : Width of face plate (mm)

t_f : Thickness (mm) of face plate

For bulb sections, the mean thickness of the bulb is to be used.

t_e : Effective thickness (mm) of attached plating, obtained from the following formula.

$$t_e = t_w \left(1 - \frac{2\pi^2}{3} \left(\frac{h_w}{s} \right)^2 \left(1 - \frac{s_e}{s} \right) \right)$$

s_e : Effective width (mm) of attached plating, obtained from the following formula.

$$s_e = \left(\frac{\sigma_{crx}}{\sigma_{Yp}} (1 - \alpha_p) + \alpha_p \right) s$$

$$\frac{\sigma_{crx}}{\sigma_{Yp}} = \frac{1}{2} \left(\frac{\sigma_{crex}}{\sigma_{Yp}} + 1 - \sqrt{\left(\frac{\sigma_{crex}}{\sigma_{Yp}} - 1 \right)^2 + 0.01} \right)$$

$$\sigma_{crex} = \kappa_x \sigma_{crex(p)}$$

$$\sigma_{crex(p)} = \frac{E\pi^2}{3(1-\nu^2)}\left(\frac{t_p}{s}\right)^2$$

$$\kappa_x = c_x\left(\frac{t_w}{t_p}\right)^3 + 1$$

c_x : Coefficient according to the type of stiffeners, which is given by the following:

$c_x = 0.07$ for angles and T-sections

$c_x = 0.02$ for flat bars

$$\alpha_p = \frac{1+(\ell/m_1 s)^4}{3+(\ell/m_1 s)^4}$$

m_1: Integer which satisfies the following formula:

$$\sqrt{(m_1-1)m_1} \le \ell/s \le \sqrt{m_1(m_1+1)}$$

w_s: Assumed imperfection of stiffeners (mm)

The value of $\ell/1000$ may be used as standard.

E : Modulus of elasticity for material:

2.06×10^5 for steel (N/mm^2)

(5) Buckling Strength Criteria

The buckling strength of stiffeners specified in **(1)** above is to comply with the following formula:

$$\frac{\sigma_{Uxp}}{\sigma_{ref}} \ge 1.15$$

σ_{ref}: Reference stress (N/mm^2) of the stiffener considered, as specified in **(3)** above

σ_{Uxp}: Buckling stress (N/mm^2) of the stiffener considered, as specified in **(4)** above

Table C31A.6.2-1 Coefficient C_1

L (m)	150	200	250	300 and over
C_1	0.525	0.4	0.35	0.3

Table C31A.6.2-2 Angle of repose

Type of cargo	Angle of repose ψ
General	30°
Iron ore, Coal	35°
Cement	25°

Fig. C31A.6.2-1

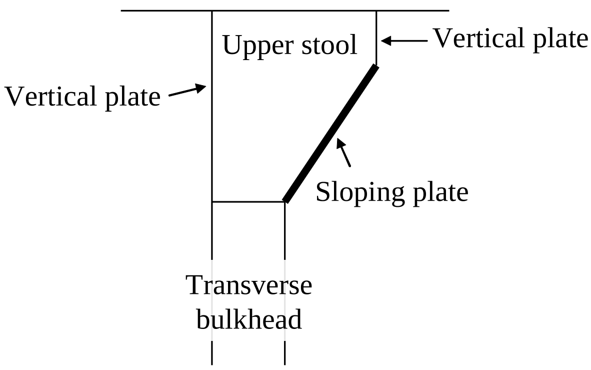


Table C31A.6.2-3 Coefficient C_2

L (m)	150	200	250	300 and over
C_2	0.4	0.3	0.25	0.2

Fig. C31A.6.2-2. Example of Reference Stress

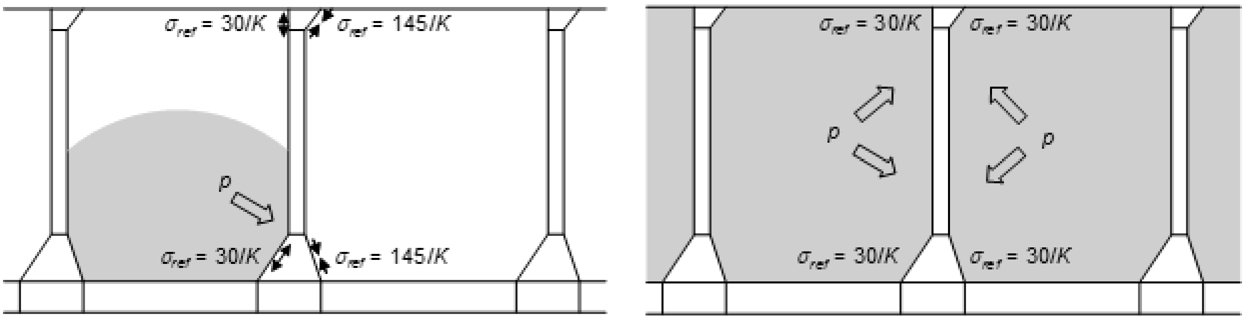


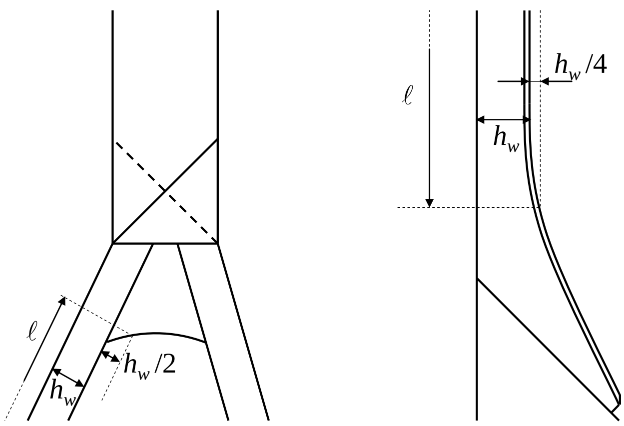
Table C31A.6.2-4 Standard deduction

Structure	Standard Deduction (*mm*)	Limit Value (*mm*)	
		Minimum	Maximum
1. Compartments carrying dry bulk cargos and void spaces 2. One side exposure to ballast and/or liquid cargo Vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line 3. Hatch side coaming	$0.05t$	0.5	1.0
1. One side exposure to ballast and/or liquid cargo Horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line 2. Two side exposure to ballast and/or liquid cargo Vertical surfaces and surfaces sloped at an angle greater 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 25° to the horizontal line	$0.15t$	2.0	4.0

Note:

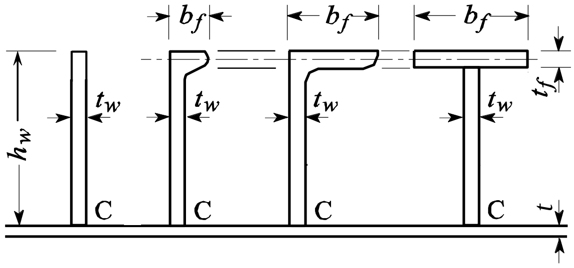
t : Thickness (*mm*) of structural members under consideration

Fig.C31A.6.2-3 Span of stiffeners



(a) (b)

Fig.C31A.6.2-4 Dimensions of stiffeners



C31B ADDITIONAL REQUIREMENTS FOR EXISTING BULK CARRIERS

C31B.1 General

C31B.1.1 Application

1 "Bulk Carriers defined in **1.3.1(13), Part B** of the Rules with single side skin construction" stipulated in **31B.1.1-1, Part C** of the Rules mean the bulk carriers defined in **1.3.1(13), Part B** of the Rules that have single side skin construction in the foremost cargo hold. In this case, double side skin construction with less than 760 *mm* between the side shell (between the bottom of top-side tank and the top of bilge hopper tank in cargo holds) and longitudinal watertight bulkhead is to be considered as single side skin construction. The distance between the side shell and longitudinal watertight bulkhead is to be measured perpendicular to the side shell.

2 Where Bulk Carriers are reinforced to comply with ice class notation in accordance with the requirements in **Chapter 8, Part I** of the Rules, the intermediate frames are not included in "cargo hold frames" as referred to in **31B.1.1-2, Part C** of the Rules.

C31B.2 Damage Stability

C31B.2.1 Survivability

1 Requirements for survivability are to be in accordance with those in **C31A.2.1**.

2 "The measures deemed appropriate by the Society" referred to in **31B2.1-2**, **Part C** of the Rules, are the following:

(1) The foremost cargo hold is examined in accordance with the requirements of **4.2.4**, **4.2.5** and **4.2.6**, **Part B** of the Rules, at Annual Surveys specified in **Chapter 3, Part B** of the Rules.

(2) The ship is provided with bilge well high water level alarms in all cargo holds, or in cargo conveyor tunnels, as appropriate, giving an audible and visible alarm in the navigation bridge according to the following **(a)** through **(e)**. An interlocking device may be installed in the water detection system for floodable cargo holds.

- (a) The presence of water is to be detected by physical contact between the sensors and the water.
- (b) In cargo holds loaded with flammable and explosive cargo, detectors are to be explosion-proof.
- (c) Sensors are to be placed in tubes or similarly protected locations to protect them from mechanical damage and to isolate them from the cargo.
- (d) Electric power is to be supplied from the main source and the emergency source or reserve source.
- (e) The alarm system is to be provided with an audible and visible electrical power failure alarm.

(3) The ship is provided with detailed information on specific cargo hold flooding scenarios. This information is accompanied by detailed instructions on evacuation preparedness and is used as the basis for crew training and drills. The information is to be prepared in accordance with the following **(a)** to **(c)**.

- (a) The information is to include at least the following:
  - i) Specific cargo hold flooding scenarios (see **(b)** below)
  - ii) Instructions for evacuation preparedness
  - iii) Details of the ship's means for leakage detection
- (b) Specific cargo hold flooding scenarios
  - i) Flooding scenarios of the ship when loaded down to the summer load line are to be developed, detailing the order of events from when flooding is detected to evacuation from the ship (*e.g.* progressive flooding to other holds or immersion of the deck). The scope covered is to include at least the following loading conditions.
    - 1) Homogenous loading condition
    - 2) Alternate hold loading condition, if applicable
    - 3) Packaged cargo condition, if applicable
  - ii) Where an above mentioned loading condition complies with the requirements of **31B.2.1-1, Part C of the Rules**, the flooding scenario for that condition does not need to be prepared provided that the compliance with the requirements is noted in the information.

iii) Where the ship is able to satisfy the requirements of **31B.2.1-1, Part C of the Rules** at a draught lower than the summer load line, guidance for counter measures to hold flooding is to be given with allowable *KG/GM* curves for complying with the requirements of **31B.2.1-1, Part C of the Rules**, for the following loading conditions.

1) Homogenous loading condition

2) Alternate hold loading condition with high density cargo in the foremost cargo hold, if applicable

3) Packaged cargo condition, if applicable

4) Empty condition

iv) The results of each scenario are to clearly indicate the reasons for non-compliance with the survival criteria given in **31B.2.1-2, Part C of the Rules** and explain the implications regarding the need to abandon ship: *e.g.* immersion of a weathertight closing appliance may indicate that there is no immediate danger of foundering if the stability characteristics are otherwise satisfactory, the bulkhead strength is adequate, the weather conditions are favourable, and bilge pumping can cope with any progressive flooding.

v) When making hold flooding calculations for flooding scenarios, the following assumptions are to apply.

1) The flooding of the foremost cargo hold is to be used as the starting point for any respective flooding scenario. Subsequent flooding of other spaces can only occur due to progressive flooding through relevant openings.

2) The permeability of a loaded hold is to be determined in accordance with **C31A.2.2**. However, when deemed appropriate by the Society, other permeability values may be assumed for particular cargoes and the remaining empty volume of the hold is assumed to have a permeability of 0.95. The permeability of a hold loaded with packaged cargo is to be assumed as 0.7.

(c) Guidance for evacuation

It should be noted that responsibility for the preparation of detailed information rests with the operator of the ship. With regard to preparation for evacuation, the following guidance is provided as a most general guide.

i) In the event that severe flooding is detected, preparations for abandoning the ship should be envisaged in accordance with the applicable rules and procedures, such as *SOLAS* Chapter III, *STCW* and the *ISM* Code.

ii) Severe weather conditions may have substantial influence on the rate of flooding decreasing the time remaining to abandon the ship beyond that estimated in any pre-assessed flooding scenario.

(4) The ship is provided with detectors of water ingress detecting the presence of water in the cargo holds in excess of the small amounts which may be normally expected in the bilge well in addition to the bilge well high water level alarms as required in **(2)** above, according to the following **(a)** through **(f)**. An interlocking device may be installed in the water detection system for floodable cargo holds.

(a) The presence of water is to be detected by physical contact between the sensors and the water.

(b) Water ingress detectors are to be arranged to detect water when it reaches a level of 2 *metres* above the inner bottom. Audible and visible alarms that allow the flooded cargo hold to be identified are to be located in the navigation bridge and control locations.

(c) A water ingress detector is to be fitted in the aft part of each cargo hold or in cargo conveyor tunnels, as appropriate. Sensors are to be placed in tubes or similarly protected locations to protect them from mechanical damage and to isolate them form the cargo.

(d) In cargo holds loaded with flammable and explosive cargo, detectors are to be explosion-proof.

(e) Electric power is to be supplied from the main source and the emergency source or reserve source.

(f) The alarm system is to be provided with an audible and visible electrical power failure alarm.

(5) Ships which comply with the requirements of the water level detection and alarm systems specified in **13.8.5, Part D of the Rules** are regarded as complying with the provisions of **(2)** and **(4)** above.

C31B.2.2 Permeability

Requirements for permeability are to be in accordance with those in **C31A.2.2.**

C31B.3 Transverse Watertight Corrugated Bulkhead

C31B.3.6 Corrosion Addition, Steel Renewal and Reinforcement

1 Steel renewal or reinforcement is required according to the relationship between the net thickness as given in **31B.3.4, Part C** of the Rules and the gauged thickness.

(1) Where $t_{act} < t_{net} + 0.5$ (mm)

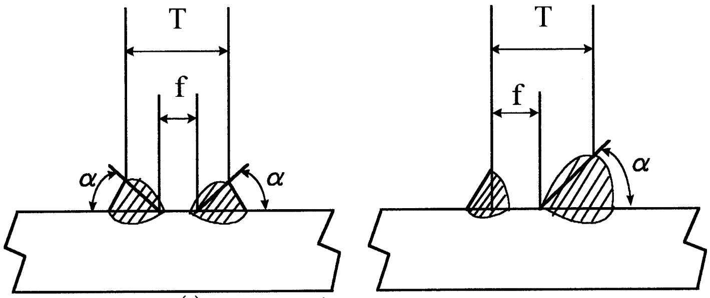
The plates are to be renewed. Alternatively, where the required net plate thickness for the bulkhead is given in **31B.3.4-4, Part C** of the Rules, reinforcing with doubling strips may be used. Where steel renewal is required, steel with a minimum thickness of $t_{net} + 2.5$ mm is to be used for renewed parts, and the corrugated bulkhead is to be connected to the lower stool shelf plate or inner bottom (if no lower stool is fitted) by deep penetration welds (See **Fig. C31B.3.6-1**)

Where reinforcing doubling strips are used, their strength is to be the same as that of steel renewal.

(2) Where $t_{net} + 0.5 \leq t_{act} \leq t_{net} + 1.0$ (mm)

Coating deemed equivalent to the original in new condition is to be applied or annual thickness measurements are to be adopted.

Fig. C31B.3.6-1.



nose (f) : 3mm～T/3mm

groove angle (α) : 40° ～60°

2 Where the following formula is satisfied, gussets with shedder plates extending from the lower end of corrugations up to a height of 0.1l or reinforcing doubling strips (on bulk corrugations and stool side plating) are to be fitted for reinforcement. Where gusset plates are fitted, the material of the gusset plates is to be the same as that of the corrugation flanges, and the gusset plates are to be connected to the lower stool shelf plate or inner bottom (if no lower stool is fitted) by deep penetration welds.

$0.8(\sigma_{Ffl} t_{fl}) > \sigma_{Fst} t_{st}$ (N)

σ_{Ffl}: Yield stress (N/mm^2) of the material used for the corrugation flanges

σ_{Fst}: Yield stress (N/mm^2) of the material used for the lower stool side plating or floors(if no stool is fitted)

t_{fl} :t_{net}, as given in **31B.3.4-4, Part C** of the Rules, +0.5 (mm); or t_{net} +2.5 (mm) where steel renewal is required

t_{st} :Original thickness (mm) of the lower stool side plating or floors (if no stool is fitted)

C31B.4 Allowable Hold Loading on Double Bottom

C31B.4.3 Shear Capacity

1 "Measurement(s) … deemed appropriate by the Society" specified in **31B.4.3-3, Part C** of the Rules refer to when the actual amount of diminution of members to be examined for shear strength is calculated based on their thickness measurements.

2 "Appropriate reinforcements … fitted to the Society's satisfaction" specified in **31B.4.3-5, Part C** of the Rules, means the following.

(1) Two horizontal stiffeners fitted on the floor and/or girder above and below the opening

(2) Doubling plate fitted in the circumference of the opening

C31B.4.4 Allowable Hold Loading Weight

1 V used for the calculation of allowable hold loading weight W of the foremost cargo hold may be the following formula:

$V = l_C B h_1 - V_{LS} - l_c b_{HT}(h_{HT} - h_{DB})$ (m^3)

l_C :Length (m) of the foremost hold

B :Ship's breadth (m) amidship

V_{LS} :Volume (m^3) of the lower stool above the inner bottom

h_{HT}: Height (m) from the baseline amidship to the top of the hopper tank

h_{DB}:Height (m) of double bottom

b_{HT}:Breadth (m) of the hopper tanks amidship

2 The requirements prescribed in **31B.4.4, Part C** of the Rules regarding the permeability of steel mill products being 0 are to be in accordance with **C31A.4.3-2**.

C31B.5 Hold Frames

C31B.5.2 Steel Renewal Criteria and Reinforcing Measures

1 A bulk carrier with ice strengthening structure in accordance with the requirements in **Chapter 8, Part I** of the Rules that withdraws its ice classification is to remain in compliance with the requirements in **31B.5, Part C** of the Rules, with the exception of existing tripping brackets which comply with the requirements of **31B.5.2-5, Part C** of the Rules.

2 For the application of **31B.5.2, Part C** of the Rules, when Zone B in **Fig. C31B.5.1, Part C** of the Rules is made up of different plate thicknesses, the lesser thickness is to be used.

3 With respect to $t_{REN,d/t}$ in **31B.5.2-1(3)(a), Part C** of the Rules, the value of t_M is to be based on Zone B in **Fig. C31B.5.1, Part C** of the Rules.

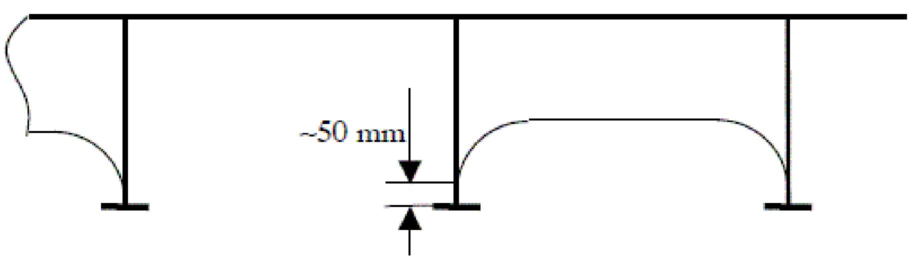
4 For the application of **31B.5.2-2, Part C** of the Rules, when lower brackets were not fitted with flanges at the design stage, flanges are to be fitted so as to meet the strength requirements in **31B.5.3-1, Part C** of the Rules. The full width of the bracket flange is to extend up beyond the point at which the frame flange reaches full width. Adequate back-up structure in the hopper is to be ensured, and the bracket is to be aligned with the back-up structure.

5 For the application of **31B.5.2-6, Part C** of the Rules, tripping brackets not connected to the frame flanges are to have soft toes, and the distance between the bracket toe and the frame flange is not to be greater than $50mm$. (see **Fig. C31B.5.2**)

6 For the application of **31B.5.2-6, Part C** of the Rules, where side frames and side shell are made of higher tensile steel, tripping brackets made of mild steel may be accepted, provided the electrodes used for welding are those required for the particular higher tensile steel grade, and the thickness of the tripping brackets is equal to the frame web thickness.

7 For the application of **31B.5.2, Part C** of the Rules, when renewal is required, surface preparation and coating for the renewed structures are to be carried out in accordance with the provisions of **C25.2.1-2(1)**.

Fig. C31B.5.2 Example of Tripping Brackets Not Connected to Frame Flanges



C31B.6 Steel Weathertight Hatch Covers

C31B.6.2 Securing Devices

"Effective devices deemed appropriate by the Society for securing weathertightness" stipulated in **31B.6.2, Part C** of the Rules refer to the devices complying with the provisions of **(1)** to **(4) of C20.2.6-2.**

C31B.6.3 Stoppers

"Effective means deemed appropriate by the Society for stoppers against the horizontal forces acting on their forward end and the side" stipulated in **31B.6.3, Part C** of the Rules refer to stoppers complying with the requirements shown in **Table C31B.6.3**

Table C31B.6.3 Strength Requirements for Stoppers

Design pressure	(1) Hatch covers for the foremost cargo hold The longitudinal forces acting on their forward end: 230 kN/m^2 (Where a forecastle is fitted, the pressure may be reduced to 175 kN/m^2.) The transverse forces: 175 kN/m^2 (2) Other hatch covers The longitudinal forces acting on their forward end and the transverse forces: 175 kN/m^2
Allowable equivalent stress	In stoppers, their supporting structures and the stopper welds (calculated at the throat of welds), the equivalent stress is not to exceed the allowable value of 0.8 *times* the yield stress of the material.

C31B.7 Restrictions for Sailing with Any Hold Empty

C31B.7.1 General

1 "Side construction deemed appropriate by the Society" stipulated in **31B.7.1-2, Part C** of the Rules refers to construction where all hold frames comply with one of the following standards.

(1) **31.6, Part C** of the Rules

(2) **31B.5, Part C** of the Rules

(3) *IACS* Unified Requirement S12 (Rev. 2.1), as amended

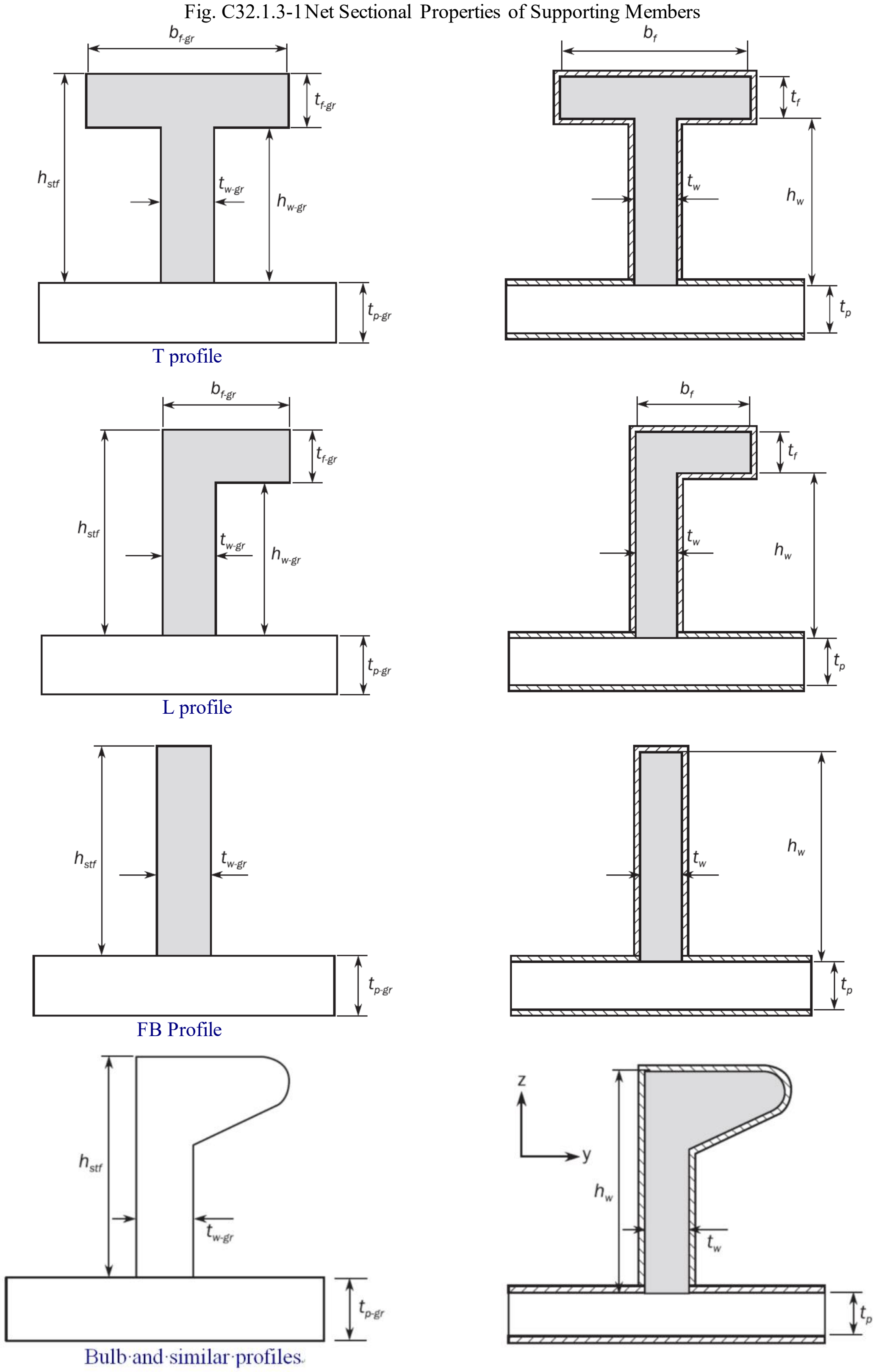
C32 CONTAINER CARRIERS

C32.1 General

C32.1.3 Net Scantling Approach

The net section modulus, moment of inertia and shear area properties of a supporting member are to be calculated using the net dimensions of the attached plate, web and flange, as defined in **Fig. C32.1.3-1**. The net cross-sectional area, the moment of inertia about the axis parallel to the attached plate and the associated neutral axis position are to be determined through applying a corrosion magnitude of $0.5\alpha t_c$ deducted from the surface of the profile cross section.

Fig. C32.1.3-1 Net Sectional Properties of Supporting Members



C32.2 Longitudinal Bending Strength

C32.2.2 Longitudinal Extent of Strength Assessment

1 "Locations where there are significant changes in hull cross section" specified in **32.2.2, Part C of the Rules** refers to the locations such as changing of framing system, the fore and aft ends of the engine room, and the fore and aft ends of the forward bridge block in case of two-island designs, etc.

2 "The method deemed appropriate by the Society" specified in **32.2.2-2, Part C of the Rules** refers to yield strength assessments and buckling strength assessments according to **32.2.6 and 32.2.7, Part C of the Rules** with necessary modifications.

C32.2.3 Loads

1 With respect to the provisions of **32.2.3, Part C of the Rules**, calculation of the vertical still water bending moment is to be as follows:

(1) To perform the calculation of the vertical still water bending moment, the method of calculation used is to be submitted for prior approval by the Society.

(2) For ships undergoing Classification Survey During Construction, calculation sheets for longitudinal strength in the still water corresponding to the actual loading plans and the data necessary for the calculations are to be submitted to the Society.

(3) In Classification Surveys, longitudinal strength calculations in still water are to be performed at the time of completion of the ship for each type of operating condition, and the necessary data and results of these calculations are to be included in the loading manual specified in **34.1.1, Part C of the Rules**.

2 For application of the provision of **32.2.3-3, Part C of the Rules**, reference is to be made to **Annex C15.2.1 "GUIDANCE FOR THE ASSESSMENT OF HULL GIRDER STRENGTH RELATED TO BALLASTING/DEBALLASTING"**.

3 "The loading conditions which are separately specified by the Society" specified in **32.2.3-5, Part C of the Rules** refers to the loading conditions specified in **1.3.1-1(1), Annex C34.1.2 "GUIDANCE FOR PREPARATION OF LOADING MANUAL"**.

4 "The calculation method which is separately specified by the Society" specified in **32.2.3-9(2), Part C of the Rules** refers to the calculation method specified in **Annex C32.2.3-4 "GUIDANCE FOR CALCULATION OF SHEAR FLOW"**.

C32.2.7 Buckling Strength Assessment

1 Maximum utilisation factor specified in **32.2.7-1, Part C of the Rules** is to be calculated in accordance with **Annex C32.2.7 "GUIDANCE FOR BUCKLING STRENGTH ASSESSMENT"**.

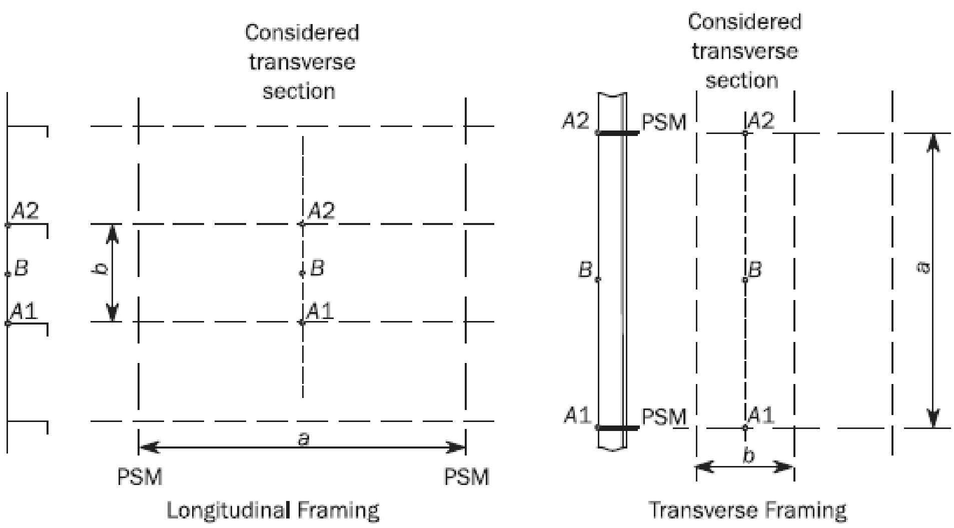
2 The hull girder bending stress and shear stress for elementary plate panels (EPP) are to be calculated at the load calculation points defined in **Table C32.2.7-1**. Here, "elementary plate plane" refers to the unstiffened part of the plating as well as all edges which are forced to remain straight due to the surrounding structure/neighbouring plates.

3 The hull girder bending stress and shear stress for longitudinal stiffeners are to be calculated at the following calculation point, which is at the mid-length of the considered stiffener, and at the intersection point between the stiffener and its attached plate.

Table C32.2.7-1 Load Calculation Point (*LCP*) Coordinates for Plate Buckling Assessment

LCP coordinate	Hull girder bending stress		Hull girder shear stress
	Non horizontal plating	Horizontal plating	
X coordinate	Mid-length of the EPP		
Y coordinate	Corresponding to *X* and *Z*	Outboard and inboard ends of the EPP (points A1 and A2 in **Fig. C32.2.7-1**)	Mid-point of EPP (point B in **Fig. C32.2.7-1**)
Z coordinate	Upper and lower ends of EPP (points A1 and A2 in **Fig. C32.2.7-1**)	Corresponding to *X* and *Y* values	

Fig. C32.2.7-1 *LCP* for Plate Buckling Assessment (PSM Stands for Primary Supporting Members)



C32.2.8 Hull Girder Ultimate Strength Assessment

1 "The method which is separately specified by the Society" to calculate M_U (*kN-m*) specified in **32.2.8-1, Part C of the Rules** refers to the method specified in **Annex C32.2.8-1 "GUIDANCE FOR THE HULL GIRDER ULTIMATE STRENGTH ASSESSMENT"**.

2 "The method which is separately specified by the Society" to calculate M_{U_DB} (*kN-m*) specified in **32.2.8-2, Part C of the Rules** refers to the method specified in **Annex C32.2.8-2 "GUIDANCE FOR THE HULL GIRDER ULTIMATE STRENGTH ASSESSMENT CONSIDERING THE EFFECT OF LATERAL LOADS"**.

C32.2.9 Calculation of Section Modulus and Moment of Inertia of Transverse Section of Hull

1 The section modulus and moment of inertia of transverse section of hull is to have five significant figures.

2 The ratio of inclusion of members effective for longitudinal strength is to be as follows.

(1) All intercostal plates may be included if the fillet welding complies with **Note 1** of **Table C1.5, Part C**.

(2) All doubling plates may be included if fitted during ship construction or 90% if fitted during conversion or addition.

(3) For side stringers, slots for frames are to be deducted.

(4) Scallops complying with the following conditions need not be deducted from the sectional area. (*See* **Fig. C32.2.9-1**)

(a) d_s not exceeding $d/4$ nor exceeding $7t$, maximum 75 *mm*

(b) S more than $5b$ and more than $10d_s$

(5) As for the longitudinal continuous decks between hatchways of ships having 2 or 3 rows of cargo hatches, the ratio of sectional area to be included in the calculation of the section modulus is to be obtained from **Table C32.2.9-1**. For intermediate values of ξ and l/L, linear interpolation is to be applied.

(6) Where the sectional area of longitudinals, which are unable to be continued due to factors such as the arrangement of small hatch openings are compensated by adjacent ones, they may be included in the calculation of the section modulus of the transverse section.

3 Openings in strength decks are to be treated as mentioned below.

(1) Where the shape and dimensions do not meet the conditions in **Table C32.2.9-2**, reinforcement by means of rings, thicker plates, etc. is required (*See* **Fig. C32.2.9-3** and **Fig. C32.2.9-4**).

(2) Where the intervals between centres of holes e do not meet the conditions in **Fig. C32.2.9-5**, reinforcement as per **(1)** above is needed.

Fig. C32.2.9-1 S, b and d_s of Scallops

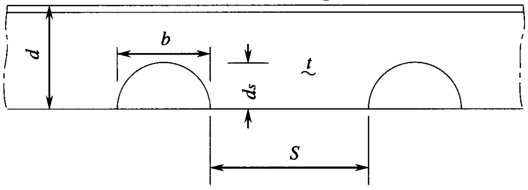


Table C32.2.9-1 Ratio of Inclusion of Sectional Area

	Hatches in 2 rows			Hatches in 3 or more rows		
ξ	l/L					
	0.10	0.20	0.30	0.10	0.15	0.20
0	0.96	0.85	0.70	0.96	0.91	0.85
0.5	0.65	0.57	0.48	0.89	0.80	0.69
1.0	0.48	0.43	0.36	0.83	0.73	0.62
2.0	0.32	0.29	0.25	0.73	0.63	0.53
3.0	0.24	0.22	0.18	0.65	0.57	0.47

Notes:

ξ = Values obtained from the following formula:

$$\frac{ab^3}{lI_c}\left\{\frac{1+2\mu}{6(2+\mu)}\times 10^4 + 2.6\frac{I_c}{a_c b^2}\right\}$$

Where:

I_c: Moment of inertia (cm^4) of deck between hatches, including hatch coamings

a_c: Effective shear area (cm^2) of deck between hatches

a : Sectional area (cm^2) of continuous deck between hatches (port or starboard side half)

l : Length (m) of hatch

μ, b : As per **Fig. C32.2.9-2** (m)

Table C32.2.9-2

	Elliptic holes	Circular holes
Oil tankers	$\frac{a}{b}\le\frac{1}{2}, a\le 0.06B$ ($a_{max}=900\ mm$)	$a\le 0.03B$ ($a_{max}=450\ mm$)
Cargo ships	$\frac{a}{b}\le\frac{1}{2}, a\le 0.03(B-b_H)$ ($a_{max}=450\ mm$)	$a\le 0.015(B-b_H)$ ($a_{max}=200\ mm$)

Fig. C32.2.9-2 l, b and μ

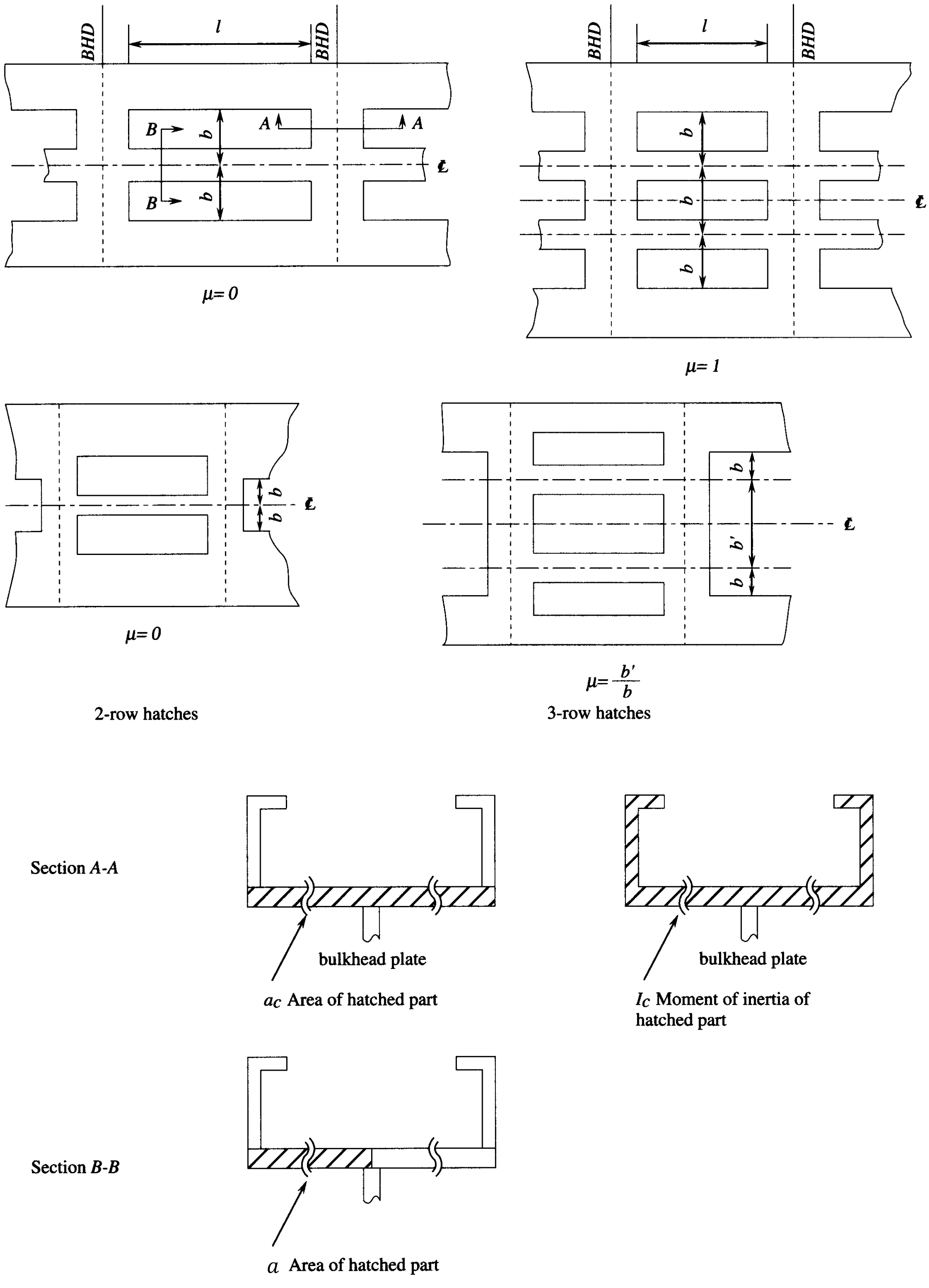


Fig. C32.2.9-3 Where Elliptic Hole and Circular Hole are in Same Cross-section

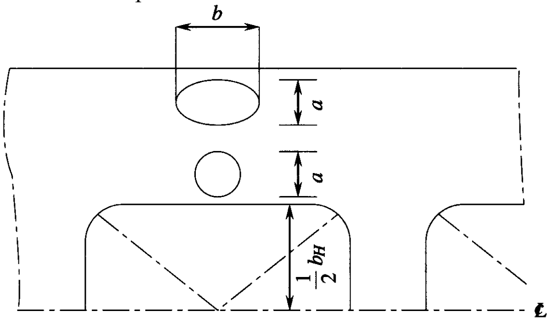


Fig. C32.2.9-4 Reinforcement by Means of Ring

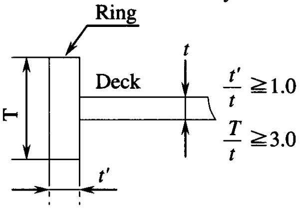
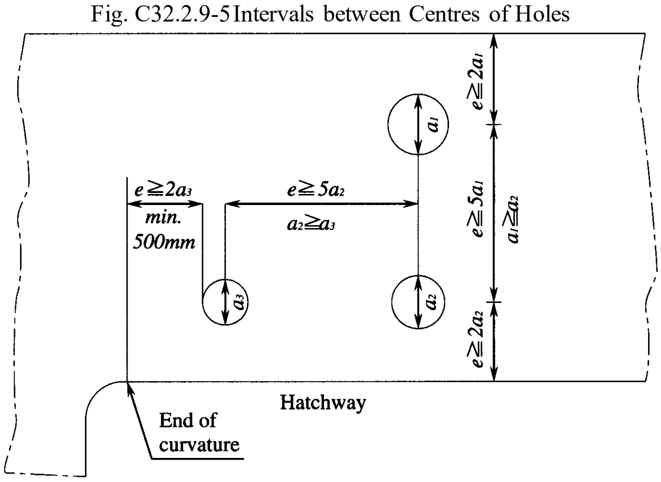


Fig. C32.2.9-5 Intervals between Centres of Holes



C32.3 Torsional Strength

C32.3.1 Application

1 "Torsional strength assessments deemed appropriate by the Society" in **32.3.1-2, Part C of the Rules** means that the following relationship is satisfied at each sectional position from collision bulkheads to the watertight bulkheads at the fore ends of machinery spaces.

$$\sqrt{(0.75\sigma_V)^2 + \sigma_H^2 + \sigma_\omega^2} + \sigma_S \leq \frac{1000}{5.72K}$$

Where:

σ_S, σ_V and σ_H: As obtained from the following formula

However, warping stress is added to σ_S in case where torsional moment by unbalanced loading of cargoes is considered.

$$\sigma_S = 1000\frac{|M_S|}{Z_V}$$

$$\sigma_V = 1000\frac{M_W}{Z_V}$$

$$\sigma_H = 1000\frac{M_H}{Z_H}$$

M_S, M_W: Vertical still water bending moment and vertical wave induced bending moment for the load cases "hogging" and "sagging" as specified in **32.2.3-8, Part C of the Rules**

M_H: As obtained from the following formula:

$0.45C_1L_1^2d(C_b+0.05)C_H$ (kN-m)

C_H: Coefficient, as given in **Table C32.3.1-1**, based on the ratio of L_1 to x, where x is the distance (m) from the aft end of L_1 to the section under consideration.

Intermediate values are to be determined by interpolation.

Z_V: Section modulus (cm^3) of strength deck based upon a gross scantling approach with respect to longitudinal bending of the hull at the position of the section under consideration

Z_H: Section modulus (cm^3) of hatch side based upon a gross scantling approach with respect to horizontal bending of the hull at the position of the section under consideration

C_1: As specified in **32.3.4-1, Part C of the Rules**

σ_ω: Warping stress (N/mm^2) due to torsion of the hull calculated according to the following formula for ships of ordinary construction using the dimensions and scantlings at the midship section.

Values for other types are to be in accordance with the discretion of the Society.

$$\sigma_\omega = 0.000318\frac{\omega\, l_C M_T}{I_\omega + 0.04 l_C^2 J}$$

M_T: As given by the following formula:

$7.0K_2{C_W}^2B^3\left(1.75+1.5\frac{e}{D_S}\right)$ (kN-m)

C_W: As specified in **32.3.4-2, Part C of the Rules**

e : As specified in **C32.3.4** or as given by the following formula:

$$e = e_1 - \frac{d_0}{2}$$

e_1: As given by the following formula:

$$e_1 = \frac{(3D_1 - d_1)d_1t_d + (D_1 - d_1)^2t_S}{3d_1t_d + 2(D_1 - d_1)\,t_S + B_1t_b/3}$$

d_0: Height of double bottom (m)

d_1: Breadth of double hull side (m)

D_1: As given by the following formula:

$$D_1 = D_S - \frac{d_0}{2}$$

B_1: As given by the following formula:

$$B_1 = B - d_1$$

t_d, t_S, t_b: Mean thickness (m) of deck, ship side, and bottom based upon a gross scantling approach specified in **Fig. C32.3.1-1**

Mean thickness may be determined by including all the longitudinal strength members located within this range.

K_2: As given by the following formulae:

$$K_2 = \sqrt{1-\left(\frac{300-L_1}{300}\right)^2}$$ for ships with $L_1 < 300\ m$

1.0 for ships with $L_1 \geq 300\,m$

ω: As given by the following formula:

$$\omega = \frac{B_1}{2}(D_1 - e_1) + \frac{d_1}{2}(D_1 + e_1)$$

l_C: Distance (m) from the collision bulkhead to watertight bulkhead of the fore end of the machinery room

I_ω: As given by the following formula:

$$I_\omega = {B_1}^2\{d_1t_dI_d + (D_1 - d_1)\,t_SI_S + B_1t_bI_b\}$$

I_d: As given by the following formula:

$$I_d = (D_1 - e_1)\left\{\frac{3}{2}(D_1 - e_1) - d_1\right\} + \frac{d_1^2}{3}$$

I_S: As given by the following formula:

$$I_S = (D_1 - d_1)\left\{\frac{1}{3}(D_1 - d_1) - e_1\right\} + e_1^2$$

I_b: As given by the following formula:

$$I_b = \frac{e_1^2}{6}$$

J: As given by the following formula

However, the mean thicknesses of t'_d, t'_S, t'_b (m) based upon a gross scantling approach are to be calculated using only the strength deck, side shell, bottom shell, inner bottom and longitudinal bulkhead plating. Other longitudinal strength members are not to be included.

$$J = \frac{2\{Bd_0 + 2(D_S - d_0)d_1\}^2}{3d_1/t'_d + 2(D_1 - d_1)/t'_S + B_1/t'_b}$$

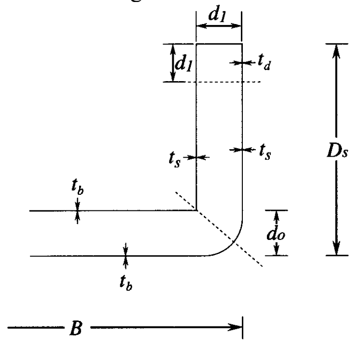
K: Coefficient corresponding to the kind of steel

e.g.,1.0 for mild steel, the values specified in **1.1.7-2(1), Part C of the Rules** for high tensile steel

Table C32.3.1-1 Coefficient C_H

x/L_1	0.0	0.4	0.7	1.0
C_H	0.0	1.0	1.0	0.0

Fig. C32.3.1-1



2 Notwithstanding the requirements of **-1** above, the torsional strength assessments specified in **32.3, Part C of the Rules** may be carried out in cases where deemed appropriate by the Society.

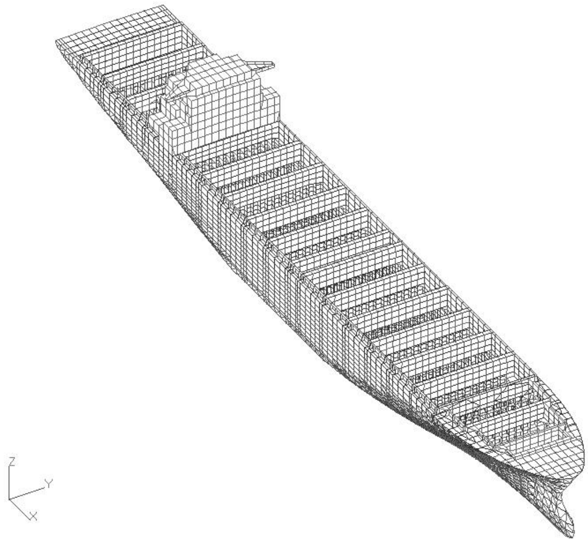
C32.3.4 Loads

The location of "shear centre" referred to in **32.3.4-2(2), Part C of the Rules** may be obtained by calculating the point of action of shear force so that the torsional moment is not generated in cross sections when horizontal shear force is acting. **Annex C32.2.3-4 "GUIDANCE FOR CALCULATION OF SHEAR FLOW"** may be applied to calculate the location of the shear centre.

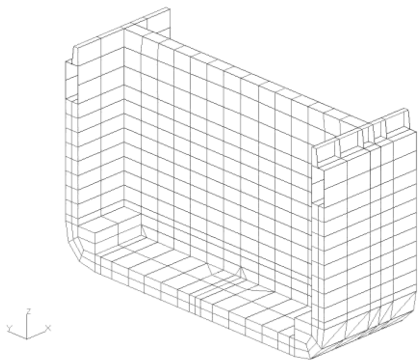
C32.3.5 Modelling for Structural Analysis

1 Examples of structural models are shown in **Fig. C32.3.5-1**.

Fig. C32.3.5-1 Structural Model



(a) Overview



(b) Around Bulkhead

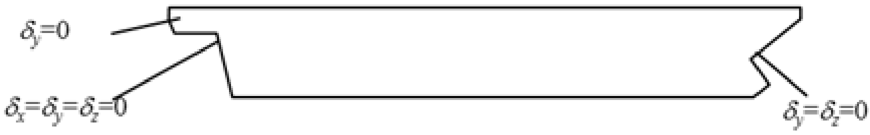
2 For the meshing of element required in **32.3.5-5, Part C of the Rules**, the following **(1)** and **(2)** are to be taken as the standard size of the meshing.

(1) The length of one edge of the meshing is to be roughly the distance between floors.

(2) The aspect ratio of the meshing is to be standardized as 1.0. (Meshings with aspect ratios quite different from 1.0 are to be avoided as much as possible).

3 Regarding the application of **32.3.6-2, Part C of the Rules**, boundary conditions that constrain the translational and rotational deflections are to be given at locations where reaction forces are considered to be small. Examples of such boundary conditions are shown in **Fig. C32.3.5-2**.

Fig. C32.3.5-2. Examples of boundary conditions for torsional moments



(a) Example 1

(b) Example 2

C32.3.6 Calculation of Stresses due to Vertical Bending Moment and Horizontal Bending Moment

1 Regarding the application of **32.3.5-6, Part C of the Rules**, boundary conditions which do not generate torsional deformation are to be given in order to calculate stress due to horizontal bending moments. Examples of boundary conditions for vertical bending moments and horizontal bending moments are shown in **Fig. C32.3.6-1** and **Fig. C32.3.6-2**.

Fig. C32.3.6-1 Examples of Boundary Conditions for Vertical Bending Moments

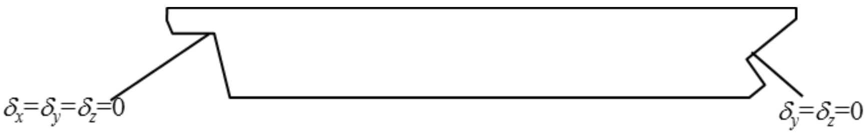
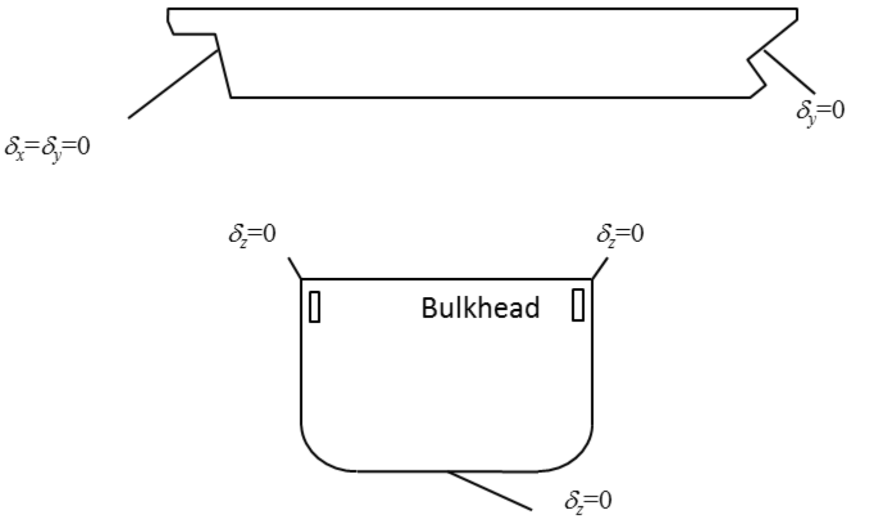


Fig. C32.3.6-2 Examples of Boundary Conditions for Horizontal Bending Moments



C32.3.7 Calculation of Warping Stresses due to Torsional Moment

1 Regarding the application of **32.3.7, Part C of the Rules**, torsional moments are to be applied to structural models in accordance with the following **(1)** to **(3)**:

(1) Torsional moments acting on hull girders are to be applied to structural model as a series of bulkhead torsional moments resulting in a stepped curve. An approximated torsional step moment curve is shown in **Fig. C32.3.7-1**.

(2) Torsional moments applied to bulkheads are the net change in torsional moment over the effective range of the bulkhead. The

effective range of a bulkhead is the distance between the midpoints of the two adjacent bulkheads. The torsional moments at bulkhead "*i*" are specified as the following formulae (See **Fig. C32.3.7-2**):

$$\delta M_{WT1i} = M_{WT1}|_{\frac{1}{2}(X_i+X_{i+1})} - M_{WT1}|_{\frac{1}{2}(X_{i-1}+X_i)}$$

$$\delta M_{WT2i} = M_{WT2}|_{\frac{1}{2}(X_i+X_{i+1})} - M_{WT2}|_{\frac{1}{2}(X_{i-1}+X_i)}$$

X_i : X-coordinate of bulkhead "*i*"

(3) The torsional moment at each bulkhead is to be reproduced by two equivalent shear forces on each side. An example of a method for applying shear force is shown in **Fig. C32.3.7-3**.

Fig. C32.3.7-1 Torsional Moment Acting on a Hull Girder
(Approximated Torsional Step Moment)

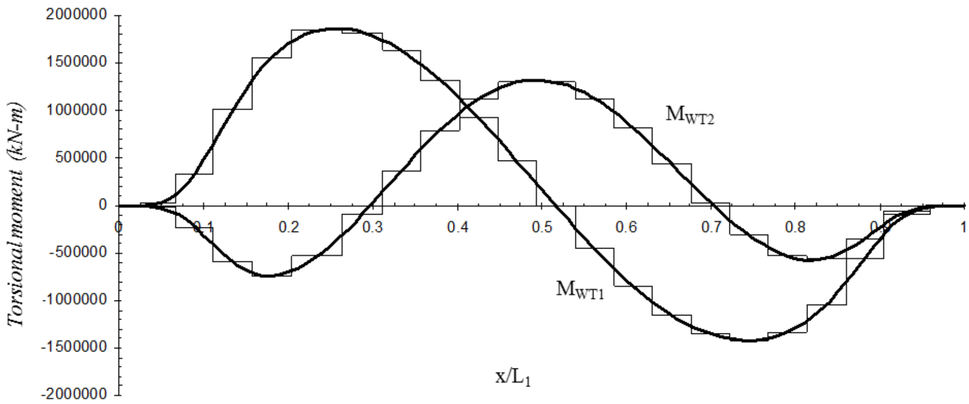


Fig. C32.3.7-2. Torsional moment applied to bulkhead "*i*"

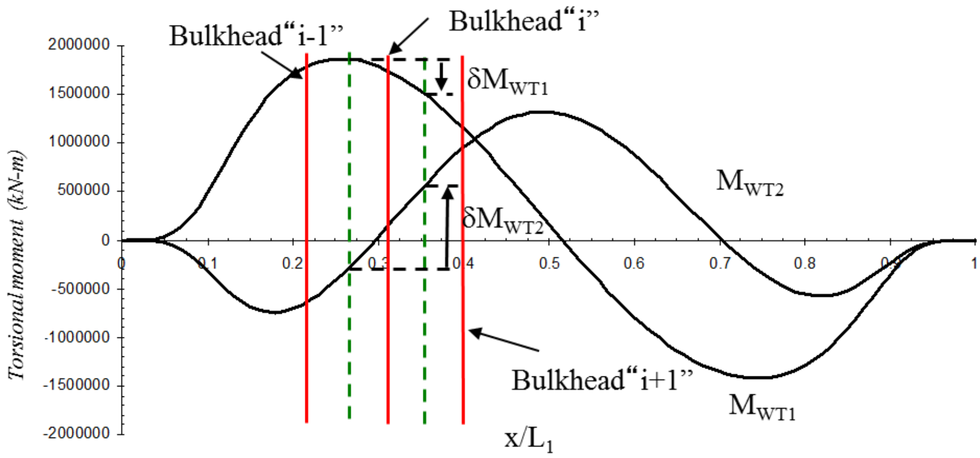
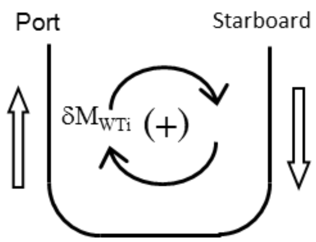


Fig. C32.3.7-3 Torsional moment reproduction due to shear force



C32.3.9 Yield Strength Assessment

Average stress corresponding to standard mesh size as specified in **C32.3.5-2** may be used in cases where mesh finer than standard mesh size is used.

C32.3.10 Buckling Strength Assessment

1 The requirements in **C32.9.9** are applied correspondingly for buckling assessments.

2 Notwithstanding **-1** above, bilge strakes longitudinally stiffened and longitudinal stiffeners attached to the bilge strakes may be verified in accordance with the requirements of the following **(1)** or **(2)**:

(1) Bilge strakes longitudinally stiffened and the longitudinal stiffeners attached to said bilge strakes are to satisfy the following **(a)** and **(b)**. These requirements may be applied in cases where the bilge strake net thickness is not less than 14.5 *mm* and the bilge radius is not greater than 8 *m*.

(a) The evaluated stress determined in accordance with **32.3.8, Part C of the Rules** is not greater than 0.9 times the specified minimum yield stress of the relevant steel or 320 N/mm^2, whichever is smaller.

(b) The following formula is satisfied:

$$\sqrt{11 \cdot \left(\frac{t}{1000R}\right)^2 + \left(\frac{\pi t}{1000S}\right)^4} + \left(\frac{\pi t}{1000S}\right)^2 \geq 0.014$$

t: Bilge strake net thickness (mm)

S: Stiffener spacing (m). To be taken as the girth length.

R: Bilge radius (m)

(2) The evaluated stress determined in accordance with **32.3.8, Part C of the Rules** is not to be greater than 0.9 times the buckling strength obtained using non-linear analysis, etc.

C32.5 Double Side Construction

C32.5.1 General

1 Where the breadth of double side construction varies in the bilge part, t_1 in **32.5.2-1** and **-2, Part C of the Rules** is to be determined as follows:

(1) β_T and β_L are to be obtained from the following formulae:

$$\beta_T = 1 + \frac{0.42\left(\frac{B}{D_S}\right)^2 - 0.5}{0.59\frac{D_S - \frac{d_0}{2} - l_{0R}}{B - d_1 - 2l_{1R}}\left(\frac{d_0}{d_1}\right)^2 + 1.0}$$

$$\beta_L = 1 + \frac{0.18\left(\frac{B}{D_S}\right)^2 - 0.5}{0.59\frac{D_S - \frac{d_0}{2} - l_{0R}}{B - d_1 - 2l_{1R}}\left(\frac{d_0}{d_1}\right)^2 + 1.0}$$

l_{0R} and l_{1R} are to be obtained as follows:

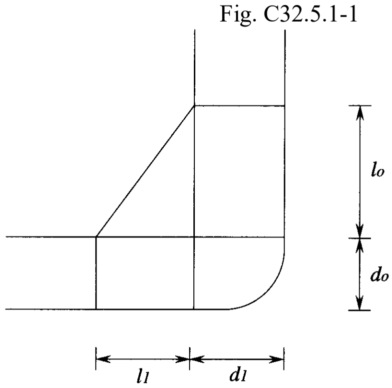
(a) Bilge hopper type (*See* **Fig. C32.5.1-1**)

(b) Stepped type (*See* **Fig. C32.5.1-2**)

(2) The lower end of h is to be a point at a height of l_{0R} above the inner bottom.

(3) $(d - l_{0R} + 0.038L')$ is to be substituted for $(d + 0.038L')$.

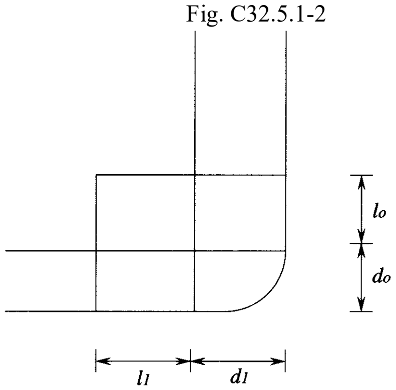
Fig. C32.5.1-1



$$l_{0R} = \frac{l_0 l_1}{d_1 + l_1}$$

$$l_{1R} = \frac{l_0 l_1}{d_0 + l_0}$$

Fig. C32.5.1-2



$$l_{0R} = l_0$$

$$l_{1R} = l_1$$

2 Where there is a combination of a cross-tie with ample sectional area and a non-watertight partial bulkhead or any other similar construction in the midway of the hold, l_H in the provisions of **32.5, Part C of the Rules** may be measured from a watertight bulkhead to this construction.

3 Where the height from the designed maximum load line to the strength deck is unusually large, t_1 as per **32.5.2-1** and **-2, Part C of the Rules** is to be calculated as follows.

(1) β_T and β_L are to be obtained from the following formulae:

$$\beta_T = 1 + \frac{0.42\dfrac{B^2}{D_S D'} - 0.5}{0.59\dfrac{D_S - \dfrac{d_0}{2}}{B - d_1}\left(\dfrac{d_0}{d_1}\right)^2 + 1.0}$$

$$\beta_L = 1 + \frac{0.18\dfrac{B^2}{D_S D'} - 0.5}{0.59\dfrac{D_S - \dfrac{d_0}{2}}{B - d_1}\left(\dfrac{d_0}{d_1}\right)^2 + 1.0}$$

Where:

D': Depth of the ship (m)

Where the imaginary freeboard deck is provided according to **C1.1.3-2(1)**, D' may be the height (m) from the top of keel to this assumed deck.

(2) The value obtained from the following formula is to be substituted for ($d + 0.038L'$).

$$(d + 0.038L') \times \sqrt{\frac{D'}{D_S}}$$

Where:

D': As per **(1)**

4 Where the breadth of angles or flat bars supporting stiffeners in the double hull of side construction is unusually large, the scantlings of stiffeners may be determined in accordance with the provision of **C1.1.13-1**.

C32.8 Strength at Large Flare Locations

C32.8.1 Shell Plating

The thickness of shell plating above the load line for 0.2L forward is to be in accordance with **C16.4.1.**

C32.8.2 Frames

The thickness t_w of web plates and the plastic section modulus Z_p of frames above the load line for 0.2L forward are to be in accordance with **C7.1.8-1.**

C32.8.3 Girders

1 The thickness t_{wG} of web plating and the section modulus Z_G of girders above the load line for 0.2L forward are to be in accordance with **C8.1.4-1.**

2 Buckling strength of girder webs specified in **-1** is to be examined by the requirements in **C8.1.4-2** and **-3**.

C32.9 Direct Strength Calculations for Primary Structural Members

C32.9.1 Application

The "formulae in this chapter which can be substituted for by direct strength calculations" specified in **32.9.1-3, Part C of the Rules** means the formulae shown in **Table C32.9.1-1**.

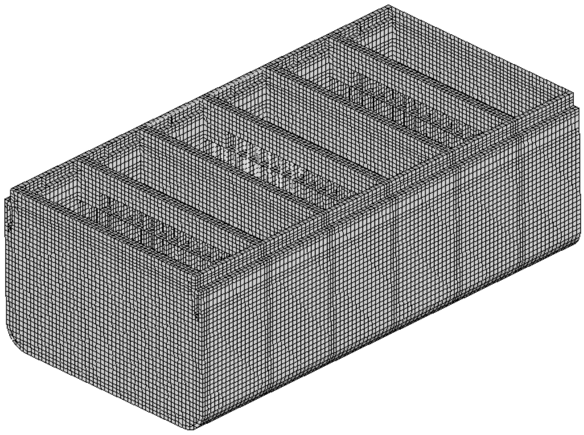
Table C32.9.1-1 Formulae which can be Substituted for by Direct Strength Calculations

Part C of the Rules	formulae
32.4.4-1	the first formula of the formulae for the thickness of inner bottom plating
32.4.5-1	the first formula of the formulae for the thickness of bottom shell plating
32.5.2-1	the formulae for the thickness of side transverse girders
32.5.2-2	the formulae for the thickness of side stringers
32.7.1(1)	the formula for the thickness of decks inside the line of deck openings
32.7.1(2)	the formula for the section modulus of decks inside the line of deck openings
32.7.1(3)	the formula for the moments of inertia of decks inside the line of deck openings
6.2.3(1) and **(2)**	the formulae for the thicknesses of centre girder plates and side girder plates
6.3.2(1) and **(2)**	the formulae for the thickness of solid floors

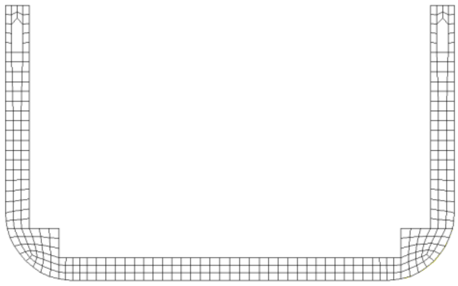
C32.9.7 Modelling for Structural Analysis

1 Examples of structural models are shown in **Fig. C32.9.7-1**.

Fig. C32.9.7-1 Example of Structural Model



(a) Overall View



(b) Transverse Section

2 $M_{V\text{-}end}$Stiffeners are to be modelled so as to take the eccentricity of the neutral axis into account.

3 As for the meshing of elements required in **32.9.7-5, Part C of the Rules**, the shell element mesh is to follow the stiffening system as far as practicable, hence representing the actual plate panels between stiffeners. In principle, the shell element mesh is to satisfy the following **(1)** to **(4)**:

(1) One element between every longitudinal stiffener. Longitudinally, element length is not to be greater than 2 longitudinal spaces with a minimum of three elements between primary supporting members;

(2) One element between every stiffener on transverse bulkheads;

(3) One element between every web stiffener on transverse and vertical web frames, and stringers; and

(4) At least 3 elements over the depth of transverse web frames, vertical web frames and horizontal stringers on transverse bulkheads.

4 The "deemed necessary by the Society" specified in **32.9.7-6, Part C of the Rules** means openings in the transverse girder in the bilge part, and openings in the vertical webs of the partial bulkheads, etc. Openings are modelled by recreating the opening's shape with fine mesh, or removing the appropriate elements in consideration of size and position of the opening.

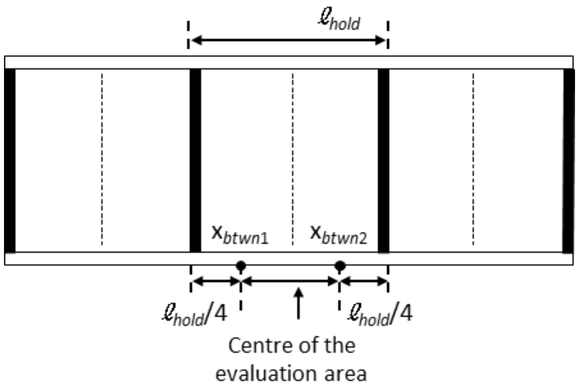
5 Where loads due to containers are to be determined in accordance with **32.9.7-7, Part C of the Rules**, the dynamic load due to a container is to be taken according to the direction of gravity and inertial force of the container, and is to be accordance with the following **(1)** and **(2)**:

(1) As for containers stowed in holds, vertical loads are applied to the structural members coming in contact with the bottom of container stack, and longitudinal and transverse loads are applied to the structural members attached to the container supporting arrangements. The longitudinal and the transverse dynamic loads of containers in holds which are applied to the structural members attached to the container supporting arrangements are considered to be the half of their respective longitudinal and transverse dynamic loads of containers in holds.

(2) As for containers stowed on decks, vertical loads are applied to the position of the top of the hatch coaming, and longitudinal loads are applied to the position of the locking devices of the hatch covers. All containers loaded on a hatch cover may be considered as a single load for said hatch cover.

6 The "centre of the evaluation area" specified in **32.9.7-7(3), Part C of the Rules** means the area of centre $\ell_{hold}/2$ in **Fig. C32.9.7-2**.

Fig. C32.9.7-2 Extent of Modelling



7 Where the adjustment moments are applied at the fore and aft ends of the model in accordance with **32.9.7-7(3), Part C of the Rules**, the procedure is to be in accordance with the following **(1)** to **(3)**:$M_{V\text{-}end}$

(1) The maximum and minimum bending moment M_{V_Max}, M_{H_Max}, M_{V_Min} and M_{H_Min}, which are taken as the maximum and minimum values between the vertical bending moment and horizontal bending moment due to local loads at location x_{btwn1} of a cargo hold in the evaluation area and those at location x_{btwn2} of a cargo hold in the evaluation area, are to be obtained by the following formulae. The weight of the hull structure, container weight, dynamic load of the container, hydrostatic pressure and hydrodynamic pressure are to be considered as local loads.

$$M_{V\_Max} = \max(M_{V\_FEM}(x_{btwn1}), M_{V\_FEM}(x_{btwn2})) \quad (kN\text{-}m)$$
$$M_{V\_Min} = \min(M_{V\_FEM}(x_{btwn1}), M_{V\_FEM}(x_{btwn2})) \quad (kN\text{-}m)$$
$$M_{H\_Max} = \max(M_{H\_FEM}(x_{btwn1}), M_{H\_FEM}(x_{btwn2})) \quad (kN\text{-}m)$$
$$M_{H\_Min} = \min(M_{H\_FEM}(x_{btwn1}), M_{H\_FEM}(x_{btwn2})) \quad (kN\text{-}m)$$

$M_{V\_FEM}(x)$: Vertical bending moment due to local loads at any position x, to be taken as follows:

$$M_{V\_FEM}(x) = -(x - x_{aft})R_{V\_aft} - (x - x_i)\sum_i^{x_i<x} f_{vi} \quad (kN\text{-}m)$$

$M_{H\_FEM}(x)$: Horizontal bending moment due to local loads at any position x, to be taken as follows:

$$M_{H\_FEM}(x) = (x - x_{aft})R_{H\_aft} + (x - x_i)\sum_i^{x_i<x} f_{hi} \quad (kN\text{-}m)$$

x_{aft}, x_{fore}: X coordinate, in m, of the support points at the fore and aft ends of the model.

R_{V_fore}, R_{V_aft}, R_{H_fore}, R_{H_aft}: Vertical and horizontal reaction forces at the support points at the fore and aft ends of the model, to be taken as follows:

$$R_{V\_fore} = -\frac{\sum_i (x_i - x_{aft}) f_{vi}}{x_{fore} - x_{aft}} \quad (kN)$$

$$R_{V\_aft} = -\sum_i f_{vi} - R_{V\_fore} \quad (kN)$$

$$R_{H\_fore} = -\frac{\sum_i (x_i - x_{aft}) f_{hi}}{x_{fore} - x_{aft}} \quad (kN)$$

$$R_{H\_aft} = -\sum_i f_{hi} - R_{H\_fore} \quad (kN)$$

x_i: X coordinate, in *metres*, of the considered longitudinal station i.

f_{vi} and f_{hi}: Vertical and horizontal local loads at x_i (kN).

x_{btwn1}: X coordinate, in *metres*, at the 1/4 length of the evaluation area forward from the aft end of the cargo hold in the evaluation area. (See **Fig. C32.9.7-2**).

x_{btwn2}: X coordinate, in *metres*, at the 3/4 length of the evaluation area forward from the aft end of the cargo hold in the evaluation area. (See **Fig. C32.9.7-2**).

(2) The adjustment vertical bending moment, M_{V-end}, and adjustment horizontal bending moment, M_{H-end}, are obtained by the following formulae.

$M_{V-end} = M_{V-HG} - M_{V\_Min} M_{V\text{-targ}} \geq 0$ (*kN-m*) for $M_{V-targ} \geq 0$

$M_{V-end} = M_{V-HG} - M_{V\_Max}$ (*kN-m*) for $M_{V-targ} < 0$

$M_{H-end} = M_{H-HG} - M_{H\_Min} M_{V\text{-targ}} \geq 0$ (*kN-m*) for $M_{H-targ} \geq 0$

$M_{H-end} = M_{H-HG} - M_{H\_Max} M_{V\text{-targ}} < 0$ (*kN-m*) for $M_{H-targ} < 0$

M_{V-HG}, M_{H-HG}: Vertical bending moment and horizontal bending moment in **32.9.6-5, Part C of the Rules**.

(3) The adjustment moments M_{V-end} and M_{H-end} derived from **(2)** above are to be applied to the support points at the fore and aft ends of the model.

8 In the application of **32.9.7-8, Part C of the Rules**, the boundary conditions applied at the fore and aft end of the model are to be according to **Table C32.9.7-1**. Rigid links are to connect the nodes on the longitudinal members at the model ends to an independent point at the neutral axis in the centreline.

Table C32.9.7-1 Boundary Constraints at Model Ends

Location	Translation			Rotation		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Aft End						
Independent point	-	Fix	Fix	Fix	$-M_{V\text{-}end}$	$-M_{H\text{-}end}$
Cross section	Rigid link	Rigid link	Rigid link	Rigid link	Rigid link	Rigid link
Fore End						
Independent point	Fix	Fix	Fix	Fix	$+M_{V\text{-}end}$	$+M_{H\text{-}end}$
Cross section	Rigid link	Rigid link	Rigid link	Rigid link	Rigid link	Rigid link

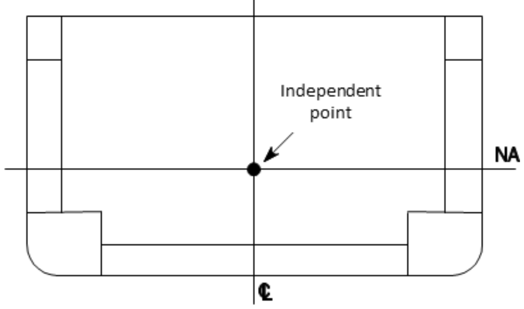
Notes:

$M_{V\text{-}end}$, $M_{H\text{-}end}$: Adjustment vertical bending moment, M_{V-end}, and adjustment horizontal bending moment, M_{H-end}, to be taken as given in **C32.9.7-7(2)**.

(1): [-] means no constraint applied (free)

(2): See **Fig.C32.9.7-3**.

Fig. C32.9.7-3 Boundary Conditions Applied at the Model End Sections



C32.9.8 Yield Strength Assessment

1 In the application of **32.9.8, Part C of the Rules**, when fine mesh is used rather than the standard mesh given in **C32.9.7-3**, the mean stress corresponding to the standard mesh may be used.

2 The "deemed appropriate by the Society" specified in **32.9.8-2, Part C of the Rules** means calculating the shear stress and the stress in the spanwise direction of girder in consideration of the effective shear area of the web. The effective shear area of the web is to be taken as the web area deducting the area lost due to openings in accordance with the following **(1)** and **(2)**:

(1) When both sides of the web are plate members, the equivalent stress σ_{eq_cor} is to be calculated with the shear stress modified in accordance with following formula:

$$\sigma_{eq\_cor} = \sqrt{{\sigma_{elem\_s}}^2 - \sigma_{elem\_s} \cdot \sigma_{elem\_d} + {\sigma_{elem\_d}}^2 + 3{\tau_{cor}}^2}$$

τ_{cor}: Corrected element shear stress, in N/mm^2, to be taken as follows:

$$\tau_{cor} = \frac{ht_{mod-n50}}{A_{shr-n50}} \tau_{elem}$$

τ_{elem}: Element shear stress (N/mm^2) before correction.

$t_{mod-n50}$: Modelled web thickness (mm) in way of the opening.

h: Height of web of girder (mm) in way of the opening.

$A_{shr-n50}$: Effective net shear area of web (mm^2) taken as the web area deducting the area lost due to openings calculated with an effective web height h_{eff} (mm). h_{eff} is to be taken as the lesser of the following, where the third formula is only taken into account for an opening located at a distance less than $h_w/3$ from the cross-section considered.

$$h_{eff} = h_w$$

$$h_{eff} = h_{w3} + h_{w4}$$

$$h_{eff} = h_{w1} + h_{w2} + h_{w4}$$

h_w : Web height of primary supporting member (mm).

h_{w1}, h_{w2}, h_{w3}, h_{w4} : Dimensions shown in **Fig. C32.9.8-1**.

σ_{elem_s}: Stress in the spanwise direction of the girder (N/mm^2) before correction.

σ_{elem_d}: Stress in the depth direction of the girder (N/mm^2) before correction.

(2) When both sides of the web are any case other than those in **(1)** above, the equivalent stress σ_{eq_cor} is to be calculated with the shear stress modified in accordance with following formula:

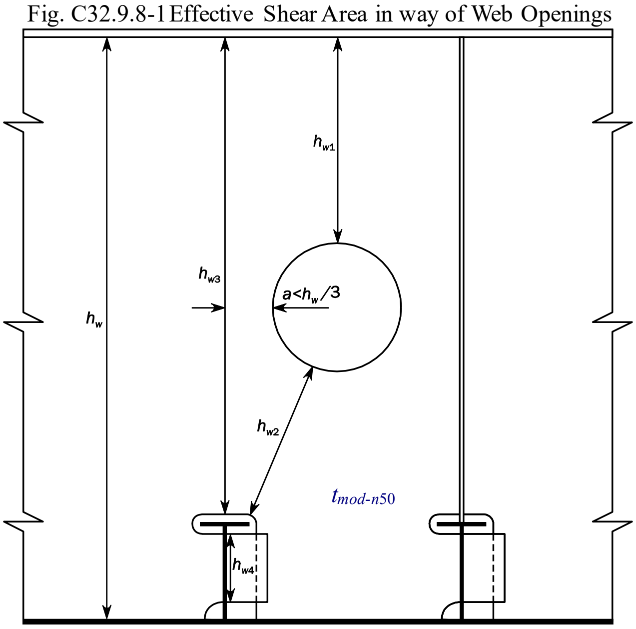
$$\sigma_{eq\_cor} = \sqrt{{\sigma_{cor\_s}}^2 - \sigma_{cor\_s} \cdot \sigma_{elem\_d} + {\sigma_{elem\_d}}^2 + 3{\tau_{cor}}^2}$$

σ_{cor_s}: Corrected stress in the spanwise direction of girder (N/mm^2) to be taken as follows:

$$\sigma_{cor\_s} = \frac{ht_{mod-n50}}{A_{shr-n50}} \sigma_{elem\_s}$$

τ_{cor}, σ_{elem_s}, σ_{elem_d}, $t_{mod-n50}$, h, $A_{shr-n50}$: As specified in **(1)** above.

Fig. C32.9.8-1 Effective Shear Area in way of Web Openings



C32.9.9 Buckling Strength Assessment

1 Where the plate thickness along a plate panel is not constant, the plate thickness used for the buckling assessment is to be modified with a weighted average thickness taken as follows:

$$t_{avr} = \frac{\sum_1^n A_i t_i}{\sum_1^n A_i}$$

A_i: Area of the i-th plate element.

t_i: Net thickness of the i-th plate element.

n: Number of finite elements defining the buckling plate panel.

2 The panel yield stress σ_{YP} is to be taken as the minimum value of the specified yield stresses of the elements within the plate panel.

3 The buckling assessment is to be carried out according to one of the following two methods, taking into account the continuity of the panel and the boundary condition types:

Method A: Critical buckling stresses are calculated by assuming that all the boundary edges of the panel are forced to remain straight due to the surrounding structure/neighbouring plates.

Method B: Critical buckling stresses are calculated by assuming that the boundary edges of the panel are not forced to remain straight due to low in-plane stiffness at the edges and/or no surrounding structure/neighbouring plates.

4 The buckling strength assessment for each member is to be accordance with the following requirements:

(1) All plate and girder members of the hull are to be modelled as plane panels, which are separated by stiffeners or girder members, and the buckling utilisation factor of each panel is to be calculated by the method given in **Annex C32.2.7 "GUIDANCE FOR BUCKLING STRENGTH ASSESSMENT"** in consideration of the following **(a)** and **(b)**.

(a) Method A is used for the rectangular shape panels of plate members, which are regularly stiffened, and the panels of girder members which are regularly stiffened in the depth direction of the girder.

(b) Method B is used for panels of plate members, which are stiffened using irregular spacing or irregular angles, and the panels of girder members which are stiffened in the spanwise direction of the girder. Non-rectangular shaped panels are to be calculated by an appropriate method so that they can be replaced by an equivalent rectangular shape panel.

(2) The buckling utilisation factors of stiffeners specified in the following **(a)** and **(b)** are to be calculated by the method given in **Annex C32.2.7 "GUIDANCE FOR BUCKLING STRENGTH ASSESSMENT"**.

(a) Stiffeners fitted on longitudinal structural members.

(b) Stiffeners other than **(a)** above, under large compression loads.

(3) For members not subject to **(1)** and **(2)** above for special reasons, the buckling utilization factor may be obtained by non-linear

analysis, etc.

5 The "deemed appropriate by the Society" specified in **32.9.9-3, Part C of the Rules** means the method given in **2.5** of **Annex C32.2.7 "GUIDANCE FOR BUCKLING STRENGTH ASSESSMENT"**.

C32.10 Fatigue Strength

C32.10.1 Fatigue Strength Assessment

1 Fatigue strength assessments for bottom longitudinals and side longitudinals are to be in accordance with the requirements in **1.1.23-4** and **-5, Part C of the Rules.**

2 Fatigue strength assessments for the longitudinal structural members of upper decks, including hatch side coamings and bench corners in forward holds, are to be as follows:

(1) Hatch side coaming top plate at hatch corner is to be in accordance with the followings:

(a) Hatch side coaming top plates at hatch corners are to have sufficient fatigue strength. The Society may require fatigue strength assessments according to the **"Guidelines for Fatigue Strength Assessment"** in the **"Guidelines for Container Carrier Structures"** in consideration of the kind of steel used, the size of the ship, and the structural arrangement, etc. Hot-spot stresses at hatch corners (hot-spot mean stress and hot-spot stress fluctuation range) are to be determined using detailed Finite Element Analysis (FEA) using fine mesh elements. Element sizes, details of analysis and so on are to be at the Society's discretion.

(b) Butt welds for hatch side coamings and fillet welded joints for attaching equipment are to be set at a sufficient distance from hatch corners so that the effects of stress concentration are avoided. The Society may require the submission of drawings and data related to arrangement of welded joints.

(2) For butt welded joints and fillet welded joints of hatch side coamings (including welds for attaching equipment, etc.), special consideration is to be given to fatigue strength. The Society may require the submission of relevant fatigue strength assessments.

(3) Fatigue strength of locations other than hatch side coamings is to be in accordance with the following:

(a) The fatigue strength at locations other than hatch side coamings (strength decks, sheer strakes, uppermost strakes of longitudinal bulkheads) are to be sufficiently considered in conjunction with increases of hull girder stress (longitudinal bending stress and torsional stress).

(b) The Society may require fatigue assessments according to the **"Guidelines for Fatigue Strength Assessment"** in the **"Guidelines for Container Carrier Structures"** in consideration of the kind of steel used, the size of the ship, and the structural arrangement, etc. If deemed necessary, the Society may require that detailed Finite Element Analysis (FEA) be used to calculate hatch corner hot-spot stresses.

(c) The fatigue strength of bench corners in way of forward holds is to be carefully considered. If deemed necessary by the Society, a fatigue strength assessment of the relevant part may be required.

3 When deemed necessary by the Society, fatigue strength assessments may be required for structural members other than those specified in **-1** and **-2** above.

C32.13 Special Requirements for Container Carriers Applying Extremely Thick Steel Plates

C32.13.3 Measures for Prevention of Brittle Fracture

1 **1** "Other measures deemed by the Society to be equivalent in effectiveness to brittle crack arrest designs" in Note (1) of **Table C32.27, Part C of the Rules** means the non-destructive inspections, particularly those using the time-of-flight diffraction (*TOFD*) technique, or the phased array ultrasonic testing (*PAUT*) specified in **M8.4.3-2, Part M of the Guidance** is carried out at the locations specified in **8.4.3-8, Part M of the Rules**.

2 Where the measures specified in **-1** above is applied, it may be considered as equivalent in effectiveness as measures specified **32.13.4-5(2)** and **(3), Part C of the Rules**.

C32.13.4 Brittle Crack Arrest Design

1 "Other weld areas" in **32.13.4-4(3), Part C of the Rules** includes the following (refer to **Fig.C32.13.4-1**):

(1) Fillet welds where hatch side coaming plating, including top plating, meets longitudinals;

(2) Fillet welds where hatch side coaming plating, including top plating and longitudinals, meets attachments. (e.g., Fillet welds where hatch side top plating meets hatch cover pad plating.);

(3) Fillet welds where hatch side coaming top plating meets hatch side coaming plating;

(4) Fillet welds where hatch side coaming plating meets upper deck plating;

(5) Fillet welds where upper deck plating meets inner hull/bulkheads;

(6) Fillet welds where upper deck plating meets longitudinals; and

(7) Fillet welds where sheer strakes meet upper deck plating.

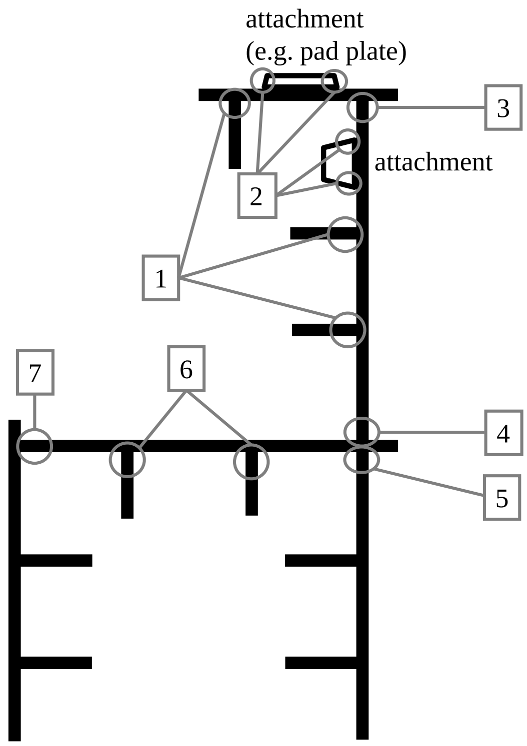
2 "Appropriate measure" in **32.13.4-5(3), Part C of the Rules** means that the block-to-block butt welds of the hatch side coaming are to be shifted from those of the strength deck, this shift is to be greater than or equal to 300*mm* in principle.

3 If detailed documentation (including information such as construction procedure, application and procedure of non-destructive inspections at joints, etc.) which demonstrates the applicability as an alternative measure to **-2** above is submitted to and approved by the Society, the following **(1)** and **(2)** may be applied instead. In such cases, where deemed necessary by the Society, brittle fracture tests may be required to confirm the effectiveness of the alternative measure.

(1) Where crack arrest holes are provided in way of the block-to-block butt welds at the region where hatch side coaming weld meets the deck weld, the fatigue strength of the lower end of the butt weld is to be assessed.

(2) Where arrest insert plates of brittle crack arrest steel or weld metal inserts with high crack arrest toughness properties are provided in way of the block-to-block butt welds at the region where hatch side coaming weld meets the deck weld.

Fig.C32.13.4-1 Other Weld Areas



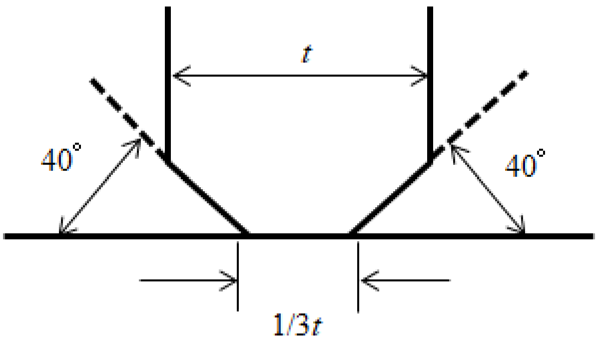
C32.13.5 Selection of Brittle Crack Arrest Steels*

1 In **32.13.5-1, Part C of the Rules**, when the steels evaluated by an evaluation method other than that specified in **3.12, Part K of the Rules** are to be brittle crack arrest steels, technical documents showing the validity of the evaluation method and the brittle crack arrest properties equivalent to the *BCA*6000 or *BCA*8000 specified in **3.12, Part K of the Rules** are to be submitted to the Society for approval. If necessary, additional tests may be required.

2 An example of "partial penetration weld" specified in **32.13.5-3, Part C of the Rules** is shown in **Fig. C32.13.5-1**. In this figure, the standard welding leg length is 5 *mm* and the standard root surface is 1/3 or more of the thickness *t* of the hatch side coaming.

3 The "alternative weld details" specified in **32.13.5-3, Part C of the Rules** refers to a full penetration weld.

Fig. C32.13.5-1 Example Partial Penetration Weld Between Hatch Side Coaming and Upper Deck



welding leg length : 5 *mm*
t : thickness of hatch side coaming

C33 DAMAGE CONTROL

C33.2 Damage Control

C33.2.1 Cargo Ports and Other Similar Openings

"Where it is to be deemed appropriate by the Society" stipulated in **33.2.1, Part C of the Rules** refers to circumstances such as where the doors are located high enough above the freeboard deck and their opening areas are considered small enough.

C33.3 Booklet and Plan for Damage Control

C33.3.1 Damage Control Plan

The damage control plan to be provided onboard ships is to include the contents shown in **Table C33.3.1-1**.

Table C33.3.1-1 The Items and Contents of the Damage Control Plan

Items	Contents
(1) Boundaries of Compartments	Boundaries of watertight compartments
(2) Watertight closing appliances of openings in the boundaries of compartments	Positions of the watertight closing appliances, indicators and alarms of openings and their control positions
(3) Weathertight closing appliances of openings in boundary walls	Positions of openings, however these are to be distinguished from the watertight ones mentioned above **(2)**.
(4) Cross-flooding appliances, if provided	Cross-flooding appliances and their control Positions
(5) Valves etc. remotely operated in order to control flooding through pipes, ducts and tunnels into other compartments	Positions of bilge and ballast pumps and their control positions and associated valves, etc. and control positions
(6) Doors in the shell of the ship	Positions of doors, including the positions of indicators, leakage detection and surveillance devices
(7) Weathertight closing appliances in local subdivision boundaries above bulkhead decks and exposed weather decks, if provided	Positions of weathertight closing appliances, including the positions of their controls and indicators

Notes:
Closing appliances provided with non-weathertight openings (*e.g.* gastight) for flooding calculations need not be shown in the damage control plan.

C33.3.2 Booklet

1 The booklet to be provided onboard ships is to include the contents shown in **Table C33.3.2-1**.

2 The booklet specified in **33.3.2, Part C of the Rules** is to contain the following **(1)** and **(2)**.

(1) General precautions

General precautions are to consist of a list of equipment conditions and operational procedures, considered by the Society to be necessary to maintain watertight integrity under normal ship operations.

(2) Specific precautions

Specific precautions are to consist of a list of elements (*i.e.* closures, sounding of alarms, etc.) considered by the Society to be vital to the survival of the ship.

Table C33.3.2-1 The Items and Contents of the Booklet

Items	Contents
(1) Boundaries of Compartments	Same as Table C33.3.1-1 (1) (A reduced scale may be accepted.)
(2) Watertight closing appliances of openings in the boundaries of compartments	In addition to Table C33.3.1-1 (2), it is clearly to be stated that closing appliances not used during navigation shall be kept closed and that closing appliances to be used during navigation shall be closed immediately after passage.
(3) Weathertight closing appliances of openings in boundary walls	In addition to Table C33.3.1-1 (3), it is clearly to be stated that closing appliances shall be closed immediately after passage.
(4) Cross-flooding appliances, if provided	In addition to Table C33.3.1-1 (4), operating procedures and an operating time to reach equilibrium condition for cross-flooding appliances are to be included.
(5) Valves etc. remotely operated in order to control flooding through pipes, ducts and tunnels into other compartments	In addition to Table C33.3.1-1 (5), it is clearly to be stated that valves, etc. shall be closed during navigation unless they are being used, and that valves, etc. being used at time of collision shall be closed immediately.
(6) Ballast line with hydraulic control line along the pipe	It is clearly to be stated that valves, etc. shall be closed during navigation unless they are being used.
(7) Non-automatic closing appliances of non-watertight openings through which progressive flooding might occur, if applicable	Position of opening. In addition, it is clearly to be stated that closing appliances to be used during navigation shall be closed immediately after passage.
(8) The results of the subdivision and damage stability analyses, if included	In addition to the results of subdivision and damage stability analyses, additional guidance is to be provided to ensure that the ship's officers referring to that information are aware that the results are included only to assist them in estimating the ship's relative survivability.
(9) Miscellaneous	(a) The booklet is to contain additional details regarding the following information shown on the damage control plan, if required: ・ Positions of flooding detection systems, sounding devices, tank vents and overflows which do not extend above weatherdecks ・ Pump capacities and piping diagrams ・ Means of accessing and escaping from watertight compartments below bulkhead decks ・ Alerting ship management and other organizations to stand by and co-ordinate assistance (b) The booklet is to include general instructions for controlling the effects of damage, such as the following: ・ Establishing the locations and safety of persons on board ・ To ascertain the extent of damage by sounding tanks and compartments ・ To determine rates of flooding by repeated soundings ・ Cautionary advice regarding the cause of any list ・ Cautionary advice regarding the cause of liquid transfer operations to lessen list or trim ・ Effects of creating additional free surfaces ・ Effects of initiating pumping operations to control the ingress of water

C33.3.3 Damage Stability Information

The "damage stability information deemed appropriate by the Society" referred to in **33.3.3, Part C of the Rules** is to contain the following **(1)** and **(2).**

(1) The following information for providing a master a simple and easily understandable way of assessing ship's survivability in damage cases.

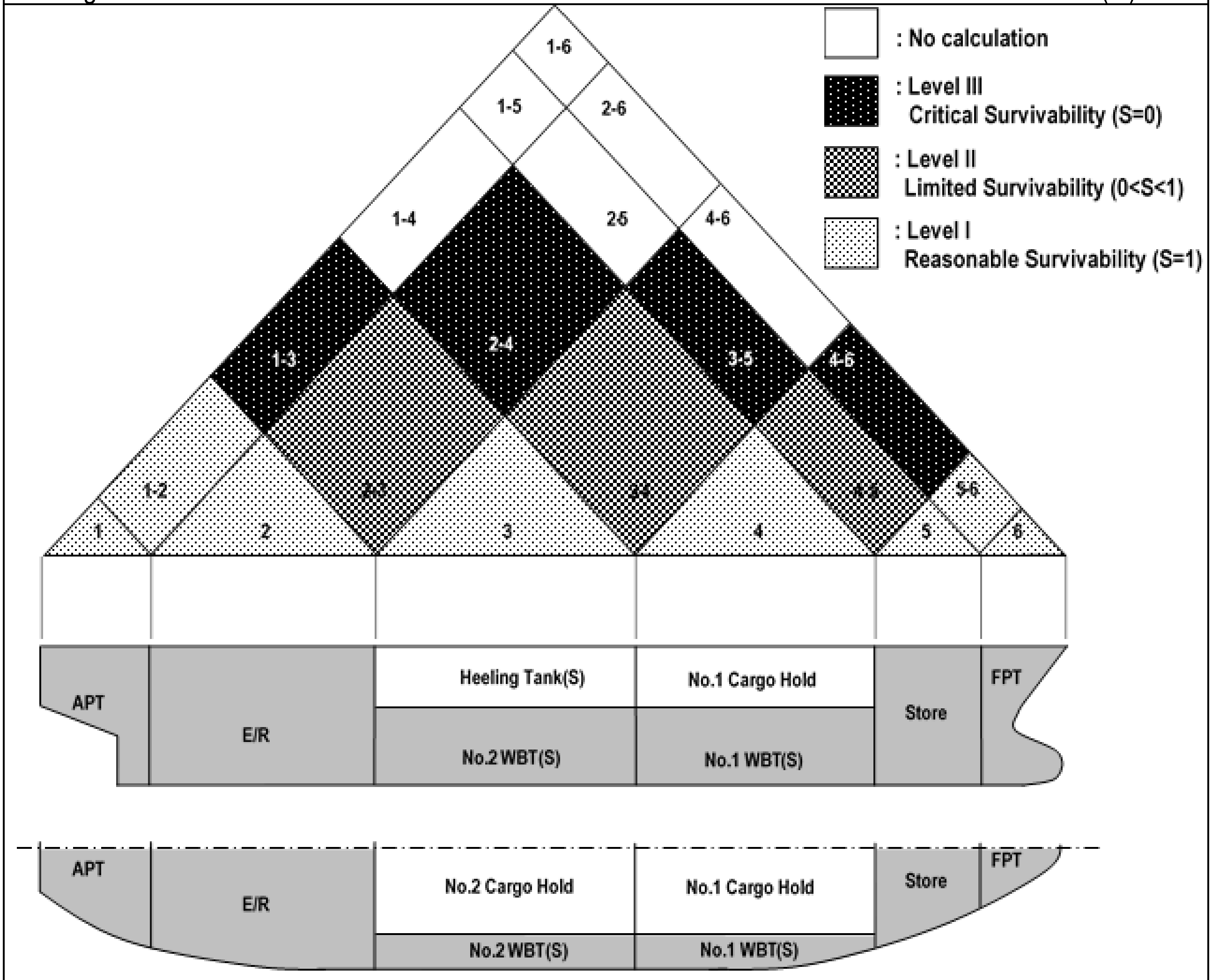
(a) The diagram of the results of the damage stability calculation required in **Chapter 4, Part C of the Rules** or **Chapter 4, Part CS of the Rules** as a rapid means to evaluate the consequences of any ship damage (*e.g.*, such as damage consequence diagrams categorized by probability of survival as shown in **Fig.C33.3.3**).

(b) A notice regarding the use of this information, which states that different results may be seen in cases where the flooding occured under actual loading conditions because the damage stability calculations given as reference are based on assumed conditions.

(2) In cases where a ship voluntarily enters into a contract to use a shore-based emergency response system, information needed for making damage stability assessment as well as the contact information for the shore-based facility is to be included as part of damage stability information.

Fig. C33.3.3

Damage: Horizontal Extent from outside shell = 1.500m Vertical Extent from base line = 9.000 (m)



Damage Zone	Damage Compartment	Horizontal Extent(m)	Vertical Extent(m)	S-value
1 Compartment flooding				
1	APT	Max	Max	1.000
2	E/R	Max	Max	1.000
3	No.2 WBT(S)	1.500	9.000	1.000
4	No.1 WBT(S)	1.500	9.000	1.000
5	STORE	Max	Max	1.000
6	FPT	Max	Max	1.000
2 Compartments flooding				
1-2	APT E/R	Max	Max	1.000
2-3	E/R No.2 WBT(S)	1.500	9.000	0.785
3-4	No.1 WBT(S) No.2 WBT(S)	1.500	9.000	0.458
4-5	No.1 WBT(S) STORE	1.500	9.000	0.882
5-6	STORE FPT	Max	Max	1.000
3 Compartments flooding				
1-3	APT E/R No.2 WBT(S)	1.500	9.000	0.0000
2-4	E/R No.1 WBT(S) No.2 WBT(S)	1.500	9.000	0.0000
3-5	No.1 WBT(S) No.2 WBT(S) STORE	1.500	9.000	0.0000
4-6	No.1 WBT(S) STORE FPT	1.500	9.000	0.0000
Notice: The above damage compartments are the flooding case of the least safety factor within the damage zone.				

C34 LOADING MANUAL AND LOADING COMPUTER

C34.1 General

C34.1.1 General

1 "Other ships deemed necessary by the Society" stipulated in **34.1.1-2(2), Part C of the Rules**, means the following ships.

(1) Ships with especially large openings in the deck to which **Chapter 32, Part C of the Rules**, is applicable, and need special considerations on the composite and torsional moment

(2) Ships loaded with cargo and ballast in an undistributed condition, applicable to **Chapter 29**, **Chapter 30** or **Chapter 31, Part C of the Rules**

C34.1.2 Loading Manual

1 The loading manual approved by the Society according to **34.1.2, Part C of the Rules**, is to be prepared in compliance with **Annex C34.1.2** "**GUIDANCE FOR PREPARATION OF LOADING MANUALS**." The manual is to be written with a language easily understood by the ship master. Where this language is not English, a translation into English is to be included.

2 The "standard loading conditions" specified in **34.1.2-1, Part C of the Rules**, are the loading conditions specified for each ship type in **1.3** of **Annex C34.1.2** "**GUIDANCE FOR PREPARATION OF LOADING MANUALS**".

C34.1.3 Loading Computer

1 Input and output of the loading computer is to be in compliance with the following requirements.

(1) Loading conditions of cargo holds, all tanks forming part of the ship's hull and independent cargo tanks are, in principle, to be inputted individually.

(2) Input data are to be verified.

(3) At least the following items are to be outputted.

(a) Displacement

(b) Draughts and trim

(c) Still water shearing force (for ships with longitudinal bulkhead, respective shearing forces acting on the longitudinal bulkhead and the shell plating considering local loads)

(d) Longitudinal still water bending moment

(4) Still water shearing force and longitudinal still water bending moment are to be outputted at the forward end transverse bulkheads of the machinery space or cargo pump room, collision bulkhead and those transverse bulkheads located between them.

(5) Longitudinal still water bending moment is capable being outputted with the maximum values of hogging moment and sagging moment. However, where these maximum values are unable to be assumed at a sufficient accuracy, this requirement may be dispensed with.

(6) The computer is to be able to readily verify the calculated values for standard loading conditions.

(7) The calculated values of still water shearing force and longitudinal still water bending moment for each loading condition are to be readily compared with the permissible values of the still water shearing force and longitudinal still water bending moment stated in the loading manual.

2 The accuracy of the loading computer is to be verified by either procedure **(1)** or **(2)** below, by selecting not less than four loading conditions stated in the loading manual. The computing accuracy may be reasonably altered at the points where the absolute values of still water shearing force and longitudinal still water bending moment become particularly insignificant.

(1) The values of still water shearing force and longitudinal still water bending moment computed by the Society are to be compared with the values computed by the loading computer, and it is to be confirmed that respective errors are to be less than ±10%.

(2) The values of still water shearing force and longitudinal still water bending moment computed by a computing procedure as deemed appropriate by the Society in accordance with the requirements of **15.2.1-1** and **15.3.1-1, Part C of the Rules** or the vertical still water shear force and vertical still water bending moment computed in accordance with the requirement of **32.2.3,**

Part C of the Rules for ships to which the requirements in **Chapter 32, Part C of the Rules** apply, are to be compared with those values computed by the loading computer under consideration, and it is to be confirmed that respective errors are to be less than ±3%. The calculation data is to be submitted to the Society.

3 As loading computers are to be capable of producing the specified performance and functions on installation specified in **34.1.3, Part C of the Rules**, those complying with the requirements of **Part 7 of the "Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use"** are recommended to be used.

4 Where input/output and computing procedures are changed, notice is to be given to the Society. The tests and inspections specified in **2.1.7, Part B of the Rules** are to be carried out again when the Society deems it necessary.

5 The operation manual and the computer output are to be prepared in a language understood by the ship master. Where this language is not English, a translation into English is to be included.

C34.2 Additional Requirements for New-building Bulk Carriers

C34.2.2 Loading Manual

1 The maximum allowable cargo mass W_{MAX} and the minimum allowable cargo mass W_{MIN} for each cargo hold which are to be described in Loading Manual as specified in **34.2.2-1(3), Part C of the Rules** are to be given by the following as a function of the draught in way of the considered cargo hold.

(1) Maximum allowable cargo mass

(a) Where the scantlings of structural members of the double bottom are determined by the formula prescribed in the requirements of the Rules;

i) The pressure which works on the ship's bottom due to the mass of cargo or ballast water, $9.81h_x\gamma$ (*kN/m*^{2}), is to be not greater than that obtained from the following formula.

$$\max\{a_1 n_{f1}, a_2 n_{f2}, \cdots, a_n n_{fn}\} + 9.81(d_x - 0.026L'\alpha_R - h_{BST})$$

h_x: Stowage height (m) to the cargo surface from the tank top at the centre line

In any case, the height of the cargo surface cannot exceed that of the upper deck.

γ : Design specific gravity of cargoes for the cargo hold which is to be taken as γ_D specified in **31.2.1-3, Part C of the Rules**

a_i : Difference in pressure (*kN/m*^{2}) in loading condition No. *i* taken from the total of *n* loading conditions, which works on the centre line of the ship's bottom due to the mass of cargo, ballast water and/or double bottom contents and by wave and still water corresponding to the draught, which is obtained from the following formula

The difference in pressure cannot, however, exceed the design pressure given to the local structural member of the double bottom where the member is reinforced to enable the ship to carry heavy cargoes such as steel coils.

$$\max\{|p_i - 9.8(d_i + 0.026L')|, |p_i - 9.81(d_i - 0.026L')|\}$$

p_i: Pressure (*kN/m*^{2}) in loading condition No. *i*, which works on the centre line of the ship's bottom by the mass of cargo, ballast water and/or double bottom contents

d_i : Draught (m) in loading condition No. *i*, at mid-hold position of cargo hold length l_H

l_H : Length (m) of cargo hold as defined in **31.2.1-4, Part C of the Rules**

L' : Length (m) of ship

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

α_R: 1.0

However, on waters where there are small effects of ocean waves such as in a port area, that may be reduced to 0.5.

n_{fi}: 0.9 in loading condition No. *i*, where the considered hold and either of the adjacent holds are loaded or empty simultaneously

In the other case, it is to be 1.0.

d_x: Draught (m) at mid-hold position of cargo hold length l_H

h_{BST}: Water heads (m) of ballast water charged in the double bottom at the centre line
In any case, it cannot exceed height of the double bottom.

ii) The maximum allowable cargo mass, W_{MAX} (*ton*), is to be not greater than that obtained from the following formula.

$\gamma f(h_x)$

$f(h_x)$: The function which shows the relationship between the stowage height h_x (m) of cargo at the centre line and the volume (m^3) of cargo loaded in the hold
In this case, the cargo may be assumed to be loaded uniformly with a level surface.

(b) Where the scantlings of structural members of the double bottom are determined by direct calculations:

i) The pressure which works on the ship's bottom due to the mass of cargo or ballast water, $9.81h_x\gamma$ (kN/m^2), is to be not greater than that obtained from the following formula.

$$\max\{a_1, a_2, \cdots, a_n\} + 10\,(d_x - 0.25H_w\alpha_{DC} - h_{BST})$$

h_x, γ, d_x and h_{BST}: As specified in **(a)i)**

a_i : Difference in pressure (kN/m^2) in loading condition No. i taken from the total of n loading conditions, which works on the centre line of the ship's bottom due to the mass of cargo, ballast water and/or double bottom contents and by wave and still water corresponding to the draught, which is obtained from the following formula
The difference in pressure cannot, however, exceed the design pressure given to the local structural member of the double bottom where the member is reinforced to enable the ship to carry heavy cargoes such as steel coils.

$$\max\{|p_i - 10(d_i + 0.25H_w)|, |p_i - 10(d_i - 0.25H_w)|\}$$

p_i : The pressure (kN/m^2) in loading condition No. i, which works on the centre line of the ship's bottom by the mass of cargo, ballast water and/or double bottom contents
In calculating the pressure which arises from the mass of cargo, the density of the cargo and the shape of the cargo surface which were applied in direct calculations may be taken into consideration.

d_i : Draught (m) in loading condition No. i, at mid-hold position of cargo hold length l_H

H_w: As obtained from the following formula

$H_w = 0.61L^{\frac{1}{2}}$ where $L \leq 150$ (m)

$H_w = 1.41L^{\frac{1}{3}}$ where $150 < L \leq 250$ (m)

$H_w = 2.23L^{\frac{1}{4}}$ where $250 < L \leq 300$ (m)

$H_w = 9.2$ where $300 < L$ (m)

α_{DC}: 1.0
On waters where there are small effects of ocean waves such as in a port area, it may be reduced to one-third.

ii) The maximum allowable cargo mass, W_{MAX} (*ton*), is to be not greater than that obtained from the following formula.

$\gamma f(h_x)$

$f(h_x)$: As specified in **(a)ii)**

(2) Minimum allowable cargo mass

(a) Where the scantlings of structural members of the double bottom are determined by the prescribed formula in the requirements of the Rules:

i) The pressure which works on the ship's bottom due to the mass of cargo or ballast water, $9.81h_x\gamma$ (kN/m^2), is to be not less than that obtained from the following formula.

$$-\max\{a_1n_{f1}, a_2n_{f2}, \cdots, a_nn_{fn}\} + 9.81\,(d_x + 0.026L'\alpha_R - h_{BST})$$

h_x, γ, a_i, n_{fi}, d_x, L', α_R and h_{BST}: As specified in **(1)(a)**

ii) Minimum allowable cargo mass W_{MIN} (*ton*) is to be not less than that obtained from the following formulas.

$\gamma f(h_x)$

$f(h_x)$: As specified in **(1)(a)**

(b) Where the scantlings of structural members of the double bottom are determined by direct calculations:

i) The pressure which works on the ship's bottom due to the mass of cargo or ballast water, $9.81h_x\gamma$ (*kN/m*^{2}), is to be not less than that obtained from the following formula.

$$\min\{a_1, a_2, \cdots, a_n\} + 10(d_x + 0.25H_w\alpha_{DC} - h_{BST})$$

h_x, γ, d_x, α_{DC}, h_{BST} and H_w: As specified in **(1)(b)**.

a_i: Difference in pressure (*N/m*^{2}) in loading condition No. *i* taken from the total of *n* loading conditions, which works on the centre line of the ship's bottom due to the mass of cargo, ballast water and/or double bottom contents and by wave and still water corresponding to the draught, which is obtained from the following formula taking a downward force as a positive value

The difference in pressure cannot, however, exceed the design pressure given to the local structural member of the double bottom where the member is reinforced to enable the ship to carry heavy cargoes such as steel coils.

$$\min\{p_i - 10(d_i + 0.25H_w), p_i - 10(d_i - 0.25H_w)\}$$

p_i and d_i: As specified in **(1)(b)**

ii) Minimum allowable cargo mass W_{MIN} (*ton*) is to be not less than that obtained from the following formula.

$\gamma f(h_x)$

$f(h_x)$: As specified in **(1)(b)**

2 The maximum allowable cargo mass W_{MAX} and the minimum allowable cargo mass W_{MIN} for the cargo hold and the adjacent cargo hold (hereinafter referred to as "two adjacent holds") which are to be described in the Loading Manual as specified in **34.2.2-1(4), Part C of the Rules** are to be given by the following as a function of the draught in way of these holds.

(1) Maximum allowable cargo mass

(a) Where the scantlings of structural members of the double bottom are determined by the formula prescribed in the requirements of the Rules:

i) In each hold, the pressure which works on the ship's bottom due to the mass of cargo or ballast water is to be not greater than that obtained from the following formulas.

The pressure, $9.81h_x\gamma$ (*kN/m*^{2}), which works on the considered hold is:

$$b + 9.81(d_x - 0.026L'\alpha_R - h_{BST})$$

The pressure, $9.81h'_x\gamma'$ (*kN/m*^{2}), which works on the adjacent hold is:

$$b' + 9.81(d_x - 0.026L'\alpha_R - h'_{BST})$$

h_x and h'_x : Stowage height (*m*) to the cargo surface from the tank top at the centre line in each hold

In any case, the height of the cargo surface cannot exceed that of the upper deck.

γ and γ': Design specific gravity of cargoes for the cargo hold (specified in **31.2.1-3, Part C of the Rules**) which has the largest value under such loading conditions that two adjacent holds are empty or loaded simultaneously.

b and b' : Where a_j and a'_j satisfy the relationship defined by the following formula, b and b' take the absolute value of a_j and a'_j respectively. The absolute value cannot, however, exceed the design pressure given to the local structural member of the double bottom where the member is reinforced to enable the ship to carry heavy cargoes such as steel coils.

$$a_j a'_j = \max\{a_1 a'_1, a_2 a'_2, \cdots, a_m a'_m\}$$

a_j and a'_j : Differences in pressure (*kN/m*^{2}) of the considered hold and the adjacent hold in loading condition No. *j* taken from the total of *m* loading conditions such that two adjacent holds are empty or loaded simultaneously, which work on the centre line of the ship's bottom due to the mass of cargo, ballast water and/or double bottom contents and by wave and still water corresponding to the draught

In loading condition No. j, a_j and a'_j are to be taken as a_{jk} and a'_{jk} which are obtained from the following formulae when the wave pressure affects the still water pressure, and the difference in pressure of the considered hold and the adjacent hold have the same sign (i.e. plus or minus). Here, downward force is taken as a positive value.

$a_{jk}a'_{jk} = \max\{a_{j1}a'_{j1},\ a_{j2}a'_{j2}\}$

a_{jk} and a'_{jk} : Differences in pressure of the considered hold and the adjacent hold in loading condition No. j which are obtained from the following formulae

Where the pressure by wave is added to the pressure by still water, they are defined as a_{j1} and a'_{j1} respectively, where it is subtracted, they are defined as a_{j2} and a'_{j2}.

$a_{j1} = p_j - 9.81(d_j + 0.026L')$

$a'_{j1} = p'_j - 9.81(d'_j + 0.026L')$

$a_{j2} = p_j - 9.81(d_j - 0.026L')$

$a'_{j2} = p'_j - 9.81(d'_j - 0.026L')$

p_j and p'_j : The pressures (kN/m^2) in the considered hold and in the adjacent hold which arise at the centre line of the ship's bottom due to the mass of cargo, ballast water and/or double bottom contents in loading condition No. j

d_j and d'_j : Draught (m) at mid-hold position of cargo hold length l_H of the considered hold and the adjacent hold respectively in loading condition No. j

l_H, L' and α_R : As specified in **-1(1)(a)**

d_x : The average value (m) of d_j and d'_j

h_{BST} and h'_{BST} : Water heads (m) of ballast water in the double bottom at the centre line in the considered hold and the adjacent hold respectively

In any case, they cannot exceed the height of the double bottom.

ii) The maximum allowable cargo mass, W_{MAX} (ton), is to be not greater than that obtained from the following formula.

$\gamma f_1(h_x) + \gamma' f_2(h'_x)$

$f_1(h_x)$ and $f_2(h'_x)$: Functions (in the considered hold and the adjacent hold respectively) which shows the relationship between the stowage height of the cargo at the centre line and the volume (m^3) of the cargo loaded in the hold

In this case, the cargo may be assumed to be loaded uniformly with a level surface.

(b) Where the scantlings of structural members of the double bottom are determined by direct calculations:

i) In each hold, the pressure which works on the ship's bottom due to the mass of cargo or ballast water is to be not greater than that obtained from the following formulas.

The pressure, $9.81h_x\gamma$ (kN/m^2), which works on the considered hold is:

$b + 10(d_x - 0.25H_w\alpha_{DC} - h_{BST})$

The pressure, $9.81h'_x\gamma'$ (kN/m^2), which works on the adjacent hold is:

$b' + 10(d_x - 0.25H_w\alpha_{DC} - h'_{BST})$

$h_x, h'_x, \gamma, \gamma', d_x, h_{BST}$ and h'_{BST}: As specified in **(a)i)**

b and b': As specified in **(a)i)**

In calculating the values of a_{j1}, a'_{j1}, a_{j2} and a'_{j2} the following formulas are applied respectively.

$a_{j1} = p_j - 10(d_j + 0.25H_w)$

$a'_{j1} = p'_j - 10(d'_j + 0.25H_w)$

$a_{j2} = p_j - 10(d_j - 0.25H_w)$

$a'_{j2} = p'_j - 10(d'_j - 0.25H_w)$

p_j and p'_j: As specified in **(a)i)**

In calculating the pressure which arises from the mass of cargo, the density of the cargo and the shape of the cargo surface which were applied in direct calculations may be, however, taken into consideration.

d_j, d'_j: As specified in **(a)i)**

H_w, α_{DC}: As specified in **-1(1)(b)**

ii) The maximum allowable cargo mass, W_{MAX} (*ton*), is to be not greater than that obtained from the following formula.

$\gamma f_1(h_x) + \gamma' f_2(h'_x)$

$f_1(h_x)$ and $f_2(h'_x)$: As specified in **(a)ii)**

(2) Minimum allowable cargo mass

(a) Where the scantlings of structural members of the double bottom are determined by the formula prescribed in the requirements of the Rules:

i) In each hold, the pressure which works on the ship's bottom due to the mass of cargo or ballast water is be not less than that obtained from the following formulas.

The pressure, $9.81 h_x \gamma$ (*kN/m*^{2}), which works on the considered hold is:

$-b + 9.81(d_x + 0.026 L' \alpha_R - h_{BST})$

The pressure, $9.81 h'_x \gamma'$ (*kN/m*^{2}), which works on the adjacent hold is:

$-b' + 9.81(d_x + 0.026 L' \alpha_R - h'_{BST})$

$h_x, h'_x, \gamma, \gamma', b, b', L', \alpha_R, d_x, h_{BST}$ and h'_{BST}: As specified in **(1)(a)**

ii) The minimum allowable cargo mass, W_{MIN} (*ton*), is to be not less than that obtained from the following formula.

$\gamma f_1(h_x) + \gamma' f_2(h'_x)$

$f_1(h_x)$ and $f_2(h'_x)$: As specified in **(1)(a)ii)**

(b) Where the scantlings of structural members of the double bottom are determined by direct calculations:

i) In each hold, the pressure which works on the ship's bottom due to the mass of cargo or ballast water is to be not greater than that obtained from the following formulas.

The pressure, $9.81 h_x \gamma$ (*kN/m*^{2}), which works on the considered hold is:

$b + 10(d_x + 0.25 H_w \alpha_{DC} - h_{BST})$

The pressure, $9.81 h'_x \gamma'$ (*kN/m*^{2}), which works on the adjacent hold is:

$b' + 10(d_x + 0.25 H_x \alpha_{DC} - h'_{BST})$

$h_x, h'_x, \gamma, \gamma', d_x, h_{BST}$ and h'_{BST}: As specified in **(a)i)**

b and b': Where a_j and a'_j satisfy the relationship defined by the following formula, b and b' take the value of a_j and a'_j respectively

The absolute values of b and b' cannot, however, exceed the design pressure given to the local structural member of the double bottom where the member is reinforced to enable the ship to carry heavy cargoes such as steel coils.

$|a_j| a'_j = \min\{|a_1| a'_1, |a_2| a'_2, \cdots, |a_m| a'_m\}$

a_j and a'_j: Differences in pressure (*kN/m*^{2}) of the considered hold and the adjacent hold in loading condition No. *j* taken from the total of *m* loading conditions such that two adjacent holds are empty or loaded simultaneously, which works on the centre line of the ship's bottom due to the mass of cargo, ballast water and/or double bottom contents and by wave and still water corresponding to the draught

In loading condition No. *j*, a_j and a'_j are to be taken as a_{jk} and a'_{jk} which are obtained from the formulas when the wave pressure affects the still water pressure, and the difference in pressure of the considered hold and the adjacent hold have the same sign (i.e. plus or minus). Here, downward force is taken as a positive value.

$|a_{jk}| a'_{jk} = \min\{|a_{j1}| a'_{j1}, |a_{j2}| a'_{j2}\}$

a_{jk} and a'_{jk}: Differences in pressure of the considered hold and adjacent hold in loading condition No. *j*, which are obtained from the following formulas

Where the pressure by wave is added to the pressure by still water they are defined as a_{j1} and a'_{j1} respectively, where it is subtracted, they are defined as a_{j2} and a'_{j2}.

$a_{j1} = p_j - 10(d_j + 0.25H_w)$

$a'_{j1} = p'_j - 10(d'_j + 0.25H_w)$

$a_{j2} = p_j - 10(d_j - 0.25H_w)$

$a'_{j2} = p'_j - 10(d'_j - 0.25H_w)$

p_j and p'_j: As specified in **(1)(b)**

In calculating the pressure which arises from the mass of cargo, the density of the cargo and the shape of the cargo surface which were applied in direct calculations may be, however, taken into consideration.

d_j and d'_j: As specified in **(1)(b)**

ii) The minimum allowable cargo mass, W_{MIN} (*ton*), is to be not less than that obtained from the following formula.

$\gamma f_1(h_x) + \gamma' f_2(h'_x)$

$f_1(h_x)$ and $f_2(h'_x)$: As specified in **(1)(b)ii)**

3 Notwithstanding the provisions of **-1** above, the maximum allowable cargo mass W_{MAX} and the minimum required cargo mass W_{MIN} for the cargo holds of *BC-A*, *BC-B* and *BC-C* ships specified in **31.1.2-1, Part C of the Rules** may be determined by the following formulae. (See **Fig. C34.2.2-1**)

$$W_{MAX} = W_{\max}(0) + 1.025V\frac{d_x}{h} \ (ton)$$

However, W_{MAX} is not to be greater than M_D specified in **31.2.1-3, Part C of the Rules**.

$$W_{MIN} = W_{\min}(0) + 1.025V\frac{d_x}{h} \ (ton)$$

However, W_{MIN} is not to be less than 0.

$$W_{\max}(0) = \max\left\{W_{\max}(d_i) - 1.025V\frac{d_i}{h}\right\}$$

$$W_{\min}(0) = \min\left\{W_{\min}(d_i) - 1.025V\frac{d_i}{h}\right\}$$

$W_{\max}(d_i)$ and $W_{\min}(d_i)$: Maximum allowable cargo mass (*ton*) and minimum required cargo mass (*ton*) corresponding to the draught d_i, determined based on the loading condition No.*i* of loading conditions applied in accordance with the type of ship

d_i : Draught (*m*) in the loading condition No.*i*, at mid-hold position of cargo hold length l_H

V : Volume (m^3) of the cargo hold excluding the volume of the hatchway part

h : Vertical distance (*m*) from the top of the inner bottom plating to the upper deck plating at the ship's centre line

d_x: As specified in **C34.2.2-1(1)(a)i)**

4 Notwithstanding the provisions of **-2** above, the maximum allowable cargo mass W_{MAX} and the minimum required cargo mass W_{MIN} for two adjacent holds of *BC-A*, *BC-B* and *BC-C* ships specified in **31.1.2-1, Part C of the Rules** may be determined by the following formulae. (See **Fig. C34.2.2-2**)

$$W_{MAX} = 2M_{Full} + 1.025(V_f + V_a)\frac{d_x - 0.67d}{h} \ (ton)$$

However, W_{MAX} is not to be greater than the total value of M_D specified in **31.2.1-3, Part C of the Rules** for each cargo hold.

$$W_{MIN} = 1.025(V_f + V_a)\frac{d_x - d_{\min}}{h} \ (ton)$$

However, W_{MIN} is not to be less than 0.

V_f and V_a: Volume (m^3) of the forward and after cargo hold excluding the volume of the hatchway part

$d_{\min}$: $0.75d$ or draught (*m*) in ballast conditions with two adjacent cargo holds empty, whichever is greater

Fig. C34.2.2-1 Maximum Allowable Cargo Mass and Minimum Required Cargo Mass for a Cargo Hold (Example of Loaded Hold in BC-A Ship)

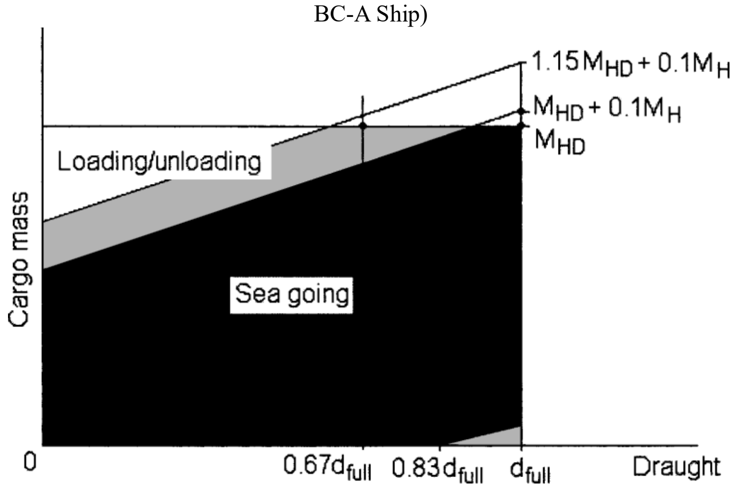
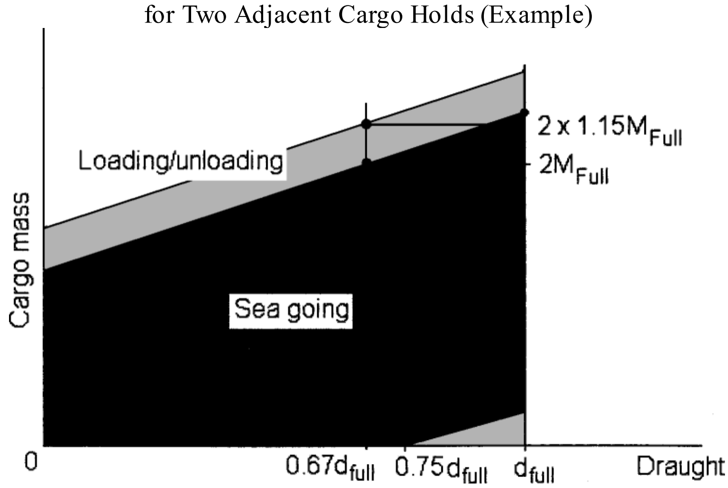


Fig. C34.2.2-2 Maximum Allowable Cargo Mass and Minimum Required Cargo Mass for Two Adjacent Cargo Holds (Example)



5 In the cases specified in **-3** and **-4**, maximum allowable cargo mass and minimum required cargo mass corresponding to the draught for loading/unloading conditions in harbour may be increased/decreased by 15% of the maximum allowable mass for the cargo hold (in the case specified in **-4**, the maximum allowable mass for the two adjacent cargo holds) at designed maximum load draught in sea-going condition. However, the maximum allowable mass is not to be greater than the maximum allowable cargo mass at the designed maximum load draught for each cargo hold.

6 Notwithstanding **-1** and **-4** above, where the scantlings of the double bottom structure is determined for loading conditions other than those given in **-1** or **-3** above, the maximum allowable and minimum required mass of cargo may be determined according to that condition. The maximum allowable and minimum required mass of cargo may be greater or less than the values given in **-1 and -4** when the strength of the double bottom is determined by additional direct calculations.

7 In relation to **-1** and **-6** above, the following notice referring to the maximum allowable and minimum required mass of cargo is to be described in the loading manual.

The maximum allowable and minimum required mass of cargo is to be considered when loading cargoes such as steel coils that may adversely affect the local strength of the double bottom and that are needed to be loaded in such a way that is not described in the Loading Manual.

8 The typical loading/unloading sequences required in **34.2.2-2(7), Part C of the Rules** are to include the following load conditions and are to be approved by the Society. However, with the exclusion of **(2)** below, only loading conditions that the ship is designed to accommodate need to be included in the loading manual.

(1) Alternate loading condition specified in **34.2.2-2(1), Part C of the Rules**

(2) Homogeneous loading condition specified in **34.2.2-2(2), Part C of the Rules**

(3) Short voyage condition specified in **34.2.2-2(4), Part C of the Rules**

(4) Multiple port loading/unloading condition specified in **34.2.2-2(5), Part C of the Rules**

(5) Deck cargo condition specified in **34.2.2-2(6), Part C of the Rules**

(6) Block loading (partial loading condition; loaded cargo in over two adjacent holds)

9 The steps of a sequence required in **-8** above are specified as follows. A step is defined as each time the loading equipment changes its position to a new hold.

(1) For loading cargo: Each step between commencement of cargo loading in the ballasted condition and the planned loading condition

(2) For unloading cargo: Each step between commencement of unloading cargo in the planned loading condition and the ballast condition at departure

10 Each step of the sequences specified in **-8** above is to be within the allowable limits of longitudinal bending moments and shear forces.

11 In addition to **-7** above, the loading manual is to contain the loading/unloading sequence summary forms as specified in **Table C34.2.1** in **34.2.2-2(7), Part C of the Rules** with the following note:

"When loading/unloading not in the planned way or as prescribed in the loading manual, new loading/unloading sequences are to be developed with the prescribed forms, paying attention to loading rate, ballasting/deballasting capability, longitudinal strength, and maximum allowable and minimum required mass of cargo and double bottom contents."

C34.2.3 Loading Computer

1 Longitudinal still water bending moment and still water shear force in flooded conditions are to be in accordance with **C34.1.3**. These flooded conditions are specified in **34.2.3-1(3), Part C of the Rules**.

C34.3 Additional Requirements for Existing Bulk Carriers, Ore Carriers and Combination Carriers

C34.3.1 Loading Manual

1 The typical loading/unloading sequences required in **34.3.1-1, Part C of the Rules** are to include the following load conditions and are to be approved by the Society. However, with the exclusion of **(2)** below, only loading conditions that the ship is designed to accommodate need to be included in the loading manual.

(1) Alternate loading condition (full load condition)

(2) Homogeneous loading condition (full load condition)

(3) Multi port loading/unloading condition

2 The steps of sequences required in **-1** above are specified as follows.

(1) For loading cargo: Each step between commencement of cargo loading in the ballasted condition and the planned loaded condition

(2) For unloading cargo: Each step between commencement of unloading cargo in the planned loading condition and the ballast condition at departure

3 Each step of the sequences specified in **-1** above is to be within the allowable limits of longitudinal bending moments and shear forces.

4 The following note is to be inscribed in the Loading Manual. A format equivalent to the one shown in **Table C34.2.1, Part C** of the Rules may be used.

"When loading/unloading not in the planned way or as prescribed in the loading manual, new loading/unloading sequences are to be developed with the prescribed forms, paying attention to loading rate, the ballasting/deballasting capacity, longitudinal strength, and maximum allowable and minimum required mass of cargo and double bottom contents."

C35 MEANS OF ACCESS

C35.1 General Rules

C35.1.1 General

1 Means of access specified in **35.1.1**, **Part C** of the Rules are arranged for the purpose of detecting disorders such as damage, corrosion, etc. which may occur on the boundaries of compartments and important internal structural members fitted thereon, such as transverse rings, web frames, girders, struts, etc. at an early stage. Accordingly, the arrangement is to be such that any one side of these members can be easily and safely inspected from within a distance of not more than 3 *m*. This distance may be properly modified, depending on the actual conditions, when easy access and/or ample illumination is available.

2 The means of access may be those permanently fixed to the hull, such as stagings, walkways, ladders, and steps (hereinafter, referred to as "permanent means of access") and those that are prepared for temporary use, such as inflatable rafts and portable ladders. Where structural members can be utilized as stagings or walkways, they can be regarded as permanent means of access.

C35.1.2 Means of Access to Spaces

1 With respect to the provisions of **35.1.2**, **Part C** of the Rules, permanent means of access where deemed as impracticable by the Society may be placed with portable ladders.

2 The openings of hatches or manholes for the means of access to the hold spaces for independent tanks are to be not less than those required by **g.** of **Table C35.1.2**.

C35.1.3 Means of Access within Spaces

1 With respect to the provisions of **35.1.3**, **Part C** of the Rules, the following spaces and places are to be provided with permanent means of access.

(1) Fore peak tanks

(2) Aft peak tanks

(3) Cofferdams

(4) One side tank situated at or near the forward end of the parallel body of the hull and one or more tank(s) in other parts (water ballast tank if possible)

(5) Any one or more tank(s) from among centre tanks

(6) Watertight and oiltight bulkheads having horizontal girders

(7) Cargo holds with bilge hopper tanks whose height is over 3 *m* at side from the top of inner bottom plates to upper end of bilge hopper tanks

2 The permanent means of access in the spaces and places prescribed in **-1** above are to be arranged in accordance with the following:

(1) In side tanks, ladders or steps are to be so arranged that all corners and structural ends of one or more transverse ring(s) (preferably at mid-tank) can be inspected.

(2) In centre tanks, ladders or steps are to be so arranged that both ends of one or more bottom transverse(s) (preferably at mid-length of tank) can be inspected.

(3) For watertight and oiltight bulkheads with horizontal girders, ladders or steps are to be arranged for access to such girders.

(4) Ladders or steps for access to a height up to about 1.5 *m* above the bottom or a horizontal girder may be omitted where access is available by means of longitudinal frames, horizontal stiffeners, etc.

(5) On both sides of each cargo hold specified in **-1(7)** above at the forward, middle and aft parts, ladders (or steps) and hand rails are to be available for inspection of lower parts of hold frames together with their end brackets. Hand rails are to be fitted within the spaces between three hold frames at least. However, a portable ladder may be acceptable instead of fixed ladders (or steps) and hand rails may be omitted subject to approval by the Society.

3 The clearances for inspections and means of access within the hold spaces for independent tanks is to be not less than those required by **a.** to **f.** of **Table C35.1.2**.

Table C35.1.2

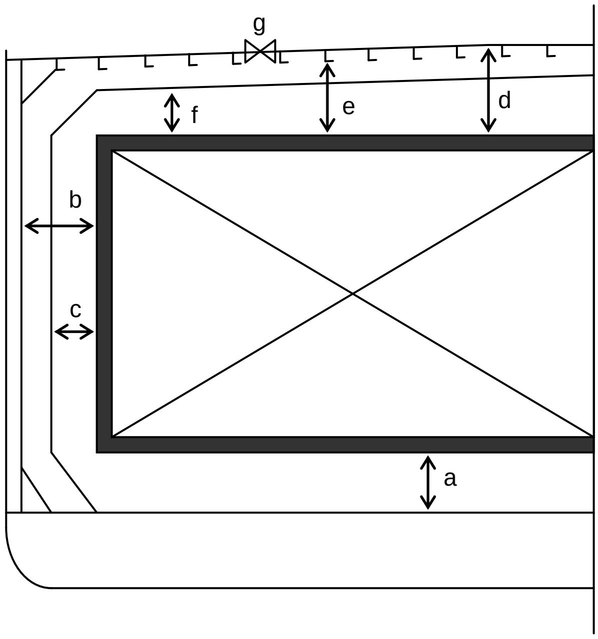
Location(1)	ships not less than 5,000 tonnes deadweight	ships less than 5,000 tonnes deadweight
a. insulation ~ inner bottom plate	600 *mm*	600 *mm*
b. insulation ~ side frame	600 *mm*	450 *mm*
c. insulation ~ girder	450 *mm*(2)	450 *mm*(2)
d. insulation ~ upper deck	600 *mm*	600 *mm*
e. insulation ~ deck beam	600 *mm*	450 *mm*
f. insulation ~ deck girder	450 *mm*(2)	450 *mm*(2)
g. horizontal opening	600 *mm* ×600 *mm*	500 *mm* ×500 *mm*

Notes:

(1) Refer to **Fig. C35.1.2** for the relevant locations

(2) Where openings are provided in order to make the relevant location readily accessible from each side, it may be 0.5 times the width of face plate or 50 *mm*, whichever is smaller.

Fig. C35.1.2



C35.1.4 Specifications of Means of Access and Ladders

1 Means of access that are safe to use referred to in **35.1.4-1, Part C** of the Rules mean those meeting the following conditions.

(1) Ladders and steps are not to be fitted on a surface which is unnecessarily outside the inside line of the hatch coaming.

(2) Hand grips are to be provided appropriately.

(3) Ladders and steps are to be extended upward and downward as deemed necessary.

(4) No hollows are to be allowed in flights of ladders.

2 With respect to the provisions of **35.1.4, Part C** of the Rules, stagings and walkways forming sections of permanent means of access are to be constructed as follows.

(1) The clear width of stagings and walkways is not to be less than 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.

(2) Elevated passageways forming sections of a permanent means of access are to be provided with guard rails of 750 *mm* in height on the open side.

(3) Where horizontal girders or similar structures are utilized as stagings, etc., lightening holes of a diameter exceeding 100 *mm* are to have fixed gratings.

3 With respect to the provisions of **35.1.4, Part C** of the Rules, ladders and steps utilized for permanent means of access are to be constructed as follows.

(1) The width of ladders and steps is to be not less than 250 *mm* and the distance from the wall to the free edge of footsteps, not

less than 120 *mm*. Footsteps are to be arranged at a regular interval not less than 250 *mm* but not more than 350 *mm*, or of an equivalent arrangement.

(2) Landings are to be provided at an interval not exceeding 9 *m* on vertical ladders and at a vertical interval of 12 *m* on inclined ladders.

4 Where portable ladders are utilized in accordance with the provisions of **C35.1.3-2(5)**, appropriate measures such as horizontal bars which are provided between two transverse frames for hanging a ladder, are to be taken for their safe use.

5 Where rafts are utilized for means of access, they are to comply with the following conditions.

(1) The tanks are to have pumping arrangements for filling and discharging a capacity appropriate for ordinary water ballast tanks.

(2) Where swash bulkheads are provided in the tank, they are to have openings for passage in their upper part, or each part that is separated from others by such swash bulkheads is to have an access hatch or manhole. The dimensions of these hatches or manholes may be determined assuming that rafts will be inflated in the tanks.

(3) The raft is to be capable of carrying 3 persons, and where an inflatable type is used, be able to stay afloat safely even if one of the airtight chambers is broken. A ship is to have at least one raft, but it is recommended to have at least two.

C35.2 Special Requirements for Oil Tankers and Bulk Carriers

C35.2.1 Application

1 With respect to the provisions of **35.2**, **Part C of the Rules**, this regulation does not apply to oil tankers other than those having integral tanks for the carriage of oil in bulk. Even in cases where the provisions of **35.2**, **Part C of the Rules** are applied, **C35.1.2-2** and **C35.1.3-3** are also to be applied to the means of access to the hold spaces for independent tanks as well as and to the means of access within said hold spaces.

C35.2.2 General

1 For the purpose of **35.2, Part C** of the Rules, appropriate means of access are to be provided to enable close-up examinations of positions where close-up examinations and thickness measurements are required in accordance with the provisions of **Part B** of the Rules and positions with critical structural areas. In application, “critical structural areas” are locations which have been identified from calculations to require monitoring or from the service history of similar or sister ships to be susceptible to cracking, buckling, deformation or corrosion which would impair the structural integrity of the ship. Each space for which close-up inspection is not required such as fuel oil tanks and void spaces forward of cargo area, may be provided with a means of access necessary for overall survey intended to report on the overall conditions of the hull structure.

2 For the purpose of **35.2**, **Part C** of the Rules, the following definitions apply.

(1) Rung means the step of a vertical ladder or step on a vertical surface.

(2) Tread means the step of an inclined ladder or step for a vertical access opening.

(3) Flight of an inclined ladder means the actual stringer length of an inclined ladder. For vertical ladders, it is the distance between the platforms.

(4) Stringer means either:

  (a) The frame of a ladder

  (b) The stiffened horizontal plating structure fitted on the side shell, transverse bulkheads and/or longitudinal bulkheads in the space

  For the purpose of ballast tanks of less than 5 *m* width forming double side spaces, the horizontal plating structure is credited as a stringer and a longitudinal permanent means of access, if it provides a continuous passage of 600 *mm* or more in width past frames or stiffeners on the side shell or longitudinal bulkhead. Openings in stringer plating utilized as permanent means of access shall be arranged with guard rails or grid covers to provide safe passage on the stringer or safe access to each transverse web.

(5) Vertical ladder means a ladder of which the inclined angle is 70 degrees and over up to 90 degrees. A vertical ladder shall not be skewed by more than 2 degrees.

(6) Overhead obstructions mean the deck or stringer structure including stiffeners above the means of access.

(7) Distance below deck head means the distance below the plating.

(8) Cross deck means the transverse area of the main deck which is located inboard and between hatch coamings.

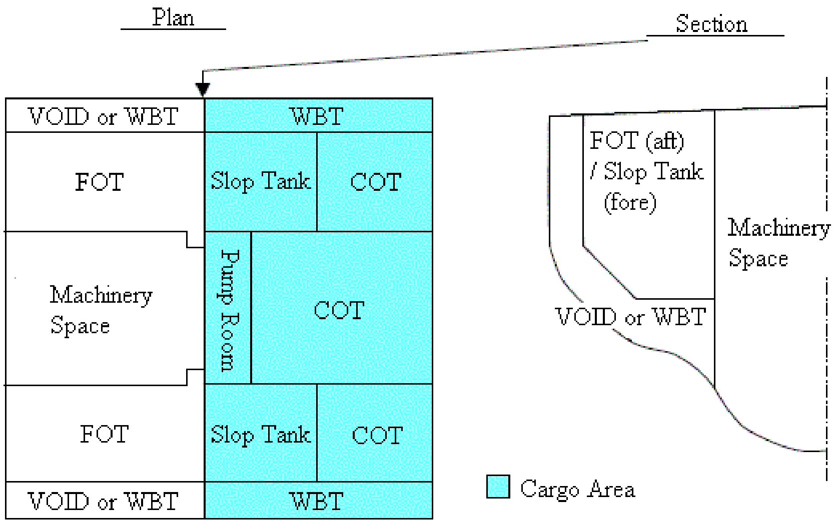
(9) Cargo area means either:

(a) For oil tankers, area as defined in 2.1.35, Part A of the Rules but excluding deck areas

However, spaces protecting oil fuel tank(s) in the machinery space as shown in Fig. C35.2.2 need not be applicable to the provisions of 35.2, Part C of the Rules, even though they have a cruciform contact with the cargo oil tank or slop tank.

(b) For bulk carriers, cargo spaces and other spaces such as ballast tanks, cofferdams and void spaces within cargo spaces or adjacent to cargo spaces in the ship's transverse section

Fig. C35.2.2



C35.2.3 Means of Access to Spaces

1 With respect to the provisions of 35.2.3, Part C of the Rules, the vertical distance between deck and horizontal stringer; horizontal stringers; deck or horizontal stringer and the bottom of the space; deck or horizontal stringer and platform; and platforms means the vertical distance between the upper surface of the lower deck, horizontal stringer or platform and the lower surface of the upper deck, horizontal stringer or platform

2 With respect to the provisions of 35.2.3, Part C of the Rules, special attention is to be paid to the structural strength where any access opening is provided in the main deck or cross deck.

3 With respect to the provisions of 35.2.3-2, Part C of the Rules, the wording "not intended for the carriage of oil or hazardous cargoes" applies only to "similar compartments", and access may be from pump-rooms, deep cofferdams, pipe tunnels, cargo holds and double hull spaces.

4 "Deck" specified in 35.2.3-3, Part C of the Rules means "weather deck".

5 With respect to the provisions of 35.2.3-4, Part C of the Rules, where deemed necessary for aligning resting platform arrangements with hull structures, the vertical distance from the deck to a platform, between such platforms, or a platform and the tank bottom may be not more than 6.6 *m*.

6 With respect to the provisions of **35.2.3-4(2)**, **(4)**, **-5(3)** and **(7), Part C of the Rules**, adjacent sections of a vertical ladder are to be in accordance with following **(1)** to **(3)**. (Refer to **Fig. C35.2.3-1**, **Fig. C35.2.3-2** and **Table C35.2.3**)

(1) The minimum "lateral offset" between two adjacent sections of a vertical ladder is the distance between the sections, upper and lower, so that the adjacent stringers are spaced at least 200 *mm* apart, measured from half thickness of each stringer.

(2) Adjacent sections of vertical ladder are to be installed so that the upper end of the lower section is vertically overlapped, in respect to the lower end of the upper section, to a height of 1,500 *mm* in order to permit a safe transfer between ladders. However, this requirement does not apply to cases where structural members (e.g. side stringers) are used to move between adjacent vertical ladders and are provided with safety measures such as handrails.

(3) No section of the access ladder is to be terminated directly or partly above an access opening.

Fig. C35.2.3-1 Vertical Ladder – Ladder Passing through Linking Platform

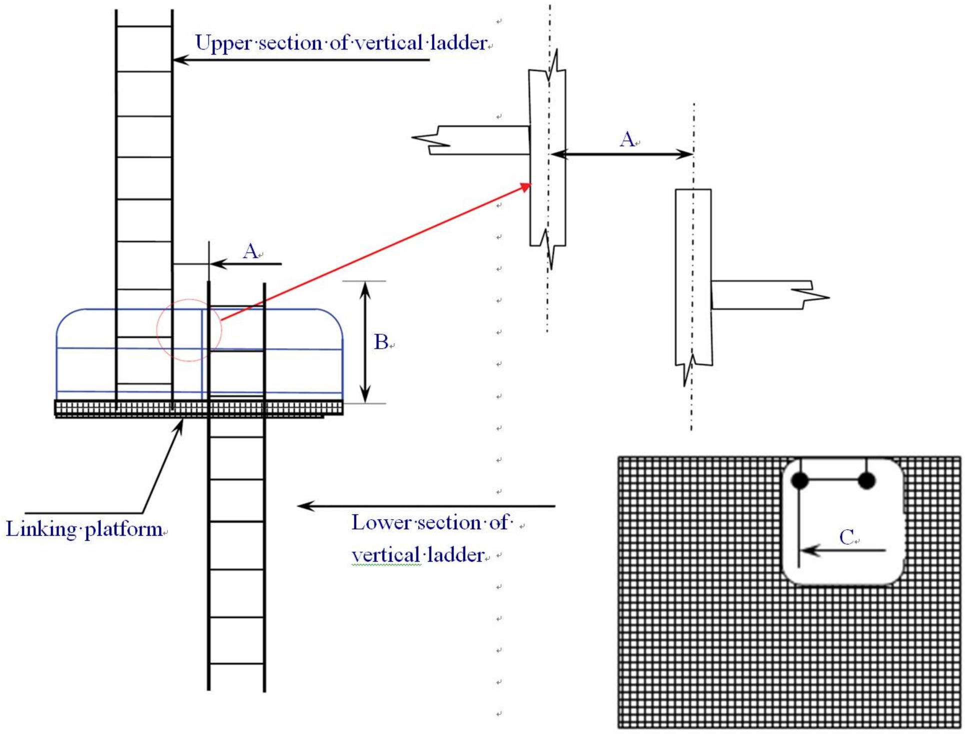


Fig. C35.2.3-2 Vertical Ladder - Side Mount

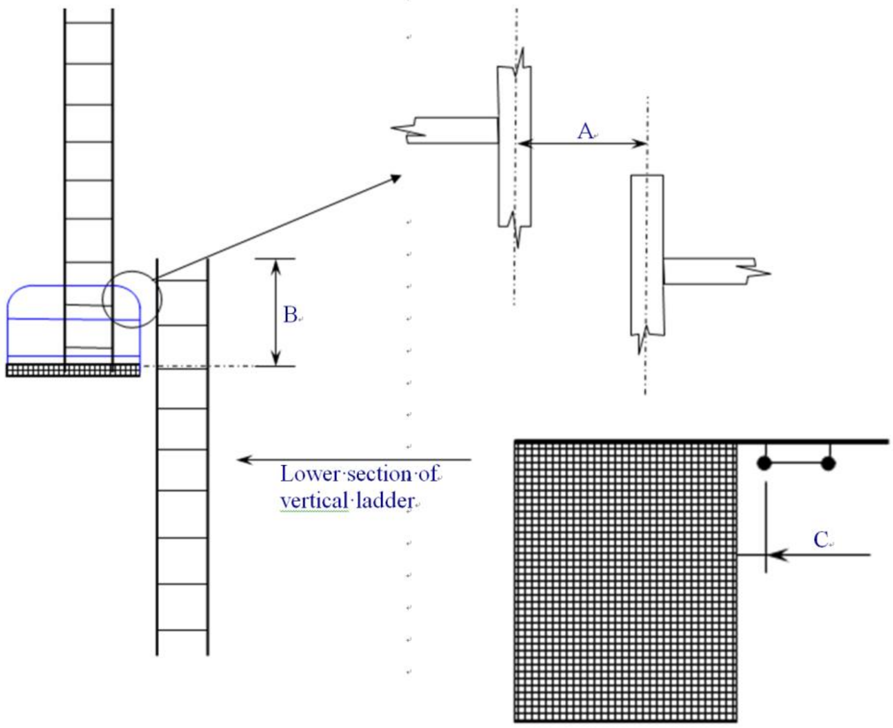


Table C35.2.3 Dimensions

A	Horizontal separation between two vertical ladders, stringer to stringer	≥ 200 *mm*
B	Stringer height above landing or intermediate platform	≥ 1,500* *mm*
C	Horizontal separation between ladder and platform	100 *mm* ≤ C < 300 *mm*
Note * : the minimum height of the handrail of resting platform is 1,000 *mm*		

C35.2.4 Means of Access within Spaces

1 Alternative means of access specified in **35.2.4**, **Part C** of the Rules include, but are not limited to, such devices as:

(1) Hydraulic arm fitted with a stable base

(2) Wire lift platform

(3) Staging

(4) Rafting

(5) Robot arm or remotely operated vehicle (*ROV*)

(6) Portable ladders more than 5 *m* long are only to be utilized if fitted with a mechanical device to secure the upper end of the ladder. Where hooks for securing at the upper end of a ladder are provided as a mechanical device, such hooks are to be designed so that a movement fore/aft and sideways can be prevented at the upper end of the ladder

(7) Other means of access, approved by and acceptable to the Society

2 With respect to the provisions of **35.2.4, Part C** of the Rules, the selection of an alternative means of access is to be based on the following conditions. Refer to **Annex C35.2.4** for details.

(1) Such means provide accessibility and safety equivalent to permanent means

(2) Such means are suitable for use in an environment of the intended spaces

(3) Where the use of means such as *ROV* for the inspection of under deck structures, such means can be introduced into the space directly from a deck access

(4) Such means comply with or are based on appropriate safety standards

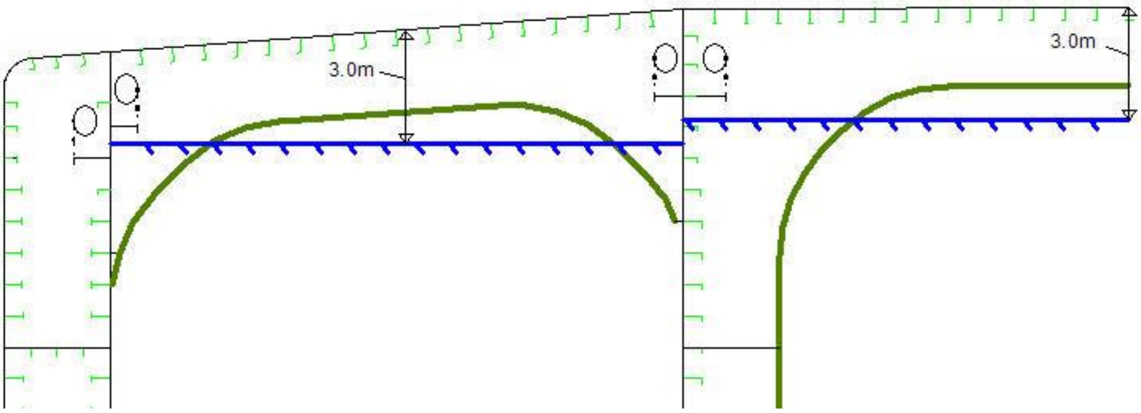
(5) Where the use of means other than those specified in **C35.2.4-1(3)**, **(4)** or **(6)**, such means are approved by the Administration and the ship's owner

3 Where a boat is used as an alternative means, **C35.1.4-5** is to apply. Rafts or boats alone may be allowed for survey of the under deck areas for tanks or spaces if the depth of the webs is not more than 1.5 *m*. If the depth of the webs is more than 1.5 *m*, rafts or boats alone may be allowed only if permanent means of access are provided to allow safe entry and exit. This means either:

(1) Access direct from the deck via a vertical ladder and small platform approximately 2 *m* below the deck in each bay

(2) Access to the deck from a longitudinal permanent platform having ladders to the deck at each end of the tank
The platform is to, for the full length of the tank, be arranged at or above the maximum water level needed for rafting of the under deck structure. For this purpose, the ullage corresponding to the maximum water level is to be assumed not more than 3 *m* from the deck plate measured at the midspan of the deck transverses and in the middle of the length of the tank. (Refer to **Fig. C35.2.4**) A permanent means of access from the longitudinal permanent platform to the water level indicated above is to be fitted in each bay (*e.g.*, permanent rungs on one of the deck webs inboard of the longitudinal permanent platform).

Fig. C35.2.4 Use of Rafts/Boats



4 With respect to the provisions of **35.2.4**, **Part C** of the Rules, it is to be demonstrated that portable means for inspection can be deployed and made readily available in the areas where needed.

5 For the purpose of **35.2.4**, **Part C** of the Rules, the height of a space means the vertical distance between the top surface of the bottom plate of the space and the lower surface of the top plate of the space. In general, the height is to be measured from the lowest position to the highest position in each tank. However, for a space the height of which varies at different bays/sections, the requirements of **35.2.4**, **Part C** of the Rules may be applied to such bays/sections of that space which fall under the criteria.

6 With respect to the provisions of **35.2.4**, **Part C** of the Rules, special attention is to be paid to the structural strength where any access opening is provided in the structural members.

7 Unless stated otherwise in **35.2.4**, **Part C** of the Rules, vertical ladders that are fitted on vertical structures for inspection are to comprise of 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. For the purpose of complying with the above, adjacent sections of ladders are to be in accordance with **C35.2.3-6**.

8 The requirements of **35.2.4-1**, **Part C** of the Rules are also to be applied to void spaces in the cargo area, comparable in volume to cargo tanks and ballast tanks.

9 In the application of **35.2.4-1(1)**, **Part C** of the Rules, the provisions of **(a)** to **(c)** define access to underdeck structures and the provisions of **(d)** to **(f)** define access to vertical structures. These provisions are linked to the presence of underdeck structures and transverse webs on longitudinal bulkheads. If there are no underdeck structures (deck longitudinals and deck transverses) but there are vertical structures in the cargo tank supporting transverse and longitudinal bulkheads (including brackets supporting deck transverses), in addition to access in accordance with applicable provisions of **(d)** to **(f)** of **35.2.4-1(1)**, **Part C** of the Rules, access in accordance with the provisions of **(a)** to **(c)** of **35.2.4-1(1)**, **Part C** of the Rules is to be provided for inspection of the upper parts of vertical structure on transverse and longitudinal bulkheads. For example, there is need to provide continuous longitudinal permanent means of access in accordance with the provisions of **35.2.4-1(1)(b)**, **Part C** of the Rules when the deck longitudinals and deck transverses are fitted on the deck but supporting brackets are fitted under the deck.

10 In the application of **35.2.4-1(1)(d)**, **Part C of the Rules**, for water ballast tanks of 5 *m* or more in width, such as on an ore carrier, side shell plating shall be considered in the same way as "longitudinal bulkhead".

11 Notwithstanding **-1**, for the application of **35.2.4-1(1)(d)**, **Part C** of the Rules, wire lift platforms or other means which can provide an equal level of safety as permanent means of access specified in that sub-paragraph, are assumed as alternative means of access. However, rafting and permanent fittings for rafting are not permitted as alternatives to the continuous longitudinal permanent means of access specified in **35.2.4-1(1)(d)**, **Part C** of the Rules.

12 "Means of access deemed appropriate by the Society" stipulated in **35.2.4-1(4), Part C** of the Rules generally presumes the use of boats. The provisions of **-3** above apply.

13 The requirements of **35.2.4-2**, **Part C** of the Rules also apply to wing tanks designed as void spaces.

14 For the purpose of **35.2.4-2**, **Part C** of the Rules, the continuous permanent means of access may be a wide longitudinal, which provides access to critical details on the opposite side by means of platforms attached as necessary on the web frames. Where the vertical opening of the web frame is located in way of the open part between the wide longitudinal and the longitudinal on the opposite side, platforms are to be provided on both sides of the web frames to allow safe passage through the web frame.

15 With respect to the vertical distance of 6 *m* specified in **35.2.4-2(1)(a)** and **(b)**, **Part C** of the Rules, excess of not more than 10% may be accepted as a reasonable deviation, where deemed necessary for the integration of the permanent means of access with the structure itself.

16 Means of access specified in **35.2.4-2(1)(a)**, **Part C** of the Rules are to be connected to an access ladder from the deck required in **35.2.3-1**, **Part C** of the Rules. Where two access hatches are required, access ladders at each end of the tank are to lead to the means of access.

17 With respect to the provisions of **35.2.4-2(2)**, **Part C** of the Rules, notwithstanding the provisions of **-5**, the height of a bilge hopper tank located outside of the parallel part of the ship may be taken as the maximum of the clear vertical distance measured from the bottom plating to the hopper plating of the tank.

18 With respect to the provisions of **35.2.4-2(2)**, **Part C** of the Rules in regards to the foremost and aftermost bilge hopper ballast tanks with raised bottoms, a combination of transverse and vertical means of access for access to the upper knuckle point for each transverse web may be accepted in place of the longitudinal permanent means of access.

19 With respect to the provisions of **35.2.4-2(2)**, **Part C** of the Rules, a ladder or ladders are to be provided between the longitudinal continuous permanent means of access and the bottom of the space.

20 The movable means of access to the underdeck structure of the cross deck required in **35.2.4-3(5)**, **Part C** of the Rules need not necessarily be carried aboard the ship.

21 "Readily available" referred to in **35.2.4-4(3)**, **Part C of the Rules**, means capable of being transported to location in cargo hold and safely erected by ship's staff.

22 With respect to the provisions of **35.2.4-5**, **Part C** of the Rules, notwithstanding the provisions of **-5**, the height of a topside tank is to be the vertical distance measured at the ship's side.

23 With respect to the provisions of **35.2.4-6**, **Part C** of the Rules, notwithstanding the provisions of **-5**, the height of a bilge hopper tank located outside of the parallel part of the vessel may be taken as the maximum of the clear vertical height measured from the bottom plating to the hopper plating of the tank.

24 In the application of **35.2.4-6(1)(b)**, **Part C of the Rules,** the foremost and aftermost bilge hopper ballast tanks with raised bottom, a combination of transverse and vertical means of access for access to the sloping plate of hopper tank connection with side shell plating for each transverse web can be accepted in place of the longitudinal permanent means of access.

25 The height of web frame rings specified in **35.2.4-6(2)**, **Part C** of the Rules is to be measured in way of side shell and tank base.

26 With respect to the provisions of **35.2.4-9**, **Part C** of the Rules, the use of alternative means of access may be accepted where:

(1) Such means provide accessibility and safety equivalent to permanent means

(2) The use of such means are approved by the Administration and the ship's owner

C35.2.5 Specifications for Means of Access and Ladders

1 With respect to the provisions of **35.2.5-1**, **Part C** of the Rules, permanent means of access are to be designed so as to ensure sufficient residual strength during the service life of the ship and, in general, the initial corrosion protection which is the same as the hull structural members is to be applied.

2 With respect to the provisions of **35.2.5-3**, **Part C** of the Rules, slopping structures are structures that are sloped by 5 or more degrees from the horizontal plane when a ship is in the upright position at even-keel. Non-skid construction is to be such that the surface on which personnel walk provides sufficient friction to the sole of boots even when the surface is wet and covered with thin sediment.

3 Details of the guard rails required in **35.2.5-4, Part C** of the Rules are to be in accordance with the following.

(1) Where guard rails are divided into several parts, the gaps of discontinuous top handrail are not to exceed 50 *mm*. When the top and mid handrails are connected by a bent rail, the outside radius of the bent part is not to exceed 100 *mm* (see **Fig. C35.2.5-1**).

(2) The gaps between the top handrail and other structural members are not to exceed 50 *mm*.

(3) Where guard rails are divided into several parts, the maximum distance between the adjacent stanchions across the handrail gaps is to be 350 *mm*. However, when the top and mid handrails are connected together, the maximum distance may be 550 *mm* (see **Fig. C35.2.5-1**).

(4) The maximum distance between the stanchion and other structural members is not to exceed 200 *mm*. However, when the top and mid handrails are connected together, the maximum distance may be 300 *mm* (see **Fig. C35.2.5-1**).

4 For guard rails required in **35.2.5-4**, **Part C** of the Rules, use of alternative materials such as *GRP* is to be subject to compatibility with the liquid carried in the tank. Non-fire resistant materials are not to be used for means of access to a space with a view to securing an escape route at high temperatures.

5 The minimum clear opening of 600 *mm* × 600 *mm* specified in **35.2.5-5**, **Part C** of the Rules is to be rounded appropriately and may have corner radii up to 100 *mm* maximum. Where larger corner radii are adopted for avoiding stress concentration, a larger opening is to be provided so as to ensure accessibility equivalent to a opening of 600 *mm* × 600 *mm*. For example, 600 *mm* × 800 *mm* with 300 *mm* of corner radii may be accepted.

6 The minimum clear opening of 600 *mm* × 800 *mm* specified in **35.2.5-6**, **Part C** of the Rules is to be rounded appropriately and may have corner radii up to 300 *mm* maximum. Such openings, in general, are to be 800 *mm* in height. However, an opening of 600 *mm* in height and 800 *mm* in width may be accepted as access openings in vertical structures where it is not desirable to make large openings in the structural strength aspects, i.e. girders and floors in double bottom tanks.

7 With respect to the provisions of **35.2.5-6**, **Part C** of the Rules, an access opening having other dimensions, i.e. an opening as shown in **Fig. C35.2.5-2**, may be accepted subject to verification of easy evacuation of an injured person on a stretcher.

8 With respect to the provisions of **35.2.5-6**, **Part C** of the Rules, where the vertical manhole is at a height of more than 600 *mm* above the bottom plate, it is to be demonstrated that an injured person can be easily evacuated.

9 Smaller dimensions of minimum clear opening stipulated in **35.2.5-7**, **Part C** of the Rules are to be in accordance with **Table S3.4.4**, **Part S** of the Guidance.

Fig. C35.2.5-1 Detail of Handrails

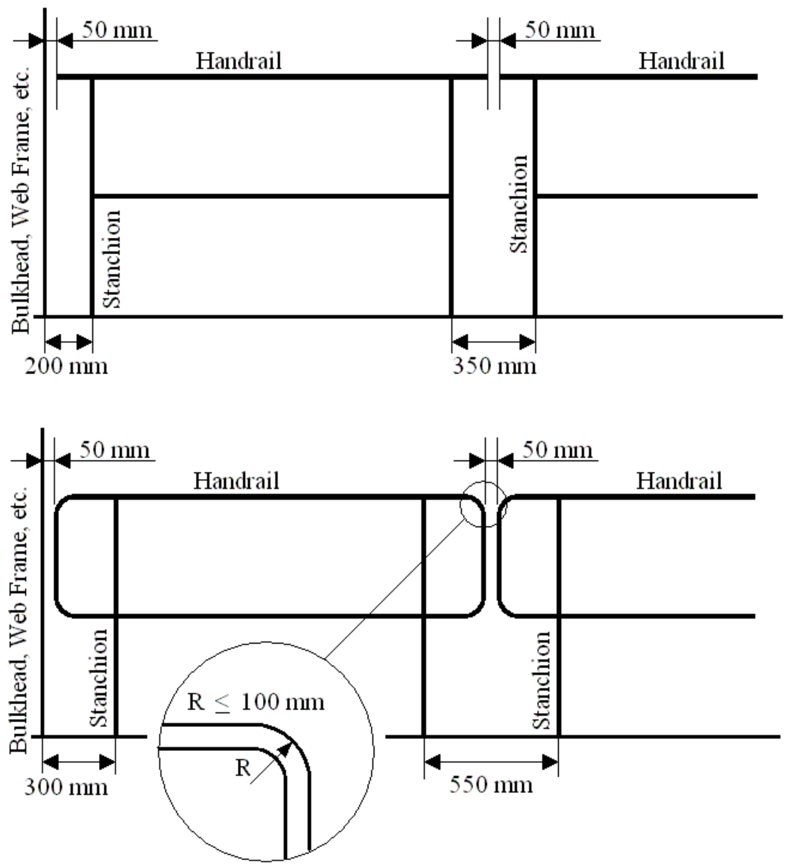
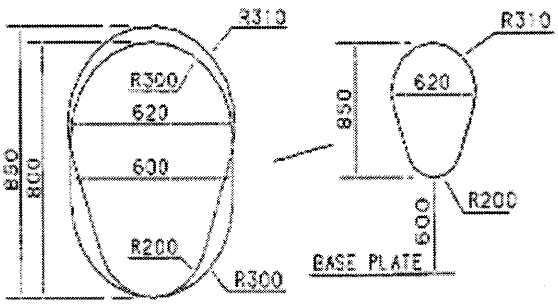


Fig. C35.2.5-2 Example of Vertical Opening



10 With respect to the provisions of **35.2.5-8**, **Part C** of the Rules, where the vertical manhole is at a height of more than 600 *mm* above the bottom plate, it is to be demonstrated that an injured person can be easily evacuated.

11 With respect to the provisions of **35.2.5-9**, **Part C** of the Rules, details of ladders and other means are to be in accordance with the following.

(1) Permanent inclined ladders are to be inclined at an angle of less than 70 degrees. There is to be no obstructions within 750 *mm* of the face of the inclined ladder, except that in way of an opening this clearance may be reduced to 600 *mm*. Such clearance is to be measured perpendicular to the face of the ladder. A minimum climbing clearance in width is to be 600 *mm*. For this purpose, handrails may be provided within such climbing clearance. Resting platforms of adequate dimensions are to be provided, normally at a maximum of 6 *m* vertical height. Where deemed necessary for aligning resting platform arrangements with hull structures, the vertical distance from deck to such platforms, between such platforms or such platforms and the tank bottom may be not more than 6.6 *m*. In this case, the flights of inclined ladders are not to be more than 9 *m* in actual length. Ladders and handrails are to be constructed of steel or equivalent material of adequate strength and stiffness and securely attached to the structure by stays. The method of support and length of stay is to be such that vibration is reduced to a practical minimum. In cargo holds, ladders are to be designed and arranged so that cargo handling difficulties are not increased and the risk of damage from cargo handling gear is minimized.

(2) The width of inclined ladders between stringers is not to be less than 400 *mm*. The width of inclined ladders for access to a cargo hold in bulk carriers is to be at least 450 *mm*. The treads are to be equally spaced at a distance apart, measured vertically, of between 200 *mm* and 300 *mm*. When steel is used, the treads are to be formed of two square bars of not less than 22 *mm* × 22 *mm* in section, fitted to form a horizontal step with the edges pointing upward. The treads are to be carried through the side stringers and attached thereto by double continuous welding. All inclined ladders are to be provided with handrails of substantial construction on both sides. The vertical height of handrails is not to be less than 890 *mm* from the centre of the step and two course handrails is to be provided where the gap between stringer and top handrail is greater than 500 *mm*.

(3) For vertical ladders, the width and construction are to be in accordance with the following. Other details are to be in accordance with international or national standards accepted by the Society.

(a) The minimum width of vertical ladders, except those specified in **35.2.4-4(4)**, **Part C** of the Rules, is to be 350 *mm*.

(b) The vertical distance between the rungs is to be equal and is to be between 250 *mm* and 350 *mm*.

(c) When steel is used, the rungs are to be formed of single square bars of not less than 22 *mm* × 22 *mm* in section, fitted to form a horizontal step with the edges pointing upward.

(d) Vertical ladders are to be secured at intervals not exceeding 2.5 *m* apart to prevent vibration.

(e) A minimum climbing clearance in width is to be 600 *mm* other than the ladders placed between the hold frames. A clearance of 600 *mm* perpendicular to the ladder is to be kept as far as possible.

(4) For spiral ladders, the width and construction are to be in accordance with international or national standards accepted by the Society.

(5) Resting platforms placed between ladders are to follow the provisions of **35.2.5-1** to **-2**, **Part C** of the Rules.

(6) Portable ladders are to be in accordance with or are based on appropriate safety standards. No free-standing portable ladder is to be more than 5 *m* long unless accepted by the provisions of **C35.2.4-1(6)**.

(7) For the selection of portable and movable means of access, refer to **Annex C35.2.4**.

C35.2.6 Ship Structure Access Manual

1 The Ship Structure Access Manual required in **35.2.6-1**, **Part C** of the Rules is to contain at least the following two parts.

(1) Part I

This part is to comprise plans, instructions and inventory required in **35.2.6-1(1)** to **(7)**, **Part C** of the Rules and the following matters are to be addressed. This part is to be approved by the Society when any content is changed.

(a) Approval/re-approval procedure for the manual, i.e. any changes of the permanent, portable, movable or alternative means of access within the scope of **35.2**, **Part C** of the Rules are subject to review and approval by the Society.

(b) Verification of means of access is to be part of a survey for continued effectiveness of the means of access in that space which is subject to the survey.

(c) Inspection of means of access is to be carried out by the crew and/or a competent inspector of the company as a part of regular inspection and maintenance.

(d) Actions to be taken if means of access are found unsafe to use.

(e) In case of use of portable equipment, plans showing the means of access within each space indicating from where and how each area in the space can be inspected.

(2) Part II

This part is to comprise of forms for record of inspections and maintenance, and change of inventory of portable equipment due to additions or replacements after construction. The form in this part is approved by the Society when the ship is under survey for classification during construction.

2 The Ship Structure Access Manual required in **35.2.6-1**, **Part C** of the Rules is to be prepared in a language(s) which all the crew can understand. As a minimum the English version is to be provided.

3 "Critical structural areas" specified in **35.2.6-1(3)**, **Part C** of the Rules are to be in accordance with the provisions of **C35.2.2-1**.

Annex C1.1.7-1 GUIDANCE FOR HULL CONSTRUCTION CONTAINING HIGH TENSILE STEEL MEMBERS

1.1 General

1.1.1 Application

Where materials of high tensile steel *KA*32, *KD*32, *KE*32, *KF*32 (hereinafter to be referred to as "*HT*32"), *KA*36, *KD*36, *KE*36 and *KF*36 (hereinafter to be referred to as "*HT*36") and *KA*40, *KD*40, *KE*40 and *KF*40 (hereinafter to be referred to as "*HT*40") prescribed in **Chapter 3, Part K** of the Rules are used as structural members, the constructions and scantlings are to comply with the following provisions, in addition to those prescribed in the Rules. Where materials of high tensile steel other than *HT*32, *HT*36 and *HT*40 are used, the constructions and scantlings may be properly modified with due consideration for the mechanical properties of the materials to be used.

1.1.2 Details of Construction

1 Where materials of different strengths are mixed in the hull structure, due consideration is to be given to the stress in the lower tensile materials adjacent to high tensile materials.

2 Where stiffeners of lower tensile material are supported by girders of high tensile material, due consideration is to be given to the stiffness of girders and the dimensions of stiffeners to avoid excessive stress in the stiffeners.

3 For members of high tensile steel, special attention is to be paid to the details of constructions to avoid high concentration of stress.

4 Where materials of high tensile steel are extensively used in the hull structure, its designs are to be subjected to detailed study of strength, and their results are to be submitted to the Society.

1.2 Structural Members

1.2.1 General

1 Scantlings of Structural Members

(1) The scantlings of structural members of high tensile steel are not to be less than that obtained by the methods stipulated under **1.2.2** below.

(2) Where scantlings of structural members are determined by direct calculation methods according to the prescriptions in **29.6.2**, **30.1.2** or **31.1.5, Part C** of the Rules, the standard permissible stresses in members of high tensile steel are the values determined in accordance with the **C29.6.2, C30.1.2** and **C31.1.5**. Further, the structures are to be subjected to examinations on strength against buckling under the load conditions prescribed in the Guidance.

(3) Where the section modulus of hull girder amidships is reduced by using high tensile steel in accordance with the provisions in **1.1.7-2(1), Part C** of the Rules, the constructions and scantlings are to comply with the provisions under **1.2.3**, in addition to compliance with **(1)** and **(2)** above, if the strength deck and the bottom are constructed on the longitudinal framing system. If the strength deck or the bottom is constructed on the transverse framing system, the constructions and scantlings are to be subject to Society's special consideration.

2 Expressions

Unless specified otherwise, the expressions employed in this Guidance are to be as stipulated in **(1)** to **(4)** below.

(1) f_{DH} and f_{BH} are to be as follows:

$$f_{DH} = \frac{Z_{Mreq}}{Z_{DH\ ship}}$$

$$f_{BH} = \frac{Z_{Mreq}}{Z_{BH\ ship}}$$

Z_{Mreq}: Section modulus of hull determined according to the requirements in **Chapter 15, Part C** of the Rules when mild steel is used.

$Z_{DH\ ship}$ and $Z_{BH\ ship}$: Actual hull section moduli at strength deck and bottom respectively.

(2) K is the coefficient corresponding to the kind of steel:

0.78 (for $HT32$)

0.72 (for $HT36$)

0.68 (for $HT40$, however, 0.66 may be taken where a fatigue assessment of the structure is performed to verify compliance with the requirements of the Society.)

The values specified in **1.1.7-3, Part C** of the Rules (for stainless steel and stainless clad steel)

(3) Plate thickness t_M, section modulus Z_M and moment of inertia I_M are those required by the Rules for members and structures of mild steel, and t_H, Z_H and I_H are those for high tensile steel.

(4) Expressions not stipulated here are to be as defined in relevant provisions in **Part C** of the Rules.

1.2.2 Determination of Scantlings of Structural Members

1 Double Bottoms

The formulae for determining the scantlings of structural members of the double bottom prescribed in **Chapter 6, Part C** of the Rules, are to be replaced by the formulae in **Table 2.1**.

2 Frames

(1) The formulae for determining the scantlings of frames prescribed in **Chapter 7, Part C** of the Rules, are to be replaced by the formulae in **Table 2.2**.

(2) Lower ends of frames

At the lower ends of hold frames and web frames, their section moduli in a range of about 300 *mm* from the upper end of lower brackets are not to be less than the values determined by the following formula:

$$Z_H = Z_M$$

Where appropriate considerations are given to the construction of the lower ends of frames, however, Z_H may be as determined by the formulae in **Table 2.2**.

3 Web Frames and Side Stringers

(1) The formulae for determining the scantlings of web frames and side stringers in **Chapter 8, Part C** of the Rules, are to be replaced by the formulae in **Table 2.3**.

(2) Lower ends of frames

At the lower ends of web frames, their section moduli in a range of about 300 *mm* from the upper end of lower brackets are not to be less than the values determined by the following formula:

$$Z_H = Z_M$$

Where appropriate considerations are given to the construction of the lower ends of frames, however, Z_H may be as determined by the formulae in **Table 2.3**.

4 Beams, Pillars and Deck Girders

The formulae in **Chapters 10**, **11** and **12, Part C** of the Rules, for determining the scantlings of beams, pillars and deck girders are to be replaced by those in **Table 2.4**.

5 Watertight Bulkheads

The formulae in **Chapter 13, Part C** of the Rules, for determining the scantlings of watertight bulkheads are to be replaced by those in **Table 2.5**.

6 Deep Tanks

The formulae in **Chapter 14, Part C** of the Rules, for determining scantlings of deep tanks are to be replaced by those in **Table 2.6**. The minimum thickness prescribed in **14.1.4, Part C** of the Rules, may be modified at the discretion of the Society.

7 Shearing Strength of Side Shell and Longitudinal Bulkheads

The formulae in **Chapter 15, Part C** of the Rules, related to the shearing strength of side shell and longitudinal bulkheads are to be replaced by the following formulae:

Side shell: $t_H = Kt_M$ (mm)

Longitudinal bulkheads: $t_H = Kt_M$ (mm)

8 Shell Plating

The formulae in Chapter 16, Part C of the Rules, for shell plating are to be replaced by those in Table 2.7.

9 Decks

The formulae in Chapter 17, Part C of the Rules, for thickness of deck plating are to be replaced by the following formula:

$$t_H = \sqrt{K}(t_M - 2.5) + 2.5 \quad (mm)$$

Table 2.1 Double Bottoms

Members	Paragraph No.	Scantlings
Centre girders and Side girders	**6.2.3(1)** **6.2.3(2)**	Thickness (i) $C_1 K \frac{SBd}{d_0 - d_1}\left(2.6\frac{x}{l_H} - 0.17\right)\left\{1 - 4\left(\frac{y}{B}\right)^2\right\} + 2.5 \quad (mm)$ (ii) $\frac{C'_1 d_0}{\sqrt{K}} + 2.5 \quad (mm)$
Solid floors	**6.3.2(1)** **6.3.2(2)**	Thickness (i) $t_1 = C_2 K \frac{SB'd}{d_0 - d_1}\left(\frac{2y}{B''}\right) + 2.5 \quad (mm)$ (ii) $t_2 = 8.6\sqrt[3]{\frac{H^2 d_0^2}{C'_2 K}(t_1 - 2.5)} + 2.5 \quad (mm)$
Bottom longitudinals	**6.4.3-1**	Section modulus $\frac{100CK}{24 - 15.5 f_{BH} K}(d + 0.026L')Sl^2 \quad (cm^3)$
Inner bottom longitudinals	**6.4.3-2**	Section modulus $\frac{100C'KShl^2}{24 - 12 f_{BH} K} \quad (cm^3)$
Vertical struts	**6.4.4-2**	Sectional area $18CKSbh \quad (cm^2)$ C is to be 1.43 or the value obtained from the following formula, whichever is greater. $\frac{1}{1 - 0.5\frac{l_s}{k\sqrt{K}}}$
Inner bottom plating	**6.5.1-1**	Thickness of inner bottom plating (i) $\frac{C_H K}{1000} \cdot \frac{B^2 d}{d_0} + 2.5 \quad (mm)$ where C_H is the value of C in 6.5.1-1, Part C of the Rules. In applying this prescription, α is to be replaced with the following. $\frac{13.8}{24 - 11 f_{BH} K}$ (ii) $C'S\sqrt{Kh} + 2.5 \quad (mm)$

Bottom shell plating	**6.5.5**	Thickness of bottom shell plating $\frac{C_H K}{1000}\cdot\frac{B^2 d}{d_0}+2.5$ (mm) where C_H is the value of C in **6.5.1-1, Part C** of the Rules. In applying this prescription, α is to be replaced with the following. $\frac{13.8}{24-15.5 f_{BH} K}$
Longitudinal shell stiffeners & bottom longitudinals in strengthened bottom forward	**6.8.4-1**	Section modulus $0.53 K P \lambda l^2$ (cm^3)

10 Bulk Carriers

(1) Double bottoms

The formulae in **Chapter 31, Part C** of the Rules, for the scantlings of members of the double bottom are to be replaced by those in **Table 2.8**.

(2) Bilge hopper tanks and topside tanks

The formulae in **Chapter 31, Part C** of the Rules, for the scantlings of members of bilge hopper tanks and topside tanks are to be replaced by those in **Table 2.9**.

(3) Hold frames and bottom shell plating

(a) The formulae in **Chapter 31, Part C** of the Rules, for the scantlings of members of hold frames and bottom shell plating are to be replaced by those in **Table 2.10**.

(b) Lower ends of frames

At the lower end of frames, the section modulus of frames up to about 300 mm from the upper end of lower bracket is not to be less than that obtained from the following formula:

$$Z_H = Z_M$$

Where special considerations are given to the construction of the lower end of frames, however, the section modulus may be the value according to **Table 2.10**.

Table 2.2 Frames

Members	Paragraph No.	Scantlings
Hold frames	**7.3.2** **7.3.3**	Section modulus $Z_H = KZ_M$
Longitudinals on side shell plating	**7.4.1**	Section modulus $100C_HKShl^2$ (cm^3) $2.9K\sqrt{L'}\,Sl^2$ (cm^3) C_H is a coefficient equal to $\frac{1}{24-kK}$ k is (a) or (b), whichever is greater: (a) $15.5f_{BH}\left(1-2.5\frac{y}{D_s}\right)$ (b) $L \leq 230m: \frac{6}{a}$ $L \geq 400m: \frac{10.5}{a}$ Liner interpolation for intermediate L. a is to be $\sqrt{K}$ if at least 80% of side shell is of high tensile steel in the transverse section at amidships. Otherwise, a is to be 1.0. Further, if f_{BH} is less than (0.85/K), f_{BH} is to be taken as equal to (0.85/K).
Web frames	**7.4.2**	Depth Depth as per Rules. Section modulus$Z_H = KZ_M$ Web thickness $t_1 = \frac{C_2K}{1000}\cdot\frac{Shl}{d_0} + 2.5$ (mm) $t_2 = 8.6\sqrt[3]{\frac{d_0^2(t_1-2.5)}{kK}} + 2.5$ (mm)
Tween-deck frames	**7.6.2**	Section modulus$Z_H = KZ_M$
Transverse frames below freeboard decks forward of collision bulkhead	**7.7.1**	Section modulus$Z_H = KZ_M$
Longitudinals below freeboard decks forward of collision bulkhead	**7.7.2**	Section modulus$Z_H = KZ_M$

Table 2.3 Web Frames and Side Stringers

Members	Paragraph No.	Scantlings
Web frames	**8.2.1**	Depth Depth as per Rules Section modulus $Z_H = KZ_M$ Web thickness $t_1 = \frac{C_2K}{1000} \cdot \frac{Shl}{d_0} + 2.5\ (mm)$ $t_2 = 8.6\sqrt[3]{\frac{d_0^2(t_1-2.5)}{kK}} + 2.5(mm)$
Side stringers	**8.3.1**	Depth Depth as per Rules Section modulus $Z_H = KZ_M$ Web thickness $t_1 = \frac{C_2K}{1000} \cdot \frac{Shl}{d_0} + 2.5\ (mm)$ $t_2 = 8.6\sqrt[3]{\frac{d_0^2(t_1-2.5)}{kK}} + 2.5\ (mm)$

Table 2.4 Beams, Pillars and Deck Girders

Members	Paragraph No.	Scantlings
Longitudinal beams and Transverse beams	**10.3.3** **10.4.3**	Section modulus $Z_H = KZ_M$
Pillars	**11.2.1**	Sectional area $\frac{0.223Kw}{2.72-\frac{l}{k_0\sqrt{K}}}$ (cm^2)
Deck girders	**12.2.1** and **12.3.1** **12.2.2** and **12.3.2** **12.2.3** and **12.3.3**	Section modulus $Z_H = KZ_M$ Moment of inertia $I_H = I_M$ Web thickness (i) Longitudinal girders under strength deck outside the line of openings in midship part $10\sqrt{f_{DH}}S_1 + 2.5$ (mm) Other longitudinal and transverse girders $10S_1 + 2.5$ (mm) (ii)Within $0.2l$ from ends $\frac{4.43K}{1000} \cdot \frac{bhl}{d_0} + 2.5$ (mm) $0.813\sqrt[3]{\frac{bhlS_1^2}{d_0}} + 2.5$ (mm)

Table 2.5 Watertight Bulkhead

Members	Paragraph No.	Scantlings
Bulkhead plating	**13.2.1**	Thickness $3.2S\sqrt{Kh}+2.5$ (mm) but not to be less than $5.9S+2.5$ (mm)
Stiffeners	**13.2.3**	Section modulus $Z_H=KZ_M$
Corrugated bulkheads	**13.2.4**	Thickness $3.4CS_1\sqrt{Kh}+2.5$ (mm) but not to be less than $5.9CS_1+2.5$ (mm) Section modulus per half pitch $Z_H=KZ_M$ Plate thickness within $0.2l$ from ends of generating line Web part $0.0417\frac{CKShl}{d_0}+2.5$ (mm) $1.74\sqrt[3]{\frac{CShlb^2}{d_0}}+2.5$ (mm) Flange part $\frac{12}{\sqrt{K}}a+2.5$ (mm)
Girders supporting stiffeners	**13.2.6**	Section modulus $Z_H=KZ_M$ Moment of inertia of section $I_H=KI_M$ Thickness of web plate within $0.2l$ from ends $0.0417\frac{CKShl}{d_0}+2.5$ (mm) $1.74\sqrt[3]{\frac{CShlS_1^2}{d_0}}+2.5$ (mm)

Table 2.6 Deep Tanks

Members	Paragraph No.	Scantlings
Bulkhead plating	**14.2.2**	Thickness $t_H = \sqrt{K}(t_M - 3.5) + 3.5 \ (mm)$
Stiffeners	**14.2.3**	Section modulus $Z_H = KZ_M$
Corrugated bulkheads	**14.2.4**	Thickness $t_H = \sqrt{K}(t_M - 3.5) + 3.5 \ (mm)$ Section modulus per half pitch $Z_H = KZ_M$ Plate thickness within 0.2l from ends Web plate $0.0417\dfrac{CKShl}{d_0} + 3.5 \ (mm)$ $1.74\sqrt[3]{\dfrac{CShlb^2}{d_0}} + 3.5 \ (mm)$ Flange plate $\dfrac{12}{\sqrt{K}}a + 3.5 \ (mm)$
Girders supporting stiffeners	**14.2.5**	Section modulus $Z_H = KZ_M$ Moment of inertia of section $I_H = KI_M$ Thickness of web plate $0.0417\dfrac{CKShl}{d_1} + 3.5 \ (mm)$ $1.74\sqrt[3]{\dfrac{CShlS_1^2}{d_1}} + 3.5 \ (mm)$ $10S_1 + 3.5 \ (mm)$

Table 2.7 Shell Plating

Members	Paragraph No.	Scantlings
Shell plating under strength deck	**16.3.1**	Minimum thickness $t_H = \sqrt{KL}$ (mm)
Side shell	**16.3.2**	(i) Transverse framing system $C_1 C_2 S\sqrt{d - 0.125D + 0.05L' + h_1} + 2.5$ (mm) C_2 is to be obtained from the following formula $91\sqrt{\dfrac{K}{576 - \alpha^2 K^2 x^2}}$ α is to be (a) or (b), whichever is greater. (a) $15.5 f_{BH}\left(1 - \dfrac{y}{y_B}\right)$ (b) $L \leq 230\ m$: $\dfrac{6}{a}$ $L \geq 400\ m$: $\dfrac{10.5}{a}$ Linear interpolation for intermediate length L. a is to be $\sqrt{K}$ if at least 80% of side shell is of high tensile steel in the transverse section amidships. Otherwise, a is to be 1.0. (ii) Longitudinal framing system $C_1 C_2 S\sqrt{d - 0.125D + 0.05L' + h_1} + 2.5$ (mm) C_2 as per following formula $13\sqrt{\dfrac{K}{24 - \alpha K x}}$ but not to be less than $3.78\sqrt{K}$. α as per (i) above.
Bottom shell	**16.3.4(2)**	Thickness $C_1 C_2 S\sqrt{d + 0.035L' + h_1} + 2.5$ (mm) C_2 as per following formula, but not to be less than $3.78\sqrt{K}$. $13\sqrt{\dfrac{K}{24 - 15.5 f_{BH} K x}}$
Bilge strakes in midship part	**16.3.5**	Thickness Thickness as per Rules
Shell plating at strengthened bottom forward	**16.4.4**	Thickness $t_H = \sqrt{K}(t_M - 2.5) + 2.5$ (mm)

Table 2.8 Double Bottoms of Bulk Carriers

Members	Paragraph No.	Scantlings
Centre girders and Side girders	**31.2.2-3(1)** **31.2.2-3(2)**	Thickness (i) $C_1 K \frac{SBd}{d_0 - d_1}\left(2.6\frac{x}{l_H} - 0.17\right)\left\{1 - 4\left(\frac{y}{B}\right)^2\right\} + 2.5\ (mm)$ (ii) $\frac{C'_1 d_0}{\sqrt{K}} + 2.5\ (mm)$
Floors	**31.2.3-2(1)** **31.2.3-2(2)**	Thickness (i) $t_1 = C_2 K \frac{SB'd}{d_0 - d_1}\left(\frac{2y}{B''}\right)\left\{1 - 2\left(\frac{x}{l_H}\right)^2\right\} + 2.5\ (mm)$ (ii) $t_2 = 8.6\sqrt[3]{\frac{H^2 d_0^2}{C'_2 K}(t_1 - 2.5)} + 2.5\ (mm)$
Inner bottom plating	**31.2.4-1**	Thickness (i) $\frac{C_H K}{1000} \cdot \frac{B^2 d}{d_0} + 2.5\ (mm)$ where C_H is C_3 in **31.2.4-1, Part C of the Rules**. In applying the prescriptions, α is to be replaced with the following: $\frac{13.8}{24 - 11 f_{BH} K}$ (ii) $C'_3 S\sqrt{Kh} + 2.5\ (mm)$
Bottom longitudinals	**31.2.5-1**	Section modulus $\frac{100CK}{24 - 15.5 f_{BH} K}(d + 0.026L')Sl^2\ (cm^3)$
Inner bottom longitudinals	**31.2.5-2**	Section modulus $\frac{100CKShl^2}{24 - 12 f_{BH} K}\ (cm^3)$
Vertical struts	**31.2.6**	Section area $1.8CKSbh\ (cm^2)$ where C is to be obtained from the following formula, but is not to be less than 1.43 $\frac{1}{1 - 0.5\frac{l_s}{\sqrt{Kk}}}$

Table 2.9 Bilge Hopper Tanks and Topside Tanks

Members	Paragraph No.	Scantlings
Bilge Hopper Tank		
Hopper plates	**31.3.2**	Thickness: $CS\sqrt{Kh}+2.5$ (mm)
Longitudinal stiffeners	**31.3.3-1**	Section modulus: $CKShl^2$ (cm^3) C as per following formula $\dfrac{\alpha}{24-15.5f_{BH}K\dfrac{y}{y_B}}$
Transverse stiffeners	**31.3.3-2**	Section modulus: $CKShl^2$ (cm^3)
Transverse webs	**31.3.4**	Depth Depth required by the Rules. Section modulus $Z_H=KZ_M$ Web thickness $10d_0+2.5$ (mm) $\dfrac{CK}{1000}\cdot\dfrac{Shl}{d_0-a}+2.5$ (mm) within $0.2l$ from ends $0.502\sqrt[3]{\dfrac{CShlS_1^2}{d_0-a}}+2.5$ (mm) S_1 is the spacing (m) of stiffeners of transverse webs or depth of web, whichever is smaller.
Top Side Tank		
Sloping plates	**31.4.2**	Thickness:$4.6S\sqrt{Kh}+2.5$ (mm)
Longitudinal stiffeners	**31.4.3-1**	Section modulus: $CKShl^2$ (cm^3) C as per for following formula $\dfrac{100}{24-15.5f_{DH}K\dfrac{y}{y_D}}$
Transverse stiffeners	**31.4.3-2**	Section modulus: $6.8KShl^2$ (cm^3)
Side frames	**31.4.5-2**	Section modulus: $6KShl^2$ (cm^3)
Transverse webs	**31.4.6**	Depth Depth required by the Rules Section modulus $Z_H=KZ_M$ Web thickness $10d_0+2.5$ (mm) $0.0417\dfrac{KShl}{d_0-a}+2.5$ (mm) within $0.2l$ from ends $1.74\sqrt[3]{\dfrac{ShlS_1^2}{d_0-a}}+2.5$ (mm) S_1 is the spacing (m) of stiffeners of transverse webs or depth of web, whichever is smaller.
Longitudinal diaphragms	**31.4.7**	Thickness $19.8S\sqrt{\dfrac{f_{DH}y}{D}}+2.5$ (mm)

Table 2.10 Hold Frames and Bottom Shell Plating

Members	Paragraph No.	Scantlings
Hold frames	**31.6.1-1** **31.6.1-2** **31.6.1-6** **31.6.1-7**	Section modulus $Z_H = KZ_M$ The web depth to thickness ratio of hold frames $60\sqrt{K}$ *for* symmetrically flanged hold frames $50\sqrt{K}$ *for* asymmetrically flanged hold frames The width of outstanding face or flange to thickness ratio of hold frames $10\sqrt{K}$
Bottom shell plating	**31.7.3**	Thickness (i) $\frac{C_H K}{1000} \cdot \frac{B^2 d}{d_0} + 2.5\ (mm)$ where C_H is C_3 in **31.2.4-1, Part C of the Rules**. In applying this prescription, α is to be replaced with the following. $\frac{13.8}{24 - 15.5 f_{BH} K}$ (ii) Where high tensile steel is used in bottom shell plating under holds kept empty under full load condition, the data of direct calculations necessary for confirming sufficient buckling strength is to be submitted to the Society.

1.2.3 Special Rules for Longitudinal Strength Members

1 Application

The provisions under this paragraph apply to the use of high tensile steel for the reduction of the hull girder section modulus in the midship part according to **1.1.7-2(1), Part C** of the Rules in ships having longitudinally framed strength deck and bottom.

2 Extents of Use of High Tensile Steel

Materials of high tensile steel are to be used in the following parts **(1)** to **(7)**.

(1) Longitudinal strength members from the strength deck or the bottom to the points specified below respectively. (*See* **Fig. 2.1** and **Fig. 2.2**)

(a) Strength deck part

$$b_D = y_D\left(1 - \frac{1}{f_{DH}}\right)\ (m)$$

Where y_D is the distance (m) from the neutral axis of the cross-section of hull to the strength deck

(b) Bottom part

$$b_B = y_B\left(1 - \frac{1}{f_{BH}}\right)\ (m)$$

Where y_B is the distance (m) from the neutral axis of the cross-section of hull to the top of the keel

(2) Longitudinal strength members on strength deck

(3) Portions as shown in **Fig. 2.3** of the deck inside the line of openings

(4) Hatch coamings and their horizontal stiffeners within the extents shown in **Fig. 2.4**.

(5) Gutter bars and bilge keels welded to high tensile steel materials

Where bilge keels are of riveted construction, materials except flat bars welded to shell plating do not need to be of high tensile steel.

(6) Doubling plates fitted to longitudinal strength members of high tensile steel for reinforcing openings, etc.

(7) It is recommended that the range of $0.5L$ amidships be constructed of high tensile steel. If the range of $0.5L$ amidships is not covered by high tensile steel, special consideration should be given to the continuity of section modulus of hull girder between the ranges of $0.4L$ and $0.5L$ amidships.

Fig. 2.1 High Tensile Steel Used in Deck and Bottom

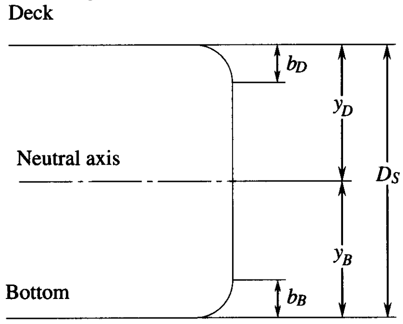


Fig. 2.2 High Tensile Steel Used in Deck only

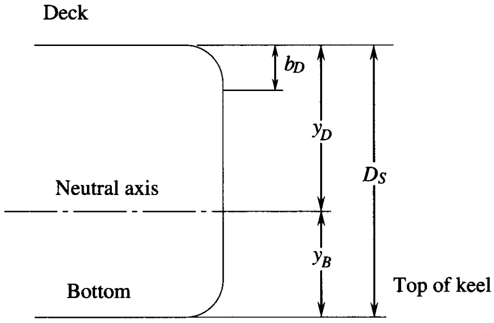


Fig. 2.3 Deck

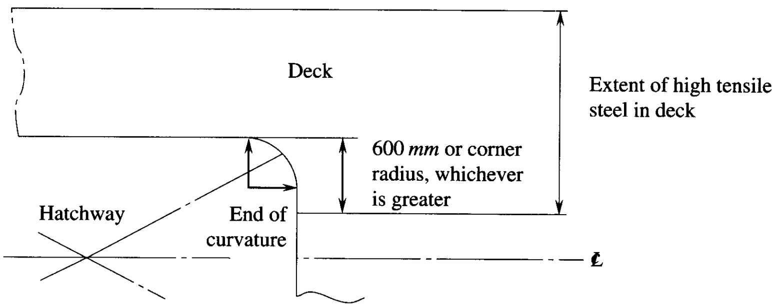
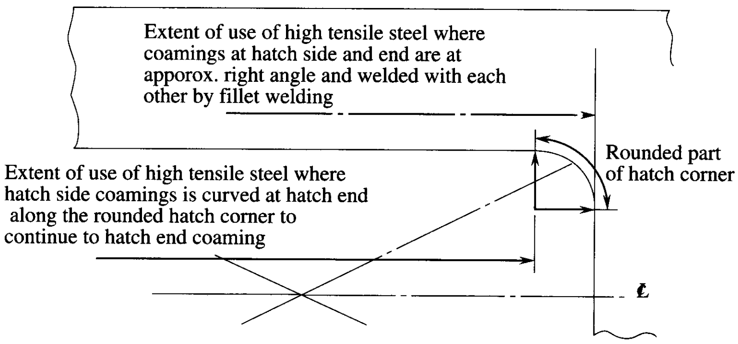


Fig. 2.4 Hatch Coaming



3 Scantlings of Structural Members

(1) The scantlings of structural members of high tensile steel are to be in accordance with **(3)** below, in addition to compliance with 1.2.2 above.

(2) The scantlings of structural members of mild steel are to be in accordance with **(3)** below, in addition to compliance with the Rules, provided that f_D and f_B in the formulae in the provisions concerned are to be replaced by f_{DH} and f_{BH} in 1.2.1-2 above respectively.

(3) The ratio of depth to thickness of flat bars used in longitudinal beams and frames, and the slenderness ratio of longitudinal side

frames attached to longitudinal beams and shear strakes are to be as specified in the Rules.

4 Tapering of Longitudinal Strength Members

(1) The manner of tapering of longitudinal strength members of high tensile steel is to comply with the provisions of the Rules, assuming that the entire hull be constructed of high tensile steel.

(2) Where the midship part is constructed of high tensile steel, the scantlings of mild steel members forward of and abaft the midship part are to be in accordance with **Fig. 2.5**.

(3) At the connection point of high tensile steel materials and mild steel materials, due consideration should be given to the continuity of strength so that an appreciable difference of plate thickness may be avoided.

(a) Thickness of shell plating and longitudinal bulkheads

$$\frac{1}{\sqrt{K}}(a - t_c) + t_c \ (mm)$$

t_c: As follows:

Side shell plating

2.5 (mm), for tankers (however, 3.0, where side shell plating forms boundaries of cargo oil tanks planned to carry ballast as well)

2.5 (mm), for other ships

Longitudinal bulkhead

3.5 (mm), for tankers

2.5, for other ships (mm)

(b) Effective sectional area of longitudinal strength members of strength deck

$b = \beta a$

Where β is to be as follows:

For tankers

1.27 (for $HT32$)

1.38 (for $HT36$)

1.46 (for $HT40$)

For other ships

1.34 (for $HT32$)

1.45 (for $HT36$)

1.54 (for $HT40$)

However, where the effective sectional area of longitudinal strength members of the strength deck in the middle of L has been determined, where mild steel construction is assumed, the value may be given as follows:

$$\beta = \frac{S_{e1}}{S_{e2}}$$

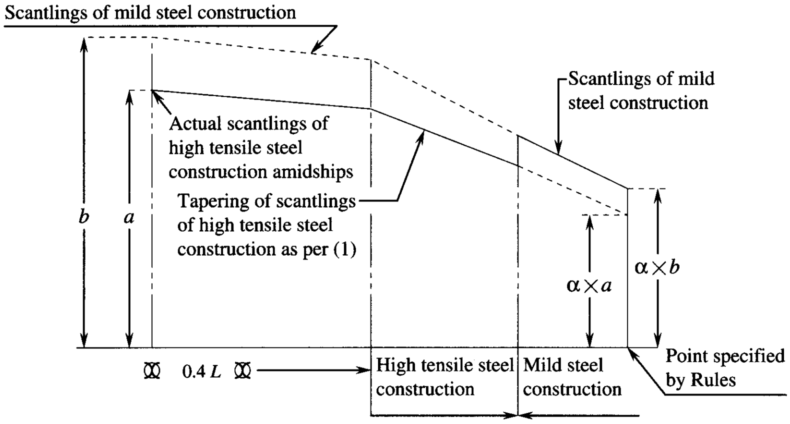
S_{e1}: Effective sectional area of the strength deck at the middle of L, where mild steel construction is assumed

S_{e2}: Effective sectional area of the strength deck at the middle of L, for ships made of high tensile steels

(c) Section modulus of stiffeners of longitudinal frames, beams and bulkheads

$$\frac{a}{K}$$

Fig. 2.5 Scantlings of Mild Steel Members at Fore and Aft Part of Ship



Where:

α: Rule reduction ratio at the point specified by the Rules

a: Actual scantlings of high tensile steel members at the middle of L

b: Scantlings of members at the middle of L for mild steel construction given as follows:

Annex C1.1.7-5 GUIDANCE FOR THE USE OF FIBER REINFORCED PLASTIC (FRP)

1.1 General

1.1.1 Application

This Annex provides standards for choosing appropriate Fiber Reinforced Plastic (hereinafter, referred to as "FRP") products, in cases where their use has been approved by the Society, for each ship design in accordance with their purpose of use and location of use on a case by case basis.

1.1.2 Documents to be Submitted

The following plans and documents are to be submitted.

(1) Plans that indicate the location of use, service conditions, arrangement, etc.

(2) Documents describing any special electrical characteristics and service conditions of FRP to be used.

(3) Plans and Documents regarding the application procedures and joint procedures of the FRP to be used.

(4) Other drawings and data considered necessary by the Society

1.2 General for FRP

1.2.1 General

1 All FRP have to be approved by the Society in accordance with the requirements in **Chapter 9**, **Part 2** of **Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use** and be adequate for the service conditions of its use.

2 All FRP are to be resistant to any substances they are expected to be exposed to during service.

1.2.2 Strength of Connections

1 The connections of FRP are to be of sufficient strength.

2 All tightening of joints is to be performed in accordance with the Manufacturer's instructions.

3 All bonding procedure specifications are to be submitted to the Society.

1.3 Requirements for FRP Depending On Service and/or Locations

1.3.1 Requirements for FRP Depending On Service and/or Locations

1 The requirements for fire integrity, fire retardance, flame spread and surface flammability as well as smoke generation required for FRP are, in principle, to be in accordance with those given in **Table 1.3.1**. If a FRP corresponds to the multiple classifications of service in **Table 1.3.1**, it is to satisfy the most stringent requirements.

2 Subdivisions other than those specified in **Table 1.3.1** are to be deemed appropriate by the Society.

3 Where the fire integrity test, the flame spread and surface flammability test have been approved as Approval Tests specified in **Chapter 9, Part 2 of the Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use** in accordance with *ASTM F 3059-14*, notwithstanding the requirement in **-1** above, applicable requirements can be in accordance with *ASTM F 3059-14*.

4 Notwithstanding the requirements in **-1** and **-3** above, FRP used for safe access to tanker bows specified in **23.7.2, Part C of the Rules** is to be tested and approved in accordance with the fire integrity test specified in **9.4.2-1(4)**, the flame spread and surface flammability test specified in **9.4.2-3(2)**, the smoke generation test specified in **9.4.2-4(2)** and the toxicity test specified in **9.4.2-5(1), Chapter 9, Part 2 of the Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use** by the Society.

5 FRP may be used for ladders, handrails, steps and small platforms, etc. because they are not considered to be part of the hull and, therefore, required to have the means of access specified in **Chapter 35**, **Part C of the Rules**.

6 In cases where FRP are installed in the hazardous areas specified in **4.3** and **4.7**, **Part H of the Rules**, the risks of FRP taking charge are to be taken into account. In cases where FRP are installed in cargo tanks, fuel oil tanks or the areas deemed necessary by the Society, such FRP are not to have electrostatic properties. Generally, in cases where like gratings of personnel walkways are installed in areas except for those mentioned above, FRP that have electrostatic properties may be used. No electrostatic properties means that the earth resistance of these products at any point is not greater than $1\ M\Omega$.

Table 1.3.1 Applicable Requirements of FRP

Location	Service	Fire Integrity	Fire Retardance	Flame Spread and Surface Flammability	Smoke Generation	Toxicity
Cargo Pump Rooms	All personnel walkways, catwalk, ladder, platforms or access areas	L1	○	○	-	-
Cargo Holds	Walkways or areas which may be used for escape, or access for firefighting, emergency operation or rescue	L1	○	-	-	-
	Personnel walkways, catwalks, ladders, platforms or access areas other than those described above	-	○	-	-	-
Cargo Tanks	All personnel walkways, catwalks, ladders, platforms or access areas	Note 3)	○	-	-	-
Fuel Oil Tanks	All personnel walkways, catwalks, ladders, platforms or access areas	Note 3)	○	-	-	-
Ballast Water Tanks	All personnel walkways, catwalks, ladders, platforms or access areas	Note 4)	○	-	-	-
Cofferdams, void spaces, double bottoms, pipe tunnels, etc.	All personnel walkways, catwalks, ladders, platforms or access areas	Note 4)	○	-	-	-
Accommodation, service, and control spaces	All personnel walkways, catwalks, ladders, platforms or access areas	L1	○	○	○	-
Lifeboat embarkation or temporary safe refuse stations in open deck areas	All personnel walkways, catwalks, ladders, platforms or access areas	L2	○	-	-	-
Open Decks or semi-enclosed areas	Walkways or areas which may be used for escape, or access for firefighting, emergency operation or rescue [6)]	L3[5)]	○	-	-	-
	Personnel walkways, catwalks, ladders, platforms or access areas other than those described above	-	○	-	-	-

Note:

1) SYMBOLS

○: Fire retardance test, flame spread and surface flammability test, smoke generation test, and the toxicity test specified in **9.4.2, Chapter 9, Part 2** of **Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use** are to be satisfied.

- : Not applicable

2) ABBREVIATIONS

L1: L1 is the abbreviations for fire retardance Level 1. FRP complying with L1 is the FRP specified in **9.1.2(4), Chapter 9, Part 2** of **Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**.

L2: L2 is the abbreviations for fire retardance Level 2. FRP complying with L2 is the FRP specified in **9.1.2(3), Chapter 9, Part 2** of **Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**.

L3: L3 is the abbreviations for fire retardance Level 3. FRP complying with L3 is the FRP specified in **9.1.2(2), Chapter 9, Part 2** of **Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**.

3) Fire integrity is not required. However if these spaces are normally entered when underway, FRP of L1 integrity is to be

required.

4) Fire integrity is not required. However if these spaces are normally entered when underway, FRP of L3 integrity is to be required.

5) Vessels fitted with fixed foam fire-extinguishing systems and fixed dry chemical powder type extinguishing systems on deck require FRP of L1 integrity for foam system operational areas and access routes.

6) Excluding safe access to tanker bows specified in **23.7.2, Part C of the Rules**.

Annex C1.1.22-1 GUIDANCE FOR DIRECT CALCULATIONS

1.1 General

1.1.1 General

1 Application

(1) When determining the scantlings of structural members of the hull by direct calculations, the types of members applicable to scantling determination and the scope of application of the formulae specified in the Rules and Guidance are, as a rule, to be approved by the Society beforehand.

(2) Even when the scantlings of structural members of the hull are determined by direct calculations, the requirements in **Chapter 15, Part C of the Rules** are to be complied with.

(3) Even when the plate thickness of structural members is determined by direct calculations, the minimum thicknesses specified in the Rules are to be maintained.

2 Analysis Methods

(1) The analysis methods and programs are to be such that the influences of bending, shearing, axial, and torsional deflections can be effectively taken into consideration.

(2) The analysis methods and programs are to be such that the behaviours of plane or space structures can be effectively expressed and or displayed under reasonable boundary conditions.

(3) The analysis programs are to have sufficient analysing accuracy. When considered necessary, the Society may require submission of data on the details of the analysis methods, verification of accuracy, etc.

(4) When direct calculations were used for determining scantlings, the materials and data specifying the conditions of the calculations and data summarizing their results are to be submitted to the Society.

1.2 Design Loads

1.2.1 General

1 Classification of Loads

(1) The loads due to the longitudinal bending moment of hull girders at the forward and aft end boundaries of the structure model may, as a rule, not be taken into consideration. When these loads are taken into consideration, however, the allowable stress to be applied to the results of calculations is to be determined as deemed appropriate by the Society.

(2) The design loads to be taken into consideration are, as a rule, to be the loads due to cargo and water ballast loaded on board, hydrostatic pressure and wave loads.

(3) The load due to the inertial force of cargo is to be considered in addition to those specified in **(2)** above, when the Society considers it is necessary.

(4) Special consideration is to be made for cargo holds where dynamic impact loads such as sloshing loads are predicted, and proper data in this regard is to be submitted.

(5) The loads for oil tankers, ore carriers and bulk carriers are to be in accordance with the requirements specified in **C29.6.2**, **C30.1.2** and **C31.1.5** of the Guidance respectively, in addition to those found here in **1.2**. When deemed necessary by the Society, other loading conditions described in the Loading Manual are also to be considered.

1.2.2 Loads Due to Cargo and Water Ballast

1 Loads due to Ore Cargo, Grain Cargo, and Similar Loads

(1) The density, loading height and surface of the cargo are to be determined referring to calculations such as preliminary trim calculations.

(2) The density, loading height and repose angle of cargo used in the calculations are to be clearly indicated. If considered necessary, the angle of internal friction of the cargo and the angle of friction between the cargo and wall surface are to be indicated.

2 Loads Due to Liquid Cargo, Water Ballast, and Similar Loads

(1) The upper end of the water head for a tank is to be the mid-point of the distance between the top of the tank and the top of the overflow pipe.

(2) For the water head of large deep tanks, proper additional water head corresponding to dynamical influences is to be considered in addition to the water head specified in **(1)** above.

(3) For liquid cargo and water ballast to be loaded in harbours or similar quiet waters, the water head corresponding to the actual loading height may be used as the water head.

(4) Except where considered necessary, the loads due to fuel oil, fresh water and similar consumables may not be taken into consideration.

(5) The densities and water heads of cargoes are to be specified.

1.2.3 Hydrostatic Pressure

1 Hydrostatic Pressure at Draught in Still Water

The water head at the draught in still water (d_s), corresponding to respective loading conditions is to be considered as hydrostatic pressure at the ships bottom and sides.

2 Load for Hydraulic Pressure Test

(1) The upper end of the water head of a tank being subjected to a hydraulic pressure test is to be a point at a height of 2.4 *m* above the top of the tank.

(2) The water pressure at the bottom and sides under the hydraulic pressure test is to be the hydrostatic pressure corresponding to a draught equal to 1/3 of the design load draught.

1.2.4 Wave Loads

1 Wave Induced Loads

(1) The water heads (m) corresponding to the variations H_0, H_1 and H_2 from the hydrostatic pressure at the still water draught obtained from the following formulae are to be taken into consideration as the wave induced loads corresponding to the wave crest and trough. (*See* **Fig. 2.1**)

$$H_0 = 0.5 \times H_w$$

$$H_1 = 0.9 \times H_w$$

$$H_2 = 0.25 \times H_w$$

Where H_w is determined from the following formulae.

$$H_w = 0.61L^{1/2},\ L \leq 150m$$

$$H_w = 1.41L^{1/3},\ 150m < L \leq 250m$$

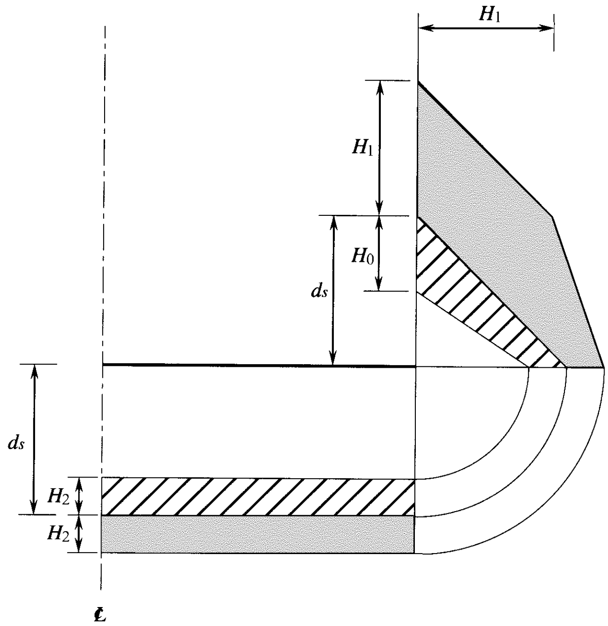
$$H_w = 2.23L^{1/4},\ 250m < L \leq 300m$$

$$H_w = 9.28,\ 300m < L$$

(2) The wave induced loads in harbours and similar quiet waters may be taken as equal to 1/3 of the values of H_0, H_1 and H_2 specified in **(1)** above.

(3) Wave induced loads may be assumed to be equally distributed throughout the ship’s length.

Fig. 2.1 Wave Induced Loads



1.3 Structural Models

1.3.1 General

1 Modelling of Structure

(1) The structural model to be analysed is to include surrounding members that are considered to have material influences on the behaviour of the members of which the scantlings are to be determined by direct calculations.

(2) The structure may be modelled as a two or three dimensional structure by using beam elements, shell elements or hybrid elements. The modelling is to be such that any proper elements chosen from among plate bending elements, membrane elements, beam elements, bar elements, etc. can reproduce the behaviours of the structure with the highest possible fidelity.

(3) The scantlings including corrosion additions which are shown on the plans may be used for modelling.

(4) When the model is not sufficiently divided into model elements for the determination of scantlings by direct calculations, the member concerned is to be remeshed with fine meshes to enable further study on the basis of the results of the analysis.

(5) The structural models of tankers, ore carriers and bulk carriers are to comply with the requirements in **C29.6.2**, **C30.1.2** and **C31.1.5** of the Guidance respectively, in addition to those specified here in **1.3**.

2 Modelling Using Shell Elements

(1) Side shells, longitudinal bulkheads and other similar members subjected to large shearing forces are preferably to be modelled into two or three dimensional structures using shell elements.

(2) When meshing, a proper mesh size is to be selected in accordance with the stress distribution in the model which can be predicted, and abnormally large aspect ratios of meshes are to be avoided.

(3) Girders and similar members having stress gradients along their depth are to be meshed so as to enable their discrimination.

3 Modelling Using Beam Elements

(1) Each member may generally include the plates up to a width of 1/10 the span of the member on either side of the beam. The plates are to be effectively reinforced by other members or are to be deemed by the Society to have sufficient thickness. However, the width of the plate is not to exceed half the distance to the neighbouring member.

(2) The model is to use rigid members for connections and bracketed parts and anywhere where constructions of high rigidity are employed.

(3) Attention is to be paid to the position of the neutral axis. In particular, offset beam elements are to be used when modelling on a hybrid structure of beam and shell elements.

1.4 Allowable Stress

1.4.1 General

1 Allowable Stress

(1) For tankers, ore carriers and bulk carriers, when the loads specified in **1.2.1-1** act on the structural model according to **1.3** above, the scantlings are to be determined so that the stress generated in each structural member does not exceed the values given in **C29.6.2**, **C30.1.2** and **C31.1.5** of the Guidance respectively.

(2) When the section modulus of hull girders contains a fair margin, the permissible value of normal stress in the lengthwise direction is to be as deemed appropriate by the Society.

Annex C1.1.22-2 GUIDANCE FOR BUCKLING STRENGTH CALCULATION

1.1 General

1.1.1 General

1 Application

(1) The buckling strength of each structural member of the hull is to be examined on the basis of the results of direct calculations carried out in accordance with **Annex C1.1.22-1** "**GUIDANCE FOR DIRECT STRENGTH CALCULATION**."

(2) This Guidance can be applied only to panels with sufficient corrosion protection. Where the panel is not appropriately protected against corrosion, the analytical procedure is to be as deemed appropriate by the Society.

(3) The buckling strength can be examined by other analytical procedures when deemed appropriate by the Society.

1.2 Working Stress

1.2.1 Working Stress in a Panel

1 Stress Components

The working in-plane stresses determined by the element coordinate systems listed below are necessary prior to analysing the panel (*See* **Fig. 2.1**):

σ_x: Compressive stress in *x*-direction (N/mm^2)

σ_{xb}: In-plane bending stress in *x*-direction (N/mm^2)

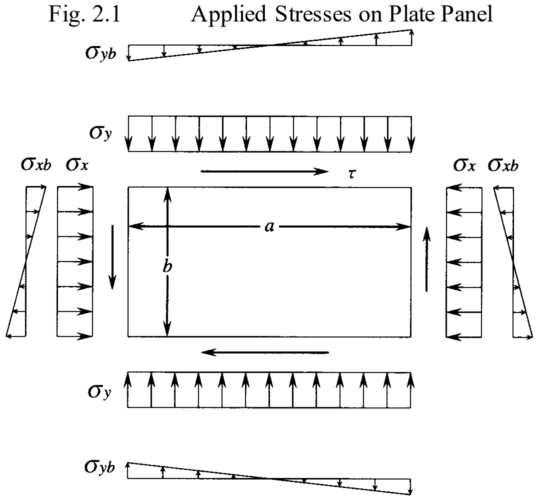
σ_y: Compressive stress in *y*-direction (N/mm^2)

σ_{yb}: In-plane bending stress in *y*-direction (N/mm^2)

τ: Shearing stress (N/mm^2)

Here, the stresses σ_x and σ_y are to be taken as positive when they are compressive stresses, and zero when they are tensile stresses.

Fig. 2.1 Applied Stresses on Plate Panel



2 Consideration for Longitudinal Bending Stress of Hull Girder

As the loads due to the longitudinal bending moment in still water at the end boundaries of the structural model are not taken into account in determining the working stresses specified in **1.2.1-1**, the stress due to the longitudinal bending moment of hull girders is to be added for specific members according to their location.

3 Grouping by Features of Stress Distribution

The members and panels are to be grouped according to **Table 2.1** depending upon the features of the distribution of their working stresses. Where the members and panels fit more than one group, examination is to be done based on each group.

4 Modification of Working Stresses

(1) The in-plane stresses determined in **1.2.1-1** are to be modified according to **Table 2.2** for each group. The x-axis and y-axis may be exchanged as necessary.

(2) The stresses modified according to **(1)** above are to be assumed as the working stresses used for the calculation of buckling strength.

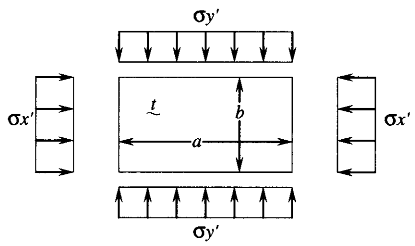
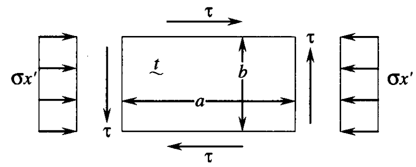
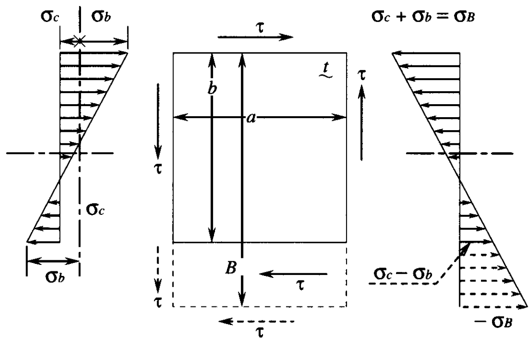
Table 2.1 Grouping

Group	Features	Examples of members to be considered	λ	Remarks
A	Relatively small shearing stress and in-plane bending stress in comparison with compressive stresses or Bi-axial compressive stress with same order	Decks, bottom and inner bottom shell related to longitudinal strength; Longitudinal bulkhead plating etc., forming bi-axial stress field	1.2	
		Transverse bulkhead plating and deep girder, etc., forming bi-axial stress field	1.2	
B	Relatively small in-plane bending stress and large uni-axial compressive stress with shearing stress	Side shell and sloped bulkhead of side tank, etc., forming uni-axial and shearing stress field; Bulkhead plating under high shearing stress; Girder and floor, etc., forming mono-axial and shearing stress field	1.2	In case of longitudinal girders related to longitudinal strength of hull girder, stress due to longitudinal still water bending moment is to be added
C	Relatively small compressive stress and large in-plane bending stress with shearing stress	Girder and floor, etc., forming bending and shearing stress field	1.2	

Note:

λ: Buckling criterion

Table 2.2 Modification of In-Plane Stresses for Each Group

Group	Stress conditions	Modified in-plane stresses
A	where $\sigma_x \geqq \sigma_{xb}$ and $\sigma_y \geqq \sigma_{yb}$, to be assumed as: $\sigma_x' = \sigma_x + 1/2 \cdot \sigma_{xb}$ $\sigma_y' = \sigma_y + 1/2 \cdot \sigma_{yb}$	
B	where $\sigma_x \geqq \sigma_{xb}$, to be assumed as: $\sigma_x' = \sigma_x + 1/2 \cdot \sigma_{xb}$	
C	where $\sigma_x < \sigma_{xb}$, to be assumed as: $\sigma_c = \sigma_x$ $\sigma_b = \sigma_{xb}$ $\sigma_B = \sigma_c + \sigma_b$	 Assumed panel width B: $B = \left(1 + \frac{\sigma_c}{\sigma_b}\right) b = \frac{\sigma_B}{\sigma_b} \cdot b$

1.3 Buckling Strength Calculation

1.3.1 Procedure of Buckling Strength Calculation (*See* Table 3.1)

1 Representative Equivalent Stress

The representative equivalent stress σ_{eq} is to be calculated as given in **Table 3.1** from the working stresses of the panel.

2 Equivalent Elastic Buckling Stress

(1) Elastic buckling stresses $\sigma_{xcr}, \sigma_{ycr}$ and τ_{cr} are to be calculated by the interaction formula given in **Table 3.2**. It is to be noted that the aspect ratio β of Group **A** should not be less than 1.0.

(2) The equivalent elastic buckling stress σ_{cr} is to be calculated from the buckling stresses $\sigma_{xcr}, \sigma_{ycr}$ and τ_{cr}.

3 Equivalent Plastic Buckling Stress

(1) When the equivalent elastic buckling stress σ_{cr} is greater than half of the yield stress σ_Y the equivalent plastic buckling stress σ'_{cr} is to be calculated as given in **Table 3.1**.

(2) The yield stress σ_Y is to be defined as the value given below:

$$\frac{235}{K}$$

Where K is the coefficient corresponding to the kind of steel

e.g. 1.0 for mild steel, the values specified in **1.1.7-2(1) of the Rules** for high tensile steel

1.3.2 Judgement of Buckling Strength

1 Assessment of the Results

(1) The results derived from **1.3.1** above are to satisfy the following conditions **(a)** or **(b)**, where λ is the buckling criterion given in **Table 2.1**.

(a) Where the equivalent elastic buckling stress σ_{cr} is greater than half of the yield stress σ_Y,

$$\sigma'_{cr} \geq \lambda\sigma_{eq}$$

(b) Where the equivalent elastic buckling stress σ_{cr} is smaller than half of the yield stress σ_Y,

$$\sigma_{cr} \geq \lambda\sigma_{eq}$$

Table 3.1 Buckling Strength Calculation

	Group A	Group B	Group C
Working stress	σ'_x, σ'_y	σ'_x, τ	σ_B, τ
σ_{eq}	$\sqrt{\sigma_x'^2 - \sigma'_x \cdot \sigma'_y + \sigma_y'^2}$	$\sqrt{(\sigma_x'^2 + 3\tau^2)}$	$\sqrt{\left(\frac{3}{4}\sigma_B\right)^2 + 3\tau^2}$
Aspect ratio β	a/b (≥ 1) See **Table 2.2**	a/b See **Table 2.2**	a/B See **Table 2.2**
Bucking stress	$\sigma_{xcr} = K_x \cdot \sigma_e$ $\sigma_{ycr} = K_y \cdot \sigma_e$	$\sigma_{xcr} = K_x \cdot \sigma_e$ $\tau_{cr} = K_s \cdot \sigma_e$	$\sigma_{Bcr} = K_B \cdot \sigma_e$ $\tau_{cr} = K_s \cdot \sigma_e$
Euler's stress of plate σ_e	$\frac{E\pi^2}{12(1-\nu^2)}\left(\frac{t}{b}\right)^2$ See **Table 2.2**		$\frac{E\pi^2}{12(1-\nu^2)}\left(\frac{t}{B}\right)^2$ See **Table 2.2**
σ_{cr}	$\sqrt{\sigma_{xcr}^2 - \sigma_{xcr} \cdot \sigma_{ycr} + \sigma_{ycr}^2}$	$\sqrt{\sigma_{xcr}^2 + 3\tau_{cr}^2}$	$\sqrt{\left(\frac{3}{4}\sigma_{Bcr}\right)^2 + 3\tau_{cr}^2}$
σ'_{cr}	where $\sigma_{cr} > 1/2 \cdot \sigma_r$ $\sigma'_{cr} = \sigma_Y\left(1 - \frac{\sigma_Y}{4\sigma_{cr}}\right)$ σ_Y: the yield stress of material specified in **1.3.1-3(2)**		

Notes:

σ_{eq}: Representative equivalent stress

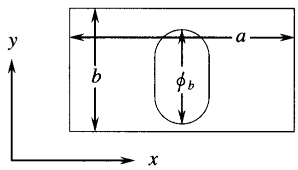
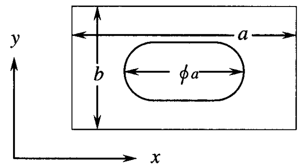
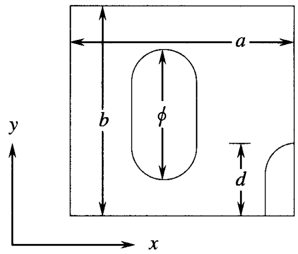
σ_{cr}: Equivalent elastic buckling stress

σ'_{cr}: Equivalent plastic buckling stress

Table 3.2 Interaction Formula for Elastic Buckling

Group A	Group B	Group C
$\frac{K_x}{K_{x0}}+\frac{K_y}{K_{y0}}=1$ $\frac{K_y}{K_x}=\frac{\sigma_y'}{\sigma_x'}$ $K_{x0}=\gamma_x\frac{\beta^2}{m^2}\left(\frac{m^2}{\beta^2}+1\right)^2$ $K_{y0}=\gamma_y\left(\frac{m^2}{\beta^2}+1\right)^2$ m: positive integer equal to the number of half waves of buckling mode which gives the minimum value of buckling stress γ_x and γ_y : reduction factor due to opening, See **Table 3.3**.	$\frac{K_x}{K_{x0}}+\left(\frac{K_s}{K_{s0}}\right)^\alpha=1$ $\frac{K_s}{K_x}=\frac{\tau}{\sigma_x'}$ $K_{x0}=\gamma_x\frac{\beta^2}{m^2}\left(\frac{m^2}{\beta^2}+1\right)^2$ K_{s0}: where $\beta<1$ $\gamma_s\left(4+\frac{5.34}{\beta^2}\right)$ where $\beta\geq 1$ $\gamma_s\left(5.34+\frac{4}{\beta^2}\right)$ m: where $\beta\leq\sqrt{2}\cdots 1$ where $\sqrt{2}<\beta\leq\sqrt{6}\cdots 2$ where $\sqrt{6}<\beta\leq\sqrt{12}\cdots 3$ where $\sqrt{12}<\beta\leq\sqrt{20}\cdots 4$ where $\sqrt{20}<\beta\cdots\beta$ α: where $\beta\geq 1/2\cdots 2$ where $\beta<1/2$ $0.7(1/\beta+1)$ or 4.9 whichever is the smaller γ_x and γ_s : reduction factor due to opening, See **Table 3.3**.	$\left(\frac{K_B}{K_{B0}}\right)^2+\left(\frac{K_s}{K_{s0}}\right)^2=1$ $\frac{K_s}{K_B}=\frac{\tau}{\sigma_B}$ K_{B0}: where $\beta\leq 2/3$ $15.87+\frac{1.87}{\beta^2}+8.6\beta^2$ where $\beta>2/3\cdots 23.9$ K_{s0}: where $\beta<1$ $\gamma_s\left(4+\frac{5.34}{\beta^2}\right)$ where $\beta\geq 1$ $\gamma_s\left(5.34+\frac{4}{\beta^2}\right)$ γ_s: reduction factor due to opening, See **Table 3.3**.

Table 3.3 Reduction Factor due to Opening

γ_x	$\gamma_x = \dfrac{1}{\{1+\phi_b/(2b)\}^2}$ where ϕ_b is the overall dimension of opening in x-direction of element coordinate system. In the case where the surroundings of the opening are properly reinforced, γ_x may be taken as 1.0.	
γ_y	$\gamma_y = \dfrac{1}{\{1+\phi_a/(2a)\}^2}$ where ϕ_a is the overall dimension of opening in y-direction of element coordinate system. In the case where the surroundings of the opening are properly reinforced, γ_y may be taken as 1.0.	
γ_s	$\gamma_s = \delta \cdot \gamma_{xy}$ where γ_{xy} is obtained from the following formula: $\gamma_{xy} = \dfrac{1}{\{1+\phi/(2S)\}^2}$ ϕ is the greater dimension of opening. S is the plate breadth in the direction of the major axis of opening. In the case where the surroundings of the opening are properly reinforced, γ_{xy} may be taken as 1.0. δ is obtained from the following formula: $\delta = \dfrac{1}{4 \cdot (d/a) - 1}$ d is the depth of slot without reinforcement; δ is to be taken as 1.0, where $d/a \leq 0.5$	

Annex C1.1.23-1 GUIDANCE FOR THE FATIGUE STRENGTH ASSESSMENT OF LONGITUDINALS

1 General

1.1 General

1.1.1 Application

1 This Annex applies to the fatigue assessment of the parts where longitudinals fitted to side shell plating, bottom shell plating, inner bottom plating, longitudinal bulkheads, and upper deck plating penetrate transverse members such as side transverses, deck transverses, floors and bulkheads.

2 Where the fatigue strength assessment of longitudinals is carried out in a different manner than that specified in the Annex, the documents related to the manner of assessment are to be submitted to the Society for approval.

1.1.2 Structural Members to be Assessed

1 The fatigue strength assessment of those parts where longitudinals penetrate transverse members except for transverse watertight bulkheads, swash bulkheads or watertight floors constraining athwartship or vertical displacements of longitudinals (hereinafter referred to as "ordinary transverse members") is to be carried out using the stress calculated in accordance with the requirements set forth in sub-section **2.1**.

2 The fatigue strength assessment of those parts where longitudinals penetrate transverse watertight bulkheads, swash bulkheads or watertight floors constraining athwartship or vertical displacements of longitudinals (hereinafter referred to as "ordinary transverse bulkheads") is to be carried out using the stress calculated by the requirements set forth in sub-section **2.2**, in addition the stress in paragraph **-1** above.

1.1.3 Navigating Conditions of the Ship

1 The navigating conditions of the ship are primarily classified into two conditions: full loading condition and ballast condition. However, for container carriers, ballast tanks are assumed to be full under both conditions.

2 Consideration will be given to the navigating condition of ships intended to navigate in any conditions other than those specified in paragraph **-1** above for a long period of time.

3 Notwithstanding the provisions of **-1,** a navigating condition other than those specified in **-1** may be used where deemed appropriate by the Society.

1.1.4 Cycles of Variable Stress

The fatigue strength assessment is to be done by evaluating the cumulative fatigue damage that occurs after 10^8 stress cycles.

2 Stress Evaluation

2.1 Evaluation of Stress for Longitudinals which Penetrate Ordinary Transverse Members

2.1.1 Stress due to Static Load

The stress due to static load (σ_{PS}) is determined according to the following equation:

$$\sigma_{PS} = \sigma_{SE} + \sigma_{SI} = -\frac{1000}{12Z\,C_{Cor}} C_c P_{SE} S l^2 + \mathrm{sgn}\frac{1000}{12Z\,C_{cor}} C_c P_{SI} S l^2 \quad (N/mm^2)$$

Z: Section modulus (cm^3) of longitudinal

S: Spacing (m) between longitudinals

l: Span length (m) of longitudinal

C_{cor}: Coefficient that considers the effect of scantling reduction due to corrosion

Coefficient is to be taken as 0.93.

sgn: Indicates use of either a plus or minus sign

A "plus" sign indicates that the longitudinals are inside the subject tank being assessed, while a "minus" sign is used in cases where the longitudinals are outside (are affixed to the exterior surface of) the subject tank being assessed.

P_{SE}: Hydrostatic pressure acting on side shell and bottom is determined according to the following equation.

$P_{SE} = \rho g h = 10h$ (kN/m^2)

h: Water head (m) that is obtained from the draft corresponding to the ship's condition minus the vertical height up to the longitudinal being assessed

P_{SI}: Hydrostatic pressure due to loaded objects such as cargo including oils and ballast water is determined according to the following equation.

$p_{SI} = C_p \rho_c g h_C$ (kN/m^2)

C_P: Pressure coefficient corresponding to loaded object is given below.

For liquid cargoes and ballast water: 1.0

For bulk cargoes, the coefficient corresponding to the angle of inclination of the vertical wall of the cargo hold is given by the following equation.

$\cos^2\alpha + K_0 \sin^2\alpha$

α: Angle of inclination (*degrees*) of the said panel on the side not facing the cargo hold with respect to the horizontal panel (See **Fig. 3**)

$K_0 = 1 - \sin\psi$

ψ: Angle of repose (*degrees*) of cargo according to **Table 1**

Fig. 3 Definition of angle of inclination of vertical wall

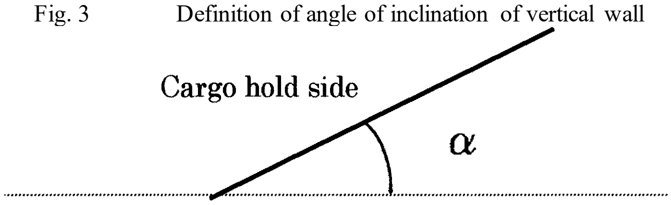


Table 1 Angle of Repose of Typical Cargoes

Type of cargo	General	Iron ore and Coal	Cement
Angle of repose (*degrees*)	30	35	25

ρ_c: Density of loaded object is given below.

For sea water: 1.025 t/m^3

For cargo oil: 0.874 t/m^3

For bulk cargoes: W/V (t/m^3)

W: Mass (t) of cargo loaded

V: Volume (m^3) of cargo hold excluding the volume enclosed by hatch coaming

g: Acceleration due to gravity is taken as $9.81 m/s^2$

h_c: Vertical distance (m) from top of the loaded object to the said longitudinal

C_c: The stress concentration factor is given by:

$$C_c = C_{c1} C_{c2}$$

C_{c1}: Stress concentration factor corresponding to the shape of a longitudinal is determined according to the following equation:

$$C_{c1} = 1.0 + \left\{0.6\left(\frac{A_f}{A_w}\right) + 0.2\right\}\left\{2.85\left(\frac{b}{b_f}\right)^2 + 0.86\left(\frac{b}{b_f}\right)\right\}$$

A_f and A_w: Section area (mm^2) of face plate and web plate of longitudinal, respectively

b_f: Breadth (mm) of face plate

b: Horizontal distance (mm) from centre of thickness of web plate to centre of breadth of face plate

C_{c2}: Stress concentration factor which corresponds to the type of intersection between longitudinal and transverse web shown in **Table 2**

2.1.2 Stress due to Wave Load

1 Stress due to wave load σ_{wj} is given in **Table 3**.

The expressions used in the table are explained below.

C_1: This value is calculated using the equations given in **Table 4**

L_1: Length (m) of ship as specified in **2.1.2**, **Part A of the Rules** or 0.97 *times* the length of the ship on the designed maximum load line, whichever is smaller

d_i: Draft (m) amidships for the relevant loading condition

y_P: Transverse horizontal distance (m) from the centreline of the ship to the point being considered in the subject section

z_P: Vertical distance (m) from the bottom of the ship to the point being considered in the midship section

B: Breadth (m) as defined in **2.1.4**, **Part A of the Rules**

T_R: Natural period of roll (s) in condition being considered

Where the full load condition and ballast condition are considered and the natural period of roll corresponding to the respective conditions is not given beforehand, it may be calculated from the following equation.

$$T_R = 1.15\frac{2K_{xx}}{\sqrt{GM}} \quad (s)$$ for tankers, ore carriers and bulk carriers

$$T_R = 1.1\frac{2K_{xx}}{\sqrt{GM}} \quad (s)$$ for container carriers

K_{xx}: Roll radius (m) of gyration at the centre of gravity of the ship corresponding to the respective condition is given below.

For full load condition $K_{xx} = 0.35B$,

For ballast condition $K_{xx} = 0.40B$

GM: Metacenter height (m) is given below, however, the actual value is to be used for ore carriers.

For Tanker:

GM=KM−KG

$$= \left\{0.42B\left(2 - \frac{d_i}{d_f}\right) - 7\left(1 - \frac{d_i}{d_f}\right)\right\} - \left\{0.54D\left(0.2 + 0.8\frac{d_i}{d_f}\right) + 3\left(1 - \frac{d_i}{d_f}\right) + 0.6\right\} \ (m)$$

For Bulk Carrier:

GM=KM−KG

$$= \left\{0.42B\left(2 - \frac{d_i}{d_f}\right) - 7\left(1 - \frac{d_i}{d_f}\right)\right\} - \left\{0.54D\left(0.4 + 0.6\frac{d_i}{d_f}\right) + 3\left(1 - \frac{d_i}{d_f}\right) + 0.6\right\} \ (m)$$

For Container Carrier:

$GM = KM - KG$

$$= \left\{0.52B + 1.25\left(1 - 2.4\frac{d_i}{d_f}\right)\right\} - \left\{0.55D\left(0.45 + 0.55\frac{d_i}{d_f}\right) - 1.95\left(1 - 2.8\frac{d_i}{d_f}\right)\right\} \ (m)$$

It is not to be less than $0.06B$.

D: Depth (m) of ship defined in **2.1.6**, **Part A of the Rules**

φ: Rolling angle (*radians*): obtained from the following formula:

$$\varphi = \frac{4}{T_R\sqrt{B}}H_j \quad \text{for tankers, ore carriers and bulk carriers}$$

$$\varphi = \frac{4}{T_E\sqrt{B}}H_j \quad \text{for container carriers}$$

T_E: As given by the following

$$T_E = 0.5\left(T_R + \sqrt{T_R^2 - \frac{2\pi}{g}VT_R}\right) \quad \text{for } T_R > \frac{2\pi}{g}V$$

$$T_E = T_R \quad \text{for } T_R \leq \frac{2\pi}{g}V$$

Where,

V: Ship speed (*knots*) as defined in **2.1.8**, **Part A of the Rules**

C: Distribution coefficient in the longitudinal direction of the ship is based on the equation given below.

Where the cross section being considered is positioned forward of amidship:

$$C = 1 + \frac{6}{C_b}\left(3 - \frac{|4y'|}{B}\right)\left(\frac{x_l}{L}\right)^3$$

Where the considered cross section is positioned afterward of amidship:

$$C = 1 + \frac{12}{C_b}\left(1 - \sqrt{\frac{|2y'|}{B}}\right)\left(\frac{x_l}{L}\right)^3$$

x_l: Longitudinal distance (m) from the midship section to the cross section being considered

y': Transverse horizontal distance (m) from the centreline of the ship to the point being considered in the subject section

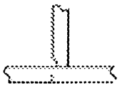
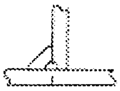
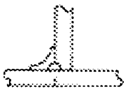
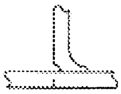
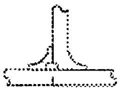
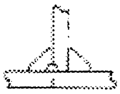
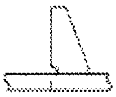
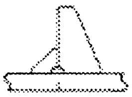
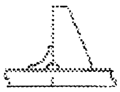
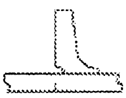
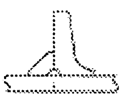
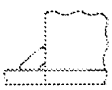
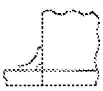
C_c, Z, S, C_{cor}, l and g are determined according to the provision in **2.1.1**.

2 Stress range near the water line corresponding to the full load condition and ballast condition is to be modified according to the equations given below, corresponding to the stress amplitude of stress due to external static pressure σ_{SE} and stress due to wave load σ_{wj}.

$$\sigma_{wj} = \sigma_{wj} \quad \frac{\sigma_{wj}}{2} \leq \sigma_{SE}$$

$$\sigma_{wj} = \frac{\sigma_{wj}}{2} + \sigma_{SE} \quad \frac{\sigma_{wj}}{2} > \sigma_{SE}$$

Table 2 Stress Concentration Factor Corresponding to the Type of Intersection between Longitudinal and Transverse Webs*1

Type of intersection	Case of penetration through transverse web in double side hull and double bottom	Case of penetration through transverse web other than in double side hull and double bottom
	1.50	1.70
	1.40	1.40
	1.35	1.40
	1.45	1.60
	0.90	0.95
	0.75	0.80
	0.90	1.00
		1.80
		0.85
		0.80
		1.80
		0.85
		0.70
		0.80
		0.70

Note:

*1 When the type of intersection between longitudinal and transverse web is other than those in **Table 2**, the documents related thereto are to be submitted to the Society for approval and the stress concentration factor approved by the Society may be used in such cases.

Table 3 Stress Range due to Wave Load

Design Condition		Design wave height H_j (m)	Wave pressure P_{Wj} (kN/m^2)	Stress σ_{Wj} (N/mm^2)
1	L-180	For tankers, ore carriers and bulk carriers $0.6175C_1\sqrt{(1.6+\frac{0.6d_i}{d_f})-\frac{25}{L}}$ For container carriers $0.6175C_1\sqrt{\left(1.5+\frac{0.5d_i}{d_f}\right)-\frac{25}{L}}$	$2.3C\left(\frac{z_p}{d_i}+\frac{\lvert 2y_p\rvert}{B}+1\right)H_j$	$1000C_C\frac{P_{Wj}Sl^2}{12ZC_{cor}}$
2	L-0	For tankers, ore carriers and bulk carriers $0.6175C_1\sqrt{(1.6+\frac{0.4d_i}{d_f})-\frac{25}{L}}$ For container carriers $0.6175C_1\sqrt{\left(1.5+\frac{d_i}{3d_f}\right)-\frac{25}{L}}$	$2.3\left(\frac{z_p}{d_i}+\frac{\lvert 2y_p\rvert}{B}+1\right)H_j$	
3	R	For tankers, ore carriers and bulk carriers $0.399C_1\sqrt{1+\frac{gT_R{}^2}{2\pi L}-\frac{25}{L}}$ For container carriers $0.399C_1\sqrt{1+\frac{gT_E{}^2}{2\pi L}-\frac{25}{L}}$	$10y'\sin\varphi+\left(\frac{\lvert 2y'\rvert}{B}+1\right)H_j$	
4	P	For tankers, ore carriers and bulk carriers $0.665C_1\sqrt{(1.2+\frac{0.4d_i}{d_f})-\frac{25}{L}}$ For container carriers $0.665C_1\sqrt{\left(1.2+\frac{0.15d_i}{d_f}\right)-\frac{25}{L}}$	For tankers, ore carriers and bulk carriers $3\left(\frac{2z_p}{d_i}+\frac{3\lvert 2y'\rvert}{B}\right)H_j$ For container carriers $2.4\left(\frac{2z_p}{d_i}+\frac{3\lvert 2y'\rvert}{B}\right)H_j$	

Table 4 Value of C_1

$L_1 \leq 300\,(m)$	$10.75-\left(\frac{300-L_1}{100}\right)^{1.5}$
$300 < L_1 \leq 350\,(m)$	10.75
$350 < L_1\,(m)$	$10.75-\left(\frac{L_1-350}{150}\right)^{1.5}$

2.1.3 Stress due to Acceleration of Ship

Stress due to acceleration of liquid in the tanks and bulk cargo in the holds induced by acceleration of the ship σ_{Tj} is according to the equations given in **Table 6** using the acceleration of the centre of gravity of the ship is given in **Table 5**.

The expressions used in **Table 5** and **Table 6** are explained below.

V: Ship speed (*knots*) as defined in **2.1.8, Part A of the Rules**

C_b: Block coefficient as defined in **2.1.14, Part A of the Rules**

sgn: Indicates use of either a plus or minus sign

A "plus" sign indicates that the longitudinals are inside the subject tank being assessed, while a "minus" sign is used in cases where the longitudinals are outside (are affixed to the exterior surface of) the subject tank being assessed.

g, S, l, Z, C_{cor}, C_C, ρ_c and C_p are determined according to **2.1.1**.

B, L, d_i, d_f and T_R are determined according to **2.1.2-1**.

T_P: As given by the following

$$T_P = \sqrt{\frac{2\pi\left\{0.6\left(1+\frac{d_i}{d_f}\right)\right\}L}{g}}\ (s) \qquad \text{for tankers, ore carriers and bulk carriers}$$

$$T_P = \sqrt{\frac{2\pi\left\{0.5\left(1+{}^{d_i}/_{d_f}\right)\right\}L}{g}}\ (s) \qquad \text{for container carriers}$$

H_1, H_3, H_4: Wave height (m) corresponding to the design condition of L-180, R and P, respectively, as given in **Table 3**

x_g: Longitudinal distance (m) from A.P. to the rotation centre of pitch motion (=0.45L)

x_t: Longitudinal distance (m) from A.P. to the centre of gravity of the tank being considered

y_t: Transverse horizontal distance (m) from the centreline of the ship to the centre of gravity of the tank being considered

y_c: Transverse horizontal distance (m) from the centre of gravity in the breadth of the tank to the longitudinal being considered

z_c: Vertical distance (m) from the tank top to the longitudinal being considered

Table 5 Acceleration of the Centre of Gravity of Ship

Heave (m/s^2)	Roll ($rad./s^2$)	Pitch ($rad./s^2$)
$a_h = \frac{3g(V+5)^{0.2}}{B^{0.6}L^{0.6}\sqrt{C_b}}H_4$	For tankers, ore carriers and bulk carriers $a_r = \frac{4H_3}{T_R\sqrt{B}}\left(\frac{2\pi}{T_R}\right)^2$ For container carriers $a_r = \frac{4H_3}{T_E\sqrt{B}}\left(\frac{2\pi}{T_R}\right)^2$	$a_p = \frac{3(V+5)^{0.2}H_1}{L^{1.2}\sqrt{C_b}}\left(\frac{2\pi}{T_p}\right)^2$

Table 6 Stress due to Acceleration of Liquid in Tanks and Bulk Cargo in Holds

Design Condition		Load due to acceleration of liquid in tanks and bulk cargo in holds P_{Tj} (kN/m^2)		Stress σ_{Tj} (N/mm^2)
1	L-180	Liquid: $\rho_c\left(\frac{d_i}{d_f}a_h+\lvert x_t-x_g\rvert a_p\right)z_c$	Bulk Cargo: $0.75C_P\rho_c\left(\frac{d_i}{d_f}a_h+\lvert x_t-x_g\rvert a_p\right)z_c$	
2	R	For tankers, ore carriers and bulk carriers Liquid: $\rho_c\left\{\left(\frac{\sqrt{L}}{40}a_h+y_t a_r\right)z_c+\left(\frac{4gH_3}{T_R\sqrt{B}}\right)y_c\right\}$ For container carriers Liquid: $\rho_c\left[\left\{\left(0.7-0.6\frac{d_i}{d_f}\right)a_h+y_t a_r\right\}z_c+\left(\frac{4gH_3}{T_E\sqrt{B}}\right)y_c\right]$	Bulk Cargo $\rho_c\left\{0.75C_P\left(\frac{\sqrt{L}}{40}a_h+y_t a_r\right)z_c+0.25\left(\frac{4gH_3}{T_R\sqrt{B}}\right)y_c\right\}$	sgn $\left(1000\frac{C_C P_{Tj} S l^2}{12 Z C_{cor}}\right)$
3	P	For tankers, ore carriers and bulk carriers Liquid: $\rho_c\left\{(a_h+0.5y_t a_r)z_c+0.5\left(\frac{4gH_3}{T_R\sqrt{B}}\right)y_c\right\}$ For container carriers Liquid: $\rho_c\left\{(a_h+0.5y_t a_r)z_c+0.5\left(\frac{4gH_3}{T_E\sqrt{B}}\right)y_c\right\}$	Bulk Cargo: $\rho_c\left\{0.75C_P(a_h+0.5y_t a_r)z_c+0.25\left(0.5\frac{4gH_3}{T_R\sqrt{B}}\right)y_c\right\}$	

2.1.4 Stress due to Longitudinal Bending Moment in Still Water

Stress due to longitudinal bending moment in still water σ_{SH} is determined according to the following equation:

$$\sigma_{SH}=1000\ C_a\frac{M_S}{Z_V C_Z}\frac{z_h}{f}\quad (N/mm^2)$$

M_S: Longitudinal bending moment (kN-m) in still water at the position being considered

This moment is to be calculated for both the full load condition and ballast condition, respectively.

Z_V: Section modulus (cm^3) about the transverse neutral axis of the cross section being considered at the bottom

z_h: Vertical distance (m) from the neutral axis of the cross section being considered to the subject position

f: Vertical distance (m) from the base line to the neutral axis of the cross section being considered

C_a: Stress concentration factor is taken as 1.25.

C_Z: Coefficient considered corrosion is taken as 0.95.

2.1.5 Stress due to Wave Induced Longitudinal Bending Moment and Horizontal Bending Moment

1 Stress due to wave induced longitudinal bending moment σ_{WVH} is determined according to the following equation.

$$\sigma_{WVH}=1000C_a\frac{(M_{wv,hogging}+M_{wv,sagging})}{2Z_V C_Z}\frac{z_h}{f}\quad (N/mm^2)$$

Z_V, z_h, f and C_a are determined according to 2.1.4.

$$M_{wv,hogging}=0.19C_1C_2L_1^2BC_b\quad (kN\text{-}m)$$

$$M_{wv,sagging}=0.11C_1C_2L_1^2B(C_b+0.7)\quad (kN\text{-}m)$$

C_1, L_1 and B are determined according to 2.1.2, C_b is determined according to 2.1.3 and C_a is determined according to 2.1.4.

C_2: Coefficient specified along the length at the section under consideration determined by liner interpolation using the following values

For $x_P = 0$ (at aft perpendicular) and $x_P = L$ (at fore perpendicular), the value is taken as 0.

For $x_P = 0.4L$ through $0.65L$, the value is taken as 1.

C_Z: Coefficient of corrosion being considered is taken as 0.95.

2 Stress due to wave induced wave horizontal moment σ_{WHH} is determined according to the following equation.

$$\sigma_{WHH} = 1000 C_a \frac{0.32 C_1 C_3 L_1^2 d_i \sqrt{(L_1 - 35)/L_1}}{Z_H C_Z} \frac{2y'}{B} \quad (N/mm^2)$$

C_1, L_1, B, d_i and y' are determined according to **2.1.2**.

C_a and C_Z are determined according to **2.1.4**.

C_3: Coefficient specified along the length at the section under consideration determined by liner interpolation using the following values.

For $x_P = 0$ (at aft perpendicular) and $x_P = L$ (at fore perpendicular), the value is taken as 0.

For $x_P = 0.35L$ through $0.65L$, the value is taken as 1.

Z_H: The section modulus (cm^3) about the vertical neutral axis of the considered cross section at ship's side

3 Variable stress due to hull girder moment is according to the following equation.

$$\sigma_{WV} = \sqrt{\sigma_{WVH}^2 + \sigma_{WHH}^2 / 2} \quad (N/mm^2)$$

2.1.6 Superimposition of Stress

1 Stress due to wave pressure, stress due to acceleration of liquid in tank and bulk cargo in hold and stress due to hull girder moment are superimposed in accordance with **Table 7**.

2 The long-term distribution of stress range is regarded as an exponential distribution and the maximum value of the stress range calculated in **2.1.2**, **2.1.3** and **2.1.5** are regarded as the response value corresponding to the exceedance probability of 10^{-4}.

Table 7 Superimposition Ratio of Stress

Design condition		Stress due to wave pressure	Stress due to acceleration of liquid in tank and bulk cargo in hold	Stress due to hull girder moment
L-180	Full load condition	-0.5	-1	1
	Ballast condition	0.8	-0.8	1
L-0	Full load condition	1	-	1
	Ballast condition	1	-	1
R	Full load condition	1	1	-
	Ballast condition	1	1	-
P	Full load condition	1*1	1*1	0.4
	Ballast condition	1*2	1*2	0.8

Notes:

*1 Where the sum of the stress due to wave pressure and 0.7 times the stress due to acceleration of liquid in tank and bulk cargo in hold is less than 0.7 times the stress due to wave pressure, the sum is to be taken as 0.7 times the stress due to wave pressure.

*2 Where the sum of the stress due to wave pressure and 0.7 times the stress due to acceleration of liquid in tank and bulk cargo in hold is less than 0.8 times the stress due to wave pressure, the sum is to be taken as 0.8 times the stress due to wave pressure.

2.2 Evaluation of Stress of Longitudinal Penetrating Ordinary Transverse Bulkheads

2.2.1 Design Load

The design load which is separately specified in "Guideline for Fatigue Strength Assessment" is to be used.

2.2.2 Stress due to Variable Load

Stress due to variable load is according to the following equation.

$$\sigma_{dv} = 1000\frac{P_{dv}}{12ZC_{cor}}Sl^2 \quad (N/mm^2)$$

P_{dv}: Valuable load (kN/m^2) obtained from 2.2.1

Z, S, l and C_{cor} are determined according to 2.1.1.

2.2.3 Additional Stress due to Relative Displacement

1 Relative displacement is the difference in calculated displacement caused by loads induced by wave troughs and crests or weather side and lee side in full load condition and ballast condition at locations where longitudinals penetrate transverse webs or floors just near the transverse bulkhead or watertight floor. This displacement is determined by direct strength analysis carried out in accordance with the "Guidance for Fatigue Strength Assessment."

2 Additional stress due to relative displacement σ_{ri} or σ_{rj} is according to the equation given below. The subscript i means that the displacement occurs in the transverse webs or floors forward of the transverse bulkhead or watertight floor and the subscript j means that the displacement occurs in the transverse webs or floors aft of the transverse bulkhead or watertight floor.

$$\sigma_{ri}\ or\ \sigma_{rj} = \frac{1.95(\delta_i\ or\ \delta_j)EI}{Zl^2C_{cor}} \times 10^{-5} \quad (N/mm^2)$$

δ_i or δ_j are applied in the athwartship direction to the longitudinals in close proximity of direction i or j of the transverse bulkhead under consideration

E: Young's modulus of steel is taken as 2.06×10^5 (N/mm^2)

I: Moment of inertia (cm^4) of longitudinal

Z, C_{cor} and l are determined according to 2.1.1.

3 The estimated stress of the fatigue strength assessment is the greater of the values calculated by the following equations.

$$C_{c1}C_{3i}\sigma_{dv,j} + C_{3ii}\sigma_{ri} + C_{3ij}\sigma_{rj} \quad (N/mm^2)$$

$$C_{c1}C_{3j}\sigma_{dv,j} + C_{3ji}\sigma_{ri} + C_{3jj}\sigma_{rj} \quad (N/mm^2)$$

$\sigma_{dv,j}$ is determined according to 2.2.2, σ_{ri} and σ_{rj} are determined according to 2.2.3, and C_{c1} is determined according to 2.1.1.

C_{3i}, C_{3j}, C_{3ii}, C_{3ij}, C_{3ji} and C_{3jj} are stress concentration factors given in **Table 8**.

2.2.4 Stresses due to Static Load

Stresses due to hydrostatic pressure and longitudinal bending moment in still water are to be determined according to 2.1.1 and 2.1.4, respectively.

2.2.5 Stresses due to Wave Induced Longitudinal Bending Moment and Horizontal Bending Moment

Stresses due to wave induced longitudinal bending moment and horizontal bending moment are to be determined according to 2.1.5.

2.2.6 Evaluated Stresses

Evaluated stresses are the stress obtained from the appropriate superimposition of the stresses specified in 2.2.2 through 2.2.5.

2.2.7 Long-term Distribution of Stress Range

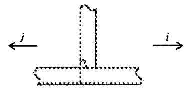
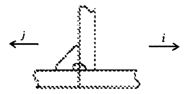
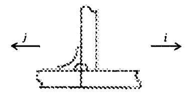
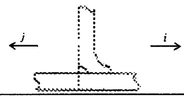
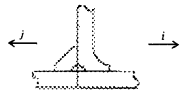
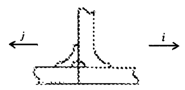
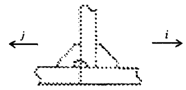
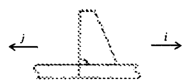
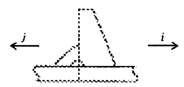
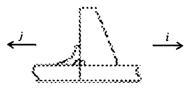
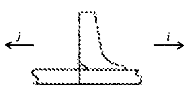
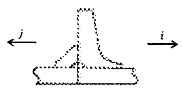
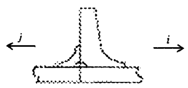
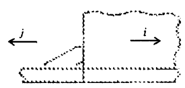
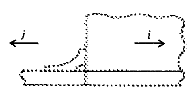
The stress range is the difference between the maximum stress and minimum stress estimated in 2.2.6, and the long-term distribution of the stress range is to be taken as an exponential distribution with a Weibull shape parameter of 1.0.

2.3 Effect of Corrosion

2.3.1 Effect of Corrosion

When the estimated stress is taken to be the stress of the subject member after taking into account the amount of scantling diminution due to corrosion in the application of 2.1 and 2.2 above, documents and supporting materials specifying the amount of scantling diminution due to corrosion considered, the method used to determine the estimated stress, and other pertinent items are to be submitted to the Society for approval.

Table 8 Stress Concentration Factors according to the Type of Intersection between Longitudinal and Ordinary Transverse Bulkheads[*1]

Type of intersection	C_{3i}	C_{3j}	C_{3ii}	C_{3ij}	C_{3ji}	C_{3jj}
	1.10	1.50	1.40	0.75	1.05	1.35
	1.40	0.90	1.50	1.05	1.00	1.25
	1.35	0.75	1.55	1.05	0.95	1.05
	0.60	1.50	1.00	0.85	1.10	1.35
	0.65	0.90	1.05	0.95	1.05	1.30
	0.65	0.75	1.05	0.90	0.95	1.10
	0.80	0.90	1.30	1.05	1.15	1.35
	0.55	1.55	1.25	0.70	1.00	1.60
	0.80	0.75	1.40	0.90	0.95	1.30
	0.80	0.60	1.35	0.85	0.85	1.10
	0.20	1.55	0.85	0.60	0.95	1.60
	0.35	0.75	0.90	0.75	0.95	1.30
	0.35	0.60	0.90	0.70	0.85	1.10
	-	0.80	-	-	-	0.95
	-	0.70	-	-	-	0.80

Note:

*1 When the type of intersection between the longitudinal and transverse web is other than those shown in **Table 8**, the documents related thereto are to be submitted to the Society for approval, and the stress concentration factor approved by the Society may be used.

3 Fatigue Strength Assessment

3.1 Calculation of Cumulative Fatigue Damage

3.1.1 Methods for Considering the Mean Stress Effect

1 Mean stress is determined according to the following equations.

For full load condition: $\sigma_{PS,Full} + \sigma_{SH,Full}$

For ballast condition: $\sigma_{PS,Ballast} + \sigma_{SH,Ballast}$

σ_{PS} is the stress due to hydrostatic pressure which is obtained from **2.1.1**.

σ_{SH} is the stress due to longitudinal bending moment in still water which is obtained from **2.1.4**.

2 Taking the stress at which the magnitude of the mean stress obtained from **-1** above is severe on the tension side as the mean stress in condition 1 σ_{m1} and taking the other stress as the mean stress in condition 2 σ_{m2}, modification considering the effect of the mean of stress is carried out by the following equations.

$$\Delta\sigma_{eq1} = \Delta\sigma_1^{0.6485}\left(350 - \frac{0.96\Delta\sigma^* - \Delta\sigma_1}{2}\right)^{1-0.6485}$$

$$\Delta\sigma\Delta\sigma_{eq2} = \begin{cases} \Delta\sigma_2{}^{0.6485}\left(350 - \frac{0.96\Delta\sigma^* - \Delta\sigma_2}{2} - (\sigma_{m1} - \sigma_{m2})\right)^{1-0.6485} \\ \quad ;\ 700 - \Delta\sigma^* > \sigma_{m1} - \sigma_{m2} \\ \Delta\sigma_2{}^{0.6485}\left(\frac{0.96\Delta\sigma^* + \Delta\sigma_2}{2} - 350\right)^{1-0.6485} \\ \quad ;\ 700 - \Delta\sigma^* \le \sigma_{m1} - \sigma_{m2} \end{cases}$$

σ_{m1} is the mean stress (N/mm^2) in condition 1

σ_{m2} is the mean stress (N/mm^2) in condition 2

$\Delta\sigma^*$ is the stress range (N/mm^2) in condition 1 which corresponds to the exceedance probability of 10^{-5}

$\Delta\sigma_i$ is the stress range (N/mm^2) for each condition

3.1.2 S-N Curves

S-N curves given by the following equations are used to assess the fatigue strength.

$$N = \begin{cases} C \cdot \Delta\sigma^{-m} & ;\ \Delta\sigma \ge (10^{-7} \cdot C)^{1/m} \\ C' \cdot \Delta\sigma^{-m'} & ;\ \Delta\sigma < (10^{-7} \cdot C)^{1/m} \end{cases}$$

$m = 4.63,\ C = 5.46 \times 10^{16},\ m' = 8.26,\ C' = 2.34 \times 10^{24}$

3.1.3 Calculation of Cumulative Fatigue Damage

Using the frequency distribution of the stress range obtained from **2.1.6-2** or **2.2.7**, cumulative fatigue damage is calculated using the following equations. In this case, the frequency distribution of the stress range is to be divided into an adequate number so that the cumulative fatigue damage can be calculated with sufficient accuracy.

$$D = D_1 + D_2$$

$$D_k = \sum_i \frac{n_i}{N_i} = \sum_i \frac{n_i}{C} \eta_v \Delta\sigma_{eq_i}{}^m$$

D_1: Cumulative fatigue damage at the condition 1

D_2: Cumulative fatigue damage at the condition 2

n_i: Number of cycles of stress range in the i-th block

σ_{eq}, C and m are obtained from **3.1.2**

η_v is the correction coefficient which depends on the type of ship and hull part where the longitudinal is fitted, as given in **Table 9**.

Table 9 Correction Coefficient

Type of Ship		Hull part where the longitudinal is fitted	η_v
Tanker		Side shell and bottom shell	0.5
		Other than the above	0.4
Ore Carrier and Bulk Carrier	$L \geq 200\ m$	Side shell and bottom shell	0.55
		Other than the above	0.45
	$L < 200\,m$	The value is determined at the discretion of the Society	
Container Carrier	Over Panamax	Side shell and bottom shell	0.5
		Other than the above	0.4
	Panamax	Side shell and bottom shell	0.35
		Other than the above	0.3
	Feeder	Side shell and bottom shell	0.3
		Other than the above	0.25

3.2 Evaluation of Cumulative Fatigue Damage

3.2.1 Evaluation of Cumulative Fatigue Damage

The fatigue strength is determined by the following equation.

$D \leq 0.6$

Annex C15.2.1 GUIDELINE FOR THE ASSESSMENT OF HULL GIRDER STRENGTH RELATING TO BALLSTING/DEBALLASTING

1.1 General

1.1.1 Application

This Annex provides general guidelines for the determination of loading conditions to be considered in the application of **32.2, Part C of the Rules** for ships subject to the requirements in **Chapter 32, Part C of the Rules** and **Chapter 15, Part C of the Rules**, for ships intended to be operated with partially filled ballast tanks and ships in which any ballasting and/or deballasting of ballast tanks is intended during voyages.

1.1.2 General Rules

1 Where a ballast tank(s) is filled partially during the voyage, it is presumed that the hull girder bending moment will exceed the designed hull girder bending moment in still water due to difficulties on precise control of the tank level and unexpected stress will act on the hull structures. Therefore, ships intending to operate with partially filled ballast tanks are required to comply with the requirements of hull girder strength even when filled to a level differing from the designed tank level.

2 For ships intending to ballast/deballast during the voyage, it is presumed that unexpected stress will act on hull structures according to the time when the ballasting/deballasting is conducted. Therefore, such ships are required either to be designed so as to comply with the requirements of hull girder strength even when the ballasting/deballasting operation is conducted at anytime during the voyage or the allowable times for the ballasting/deballasting operation are to be specified.

3 Not withstanding the provisions above, when the ship is loaded with cargo, the requirements specified in **-1** and **-2** may apply to the peak tanks only.

1.2 Guidelines for the Assessment of Hull Girder Strength

1.2.1 Loading Conditions to be Considered

1 Ships intending to operate with partially filled ballast tanks are required to be designed so as to comply with the requirements of hull girder strength specified in **32.2, Part C of the Rules** for ships subject to the requirements in **Chapter 32, Part C of the Rules** and **Chapter 15, Part C of the Rules**, when the ballast tanks are full and when they are empty. For this purpose, compliance with the hull girder strength requirements of **32.2, Part C of the Rules** for ships subject to the requirements in **Chapter 32, Part C of the Rules** and **Chapter 15, Part C of the Rules** is to be assessed for conditions just before and just after such ballasting/deballasting operation is conducted, for partially filled conditions, as well as when such ballast tanks are assumed empty or full. (Refer to **C15.2.1(4)**.)

2 Notwithstanding the provisions of **-1** above, for ore carriers defined in **1.3.1(13)(b), Part B of the Rules**, tank levels of "empty and full" referred to in **-1** above may be modified according to **C15.2.1(6)**.

3 For ships intending to ballast/deballast during the voyage, loading conditions corresponding to all steps of the ballasting/deballasting operation are to be included in the ships' loading manuals as intermediate conditions which are part of the standard loading conditions. For this purpose, "step" is a condition just before and just after a ballasting/deballasting operation for each tank. Such intermediate conditions are to be assessed in compliance with the requirements of **32.2, Part C of the Rules** for ships subject to the requirements in **Chapter 32, Part C of the Rules** and **Chapter 15, Part C of the Rules**. (Refer to **1.3.1-2 of Annex C34.1.2** and **C15.2.1(4)**)

4 Notwithstanding the provisions of **-3**, if comprehensive assessment on hull girder longitudinal strength is conducted so as to obtain operational flexibility regarding when ballasting/deballasting operations are made during the voyage, the intermediate conditions specified in **-3** above may be reduced or omitted appropriately.

5 In the application of the provisions in **-3** and **-4**, ships that have had their hull girder strength assessed on the condition that the times when ballasting/deballasting operations may be conducted are specified or limited, are to have the time parameters for ballasting/deballasting complying with the strength criteria and appropriate instructions regarding ballasting/deballasting based on these time parameters included in the loading manual.

6 Examples of relationships between loading conditions specified in the ships' loading manuals and those for the assessment of hull girder strength are given as the following **(1)** to **(4)**.

(1) Where no ballast tank is partially filled

For example, when loading conditions as shown in **(a)** are deemed as standard loading conditions, additional conditions are not required to be assessed.

(a) Loading conditions specified in the ship's loading manual

i) Departure (Consumables: 100%, No.6 WBT(P/S): 0%)

ii) Intermediate condition 1 (Consumables: 50%, No.6 WBT(P/S): 0%)

iii) Intermediate condition 2 (Consumables: 50%, No.6 WBT(P/S): 100%)

iv) Arrival (Consumables: 10%, No.6 WBT(P/S): 100%)

(2) Where ballasting/deballasting operations are permitted anytime during the voyage

For example, when loading conditions as shown in **(a)** are deemed standard loading conditions, additional conditions such as in **(b)** are required to be assessed.

(a) Loading conditions specified in the ship's loading manual

i) Departure (Consumables: 100%, No.6 WBT(P/S): 0%)

ii) Intermediate condition 1 (Consumables: 50%, No.6 WBT(P/S): 0%)

iii) Intermediate condition 2 (Consumables: 50%, No.6 WBT(P/S): 60%)

iv) Intermediate condition 3 (Consumables: 20%, No.6 WBT(P/S): 60%)

v) Intermediate condition 4 (Consumables: 20%, No.6 WBT(P/S): 100%)

vi) Arrival (Consumables: 10%, No.6 WBT(P/S): 100%)

(b) Additional loading conditions for the assessment of hull girder strength are to be as follows. Conditions **ii)** and **iii)** may be guaranteed by the assessment of conditions **i)** and **iv)** respectively, however it should be determined on a case by case basis.

i) Departure (Consumables: 100%, No.6 WBT(P/S): 100%)

ii) Intermediate condition 1/2 (Consumables: 50%, No.6 WBT(P/S): 100%)

iii) Intermediate condition 3/4 (Consumables: 20%, No.6 WBT(P/S): 0%)

iv) Arrival (Consumables: 10%, No.6 WBT(P/S): 0%)

(3) Where ballasting/deballasting operations are permitted only at certain times during the voyage

For example, when loading conditions as shown in **(a)** are deemed as standard loading conditions and ballasting/deballasting operations are assumed to be made when remaining consumables reach levels of 50% and 20%, additional conditions such as in **(b)** are required to be assessed. It is to be noted in the ship's loading manual that the timing for ballasting/deballasting is assumed to take place when the remaining consumables are at 50% and 20% for the purpose of complying with the hull girder strength requirements and for ballasting/deballasting at other times, the hull girder strength of the ship is to be assessed while carefully noting the filling level of the ballast tanks .

(a) Loading conditions specified in the ship's loading manual

i) Departure (Consumables: 100%, No.6 WBT(P/S): 0%)

ii) Intermediate condition 1 (Consumables: 50%, No.6 WBT(P/S): 0%)

iii) Intermediate condition 2 (Consumables: 50%, No.6 WBT(P/S): 60%)

iv) Intermediate condition 3 (Consumables: 20%, No.6 WBT(P/S): 60%)

v) Intermediate condition 4 (Consumables: 20%, No.6 WBT(P/S): 100%)

vi) Arrival (Consumables: 10%, No.6 WBT(P/S): 100%)

(b) Additional loading conditions for the assessment of hull girder strength are to be as follows.

i) Intermediate condition 1/2 (Consumables: 50%, No.6 WBT(P/S): 100%)

ii) Intermediate condition 3/4 (Consumables: 20%, No.6 WBT(P/S): 0%)

(4) Where an ore carrier conducts ballasting/deballasting operations on 2 pairs of ballast tanks only at certain times during the voyage

For example, when loading conditions as shown in **(a)** are deemed standard loading conditions and ballasting/deballasting operations are assumed to be made when remaining consumables reach levels of 50% and 20%, additional conditions such as in **(b)** are required to be assessed. It is to be noted in the ship's loading manual that the timing for ballasting/deballasting is assumed to take place when the remaining consumables are at 50% and 20% for the purpose of complying with the hull girder strength requirements and for ballasting/deballasting at other times the hull girder strength of the ship is to be assessed while carefully noting the filling level of the ballast tanks.

(a) Loading conditions specified in the ship's loading manual
   i) Departure (Consumables: 100%, No.1 WBT(P/S): 60%, No.5 WBT(P/S): 30%)
   ii) Intermediate condition 1 (Consumables: 50%, No.1 WBT(P/S): 60%, No.5 WBT(P/S): 30%)
   iii) Intermediate condition 2 (Consumables: 50%, No.1 WBT(P/S): 30%, No.5 WBT(P/S): 50%)
   iv) Intermediate condition 3 (Consumables: 20%, No.1 WBT(P/S): 30%, No.5 WBT(P/S): 50%)
   v) Intermediate condition 4 (Consumables: 20%, No.1 WBT(P/S): 10%, No.5 WBT(P/S): 70%)
   vi) Arrival (Consumables: 10%, No.1 WBT(P/S): 10%, No.5 WBT(P/S): 70%)

(b) Additional loading conditions for the assessment of hull girder strength are to be as follows. "Max." and "Min." in the following conditions refer to the maximum and minimum filling levels specified in **C15.2.1(6)**.
   i) Departure (Consumables: 100%, No.1 WBT(P/S): 60%, No.5 WBT(P/S): 30%)
      1) Consumables: 100%, No.1 WBT(P/S): 60%, No.5 WBT(P/S): Max.
      2) Consumables: 100%, No.1 WBT(P/S): 60%, No.5 WBT(P/S): Min.
      3) Consumables: 100%, No.1 WBT(P/S): 100%, No.5 WBT(P/S): Max.
      4) Consumables: 100%, No.1 WBT(P/S): 100%, No.5 WBT(P/S): Min.
      5) Consumables: 100%, No.1 WBT(P/S): 0%, No.5 WBT(P/S): Max.
      6) Consumables: 100%, No.1 WBT(P/S): 0%, No.5 WBT(P/S): Min.
      7) Consumables: 100%, No.1 WBT(P/S): Max., No.5 WBT(P/S): 30%
      8) Consumables: 100%, No.1 WBT(P/S): Min., No.5 WBT(P/S): 30%
      9) Consumables: 100%, No.1 WBT(P/S): Max., No.5 WBT(P/S): 100%
      10) Consumables: 100%, No.1 WBT(P/S): Min., No.5 WBT(P/S): 100%
      11) Consumables: 100%, No.1 WBT(P/S): Max., No.5 WBT(P/S): 0%
      12) Consumables: 100%, No.1 WBT(P/S): Min., No.5 WBT(P/S): 0%
   ii) Intermediate condition 1 (Consumables: 50%, No.1 WBT(P/S): 60%, No.5 WBT(P/S): 30%)
      1) Consumables: 50%, No.1 WBT(P/S): 60%, No.5 WBT(P/S): Max.
      2) Consumables: 50%, No.1 WBT(P/S): 60%, No.5 WBT(P/S): Min.
      3) Consumables: 50%, No.1 WBT(P/S): 100%, No.5 WBT(P/S): Max.
      4) Consumables: 50%, No.1 WBT(P/S): 100%, No.5 WBT(P/S): Min.
      5) Consumables: 50%, No.1 WBT(P/S): 0%, No.5 WBT(P/S): Max.
      6) Consumables: 50%, No.1 WBT(P/S): 0%, No.5 WBT(P/S): Min.
      7) Consumables: 50%, No.1 WBT(P/S): Max., No.5 WBT(P/S): 30%
      8) Consumables: 50%, No.1 WBT(P/S): Min., No.5 WBT(P/S): 30%
      9) Consumables: 50%, No.1 WBT(P/S): Max., No.5 WBT(P/S): 100%
      10) Consumables: 50%, No.1 WBT(P/S): Min., No.5 WBT(P/S): 100%
      11) Consumables: 50%, No.1 WBT(P/S): Max., No.5 WBT(P/S): 0%
      12) Consumables: 50%, No.1 WBT(P/S): Min., No.5 WBT(P/S): 0%
   iii) Intermediate condition 2 (Consumables: 50%, No.1 WBT(P/S): 30%, No.5 WBT(P/S): 50%)
      1) Consumables: 50%, No.1 WBT(P/S): 30%, No.5 WBT(P/S): Max.
      2) Consumables: 50%, No.1 WBT(P/S): 30%, No.5 WBT(P/S): Min.
      3) Consumables: 50%, No.1 WBT(P/S): Max., No.5 WBT(P/S): 50%
      4) Consumables: 50%, No.1 WBT(P/S): Min., No.5 WBT(P/S): 50%
   iv) Intermediate condition 3 (Consumables: 20%, No.1 WBT(P/S): 30%, No.5 WBT(P/S): 50%)
      1) Consumables: 20%, No.1 WBT(P/S): 30%, No.5 WBT(P/S): Max.
      2) Consumables: 20%, No.1 WBT(P/S): 30%, No.5 WBT(P/S): Min.
      3) Consumables: 20%, No.1 WBT(P/S): 100%, No.5 WBT(P/S): Max.
      4) Consumables: 20%, No.1 WBT(P/S): 100%, No.5 WBT(P/S): Min.

5) Consumables: 20%, No.1 WBT(P/S): 0%, No.5 WBT(P/S): Max.
6) Consumables: 20%, No.1 WBT(P/S): 0%, No.5 WBT(P/S): Min.
7) Consumables: 20%, No.1 WBT(P/S): Max., No.5 WBT(P/S): 50%
8) Consumables: 20%, No.1 WBT(P/S): Min., No.5 WBT(P/S): 50%
9) Consumables: 20%, No.1 WBT(P/S): Max., No.5 WBT(P/S): 100%
10) Consumables: 20%, No.1 WBT(P/S): Min., No.5 WBT(P/S): 100%
11) Consumables: 20%, No.1 WBT(P/S): Max., No.5 WBT(P/S): 0%
12) Consumables: 20%, No.1 WBT(P/S): Min., No.5 WBT(P/S): 0%

v) Intermediate condition 4 (Consumables: 20%, No.1 WBT(P/S): 10%, No.5 WBT(P/S): 70%)
1) Consumables: 20%, No.1 WBT(P/S): 10%, No.5 WBT(P/S): Max.
2) Consumables: 20%, No.1 WBT(P/S): 10%, No.5 WBT(P/S): Min.
3) Consumables: 20%, No.1 WBT(P/S): Max., No.5 WBT(P/S): 70%
4) Consumables: 20%, No.1 WBT(P/S): Min., No.5 WBT(P/S): 70%

vi) Arrival (Consumables: 10%, No.1 WBT(P/S): 10%, No.5 WBT(P/S): 70%)
1) Consumables: 10%, No.1 WBT(P/S): 10%, No.5 WBT(P/S): Max.
2) Consumables: 10%, No.1 WBT(P/S): 10%, No.5 WBT(P/S): Min.
3) Consumables: 10%, No.1 WBT(P/S): 100%, No.5 WBT(P/S): Max.
4) Consumables: 10%, No.1 WBT(P/S): 100%, No.5 WBT(P/S): Min.
5) Consumables: 10%, No.1 WBT(P/S): 0%, No.5 WBT(P/S): Max.
6) Consumables: 10%, No.1 WBT(P/S): 0%, No.5 WBT(P/S): Min.
7) Consumables: 10%, No.1 WBT(P/S): Max., No.5 WBT(P/S): 70%
8) Consumables: 10%, No.1 WBT(P/S): Min., No.5 WBT(P/S): 70%
9) Consumables: 10%, No.1 WBT(P/S): Max., No.5 WBT(P/S): 100%
10) Consumables: 10%, No.1 WBT(P/S): Min., No.5 WBT(P/S): 100%
11) Consumables: 10%, No.1 WBT(P/S): Max., No.5 WBT(P/S): 0%
12) Consumables: 10%, No.1 WBT(P/S): Min., No.5 WBT(P/S): 0%

Annex C20.2 BUCKLING STRENGTH ASSESSMENT OF SHIP STRUCTURAL ELEMENTS

1 Application and Definitions

Symbols

EPP : Elementary Plate Panel, as specified in **1.2.3.1**

PSM : Primary Supporting Member

SP : Stiffened Panel, as specified in **1.2.3.3**

UP : Unstiffened Panel, as specified in **1.2.3.3**

1.1 Application

1.1.1 General

1.1.1.1

This annex specifies a general buckling assessment procedure and is to be applied in conjunction with relevant requirements.

1.1.2 Overview

1.1.2.1

The buckling checks are to be performed according to

1: General definitions regarding buckling capacity, allowable buckling utilisation factors and buckling check criteria.

2: The slenderness requirements of longitudinal and transverse stiffeners.

3: The prescriptive buckling requirements of plates, longitudinal and transverse stiffeners, primary supporting members and other structures subject to hull girder stresses.

4: Direct strength analysis (usually by finite element method) buckling requirements of hatch cover structural members including plates, stiffeners and primary supporting members.

5: The determination of buckling capacities of plate panels, stiffeners, primary supporting members and column structures.

1.1.2.2 Buckling Assessment

For the buckling assessment of a ship hull girder, a hatch cover or some structural component, the slenderness requirements as specified in 2, and the buckling requirements as specified in 3 or 4 are to be checked as per the requirements of the applicable relevant requirements.

1.1.2.3 Alternative Methods

This annex contains the general methods for the determination of buckling capacities of plate panels, stiffeners, primary supporting members, and columns. For special cases not covered in this annex, such as a whole plate structure with stiffeners in two directions (i.e. a stiffened panel with both primary and secondary stiffeners), other more advanced methods, such as finite element analysis methods, can be used as deemed appropriate by the Society.

1.2 Terms and Assumptions

1.2.1 Buckling

1.2.1.1 Buckling Strength

Buckling strength or capacity refers to the strength of a structure under in-plane compressions and/or shear and lateral load. Buckling strength with consideration of the buckling behavior in **1.2.1.2** gives a lower bound estimate of ultimate capacity, or the maximum load a structural member can carry without suffering major permanent set.

For each structural member, its buckling strength is to be taken as corresponding to the most unfavourable or critical buckling mode.

1.2.1.2 Buckling Behaviour

Buckling strength assessment takes into account both elastic buckling and post-buckling behaviours. Post-buckling can consider the internal redistribution of loads depending on the load situation, slenderness and type of structure. Such as for the buckling assessment of plates, generally its positive elastic post-buckling effect can be utilised.

As such, for slender structures, the calculated buckling strength is typically higher than the ideal elastic buckling stress (minimum eigenvalue). Accepting elastic buckling of slender plate panels implies that large elastic deflections and reduced in-plane stiffness may occur at higher buckling utilisation levels.

1.2.2 Net Scantling Approach

1.2.2.1 General

Unless otherwise specified, all the scantling requirements, including slenderness requirements, in this annex are based on net scantlings obtained by removing full corrosion addition t_c from the gross offered thicknesses.

1.2.2.2 Corrosion Addition

Corrosion addition t_c referred in this annex is defined in the relevant requirements.

1.2.2.3 Stress Calculation Models

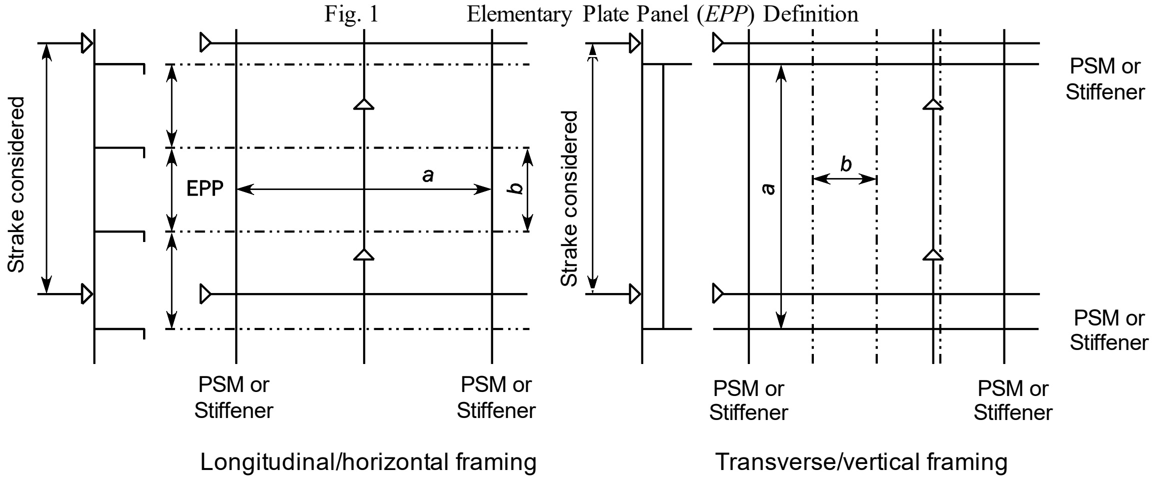
The structural models used for the calculation of stresses to be applied for buckling assessment, which are usually based on net scantlings, are defined in the relevant requirements.

1.2.3 Structural Idealisation

1.2.3.1 Elementary Plate Panel

An elementary plate panel (*EPP*) is the unstiffened part of the plating between stiffeners and/or primary supporting members. The plate panel length, a, and breadth, b, of the *EPP* are defined respectively as the longest and shortest plate edges, as shown in **Fig. 1**.

Fig. 1 Elementary Plate Panel (*EPP*) Definition



1.2.3.2 Standard Types of Stiffeners

Definitions of the cross-sectional dimensions of typical stiffener types are shown in **Fig. 2**, which are flat bars, bulb flats, angles, L2 and T bars. If applicable, other types of stiffeners can be idealised to one of the typical types in **Fig. 2** for buckling check. For the U-type stiffener which is usually fitted in some hatch covers, the definition of its cross-sectional dimensions is shown in **Fig. 3**.

Unless otherwise specified, the full span or full length ℓ (mm) of a stiffener is to be used for buckling check, which equals to the spacing between primary supporting members.

Symbolic dimensions of the cross-sections are as below:

b_1 : Width (mm) of the attached plate enclosed by the U-type stiffener, as shown in **Fig. 3**.

b_2 : Width (mm) of the attached plate between adjacent U-type stiffeners, as shown in **Fig. 3**.

b_f : Width (mm) of the flange or face plate of the stiffener, as shown in **Fig. 2** and **Fig. 3**.

b_{f-out}: Maximum distance (mm) from mid thickness (mm) of the web to the flange edge, as shown in **Fig. 2**.

d_f: Breadth (mm) of the extended part of the flange for L2 profiles, as shown in **Fig. 2**.

e_f: Distance (mm) from attached plating to centre of flange, as shown in **Fig. 2**. For its detailed definition, refer to **5 Symbols**.
h_w: Depth (mm) of stiffener web, as shown in **Fig. 2** and **Fig. 3**.
t_f: Net flange thickness (mm).
t_p: Net thickness of plate (mm).
t_w: Net web thickness (mm).

Fig. 2 Dimensions of Typical Stiffener Cross Sections

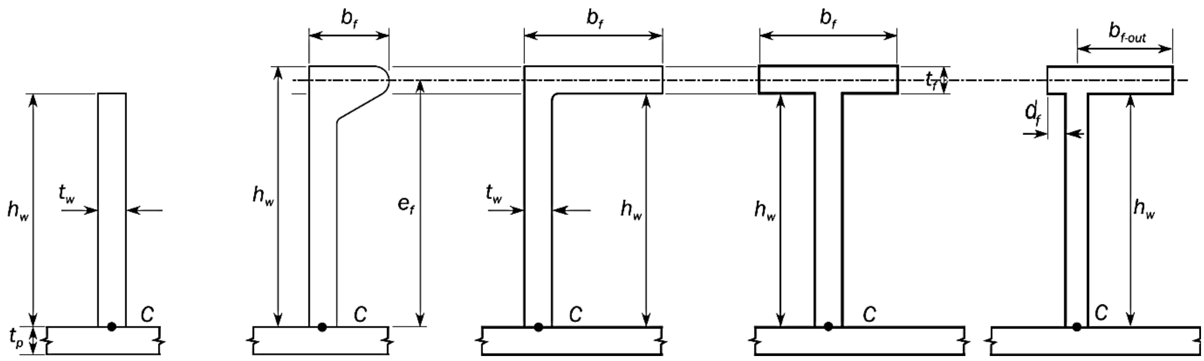
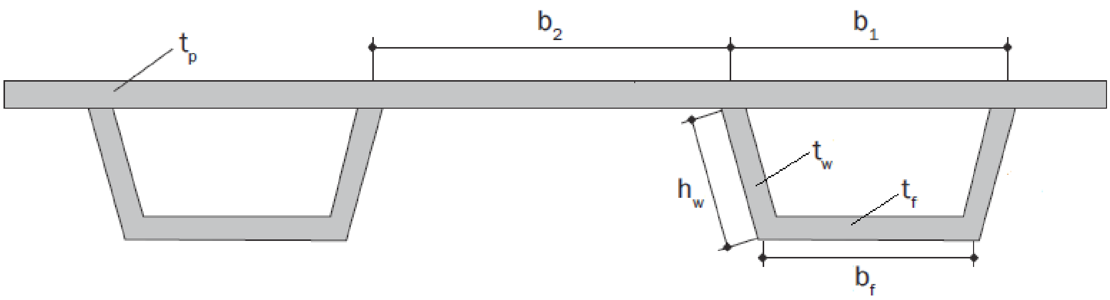


Fig. 3 Dimensions of a U-type Stiffener Cross Section



1.2.3.3 Stiffened Panel (SP) and Unstiffened Panel (UP)

For a panel with relatively strong interactive effect between the stiffener and its attached plate, each stiffener with its attached plate as a whole is to be modelled as a stiffened panel (*SP*), so as to be able to consider both of its local and global buckling modes.

However, for an *EPP*, if its buckling strength can be checked without considering its interactive effect with stiffeners fitted along its edges, it's to be modelled as an unstiffened panel (*UP*).

1.2.4 Sign Convention

1.2.4.1 Stresses

In this annex, compressive and shear stresses are to be taken as positive, tension stresses are to be taken as negative.

1.3 Assessment Methods and Acceptance Criteria

1.3.1 Assessment Methods

1.3.1.1 Method A and Method B

The buckling assessment is to be carried out according to one of the following two methods taking into account different boundary condition types:

- Method A: All the edges of the *EPP* are forced to remain straight (but free to move in the in-plane directions) due to the surrounding structure/neighbouring plates.
- Method B: The edges of the *EPP* are not forced to remain straight due to low in-plane stiffness at the edges and/or no

surrounding structure/neighbouring plates.

1.3.1.2 SP-A, SP-B, UP-A and UP-B Models

For the buckling assessment of the stiffened panel (*SP*) and unstiffened panel (*UP*) structural models defined in **1.2.3.3**, with application of either Method A or Method B for the plate buckling assessment, the following four buckling assessment models are established:

- SP-A: a stiffened panel with application of Method A
- SP-B: a stiffened panel with application of Method B
- UP-A: an unstiffened panel with application of Method A
- UP-B: an unstiffened panel with application of Method B

1.3.2 Buckling Utilisation Factor

1.3.2.1

The utilisation factor, η, is defined as the ratio between the applied loads and the corresponding buckling capacity.

1.3.2.2

For combined loads, the utilisation factor, η_{act}, is to be defined as the ratio of the applied equivalent stress and the corresponding buckling capacity, as shown in **Fig. 4**, and is to be taken as:

$$\eta_{act} = \frac{W_{act}}{W_U} = \frac{1}{\gamma_c}$$

Where:

W_{act} : Equivalent applied stress. The actual applied stresses are given in **3** and **4** respectively for buckling assessment by prescriptive and direct strength analysis.

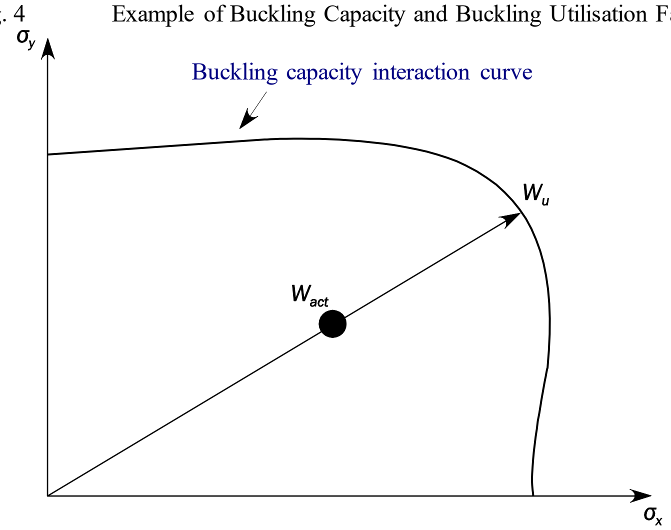
W_u : Equivalent buckling capacity. For plates and stiffeners, their respective buckling or ultimate capacities are given in **5**.

γ_c: Stress multiplier factor at failure.

For each typical failure mode, the corresponding buckling capacity of the panel is calculated by applying the actual stress combination and then increasing or decreasing the stresses proportionally until collapse occurs, i.e. when the increased or decreased stresses are on a buckling strength interaction curve or surface.

Fig. 4 illustrates the buckling capacity and the buckling utilisation factor of a structural member subject to σ_x and σ_y stresses.

Fig. 4 Example of Buckling Capacity and Buckling Utilisation Factor



1.3.3 Allowable Buckling Utilisation Factor

1.3.3.1

The allowable buckling utilisation factor η_{all} is to be taken according to the relevant requirements.

1.3.4 Buckling Acceptance Criteria

1.3.4.1

A structural member is considered to have an acceptable buckling strength if it satisfies the following criterion:

$$\eta_{act} \leq \eta_{all}$$

Where:

η_{act}: Buckling utilisation factor based on the applied stress, defined in **1.3.2.2**.

η_{all}: Allowable buckling utilisation factor as defined in **1.3.3.1**.

2 Slenderness Requirements

Symbols

For symbols not defined in this section, refer to **1.2.3.2**.

σ_Y: Specified minimum yield stress (N/mm^2) of the structural member being considered

2.1 General

2.1.1 Introduction

2.1.1.1

The stiffener elements except for U-type stiffeners are to comply with the applicable slenderness and proportion requirements given in **2**.

2.2 Stiffeners

2.2.1 Proportions of Stiffeners

2.2.1.1 Net Thickness of All Stiffener Types

The net thickness of stiffeners is to satisfy the following criteria:

(a) Stiffener web plate:

$$t_w \geq \frac{h_w}{C_w}\sqrt{\frac{\sigma_Y}{235}}$$

(b) Flange:

$$t_f \geq \frac{b_{f-out}}{C_f}\sqrt{\frac{\sigma_Y}{235}}$$

C_w, C_f: Slenderness coefficients given in **Table 1**

If requirement **(b)** is not fulfilled, the effective free flange outstand (mm) used in strength assessment including the calculation of actual net section modulus, is to be taken as:

$$b_{f-out-max} = C_f t_f \sqrt{\frac{235}{\sigma_Y}}$$

Table 1 Slenderness Coefficients

Type of Stiffener	C_w	C_f
Angle and L2 bars	75	12
T-bars	75	12
Bulb flats	45	-
Flat bars	22	-

For built-up profile where the relevant yielding strength for the web of built-up profile without the edge stiffener is acceptable, as an alternative the web can be assessed according to the web requirements of Angle and L2 bars in **Table 1**, and the edge stiffener can be assessed as a flat bar stiffener according to **2.2.1.1**. The requirement to flange in **2.2.1.2** is to apply.

2.2.1.2 Net Dimensions of Angle and T-Bars

The total flange breadth b_f (mm) for angle and T-bars is to satisfy the following criterion:

$$b_f \geq 0.2 h_w$$

2.3 Primary Supporting Members

2.3.1 Proportions and Stiffness

2.3.1.1 Proportions of Web Plate and Flange

The scantlings of webs and flanges of primary supporting members are to comply with the relevant requirements.

3 Buckling Requirements for Hull Girder

Symbols

η_{all}: Allowable buckling utilisation factor, as defined in **1.3.3.1**

LCP: Load Calculation Point as defined in **3.1.2.1**

3.1 General

3.1.1 Introduction

3.1.1.1

This section applies to plate panels including plane and curved plate panels, stiffeners and corrugation of longitudinal corrugated bulkheads subject to hull girder compression and shear stresses.

3.1.1.2

The ship longitudinal extent where the buckling check is performed for structural elements subject to hull girder stresses is to be in accordance with the relevant requirements.

3.1.1.3 Design Load Sets

The buckling check is to be performed for all design load sets corresponding to the design loading conditions defined in the relevant requirements with most unfavourable pressure combinations.

For each design load set, for all static and dynamic load cases, the lateral pressure is to be determined at the load calculation point defined in **3.1.2.1**, and is to be applied together with the hull girder stress combinations defined in the relevant requirements.

3.1.2 Definitions

3.1.2.1 Load Calculation Point

The load calculation points (*LCP*) for both elementary plate panels (*EPP*) and stiffeners are defined as follows:

(a) *LCP* for hull girder stresses of *EPP*

The hull girder stresses for *EPP* are to be calculated at the load calculation points defined in **Table 2**.

(b) *LCP* for hull girder stresses of longitudinal stiffeners

The hull girder stresses for longitudinal stiffeners are to be calculated at the following load calculation point:

- at the mid length of the considered stiffener
- at the intersection point between the stiffener and its attached plate

(c) *LCP* for pressure of horizontal stiffeners

The load calculation point for the pressure is located at:

- Middle of the full length, ℓ, of the considered stiffener
- The intersection point between the stiffener and its attached plate

(d) *LCP* for pressure of non-horizontal stiffeners

The lateral pressure, P is to be calculated as the maximum between the value obtained at middle of the full length, ℓ, and the value obtained from the following formulae:

$P = \frac{p_U + p_L}{2}$ when the upper end of the vertical stiffener is below the lowest zero pressure level.

$P = \frac{\ell_1}{\ell}\frac{p_L}{2}$ when the upper end of the vertical stiffener is at or above the lowest zero pressure level, see **Fig. 6**.

Where:

ℓ_1: Distance (m) between the lower end of vertical stiffener and the lowest zero pressure level.

p_U, p_L: Lateral pressures at the upper and lower end of the vertical stiffener span ℓ, respectively.

Fig. 5 *LCP* for Plate Buckling Assessment

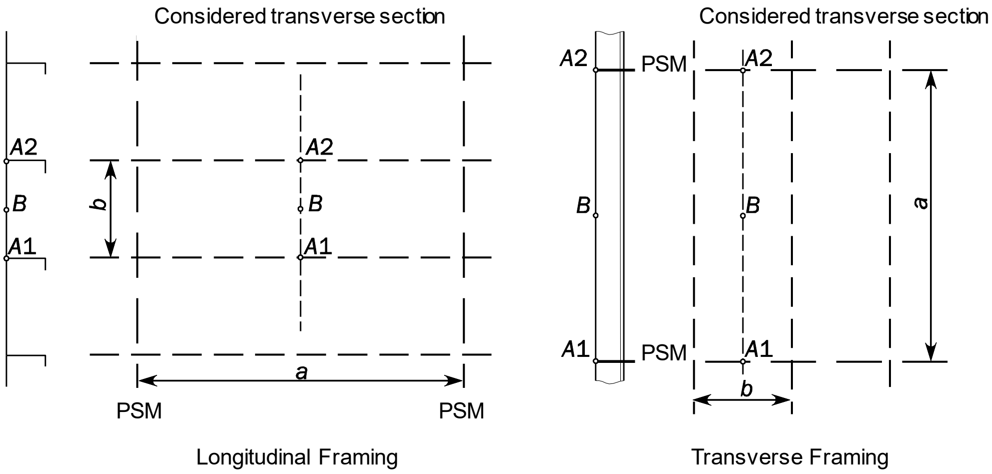


Fig. 6 Definition of Pressure for Vertical Stiffeners

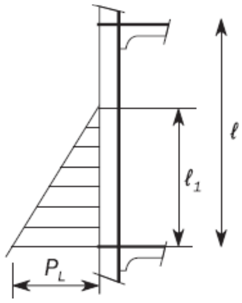


Table 2 Load Calculation Points (*LCP*) Coordinates for Plate Buckling Assessment

LCP coordinates	Hull girder bending stress		Hull girder shear stress
	Non horizontal plating	Horizontal plating	
x coordinate	Mid-length of the *EPP*		
y coordinate	Both upper and lower ends of the *EPP* (points *A*1 and *A*2 in **Fig. 5**)	Outboard and inboard ends of the *EPP* (points *A*1 and *A*2 in **Fig. 5**)	Mid-point of *EPP* (point *B* in **Fig. 5**)
z coordinate	Corresponding to *x* and *y* values		

3.1.3 Assumptions for Equivalent Plate Panels

3.1.3.1 Longitudinal Stiffening with Varying Plate Thickness

In longitudinal stiffening arrangement, when the plate thickness varies over the width b, of a plate panel, the buckling check is to be performed for an equivalent plate panel width, combined with the smaller plate thickness, t_1. The width (*mm*) of this equivalent plate panel, b_{eq} is defined by the following formula:

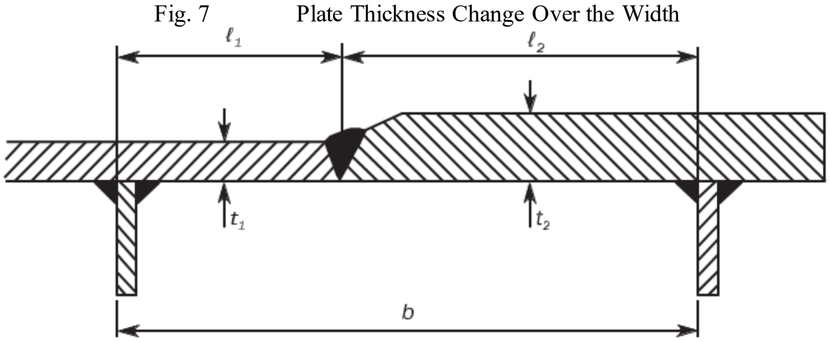
$$b_{eq} = \ell_1 + \ell_2 \left(\frac{t_1}{t_2}\right)^{1.5}$$

Where:

ℓ_1 : Width of the part of the plate panel with the smaller plate thickness, t_1 (*mm*) as defined in **Fig. 7**.

ℓ_2 : Width of the part of the plate panel with the greater plate thickness, t_2 (*mm*) as defined in **Fig. 7**.

Fig. 7 Plate Thickness Change Over the Width



3.1.3.2 Transverse Stiffening with Varying Plate Thickness

In transverse stiffening arrangement, when an *EPP* is made with different thicknesses, the buckling check of the plate and stiffeners is to be made for each thickness considered constant on the *EPP*, the stresses and pressures being estimated for the *EPP* at the *LCP*.

3.1.3.3 Plate Panel with Different Materials

When the plate panel is made of different materials, the minimum yield strength is to be used for the buckling assessment.

3.2 Buckling Criteria

3.2.1 Overall Stiffened Panel

3.2.1.1

The buckling strength of overall stiffened panels is to satisfy the following criterion:

$\eta_{overall} \leq \eta_{all}$

$\eta_{overall}$: Maximum overall buckling utilisation factor as defined **5.2.1**.

3.2.2 Plates

3.2.2.1

The buckling strength of elementary plate panels is to satisfy the following criterion:

$\eta_{plate} \leq \eta_{all}$

Where:

η_{plate}: Maximum plate buckling utilisation factor as defined in **5.2.2** where SP-A model is to be used.

For the determination of η_{plate} of the vertically stiffened side shell plating of single side skin bulk carrier between hopper and topside tanks, the cases 12 and 16 of **Table 5** corresponding to the shorter edge of the plate panel clamped are to be considered together with a mean σ_y stress and $\psi_y = 1$.

3.2.3 Stiffeners

3.2.3.1

The buckling strength of stiffeners or of side frames of single side skin bulk carriers is to satisfy the following criterion:

$\eta_{stiffener} \leq \eta_{all}$

Where:

$\eta_{stiffener}$: Maximum stiffener buckling utilisation factor as defined in **5.2.3**.

Note 1: This buckling check can only be fulfilled when the overall stiffened panel buckling check, as defined in **3.2.1**, is satisfied.

Note 2: The buckling check of the stiffeners is only applicable to the stiffeners fitted along the long edge of the buckling panel.

3.2.4 Vertically Corrugated Longitudinal Bulkheads

3.2.4.1

The shear buckling strength of vertically corrugated longitudinal bulkheads is to satisfy the following criterion:

$\eta_{shear} \leq \eta_{all}$

η_{shear}: Maximum shear buckling utilisation factor defined as

$$\eta_{shear} = \frac{\tau_{bhd}}{\tau_c}$$

τ_{bhd}: Shear stress (N/mm^2) in the bulkhead taken as the hull girder shear stress defined in the relevant requirements.

τ_c: Shear critical stress (N/mm^2) as defined in **5.2.2.3**.

3.2.5 Horizontally Corrugated Longitudinal Bulkheads

3.2.5.1

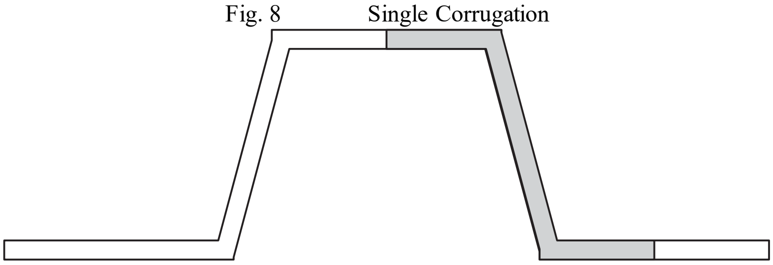
Each corrugation unit within the extension of half flange, web and half flange (i.e. single corrugation as shown in grey in **Fig. 8**) is to satisfy the following criterion:

$\eta_{column} \leq \eta_{all}$

Where:

η_{column}: Overall column buckling utilisation factor, as defined in **5.3.1**.

Fig. 8 Single Corrugation



4 Buckling Requirements for Direct Strength Analysis of Hatch Covers

Symbols

σ_{Y_P}: Yield stress of the plate panel, as defined in **4.2.1.3**

σ_{Y_S}: Yield stress of the stiffener, as defined in **4.2.1.3**

α: Aspect ratio of the plate panel, as defined in the symbol list of **5**

η_{all}: Allowable buckling utilisation factor, as defined in **1.3.3.1**

4.1 General

4.1.1 Introduction

4.1.1.1

The requirements of this section apply for the buckling assessment of hatch cover structural members based on direct strength analysis (usually by finite element method) and subjected to normal stress, shear stress and lateral pressure.

4.1.1.2

All structural elements in the direct strength analysis carried out according to the relevant requirements are to be assessed individually. The buckling checks are to be performed for the following structural elements:

- Stiffened and unstiffened panels
- Web plate in way of openings

4.2 Stiffened and Unstiffened Panels

4.2.1 General

4.2.1.1

The plate panel of a hatch cover structure is to be modelled as stiffened panel (SP) or unstiffened panel (UP), with either Method A or Method B as defined in **1.3.1.1** to be used for the calculation of the plate buckling capacity, which in combination is also equivalent to use the buckling assessment models defined in **1.3.1.2**.

4.2.1.2 Average Thickness of Plate Panel

For FE analysis, where the plate thickness along a plate panel is not constant, the panel used for the buckling assessment is to be modelled with a weighted average thickness taken as:

$$t_{avr} = \frac{\sum_1^n A_i t_i}{\sum_1^n A_i}$$

Where:

A_i : Area of the i-th plate element.

t_i : Net thickness of the i-th plate element.

n : Number of finite elements defining the buckling plate panel.

4.2.1.3 Yield Stress of the Plate Panel and Stiffener

The panel yield stress σ_{Y_P} is taken as the minimum value of the specified yield stresses of the elements within the plate panel. The stiffener yield stress σ_{Y_S} is taken as the minimum value of the specified yield stresses of the elements within the stiffener.

4.2.2 Stiffened Panels

4.2.2.1

For a stiffened panel (SP), each stiffener with attached plate is to be idealised as a stiffened panel model of the extent defined in the relevant requirements.

4.2.2.2

If the stiffener properties or stiffener spacing varies within the stiffened panel, the calculations are to be performed separately for all configurations of the panels, i.e. for each stiffener and plate between the stiffeners. Plate thickness, stiffener properties and stiffener spacing at the considered location are to be assumed for the whole panel.

4.2.2.3

The buckling check of the stiffeners of stiffened panels is only applicable to the stiffeners fitted along the longer side edges of the buckling panel.

4.2.3 Unstiffened Panels

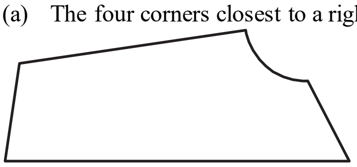
4.2.3.1 Irregular Plate Panel

In way of web frames and brackets, the geometry of the panel (i.e. plate bounded by web stiffeners/face plate) may not have a rectangular shape. In this case, for FE analysis, an equivalent rectangular panel is to be defined according to **4.2.3.2** for irregular geometry and **4.2.3.3** for triangular geometry and to comply with buckling assessment.

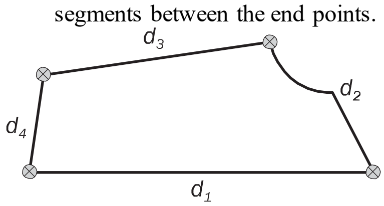
4.2.3.2 Equivalent EPP of an Unstiffened Panel with Irregular Geometry

Unstiffened panels with irregular geometry are to be idealised to equivalent panels for plate buckling assessment according to the following procedure:

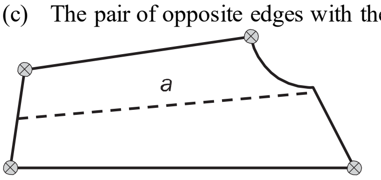
(a) The four corners closest to a right angle, 90 deg, in the bounding polygon for the plate are identified.



(b) The distances along the plate bounding polygon between the corners are calculated, i.e. the sum of all the straight-line segments between the end points.



(c) The pair of opposite edges with the smallest total length is identified, i.e. minimum of d_1+d_3 and d_2+d_4.



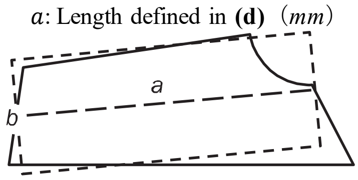
(d) A line joins the middle points of the chosen opposite edges (i.e. a mid-point is defined as the point at half the distance from one end). This line defines the longitudinal direction for the capacity model. The length of the line defines the length of the capacity model, *a* measured from one end point.

(e) The length of shorter side, b (mm) is to be taken as:

$$b = \frac{A}{a}$$

A: Area of the plate (mm^2)

a: Length defined in **(d)** (mm)

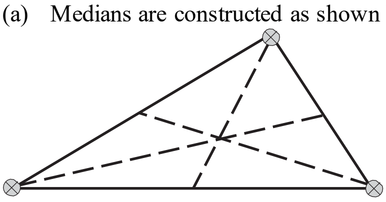


(f) The stresses from the direct strength analysis are to be transformed into the local coordinate system of the equivalent rectangular panel. These stresses are to be used for the buckling assessment.

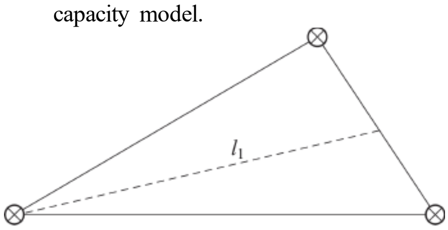
4.2.3.3 Modelling of an Unstiffened Plate Panel with Triangular Geometry

Unstiffened panels with triangular geometry are to be idealised to equivalent panels for plate buckling assessment according to the following procedure:

(a) Medians are constructed as shown below.



(b) The longest median is identified. This median the length of which is ℓ_1 (mm) defines the longitudinal direction for the capacity model.

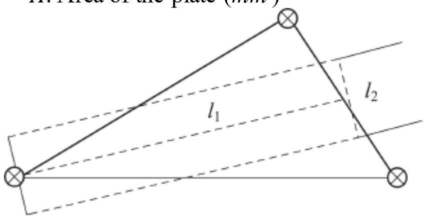


(c) The width of the model, ℓ_2 (mm) is to be taken as:

$$\ell_2 = \frac{A}{\ell_1}$$

Where:

A: Area of the plate (mm^2)



(d) The lengths of shorter side, b (mm), and of the longer side, a (mm) of the equivalent rectangular plate panel are to be taken as:

$$b = \frac{\ell_2}{C_{tri}}$$

$$a = \ell_1 C_{tri}$$

Where:

$$C_{tri} = 0.4\frac{\ell_2}{\ell_1} + 0.6$$

(e) The stresses from the direct strength analysis are to be transformed into the local coordinate system of the equivalent rectangular panel and are to be used for the buckling assessment of the equivalent rectangular panel.

4.2.4 Reference Stress

4.2.4.1

The stress distribution is to be taken from the direct strength analysis according to the relevant requirements and applied to the buckling model.

4.2.4.2

For FE analysis, the reference stresses are to be calculated using the stress based reference stresses as defined in **Appendix C20.2 "STRESS BASED REFERENCE STRESSES"**.

4.2.5 Lateral Pressure

4.2.5.1

The lateral pressure applied to the direct strength analysis is also to be applied to the buckling assessment.

4.2.5.2

For FE analysis, where the lateral pressure is not constant over a buckling panel defined by a number of finite plate elements, an average lateral pressure (N/mm^2) is calculated using the following formula:

$$P_{avr} = \frac{\sum_1^n A_i P_i}{\sum_1^n A_i}$$

Where:

A_i: Area of the i-th plate element (mm^2)

P_i: Lateral pressure of the i-th plate element (N/mm^2)

n: Number of finite elements in the buckling panel

4.2.6 Buckling Criteria

4.2.6.1 UP-A

The compressive buckling strength of UP-A is to satisfy the following criterion:

$$\eta_{UP-A} \leq \eta_{all}$$

Where:

η_{UP-A}: Plate buckling utilisation factor, equal to η_{plate} as defined in 5.2.2 where UP-A model is to be used.

4.2.6.2 UP-B

The compressive buckling strength of UP-B is to satisfy the following criterion:

$\eta_{UP-B} \leq \eta_{all}$

Where:

η_{UP-B}: Plate buckling utilisation factor, equal to η_{plate} as defined in 5.2.2 where UP-B model is to be used.

4.2.6.3 SP-A

The compressive buckling strength of SP-A is to satisfy the following criterion:

$\eta_{SP-A} \leq \eta_{all}$

Where:

η_{SP-A}: Buckling utilisation factor of the stiffened panel, taken as the maximum of the buckling utilisation factors calculated as below:

- The overall stiffened panel buckling utilisation factor $\eta_{overall}$ as defined in 5.2.1.
- The plate buckling utilisation factor η_{plate} as defined in 5.2.2 where SP-A model is to be used.
- The stiffener buckling utilisation factor $\eta_{stiffener}$ as defined in 5.2.3 considering separately the properties (thickness, dimensions), the pressures defined in 4.2.5.2 and the reference stresses of each *EPP* at both sides of the stiffener.

Note 1: The stiffener buckling strength check can only be fulfilled when the overall stiffened panel capacity check, as defined in 5.2.1 is satisfied.

4.2.6.4 SP-B

The compressive buckling strength of SP-B is to satisfy the following criterion:

$\eta_{SP-B} \leq \eta_{all}$

Where:

η_{SP-B}: Buckling utilisation factor of the stiffened panel, taken as the maximum of the buckling utilisation factors calculated as below:

- The overall stiffened panel buckling utilisation factor $\eta_{overall}$ as defined in 5.2.1.
- The plate buckling utilisation factor η_{plate} as defined in 5.2.2 where SP-B model is to be used.
- The stiffener buckling utilisation factor $\eta_{stiffener}$ as defined in 5.2.3 considering separately the properties (thickness, dimensions), the pressures defined in 4.2.5.2 and the reference stresses of each *EPP* at both sides of the stiffener.

Note 1: The stiffener buckling strength check can only be fulfilled when the overall stiffened panel capacity check, as defined in 5.2.1, is satisfied.

4.2.6.5 Web Plate in Way of Openings

The web plate of primary supporting members with openings is to satisfy the following criterion:

$\eta_{opening} \leq \eta_{all}$

Where:

$\eta_{opening}$: Maximum web plate utilisation factor in way of openings, calculated with the definition in 1.3.2.2 and the stress multiplier factor at failure γ_c which can be calculated following the requirements in 5.2.4.

5 Buckling Capacity

Symbols

A_p: Net sectional area (mm^2) of the stiffener attached plating taken as:

$$A_p = st_p$$

A_s: Net sectional area (mm^2) of the stiffener without attached plating

a: Length (mm) of the longer side of the plate panel

b: Length (mm) of the shorter side of the plate panel

b_{eff}: Effective width (mm) of the attached plating of a stiffener as defined in **5.2.3.5**

b_{eff1}: Effective width (mm) of the attached plating of a stiffener without the shear lag effect taken as:

- For $\sigma_x > 0$
  - For prescriptive assessment:
    $$b_{eff1} = \frac{C_{x1}b_1 + C_{x2}b_2}{2}$$
  - For FE analysis:
    $$b_{eff1} = C_x b$$
- For $\sigma_x \leq 0$
  $$b_{eff1} = b$$

b_f: Breadth (mm) of the stiffener flange

b_1, b_2: Width (mm) of plate panel on each side of the considered stiffener. For stiffened panels fitted with U-type stiffeners, b_1 and b_2 are as defined in **Fig. 3**.

C_{x1}, C_{x2}: Reduction factor defined in **Table 5** calculated for the *EPP*1 and *EPP*2 on each side of the considered stiffener according to case 1

d: Length (mm) of the side parallel to the cylindrical axis of the cylinder corresponding to the curved plate panel as shown in **Table 6**

d_f: Breadth (mm) of the extended part of the flange for L2 profiles as shown in **Fig. 2**

e_f: Distance (mm) from attached plating to centre of flange as shown in **Fig. 2** to be taken as:

$e_f = h_w$ for flat bar profile

$e_f = h_w - 0.5t_f$ for bulb profile

$e_f = h_w + 0.5t_f$ for angle, L2 and T profiles

F_{long}: Coefficient defined in **5.2.2.4**

F_{tran}: Coefficient defined in **5.2.2.5**

h_w: Depth (mm) of stiffener web as shown in **Fig. 2**

ℓ: Span (mm) of stiffener equal to spacing between primary supporting members or span of side frame equal to the distance between the hopper tank and top wing tank in way of the side shell

R: Radius (mm) of curved plate panel

σ_{Y_P}: Specified minimum yield stress (N/mm^2) of the plate

σ_{Y_S}: Specified minimum yield stress (N/mm^2) of the stiffener

S: Partial safety factor, unless otherwise specified in the relevant requirements, to be taken as 1.0

t_p: Net thickness (mm) of plate panel

t_w: Net stiffener web thickness (mm)

t_f: Net flange thickness (mm)

x-axis: Local axis of a rectangular buckling panel parallel to its long edge

y-axis: Local axis of a rectangular buckling panel perpendicular to its long edge

α: Aspect ratio of the plate panel, defined in **Table 5** to be taken as:

$$\alpha = \frac{a}{b}$$

β: Coefficient taken as:

$$\beta = \frac{1-\psi}{\alpha}$$

ω: Coefficient taken as:

$$\omega = \min(3, \alpha)$$

σ_x: Normal stress (N/mm^2) applied on the edge along x-axis of the buckling panel

σ_y: Normal stress (N/mm^2) applied on the edge along y-axis of the buckling panel

σ_1: Maximum normal stress (N/mm^2) along a panel edge

σ_2: Minimum normal stress (N/mm^2) along a panel edge

σ_E: Elastic buckling reference stress (N/mm^2) to be taken as:

- For the application of the limit state of plane plate panels according to 5.2.2.1:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{b}\right)^2$$

- For the application of the limit state of curved plate panels according to 5.2.2.6:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{d}\right)^2$$

τ: Applied shear stress (N/mm^2)

τ_c: Buckling strength in shear (N/mm^2) as defined in 5.2.2.3

ψ: Edge stress ratio to be taken as:

$$\psi = \frac{\sigma_2}{\sigma_1}$$

γ: Stress multiplier factor acting on loads. When the factor is such that the loads reach the interaction formulae, $\gamma = \gamma_c$.

γ_c: Stress multiplier factor at failure

γ_{GEB}: Stress multiplier factor of global elastic buckling capacity

5.1 General

5.1.1 Introduction

5.1.1.1

This section contains the methods for determination of the buckling capacities of plate panels, stiffeners, primary supporting members, and columns.

5.1.1.2

For the application of this section, the stresses σ_x, σ_y and τ applied on the structural members are defined in:

- 3 for hull girder prescriptive buckling requirements.
- 4 for direct strength analysis buckling requirements of hatch covers.

5.1.1.3 Buckling Capacity

The buckling capacity is calculated by applying the actual stress combination and then increasing or decreasing the stresses proportionally until the interaction formulae defined in 5.2.1.1, 5.2.2.1 and 5.2.3.4 are equal to 1.0, respectively.

5.1.1.4 Buckling Utilisation Factor

The buckling utilisation factor of the structural member is equal to the highest utilisation factor obtained for the different buckling modes.

5.1.1.5 Lateral Pressure

The lateral pressure is to be applied and considered as constant for the calculation of buckling capacities as defined in 5.1.1.3.

5.2 Buckling Capacity of Plate Panels

5.2.1 Overall Stiffened Panels

5.2.1.1

The elastic stiffened panel limit state is based on the following interaction formula, which sets a precondition for the buckling check of stiffeners in accordance with 5.2.3.4:

$$\frac{\gamma_c}{\gamma_{GEB}} = 1$$

with corresponding buckling utilisation factor defined as

$$\eta_{overall} = \frac{1}{\gamma_c}$$

where the stress multiplier factors of global elastic buckling capacity, γ_{GEB}, are to be calculated based on the following formulae:

$\gamma_{GEB} = \gamma_{GEB,bi+\tau}$ for $\tau \neq 0$ and $(\sigma_x > 0$ or $\sigma_y > 0)$

$\gamma_{GEB} = \gamma_{GEB,bi}$ for $\tau = 0$ and $(\sigma_x > 0$ or $\sigma_y > 0)$

$\gamma_{GEB} = \gamma_{GEB,\tau}$ for $\tau \neq 0$ and $(\sigma_x \leq 0$ and $\sigma_y \leq 0)$

where $\gamma_{GEB,bi}$, $\gamma_{GEB,\tau}$ and $\gamma_{GEB,bi+\tau}$ are stress multiplier factors of the global elastic buckling capacity for different load combinations as defined in **5.2.1.2**, **5.2.1.3** and **5.2.1.4**, respectively. For the calculation of $\gamma_{GEB,bi}$, $\gamma_{GEB,\tau}$ and $\gamma_{GEB,bi+\tau}$, neither σ_x nor σ_y are to be taken less than 0.

σ_x, σ_y: Applied normal stress (N/mm^2) to the plate panel to be taken as defined in **5.2.2.7**.

τ: Applied shear stress (N/mm^2) to be taken as defined in **5.2.2.7**.

5.2.1.2

The stress multiplier factor $\gamma_{GEB,bi}$ for the stiffened panel subjected to biaxial loads is taken as:

$$\gamma_{GEB,bi} = \frac{\pi^2}{L_{B1}^2 L_{B2}^2} \frac{[D_{11}L_{B2}^4 + 2(D_{12}+D_{33})n^2 L_{B1}^2 L_{B2}^2 + n^4 D_{22} L_{B1}^4]}{L_{B2}^2 N_x + n^2 L_{B1}^2 N_y}$$

Where:

N_x: Load per unit length applied on the edge along x-axis (N/mm) of the stiffened panel taken as

$$N_x = \sigma_{x,av}(A_p + A_s)/s$$

For stiffened panels fitted with U-type stiffeners, stiffener spacing s is taken as:

$$s = b_1 + b_2$$

where b_1 and b_2 are as defined in **Fig. 3**.

N_y: Load per unit length applied on the edge along y-axis (N/mm) of the stiffened panel taken as

$$N_y = c\sigma_y t_p$$

L_{B1}: Stiffener span (mm) distance between primary supporting members, i.e. $L_{B1} = \ell$. Specially, for vertically stiffened side shell of single side skin bulk carriers, $L_{B1} = 0.8\ell$.

L_{B2}: Total width (mm) of stiffened panel between lateral supports taken as 6 times of the stiffener spacing, i.e. $6s$.

n: Number of half waves along the direction perpendicular to the stiffener axis. The factor $\gamma_{GEB,bi}$ is to be minimised with respect to the wave parameters n, i.e. to be taken as the smallest value larger than zero.

c: Factor taking into account the normal stress distribution in the attached plating acting perpendicular to the stiffener's axis:

$c = 0.5(1+\Psi)$ for $0 \leq \Psi \leq 1$

$c = \frac{1}{2(1-\Psi)}$ for $\Psi < 0$

Ψ: Edge stress ratio for case 2 according to **Table 5**

$\sigma_{x,av}$: Average stress for both plate and stiffener, taken as:

$\sigma_{x,av} = \sigma_x - \nu c \sigma_y A_s/(A_p + A_s) \geq 0$ for $\sigma_x > 0$ and $\sigma_y > 0$

$\sigma_{x,av} = \sigma_x$ for $\sigma_x \leq 0$ or $\sigma_y \leq 0$

$D_{11}, D_{12}, D_{22}, D_{33}$: Bending stiffness coefficients (Nmm) of the stiffened panel, defined in general as:

$$\left.\begin{aligned} D_{11} &= \frac{EI_{eff}10^4}{s} \\ D_{12} &= \frac{E t_p^3 \nu}{12(1-\nu^2)} \\ D_{22} &= \frac{E t_p^3}{12(1-\nu^2)} \\ D_{33} &= \frac{E t_p^3}{12(1+\nu)} \end{aligned}\right\}$$

For stiffened panels fitted with U-type stiffeners, D_{12} and D_{22} are defined as:

$$D_{22} = \frac{E t_p^3}{12(1-\nu^2)}\left[1.2 + 4.8 \times Min\left(1.0, \frac{b_1^2}{h_w(b_1+b_2)}\right) \times Min\left(1.0, \left(\frac{t_w}{t_p}\right)^3\right)\right]$$

$$D_{12} = \nu D_{22}$$

h_w: Breadth of U-type stiffener web as defined in **Fig. 3**.

I_{eff}: Moment of inertia (cm^4) of the stiffener including effective width of attached plating, the same as I defined in **5.2.3.4**.

5.2.1.3

The stress multiplier factor $\gamma_{GEB,\tau}$ for the stiffened panel subjected to pure shear load is taken as:

$$\gamma_{GEB,\tau} = \frac{\sqrt[4]{D_{11}^3 D_{22}}}{(L_{B1}/2)^2 N_{xy}}\left[8.125 + 5.64\sqrt{\frac{(D_{12}+D_{33})^2}{D_{11}D_{22}}} - 0.6\frac{(D_{12}+D_{33})^2}{D_{11}D_{22}}\right] \quad \text{for } D_{11}D_{22} \geq (D_{12}+D_{33})^2$$

$$\gamma_{GEB,\tau} = \frac{\sqrt{2D_{11}(D_{12}+D_{33})}}{(L_{B1}/2)^2 N_{xy}}\left[8.3 + 1.525\frac{D_{11}D_{22}}{(D_{12}+D_{33})^2} - 0.493\frac{D_{11}^2 D_{22}^2}{(D_{12}+D_{33})^4}\right] \quad \text{for } D_{11}D_{22} < (D_{12}+D_{33})^2$$

Where:

$$N_{xy} = \tau t_p$$

5.2.1.4

The stress multiplier factor $\gamma_{GEB,bi+\tau}$ for the stiffened panel subjected to combined loads is taken as:

$$\gamma_{GEB,bi+\tau} = \frac{1}{2}\gamma_{GEB,\tau}{}^2\left[-\frac{1}{\gamma_{GEB,bi}} + \sqrt{\frac{1}{\gamma_{GEB,bi}{}^2} + 4\frac{1}{\gamma_{GEB,\tau}{}^2}}\right]$$

where $\gamma_{GEB,bi}$ and $\gamma_{GEB,\tau}$ are as defined in **5.2.1.2** and **5.2.1.3**, respectively.

5.2.2 Plates

5.2.2.1 Plate Limit State

The plate limit state is based on the following interaction formulae:

$$\left(\frac{\gamma_{c1}\sigma_x S}{\sigma_{cx}}\right)^{e_0} - B\left(\frac{\gamma_{c1}\sigma_x S}{\sigma_{cx}}\right)^{\frac{e_0}{2}}\left(\frac{\gamma_{c1}\sigma_y S}{\sigma_{cy}}\right)^{\frac{e_0}{2}} + \left(\frac{\gamma_{c1}\sigma_y S}{\sigma_{cy}}\right)^{e_0} + \left(\frac{\gamma_{c1}|\tau|S}{\tau_c}\right)^{e_0} = 1$$

$$\left(\frac{\gamma_{c2}\sigma_x S}{\sigma_{cx}}\right)^{2/\beta_p^{0.25}} + \left(\frac{\gamma_{c2}|\tau|S}{\tau_c}\right)^{2/\beta_p^{0.25}} = 1 \quad \text{for } \sigma_x \geq 0$$

$$\left(\frac{\gamma_{c3}\sigma_y S}{\sigma_{cy}}\right)^{2/\beta_p^{0.25}} + \left(\frac{\gamma_{c3}|\tau|S}{\tau_c}\right)^{2/\beta_p^{0.25}} = 1 \quad \text{for } \sigma_y \geq 0$$

$$\frac{\gamma_{c4}|\tau|S}{\tau_c} = 1$$

with

$$\gamma_c = Min(\gamma_{c1}, \gamma_{c2}, \gamma_{c3}, \gamma_{c4})$$

and corresponding buckling utilisation factor defined as

$$\eta_{plate} = \frac{1}{\gamma_c}$$

Where:

σ_x, σ_y: Applied normal stress (N/mm^2) to the plate panel to be taken as defined in **5.2.2.7**.

τ: Applied shear stress (N/mm^2) to the plate panel.

σ_{cx}: Ultimate buckling stress (N/mm^2) in direction parallel to the longer edge of the buckling panel as defined in **5.2.2.3**.

σ_{cy}: Ultimate buckling stress (N/mm^2) in direction parallel to the shorter edge of the buckling panel as defined in **5.2.2.3**.

τ_c: Ultimate buckling shear stress (N/mm^2) as defined in **5.2.2.3**.

$\gamma_{c1}, \gamma_{c2}, \gamma_{c3}, \gamma_{c4}$: Stress multiplier factors at failure for each of the above different limit states. γ_{c2} and γ_{c3} are only to be considered when $\sigma_x \geq 0$ and $\sigma_y \geq 0$ respectively.

B: Coefficient given in **Table 3**.

e_0: Coefficient given in **Table 3**.

β_p: Plate slenderness parameter taken as:

$$\beta_p = \frac{b}{t_p}\sqrt{\frac{\sigma_{Y\_P}}{E}}$$

Table 3 Definition of Coefficients B and e_0

Applied stress	B	e_0
$\sigma_x \geq 0$ and $\sigma_y \geq 0$	$0.7 - 0.3\,\beta_p/\alpha^2$	$2/\beta_p^{0.25}$
$\sigma_x < 0$ or $\sigma_y < 0$	1.0	2.0

5.2.2.2 Reference Degree of Slenderness

The reference degree of slenderness is to be taken as:

$$\lambda = \sqrt{\frac{\sigma_{Y\_P}}{K\sigma_E}}$$

Where:

K: Buckling factor, as defined in **Table 5** and **Table 6**.

5.2.2.3 Ultimate Buckling Stresses

The ultimate buckling stresses (N/mm^2) of plate panels are to be taken as:

$$\sigma_{cx} = C_x\sigma_{Y\_P}$$
$$\sigma_{cy} = C_y\sigma_{Y\_P}$$

The ultimate buckling stress of plate panels subject to shear (N/mm^2) is to be taken as:

$$\tau_c = C_\tau\frac{\sigma_{Y\_P}}{\sqrt{3}}$$

Where:

C_x, C_y, C_τ : Reduction factors, as defined in **Table 5**

- For the 1st Equation of **5.2.2.1**, when $\sigma_x < 0$ or $\sigma_y < 0$, the reduction factors are to be taken as:

  $$C_x = C_y = C_\tau = 1$$

- For other cases:
  - For SP-A and UP-A, C_y is calculated according to **Table 5** by using

    $$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

  - For SP-B and UP-B, C_y is calculated according to **Table 5** by using

    $$c_1 = 1$$

  - For vertically stiffened single side skin of bulk carrier, C_y is calculated according to **Table 5** by using

    $$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

  - For corrugation of corrugated bulkheads, C_y is calculated according to **Table 5** by using

    $$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

The boundary conditions for plates are to be considered as simply supported, see cases 1, 2 and 15 of **Table 5**. If the boundary conditions differ significantly from simple support, a more appropriate boundary condition can be applied according to the different cases of **Table 5** subject to the agreement of the Society.

5.2.2.4 Correction Factor F_{long}

The correction factor F_{long} depending on the edge stiffener types on the longer side of the buckling panel is defined in **Table 4**. An average value of F_{long} is to be used for plate panels having different edge stiffeners. For stiffener types other than those mentioned in **Table 4**, the value of c is to be agreed by the Society. In such a case, value of c higher than those mentioned in **Table 4** can be used, provided it is verified by buckling strength check of panel using non-linear FE analysis and deemed appropriate by the Society.

Table 4 Correction Factor F_{long}

<table>
<tr><td colspan="3">Structural element types</td><td>F_{long}</td><td>c</td></tr>
<tr><td colspan="3">Unstiffened Panel</td><td>1.0</td><td>N/A</td></tr>
<tr><td rowspan="8">Stiffened Panel</td><td colspan="2">Stiffener not fixed at both ends</td><td>1.0</td><td>N/A</td></tr>
<tr><td rowspan="7">Stiffener fixed at both ends</td><td>Flat bar(1)</td><td rowspan="4">$F_{long} = c + 1 \ for \ \frac{t_w}{t_p} > 1$
$F_{long} = c\left(\frac{t_w}{t_p}\right)^3 + 1 \ for \ \frac{t_w}{t_p} \leq 1$</td><td>0.10</td></tr>
<tr><td>Bulb profile</td><td>0.30</td></tr>
<tr><td>Angle and L2 profiles</td><td>0.40</td></tr>
<tr><td>T profile</td><td>0.30</td></tr>
<tr><td>Girder of high rigidity (e.g. bottom transverse)</td><td>1.4</td><td>N/A</td></tr>
<tr><td>U-type profile fitted on hatch cover(2)</td><td>- Plate on which the U-type profile is fitted, including EPP b_1 and EPP b_2
- For $b_2 < b_1$: $F_{long} = 1$
- For $b_2 \geq b_1$:
$F_{long} = \left(1.55 - 0.55\frac{b_1}{b_2}\right)\left[1 + c\left(\frac{t_w}{t_p}\right)^3\right]$
- Other plates of the U-type profile:
$F_{long} = 1$</td><td>0.2</td></tr>
<tr><td colspan="5">(1) t_w is the net web thickness (mm) without the correction defined in 5.2.3.2.
(2) b_1, b_2 and t_w are defined in Fig. 3.</td></tr>
</table>

5.2.2.5 Correction Factor F_{tran}

The correction factor F_{tran} is to be taken as:

- For transversely framed EPP of single side skin bulk carrier, between the hopper and top wing tank:
  - F_{tran}=1.25 when the two adjacent frames are supported by one tripping bracket fitted in way of the adjacent plate panels.
  - F_{tran}=1.33 when the two adjacent frames are supported by two tripping brackets each fitted in way of the adjacent plate panels.
  - F_{tran}=1.15 elsewhere.
- For the attached plate of a U-type stiffener fitted on a hatch cover:

  $F_{tran} = Max(3 - 0.08(F_{tran0} - 6)^2, 1.0) \leq 2.25$

  Where:

  $F_{tran0} = Min\left(\frac{b_2}{b_1} + \frac{6b_2^2}{\pi^2 h_w(b_1+b_2)}\left(\frac{t_w}{t_p}\right)^3, 6\right)$ for EPP b_2

  $F_{tran0} = Min\left(\frac{b_1}{b_2} + \frac{6b_1^2}{\pi^2 h_w(b_2+b_1)}\left(\frac{t_w}{t_p}\right)^3, 6\right)$ for EPP b_1

  with b_1, b_2 and h_w as defined in Fig. 3.

  Coefficient F defined in case 2 of Table 5 is to be replaced by the following formula:

  $F = \left[1 - \left(\frac{K_y}{0.91F_{tran}} - 1\right)/\lambda_p^2\right] c_1 \geq 0$
- For other cases: F_{tran} =1.

5.2.2.6 Curved Plate Panels

This requirement for curved plate limit state is applicable when $R/t_p \leq 2500$. Otherwise, the requirement for plate limit state given in 5.2.2.1 is applicable.

The curved plate limit state is based on the following interaction formula:

$$\left(\frac{\gamma_c \sigma_{ax} S}{C_{ax}\sigma_{Y\_P}}\right)^{1.25} - 0.5\left(\frac{\gamma_c \sigma_{ax} S}{C_{ax}\sigma_{Y\_P}}\right)\left(\frac{\gamma_c \sigma_{tg} S}{C_{tg}\sigma_{Y\_P}}\right) + \left(\frac{\gamma_c \sigma_{tg} S}{C_{tg}\sigma_{Y\_P}}\right)^{1.25} + \left(\frac{\gamma_c \tau\sqrt{3}S}{C_{\tau}\sigma_{Y\_P}}\right)^{2} = 1.0$$

with corresponding buckling utilisation factor defined as

$$\eta_{curved\_plate} = \frac{1}{\gamma_c}$$

Where:

σ_{ax}: Applied axial stress (N/mm^2) to the cylinder corresponding to the curved plate panel. In case of tensile axial stresses, $\sigma_{ax} = 0$.

σ_{tg}: Applied tangential stress (N/mm^2) to the cylinder corresponding to the curved plate panel. In case of tensile tangential stresses, $\sigma_{tg} = 0$.

C_{ax}, C_{tg}, C_{τ}: Buckling reduction factor of the curved plate panel, as defined in **Table 6**.

The stress multiplier factor, γ_c, of the curved plate panel need not be taken less than the stress multiplier factor, γ_c, for the expanded plane panel according to **5.2.2.1**.

Fig. 9 Transverse Stiffened Bilge Plating

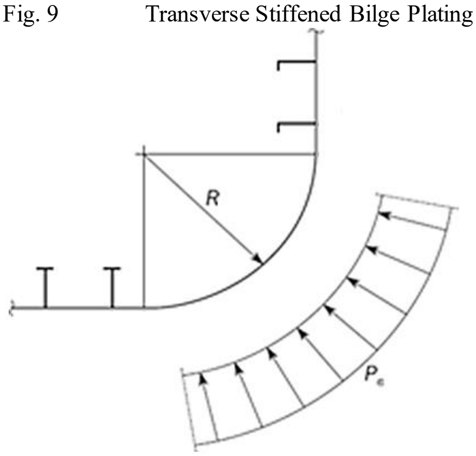
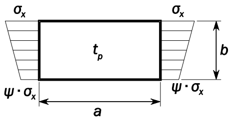
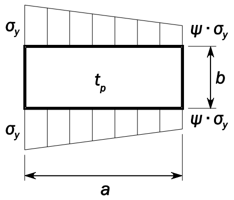
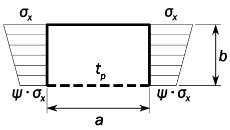
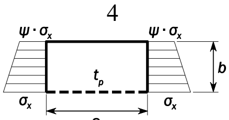
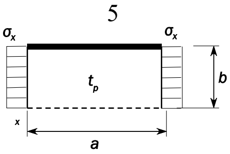
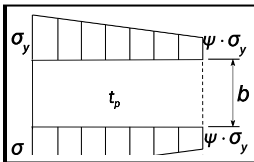
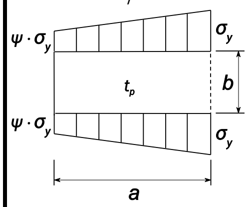
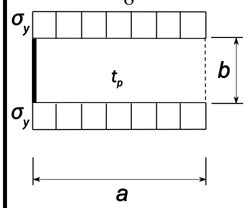
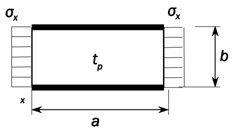
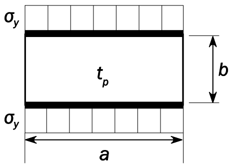
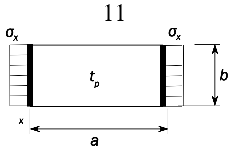
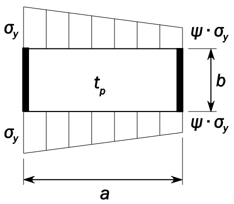
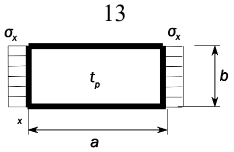


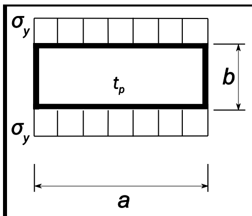
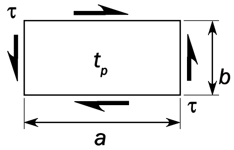
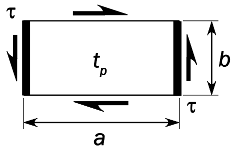
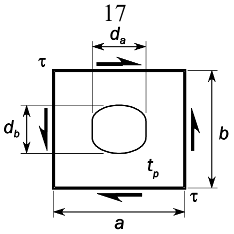
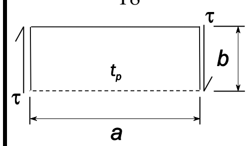
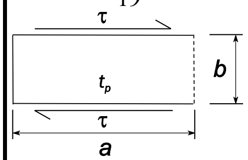
Table 5 Buckling Factor and Reduction Factor for Plane Plate Panels

<table>
<tr><th>Case</th><th>Stress ratio ψ</th><th>Aspect ratio α</th><th>Buckling factor K</th><th>Reduction factor C</th></tr>
<tr><td rowspan="3">1
</td><td>$1 \geq \psi \geq 0$</td><td colspan="2">$K_x = F_{long} \dfrac{8.4}{\psi + 1.1}$</td><td rowspan="3">When $\sigma_x \leq 0$:
$C_x = 1$
When $\sigma_x > 0$:
$C_x = 1$ for $\lambda \leq \lambda_c$
$C_x = c\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > \lambda_c$
Where:
$c = (1.25 - 0.12\psi) \leq 1.25$
$\lambda_c = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0.88}{c}}\right)$</td></tr>
<tr><td>$0 > \psi > -1$</td><td colspan="2">$K_x = F_{long}[7.63 - \psi(6.26 - 10\psi)]$</td></tr>
<tr><td>$\psi \leq -1$</td><td colspan="2">$K_x = F_{long}[5.975(1 - \psi)^2]$</td></tr>
<tr><td rowspan="7">2
</td><td rowspan="3">$1 \geq \psi \geq 0$</td><td colspan="2">$K_y = F_{tran} \dfrac{2\left(1 + \frac{1}{\alpha^2}\right)^2}{1 + \psi + \frac{(1-\psi)}{100}\left(\frac{2.4}{\alpha^2} + 6.9 f_1\right)}$</td><td rowspan="7">When $\sigma_y \leq 0$:
$C_y = 1$
When $\sigma_y > 0$:
$C_y = c\left(\dfrac{1}{\lambda} - \dfrac{R + F^2(H - R)}{\lambda^2}\right)$
Where:
$c = (1.25 - 0.12\psi) \leq 1.25$
$R = \lambda(1 - \lambda/c)$ for $\lambda < \lambda_c$
$R = 0.22$ for $\lambda \geq \lambda_c$
$\lambda_c = 0.5c\left(1 + \sqrt{1 - 0.88/c}\right)$
$F = \left[1 - \left(\dfrac{K}{0.91} - 1\right)/\lambda_p^2\right] c_1 \geq 0$
$\lambda_p^2 = \lambda^2 - 0.5$ for $1 \leq \lambda_p^2 \leq 3$
c_1 as defined in 5.2.2.3
$H = \lambda - \dfrac{2\lambda}{c(T + \sqrt{T^2 - 4})} \geq R$
$T = \lambda + \dfrac{14}{15\lambda} + \dfrac{1}{3}$</td></tr>
<tr><td>$\alpha \leq 6$</td><td>$f_1 = (1 - \psi)(\alpha - 1)$</td></tr>
<tr><td>$\alpha > 6$</td><td>$f_1 = 0.6(1 - \dfrac{6\psi}{\alpha})(\alpha + \dfrac{14}{\alpha})$
but not greater than $14.5 - \frac{0.35}{\alpha^2}$</td></tr>
<tr><td rowspan="4">$0 \geq \psi \geq 1 - \dfrac{4\alpha}{3}$</td><td colspan="2">$K_y = \dfrac{200 F_{tran}(1 + \beta^2)^2}{(1 - f_3)(100 + 2.4\beta^2 + 6.9 f_1 + 23 f_2)}$</td></tr>
<tr><td>$\alpha > 6(1 - \psi)$</td><td>$f_1 = 0.6(\dfrac{1}{\beta} + 14\beta)$
but not greater than $14.5 - 0.35\beta^2$
$f_2 = f_3 = 0$</td></tr>
<tr><td>$3(1 - \psi) \leq \alpha \leq 6(1 - \psi)$</td><td>$f_1 = \dfrac{1}{\beta} - 1$
$f_2 = f_3 = 0$</td></tr>
<tr><td>$1.5(1 - \psi) \leq \alpha < 3(1 - \psi)$</td><td>$f_1 = \dfrac{1}{\beta} - (2 - \omega\beta)^4 - 9(\omega\beta - 1)(\dfrac{2}{3} - \beta)$
$f_2 = f_3 = 0$</td></tr>
</table>

<table>
<tr><td rowspan="3"></td><td rowspan="2">$0 \geq \psi \geq 1-\frac{4\alpha}{3}$</td><td>$1-\psi \leq \alpha < 1.5(1-\psi)$</td><td>For $\alpha > 1.5$:
$f_1 = 2\left(\frac{1}{\beta} - 16(1-\frac{\omega}{3})^4\right)\left(\frac{1}{\beta} - 1\right)$
$f_2 = 3\beta - 2$
$f_3 = 0$

For $\alpha \leq 1.5$:
$f_1 = 2\left(\frac{1.5}{1-\psi} - 1\right)\left(\frac{1}{\beta} - 1\right)$
$f_2 = \frac{\psi(1-16f_4^2)}{1-\alpha}$
$f_3 = 0$
$f_4 = (1.5 - Min(1.5;\alpha))^2$</td><td rowspan="3"></td></tr>
<tr><td>$0.75(1-\psi) \leq \alpha < 1-\psi$</td><td>$f_1 = 0$
$f_2 = 1 + 2.31(\beta - 1) - 48\left(\frac{4}{3} - \beta\right) f_4^2$
$f_3 = 3f_4(\beta - 1)\left(\frac{f_4}{1.81} - \frac{\alpha - 1}{1.31}\right)$
$f_4 = (1.5 - Min(1.5;\alpha))^2$</td></tr>
<tr><td>$\psi < 1-\frac{4\alpha}{3}$</td><td colspan="2">$K_y = 5.972F_{tran}\frac{\beta^2}{1-f_3}$
Where:
$f_3 = f_5\left(\frac{f_5}{1.81} + \frac{1+3\psi}{5.24}\right)$
$f_5 = \frac{9}{16}(1 + Max(-1;\psi))^2$</td></tr>
<tr><td rowspan="2">3
</td><td>$1 \geq \psi \geq 0$</td><td colspan="2">$K_x = \frac{4(0.425 + 1/\alpha^2)}{3\psi + 1}$</td><td rowspan="5">For UP-A:
$C_x = 1$ for $\lambda \leq 0.75$
$C_x = \frac{0.75}{\lambda}$ for $\lambda > 0.75$
For UP-B:
$C_x = 1$ for $\lambda \leq 0.7$
$C_x = \frac{1}{\lambda^2 + 0.51}$ for $\lambda > 0.7$</td></tr>
<tr><td>$0 > \psi \geq -1$</td><td colspan="2">$K_x = 4(0.425 + 1/\alpha^2)(1 + \psi) - 5\psi(1 - 3.42\psi)$</td></tr>
<tr><td>4
</td><td>$1 \geq \psi \geq -1$</td><td colspan="2">$K_x = \left(0.425 + \frac{1}{\alpha^2}\right)\frac{3-\psi}{2}$</td></tr>
<tr><td rowspan="2">5
</td><td rowspan="2">–</td><td>$\alpha \geq 1.64$</td><td>$K_x = 1.28$</td></tr>
<tr><td>$\alpha < 1.64$</td><td>$K_x = \frac{1}{\alpha^2} + 0.56 + 0.13\alpha^2$</td></tr>
<tr><td>6</td><td>$1 \geq \psi \geq 0$</td><td colspan="2">$K_y = \frac{4(0.425 + \alpha^2)}{(3\psi + 1)\alpha^2}$</td><td>For UP-A:
$C_x = 1$ for $\lambda \leq 0.75$</td></tr>
</table>

	$0 > \psi \geq -1$		$K_y = 4(0.425+\alpha^2)(1+\psi)\dfrac{1}{\alpha^2}$ $-5\psi(1-3.42\psi)\dfrac{1}{\alpha^2}$	$C_x = \frac{0.75}{\lambda}$ for $\lambda > 0.75$ For UP-B: $C_y = 1$ for $\lambda \leq 0.7$ $C_y = \frac{1}{\lambda^2+0.51}$ for $\lambda > 0.7$
7 	$1 \geq \psi \geq -1$		$K_y = 4(0.425+\alpha^2)\dfrac{(3-\psi)}{2\alpha^2}$	
8 	–		$K_y = 1 + \dfrac{0.56}{\alpha^2} + \dfrac{0.13}{\alpha^4}$	
9 	–		$K_x = 6.97$	$C_x = 1$ for $\lambda \leq 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
10 	–		$K_y = 4 + \dfrac{2.07}{\alpha^2} + \dfrac{0.67}{\alpha^4}$	$C_y = 1$ for $\lambda \leq 0.83$ $C_y = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
11 	–	$\alpha \geq 4$	$K_x = 4$	$C_x = 1$ for $\lambda \leq 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
		$\alpha < 4$	$K_x = 4 + 2.74\left[\dfrac{4-\alpha}{3}\right]^4$	
12 	–		$K_y = K_y$ determined as per case 2	For $\alpha < 2$: $C_y = C_{y2}$ For $\alpha \geq 2$: $C_y = \left(1.06 + \dfrac{1}{10\alpha}\right)C_{y2}$ Where: C_{y2}: C_y determined as per case 2
13 	–	$\alpha \geq 4$	$K_x = 6.97$	$C_x = 1$ for $\lambda \leq 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
		$\alpha < 4$	$K_x = 6.97 + 3.1\left[\dfrac{4-\alpha}{3}\right]^4$	
14	–		$K_y = \dfrac{6.97}{\alpha^2} + \dfrac{3.1}{\alpha^2}\left[\dfrac{4-1/\alpha}{3}\right]^4$	$C_y = 1$ for $\lambda \leq 0.83$ $C_y = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$

			
15 	–	$K_\tau = \sqrt{3}\left[5.34 + \frac{4}{\alpha^2}\right]$	
16 	–	$K_\tau = \sqrt{3}\left\{5.34 + Max\left[\frac{4}{\alpha^2}; \frac{7.15}{\alpha^{2.5}}\right]\right\}$	$C_\tau = 1$ for $\lambda \le 0.84$ $C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$
17 	–	$K_\tau = K_{\tau case15} r$ $K_{\tau case15}$: K_τ according to case 15 r: opening reduction factor taken as: $r = \left(1 - \frac{d_a}{a}\right)\left(1 - \frac{d_b}{b}\right)$ with $\frac{d_a}{a} \le 0.7$ and $\frac{d_b}{b} \le 0.7$	
18 	–	$K_\tau = \sqrt{3}(0.6 + 4/\alpha^2)$	$C_\tau = 1$ for $\lambda \le 0.84$ $C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$
19 	–	$K_\tau = 8$	

Edge boundary conditions:

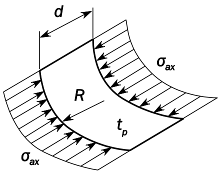
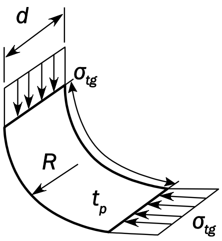
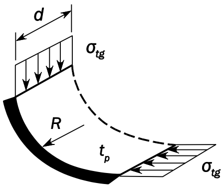
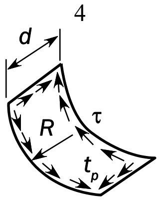
- - - - - - - - - - Plate edge free.

———————— Plate edge simply supported.

▬▬▬▬▬▬ Plate edge clamped.

Note 1: Cases listed are general cases. Each stress component (σ_x,σ_y) is to be understood in local coordinates.

Table 6 Buckling and Reduction Factor for Curved Plate Panel with $R/t_p \le 2500$

Case	Aspect ratio	Buckling factor K	Reduction factor C
1 	$\frac{d}{R} \le 0.5\sqrt{\frac{R}{t_p}}$	$K = 1 + \frac{2}{3}\frac{d^2}{Rt_p}$	For general application: $C_{ax} = 1$ for $\lambda \le 0.25$ $C_{ax} = 1.233 - 0.933\lambda$ for $0.25 < \lambda \le 1$ $C_{ax} = 0.3/\lambda^3$ for $1 < \lambda \le 1.5$ $C_{ax} = 0.2/\lambda^2$ for $\lambda > 1.5$ For curved single fields, e.g. bilge plating, which are bounded by plane panels as shown in Fig. 9: $C_{ax} = \frac{0.65}{\lambda^2} \le 1.0$
	$\frac{d}{R} > 0.5\sqrt{\frac{R}{t_p}}$	$K = 0.267\frac{d^2}{Rt_p}\left[3 - \frac{d}{R}\sqrt{\frac{t_p}{R}}\right] \ge 0.4\frac{d^2}{Rt_p}$	
2 	$\frac{d}{R} \le 1.63\sqrt{\frac{R}{t_p}}$	$K = \frac{d}{\sqrt{Rt_p}} + 3\frac{(Rt_p)^{0.175}}{d^{0.35}}$	For general application: $C_{tg} = 1$ for $\lambda \le 0.4$ $C_{tg} = 1.274 - 0.686\lambda$ for $0.4 < \lambda \le 1.2$ $C_{tg} = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$ For curved single fields, e.g. bilge plating, which are bounded by plane panels as shown in Fig. 9: $C_{ax} = \frac{0.8}{\lambda^2} \le 1.0$
	$\frac{d}{R} > 1.63\sqrt{\frac{R}{t_p}}$	$K = 0.3\frac{d^2}{R^2} + 2.25\left(\frac{R^2}{dt_p}\right)^2$	
3 	$\frac{d}{R} \le \sqrt{\frac{R}{t_p}}$	$K = \frac{0.6d}{\sqrt{Rt_p}} + \frac{\sqrt{Rt_p}}{d} - 0.3\frac{Rt_p}{d^2}$	As in load case 2.
	$\frac{d}{R} > \sqrt{\frac{R}{t_p}}$	$K = 0.3\frac{d^2}{R^2} + 0.291\left(\frac{R^2}{dt_p}\right)^2$	
4 	$\frac{d}{R} \le 8.7\sqrt{\frac{R}{t_p}}$	$K = \sqrt{3}\sqrt{28.3 + \frac{0.67d^3}{R^{1.5}t_p^{1.5}}}$	$C_\tau = 1$ for $\lambda \le 0.4$ $C_\tau = 1.274 - 0.686\lambda$ for $0.4 < \lambda \le 1.2$ $C_\tau = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$
	$\frac{d}{R} > 8.7\sqrt{\frac{R}{t_p}}$	$K = \sqrt{3}\frac{0.28d^2}{R\sqrt{Rt_p}}$	

Edge boundary conditions:

- - - - - - - - - - Plate edge free.

———————— Plate edge simply supported.

━━━━━━━━ Plate edge clamped.

5.2.2.7 Applied Normal and Shear Stresses to Plate Panels

The normal stress, σ_x and σ_y (N/mm^2) to be applied for the overall stiffened panel capacity and the plate panel capacity calculations as given in 5.2.1.1 and 5.2.2.1 respectively, are to be taken as follows:

- For FE analysis, the reference stresses as defined in 4.2.4.

- For prescriptive assessment of the overall stiffened panel capacity and the plate panel capacity, the axial or transverse compressive stresses calculated according to the relevant requirements, at load calculation points of the considered stiffener or the considered elementary plate panel, as defined in **item (a)** and **item (b)** of **3.1.2.1** respectively. However, in case of transverse stiffening arrangement, the transverse compressive stress used for the assessment of the overall stiffened panel capacity is to be taken as the compressive stress calculated at load calculation points of the stiffener attached plating, as defined in **item (a)** of **3.1.2.1**.

For grillage analysis where the stresses are obtained based on beam theory, the stresses taken as:

$$\sigma_x = \frac{\sigma_{xb} + \nu\sigma_{yb}}{1-\nu^2}$$

$$\sigma_y = \frac{\sigma_{yb} + \nu\sigma_{xb}}{1-\nu^2}$$

Where:

σ_{xb}, σ_{yb} : Stress (N/mm^2) from grillage beam analysis respectively along x or y axis of the plate attached to the PSM web.

The shear stress τ (N/mm^2) to be applied for the overall stiffened panel capacity and the plate panel capacity calculations as given in **5.2.1.1** and **5.2.2.1** respectively, are to be taken as follows:

- For FE analysis, the reference shear stresses as defined in **4.2.4**.
- For prescriptive assessment of the plate panel capacity, the shear stresses calculated according to the relevant requirements, at load calculation points of the considered elementary plate panel, as defined in **item (a)** of **3.1.2.1**.
- For prescriptive assessment of the overall stiffened panel capacity, the shear stresses calculated according to the relevant requirements, at the following load calculation point:
  - At the middle of the full span, ℓ, of the considered stiffener.
  - At the intersection point between the stiffener and its attached plating.
- For grillage beam analysis, $\tau = 0$ in the plate attached to the PSM web.

5.2.3 Stiffeners

5.2.3.1 Buckling Modes

The following buckling modes are to be checked:

- Stiffener induced failure (*SI*)
- Associated plate induced failure (*PI*)

5.2.3.2 Web Thickness of Flat Bar

For accounting the decrease of the stiffness due to local lateral deformation, the effective web thickness (mm) of flat bar stiffener is to be used in **5.2.1** and **5.2.3.4** for the calculation of the net sectional area, A_s, the net section modulus, Z, and the moment of inertia, I, of the stiffener and is taken as:

$$t_{w\_red} = t_w\left(1 - \frac{2\pi^2}{3}\left(\frac{h_w}{s}\right)^2\left(1 - \frac{b_{eff1}}{s}\right)\right)$$

5.2.3.3 Idealisation of Bulb Profile

Bulb profiles are to be considered as equivalent angle profiles. The net dimensions (mm) of the equivalent built-up section are to be obtained from the following formulae.

$$h_w = h'_w - \frac{h'_w}{9.2} + 2$$

$$b_f = \alpha\left(t'_w + \frac{h'_w}{6.7} - 2\right)$$

$$t_f = \frac{h'_w}{9.2} - 2$$

$$t_w = t'_w$$

Where:

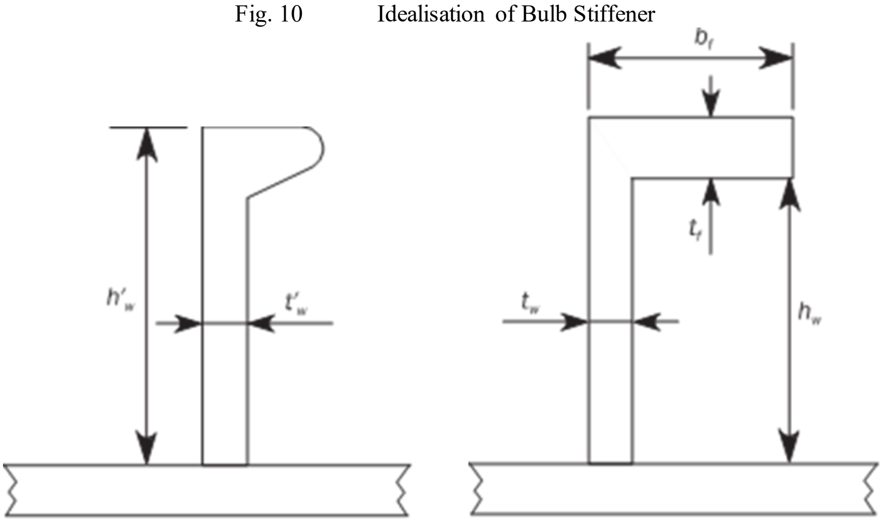
h'_w, t'_w: Net height and thickness (mm) of a bulb section as shown in **Fig. 10**.

α: Coefficient equal to:

$\alpha = 1.1 + \frac{(120-h'_w)^2}{3000}$ for $h'_w \le 120$

$\alpha = 1.0$ for $h'_w > 120$

Fig. 10 Idealisation of Bulb Stiffener



5.2.3.4 Ultimate Buckling Capacity

When $\sigma_a + \sigma_b + \sigma_w > 0$ while initially setting $\gamma = 1$, the ultimate buckling capacity for stiffeners is to be checked according to the following interaction formula:

$$\frac{\gamma_c \sigma_a + \sigma_b + \sigma_w}{\sigma_Y} S = 1$$

with the corresponding buckling utilisation factor defined as

$$\eta_{stiffener} = \frac{1}{\gamma_c}$$

Where:

σ_a : Effective axial stress (N/mm^2) at mid span of the stiffener, acting on the stiffener with its attached plating.

$$\sigma_a = \sigma_x \frac{s t_p + A_s}{b_{eff1} t_p + A_s}$$

σ_x: Nominal axial stress (N/mm^2) acting on the stiffener with its attached plating.

- For FE analysis, σ_x is the FE corrected stress as defined in 5.2.3.6 in the attached plating in the direction of the stiffener axis.
- For prescriptive assessment, σ_x is the axial stress calculated according to 3.2.2.1 at load calculation point of the stiffener, as defined in 3.1.2.1.
- For grillage beam analysis, σ_x is the stress acting along the *x*-axis of the attached buckling panel.

σ_Y: Specified minimum yield stress (N/mm^2) of the material

$\sigma_Y = \sigma_{Y\_S}$ for stiffener induced failure (*SI*).

$\sigma_Y = \sigma_{Y\_P}$ for plate induced failure (*PI*).

σ_b: Bending stress (N/mm^2) in the stiffener

$$\sigma_b = \frac{M_0 + M_1 + M_2}{1000Z}$$

Z: Net section modulus (cm^3) of stiffener including effective width of plating according to 5.2.3.5, to be taken as:

- The section modulus calculated at the top of stiffener flange for stiffener induced failure (*SI*).
- The section modulus calculated at the attached plating for plate induced failure (*PI*).

M_2: Bending moment (Nmm) due to eccentricity of sniped stiffeners, to be taken as

$M_2 = 0$ for continuous stiffeners

$M_2 = C_{snip} w_{na} \gamma \sigma_x (A_p + A_s)$ for stiffeners sniped at one or both ends.

C_{snip}: Coefficient to account for the end effect of the stiffener sniped at one or both ends, to be taken as

$C_{snip} = -1.2$ for stiffener induced failure (*SI*)

$C_{snip} = 1.2$ for plate induced failure (*PI*).

M_1: Bending moment (Nmm) due to the lateral load P:

$M_1 = C_i \frac{|P| s \ell^2}{24 \times 10^3}$ for continuous stiffener

$M_1 = C_i \frac{|P| s \ell^2}{8 \times 10^3}$ for sniped stiffener

$M_1 = C_i \frac{|P| s \ell^2}{14.2 \times 10^3}$ for stiffener sniped at one end and continuous at the other end

P: Lateral load (kN/m^2)

- For FE analysis, P is the average pressure as defined in **4.2.5.2** in the attached plating.
- For prescriptive assessment, P is the pressure calculated at load calculation point of the stiffener, as defined in **3.1.2.1**.

C_i: Pressure coefficient:

$C_i = C_{SI}$ for stiffener induced failure (SI).

$C_i = C_{PI}$ for plate induced failure (PI).

C_{PI}: Plate induced failure pressure coefficient:

$C_{PI} = 1$ if the lateral pressure is applied on the side opposite to the stiffener.

$C_{PI} = -1$ if the lateral pressure is applied on the same side as the stiffener.

C_{SI}: Stiffener induced failure pressure coefficient:

$C_{SI} = -1$ if the lateral pressure is applied on the side opposite to the stiffener.

$C_{SI} = 1$ if the lateral pressure is applied on the same side as the stiffener.

M_0: Bending moment (Nmm) due to the lateral deformation w of stiffener:

$M_0 = F_E C_{sl} \frac{\gamma}{\gamma_{GEB} - \gamma} w_0$ with precondition $\gamma_{GEB} - \gamma > 0$

γ_{GEB}: Stress multiplier factor of global elastic buckling capacity as defined in **5.2.1**.

F_E: Ideal elastic buckling force (N) of the stiffener

$$F_E = \left(\frac{\pi}{\ell}\right)^2 EI \cdot 10^4$$

I: Moment of inertia (cm^4) of the stiffener including effective width of attached plating according to **5.2.3.5**. I is to comply with the following requirement:

$$I \geq \frac{s t_p^3}{12 \cdot 10^4}$$

t_p: Net thickness of plate (mm) to be taken as

- For prescriptive requirements: the mean thickness of the two attached plating panels,
- For FE analysis: the thickness of the considered EPP on one side of the stiffener.

C_{sl}: Deformation reduction factor to account for global slenderness, to be taken as:

$C_{sl} = 1 - \frac{1}{12}\lambda_G^4$ for $\lambda_G \leq 1.56$

$C_{sl} = 3/\lambda_G^4$ for $\lambda_G > 1.56$

λ_G: The reference degree of global slenderness of the stiffened panel, to be taken as

$$\lambda_G = \sqrt{\frac{\gamma_{\sigma Y}}{\gamma_{GEB}}}$$

$$\gamma_{\sigma Y} = \frac{\min(\sigma_{Y\_P}, \sigma_{Y\_S})}{\sqrt{\sigma_{x,av}^2 + \sigma_y^2 - \sigma_{x,av}\sigma_y + 3\tau^2}}$$

$\sigma_{x,av}$: Average stress for both plate and stiffener as defined in **5.2.1.2**.

σ_y: Applied transverse stress (N/mm^2) to the plate panel as defined in **5.2.1.1**.

τ: Applied shear stress (N/mm^2) to the plate panel as defined in **5.2.1.1**.

w_0: Assumed imperfection (mm) to be taken as:

$$w_0 = \ell/1000$$

σ_w: Stress due to torsional deformation (N/mm^2) to be taken as:

- For stiffener induced failure (SI)
  - For $\sigma_a > 0$

$\sigma_w = E y_w e_f \Phi_0 \left(\frac{m_{tor}\pi}{l_{tor}}\right)^2 \left(\frac{1}{1 - \frac{\gamma\sigma_a}{\sigma_{ET}}} - 1\right)$ with precondition $\sigma_{ET} - \gamma\sigma_a > 0$

  - For $\sigma_a \leq 0$

$\sigma_w = 0$

- For plate induced failure (PI)

$\sigma_w = 0$

y_w: Distance (mm) from centroid of stiffener cross section to the free edge of stiffener flange, to be taken as:

$y_w = \frac{t_w}{2}$ for flat bar

$y_w = b_f - \frac{h_w t_w^2 + t_f b_f^2}{2A_s}$ for angle and bulb profiles

$y_w = b_{f-out} + 0.5t_w - \frac{h_w t_w^2 + t_f(b_f^2 - 2b_f d_f)}{2A_s}$ for L2 profile

$y_w = \frac{b_f}{2}$ for T profile.

Φ_0: Coefficient taken as:

$$\Phi_0 = \frac{l_{tor}}{m_{tor} h_w} 10^{-4}$$

σ_{ET}: Reference stress (N/mm^2) for torsional buckling to be taken as:

$$\sigma_{ET} = \frac{E}{I_p}\left[\left(\frac{m_{tor}\pi}{\ell_{tor}}\right)^2 I_\omega \cdot 10^2 + \frac{1}{2(1+\nu)} I_T + \left(\frac{\ell_{tor}}{m_{tor}\pi}\right)^2 \varepsilon \cdot 10^{-4}\right]$$

I_p: Net polar moment of inertia (cm^4) of the stiffener about point C as shown in **Fig. 2**, as defined in **Table 7**.

I_T: Net St. Venant's moment of inertia (cm^4) of the stiffener as defined in **Table 7**.

I_ω: Net sectorial moment of inertia (cm^6) of the stiffener about point C as shown in **Fig. 2**, as defined in **Table 7**.

ℓ_{tor}: Stiffener span, distance equal to spacing between primary supporting members, i.e. $\ell_{tor}=\ell$. When the stiffener is supported by tripping brackets, ℓ_{tor} should be taken as the maximum spacing between the adjacent primary supporting members and fitted tripping brackets.

m_{tor}: Number of half waves, taken as a positive integer so as to give smallest reference stress for torsional buckling.

ε: Degree of fixation (mm^2) to be taken as:

$\varepsilon = \left(\frac{3b}{t_p^3} + \frac{2h_w}{t_w^3}\right)^{-1}$ for bulb, angle, L2 and T profiles;

$\varepsilon = \left(\frac{t_p^3}{3b}\right)$ for flat bars.

A_w: Net web area (mm^2)

A_f: Net flange area (mm^2)

Table 7 Moments of Inertia

	Flat bars (1)	Bulb, angle, L2 and T profiles
I_P	$\frac{h_w^3 t_w}{3 \times 10^4}$	$\left(\frac{A_w(e_f - 0.5t_f)^2}{3} + A_f e_f^2\right)10^{-4}$
I_T	$\frac{h_w t_w^3}{3 \times 10^4}\left(1 - 0.63\frac{t_w}{h_w}\right)$	$\frac{(e_f - 0.5t_f)t_w^3}{3 \times 10^4}\left(1 - 0.63\frac{t_w}{e_f - 0.5t_f}\right) + \frac{b_f t_f^3}{3 \times 10^4}\left(1 - 0.63\frac{t_f}{b_f}\right)$
I_ω	$\frac{h_w^3 t_w^3}{36 \times 10^6}$	For bulb, angle and L2 profiles(2). $\frac{A_f^3 + A_w^3}{36 \times 10^6} + \frac{e_f^2}{10^6}\left(\frac{A_f b_f^2 + A_w t_w^2}{3} - \frac{(A_f(b_f - 2d_f) + A_w t_w)^2}{4(A_f + A_w)} - A_f d_f(b_f - d_f)\right)$ For T profiles. $\frac{b_f^3 t_f e_f^2}{12 \times 10^6}$

(1) t_w is the net web thickness (mm). t_{w_red} as defined in **5.2.3.2** is not to be used in this table.

(2) d_f is to be taken as 0 for bulb and angle profiles.

5.2.3.5 Effective Width of Attached Plating

The effective width of attached plating of stiffeners b_{eff} (mm) is to be taken as:

- For $\sigma_x > 0$:
  - For FE analysis,

    $b_{eff} = \min(C_x b, \chi_s s)$
  - For prescriptive assessment,

    $b_{eff} = \min(\frac{C_{x1}b_1 + C_{x2}b_2}{2}, \chi_s s)$
- For $\sigma_x \le 0$:
  - $b_{eff} = \chi_s s$

Where:

χ_s: Effective width coefficient to be taken as:

$$\chi_s = \frac{1.12}{1+\frac{1.75}{\left(\frac{\ell_{eff}}{s}\right)^{1.6}}} \le 1.0 \quad \text{for} \quad \frac{\ell_{eff}}{s} \ge 1$$

$$\chi_s = 0.407\frac{\ell_{eff}}{s} \quad \text{for} \quad \frac{\ell_{eff}}{s} < 1$$

ℓ_{eff}: Effective length (mm) of the stiffener taken as:

$\ell_{eff} = \frac{\ell}{\sqrt{3}}$ for stiffener fixed at both ends.

$\ell_{eff} = 0.75\ell$ for stiffener simply supported at one end and fixed at the other.

$\ell_{eff} = \ell$ for stiffener simply supported at both ends.

5.2.3.6 FE Corrected Stresses for Stiffener Capacity

When the reference stresses σ_x and σ_y obtained by FE analysis according to **4.2.4** are both compressive, σ_x is to be corrected according to the following formulae:

- If $\sigma_x < \nu\sigma_y$

  $\sigma_{xcor} = 0$
- If $\sigma_x \ge \nu\sigma_y$

  $\sigma_{xcor} = \sigma_x - \nu\sigma_y$

5.2.4 Primary Supporting Members

5.2.4.1 Web Plate in Way of Openings

The web plate of primary supporting members with openings is to be assessed for buckling based on the combined axial compressive and shear stresses.

The web plate adjacent to the opening on both sides is to be considered as individual unstiffened plate panels as shown in **Table 8**.

The interaction formulae of **5.2.2.1** are to be used with:

- $\sigma_x = \sigma_{av}$
- $\sigma_y = 0$
- $\tau = \tau_{av}$

Where:

σ_{av} : Weighted average compressive stress (N/mm^2) in the area of web plate being considered, i.e. *P1*, *P2*, or *P3* as shown in **Table 8**.

For the application of **Table 8**, the weighted average shear stress is to be taken as:

- Opening modelled in primary supporting members:

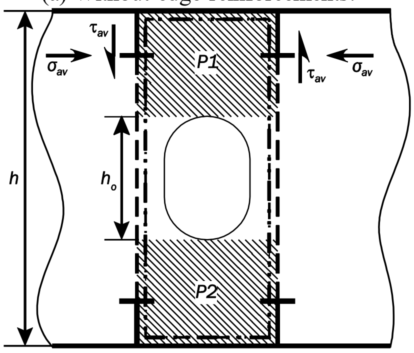
  τ_{av} : Weighted average shear stress (N/mm^2) in the area of web plate being considered, i.e. *P1*, *P2*, or *P3* as shown in **Table 8**.
- Opening not modelled in primary supporting members:

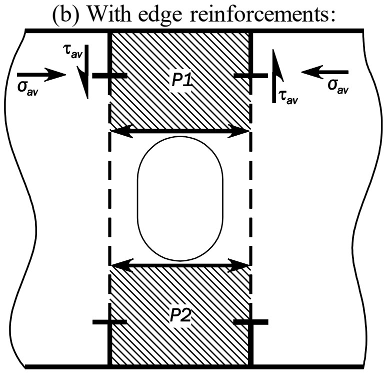
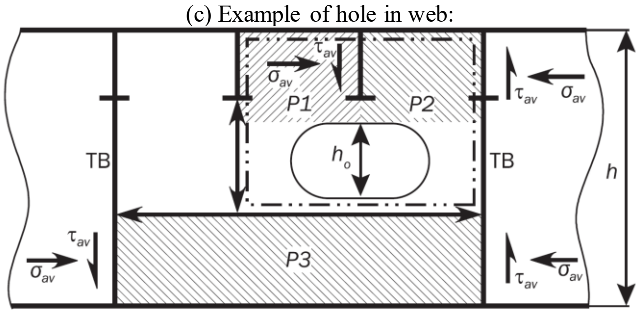
  τ_{av} : Weighted average shear stress (N/mm^2) given in **Table 8**.

5.2.4.2 Reduction Factors of Web Plate in Way of Openings

The reduction factors, C_x or C_y in combination with, C_τ of the plate panel(s) of the web adjacent to the opening is to be taken as shown in **Table 8**.

Table 8 Reduction Factors

<table>
<tr><td rowspan="2">Configuration(1)</td><td rowspan="2">C_x, C_y</td><td colspan="2">C_τ</td></tr>
<tr><td>Opening modelled in PSM</td><td>Opening not modelled in PSM</td></tr>
<tr><td>(a) Without edge reinforcements:(2)

</td><td>Separate reduction factors are to be applied to areas $P1$ and $P2$ using case 3 or case 6 in Table 5, with edge stress ratio:
$\psi = 1.0$</td><td>Separate reduction factors are to be applied to areas $P1$ and $P2$ using case 18 or case 19 in Table 5</td><td>When case 17 of Table 5 is applicable:
A common reduction factor is to be applied to areas $P1$ and $P2$ using case 17 in Table 5 with:
$\tau_{av} = \tau_{av}\ (web)$

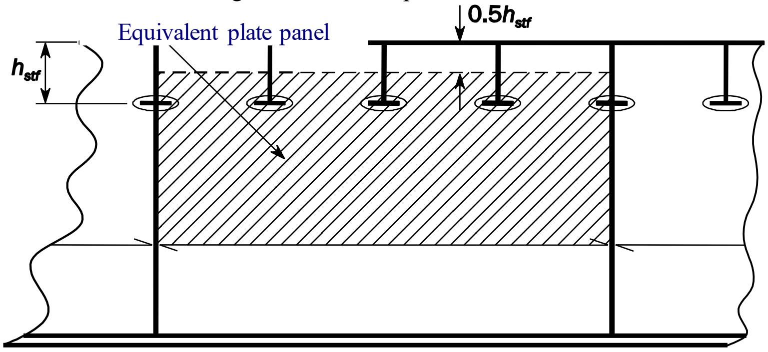
When case 17 of Table 5 is not applicable:
Separate reduction factors are to be applied to areas $P1$ and $P2$ using case 18 or case 19 in Table 5 with:
$\tau_{av} = \tau_{av}\ (web)\ h/(h\text{-}h_0)$</td></tr>
<tr><td>(b) With edge reinforcements:

</td><td>Separate reduction factors are to be applied for areas $P1$ and $P2$ using C_x for case 1 or C_y for case 2 in Table 5 with stress ratio:
$\psi = 1.0$</td><td>Separate reduction factors are to be applied for areas $P1$ and $P2$ using case 15 in Table 5.</td><td>Separate reduction factors are to be applied to areas $P1$ and $P2$ using case 15 in Table 5 with:
$\tau_{av} = \tau_{av}\ (web)\ h/(h\text{-}h_0)$</td></tr>
<tr><td colspan="2">(c) Example of hole in web:

</td><td colspan="2">Panels $P1$ and $P2$ are to be evaluated in accordance with **(a)**. Panel $P3$ is to be evaluated in accordance with **(b)**.</td></tr>
<tr><td colspan="4">Where:
h : Height (m) of the web of the primary supporting member in way of the opening.
h_0: Height (m) of the opening measured in the depth of the web.
$\tau_{av}\ (web)$: Weighted average shear stress (N/mm^2) over the web height h of the primary supporting member.
Note (1): Web panels to be considered for buckling in way of openings are shown shaded and numbered $P1$, $P2$, etc.
Note (2): For a PSM web panel with opening and without edge reinforcements as shown in configuration (a), the applicable buckling assessment method depends on its specific boundary conditions. If one of the long edges along the face plate or along the attached plating is not subject to "inline support", i.e. the edge is free to pull in, Method B should</td></tr>
</table>

be applied. In other cases, typically such as when the short plate edge is attached to the plate flanges, Method A is applicable.

5.2.4.3

The equivalent plate panel of web plate of primary supporting members crossed by perpendicular stiffeners is to be idealised as shown in **Fig. 11**.

Fig. 11 Web plate idealisation



The correction of panel breadth is applicable also for other slot configurations provided that the web or collar plate is attached to at least one side of the passing stiffener.

5.2.5 Stiffened Panels with U-type Stiffeners

5.2.5.1 Local Plate Buckling

For stiffened panels with U-type stiffeners, local plate buckling is to be checked for each of the plate panels *EPP* b_1, b_2, b_f and h_w (see **Fig. 3**) separately as follows:

- The attached plate panels *EPP* b_1 and b_2 are to be assessed using SP-A model, where in the calculation of buckling factors K_x as defined in case 1 of **Table 5**, the correction factor F_{long} for U-type stiffeners as defined in **Table 4** is to be used; and in the calculation of K_y as defined in case 2 of **Table 5**, the F_{tran} for U-type stiffeners as defined in **5.2.2.5** is to be used.
- The face plate and web plate panels *EPP* b_f and h_w are to be assessed using UP-B model with $F_{long} = 1$ and $F_{tran} = 1$.

5.2.5.2 Overall Stiffened Panel Buckling and Stiffener Buckling

For a stiffened panel with U-type stiffeners, the overall buckling capacity and ultimate capacity of the stiffeners are to be checked with warping stress $\sigma_w = 0$, and with bending moment of inertia including effective width of attached plating being calculated based on the following assumptions:

- The two web panels of a U-type stiffener are to be taken as perpendicular to the attached plate with thickness equal to t_w and height equal to the distance between the attached plate and the face plate of the stiffener.
- Effective width of the attached plating, b_{eff}, taken as the sum of the b_{eff} calculated for the *EPP* b_1 and b_2 respectively according to SP-A model.
- Effective width of the attached plating of a stiffener without shear lag effect, b_{eff1}, taken as the sum of the b_{eff1} calculated for the *EPP* b_1 and b_2 respectively.

5.3 Buckling Capacity of Column Structures

5.3.1 Column Buckling of Corrugations

5.3.1.1 Buckling Utilisation Factor

The column buckling utilisation factor, η, for axially compressed corrugations is to be taken as:

$$\eta_{column} = \frac{\sigma_{av}}{\sigma_{cr}}$$

Where:

σ_{av}:Average axial compressive stress (N/mm^2) in the member

σ_{cr}:Minimum critical buckling stress (N/mm^2) taken as:

$$\sigma_{cr} = \sigma_E \quad \text{for} \quad \sigma_E \leq 0.5\sigma_{Y\_S}$$
$$\sigma_{cr} = \left(1 - \frac{\sigma_{Y\_S}}{4\sigma_E}\right)\sigma_{Y\_S} \quad \text{for} \quad \sigma_E > 0.5\sigma_{Y\_S}$$

σ_E: Elastic column compressive buckling stress (N/mm^2) according to **5.3.1.2**.

σ_{Y_S}:Specified minimum yield stress (N/mm^2) of the considered member. For built-up members, the lowest specified minimum yield stress is to be used.

5.3.1.2 Elastic Column Buckling Stress

The elastic compressive column buckling stress, σ_E (N/mm^2) of members subject to axial compression is to be taken as:

$$\sigma_E = \pi^2 E f_{end} \frac{I}{A\ell_{pill}^2} 10^{-4}$$

Where:

I: Net moment of inertia (cm^4) about the weakest axis of the cross section

A: Net cross-sectional area (cm^2) of the member

ℓ_{pill}: Unsupported length (m) of the member

f_{end}: End constraint factor, corresponding to simply supported ends is to be applied except for fixed end support to be used in way of stool with width exceeding 2 times the depth of the corrugation, taken as:

- $f_{end} = 1.0$ where both ends are simply supported.
- $f_{end} = 2.0$ where one end is simply supported and the other end is fixed.
- $f_{end} = 4.0$ where both ends are fixed.

Appendix C20.2 STRESS BASED REFERENCE STRESSES

Symbols

a: Length (mm) of the longer side of the plate panel as defined in **5, Annex C20.2** **"BUCKLING STRENGTH ASSESSMENT OF SHIP STRUCTURAL ELEMENTS"**

b: Length (mm) of the shorter side of the plate panel as defined in **5, Annex C20.2** **"BUCKLING STRENGTH ASSESSMENT OF SHIP STRUCTURAL ELEMENTS"**

A_i: Area (mm^2) of the i-th plate element of the buckling panel

n: Number of plate elements in the buckling panel

σ_{xi}: Actual stress (N/mm^2) at the centroid of the i-th plate element in x direction, applied along the shorter edge of the buckling panel

σ_{yi}: Actual stress (N/mm^2) at the centroid of the i-th plate element in y direction, applied along the longer edge of the buckling panel

ψ: Edge stress ratio as defined in **5, Annex C20.2** **"BUCKLING STRENGTH ASSESSMENT OF SHIP STRUCTURAL ELEMENTS"**

τ_i: Actual membrane shear stress (N/mm^2) at the centroid of the i-th plate element of the buckling panel

1 Stress Based Method

1.1 Introduction

1.1.1

This section provides a method to determine stress distribution along edges of the considered buckling panel by second-order polynomial curve, by linear distribution using least square method and by weighted average approach. This method is called Stress based Method.

The reference stress is the stress components at centre of plate element transferred into the local system of the considered buckling panel.

1.1.2 Definition

A regular panel is a plate panel of rectangular shape. An irregular panel is plate panel which is not regular, as detailed in **4.2.3.1, Annex C20.2** **"BUCKLING STRENGTH ASSESSMENT OF SHIP STRUCTURAL ELEMENTS"**.

1.2 Stress Application

1.2.1 Regular Panel

The reference stresses are to be taken as defined in **2.1** for a regular panel when the following conditions are satisfied:

- At least, one plate element centre is located in each third part of the long edge a of a regular panel and
- This element centre is located at a distance in the panel local x direction not less than $a/4$ to at least one of the element centres in the adjacent third part of the panel.

Otherwise, the reference stresses are to be taken as defined in **2.2** for an irregular panel.

1.2.2 Irregular Panel and Curved Panel

The reference stresses of an irregular panel or of a curved panel are to be taken as defined in **2.2**.

2 Reference Stresses

2.1 Regular Panel

2.1.1 Longitudinal Stress

The longitudinal stress σ_x applied on the shorter edge of the buckling panel is to be calculated as follows:

- For plate buckling assessment, the distribution of $\sigma_x(x)$ is assumed as second order polynomial curve as:

$$\sigma_x(x) = Cx^2 + Dx + E$$

The best fitting curve $\sigma_x(x)$ is to be obtained by minimising the square error Π considering the area of each element as a weighting factor.

$$\Pi = \sum_{i=1}^{n} A_i[\sigma_{xi} - (Cx^2 + Dx + E)]^2$$

The unknown coefficients C, D and E must yield zero first derivatives, $\partial \Pi$ with respect to C, D and E, respectively.

$$\begin{cases} \dfrac{\partial \Pi}{\partial C} = 2\displaystyle\sum_{i=1}^{n} A_i x_i^2 \left[\sigma_{ix} - \left(Cx_i^2 + Dx_i + E\right)\right] = 0 \\ \dfrac{\partial \Pi}{\partial D} = 2\displaystyle\sum_{i=1}^{n} A_i x_i \left[\sigma_{ix} - \left(Cx_i^2 + Dx_i + E\right)\right] = 0 \\ \dfrac{\partial \Pi}{\partial E} = 2\displaystyle\sum_{i=1}^{n} A_i \left[\sigma_{ix} - \left(Cx_i^2 + Dx_i + E\right)\right] = 0 \end{cases}$$

The unknown coefficients C, D and E can be obtained by solving the 3 above equations.

$$\sigma_{x1} = \frac{1}{b}\int_0^b \sigma_x(x)dx = \frac{b^2}{3}C + \frac{b}{2}D + E$$

$$\sigma_{x2} = \frac{1}{b}\int_{a-b}^{a} \sigma_x(x)dx = \left(a^2 - ab + \frac{b^2}{3}\right)C + \left(a - \frac{b}{2}\right)D + E$$

If $-\frac{D}{2C} < \frac{b}{2}$ or $-\frac{D}{2C} > a - \frac{b}{2}$, σ_{x3} is to be ignored. Otherwise, σ_{x3} is taken as:

$$\sigma_{x3} = \frac{1}{b}\int_{x_{min}}^{x_{max}} \sigma_x(x)dx = \frac{b^2}{12}C - \frac{D^2}{4C} + E$$

Where:

$$x_{min} = -\frac{b}{2} - \frac{D}{2C}$$

$$x_{max} = \frac{b}{2} - \frac{D}{2C}$$

The longitudinal stress is to be taken as:

$$\sigma_x = max(\sigma_{x1}; \sigma_{x2}; \sigma_{x3})$$

The edge stress ratio is to be taken as:

$$\psi_x = 1$$

- For overall stiffened panel buckling and stiffener buckling assessments, the longitudinal stress σ_x applied on the shorter edge of the attached plate is to be taken as:

$$\sigma_x = \frac{\sum_{i=1}^{n} A_i \sigma_{xi}}{\sum_{i=1}^{n} A_i}$$

The edge stress ratio ψ_x for the stress σ_x is equal to 1.0.

2.1.2 Transverse Stress

The transverse stress σ_y applied along the longer edges of the buckling panel is to be calculated by extrapolation of the transverse stresses of all elements up to the shorter edges of the considered buckling panel.

The distribution of $\sigma_y(x)$ is assumed as straight line. Therefore:

$$\sigma_y(x) = A + Bx$$

The best fitting curve $\sigma_y(x)$ is to be obtained by the least square method minimising the square error Π considering area of each element as a weighting factor.

$$\Pi = \sum_{i=1}^{n} A_i\left[\sigma_{yi} - (A + Bx_i)\right]^2$$

The unknown coefficients A and B must yield zero first partial derivatives, $\partial \Pi$ with respect to A and B, respectively.

$$\frac{\partial \Pi}{\partial A} = 2\sum_{i=1}^{n} A_i\left[\sigma_{yi} - (A + Bx_i)\right] = 0$$

$$\frac{\partial \Pi}{\partial B} = 2\sum_{i=1}^{n} A_i x_i\left[\sigma_{yi} - (A + Bx_i)\right] = 0$$

The unknown coefficients A and B are obtained by solving the 2 above equations and are given as follow:

$$A = \frac{\left(\sum_{i=1}^{n} A_i\sigma_{yi}\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)\left(\sum_{i=1}^{n} A_i x_i \sigma_{yi}\right)}{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)^2}$$

$$B = \frac{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i \sigma_{yi}\right) - \left(\sum_{i=1}^{n} A_i x_i\right)\left(\sum_{i=1}^{n} A_i\sigma_{yi}\right)}{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)^2}$$

The transverse stress is to be taken as:

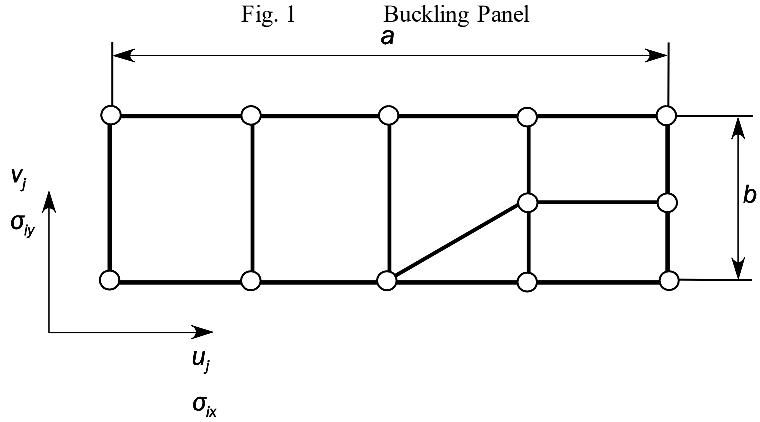
σ_y=max$(A, A+Ba)$

The edge stress ratio is to be taken as:

$\psi_y = \frac{min(A,A+Ba)}{max(A,A+Ba)}$ for $\sigma_y > 0$

ψ_y=1 for $\sigma_y \leq 0$

Fig. 1 Buckling Panel



2.1.3 Shear Stress

The shear stress τ is to be calculated using a weighted average approach and is to be taken as:

$$\tau = \frac{\sum_{i=1}^{n} A_i \tau_i}{\sum_{i=1}^{n} A_i}$$

2.2 Irregular Panel and Curved Panel

2.2.1 Reference Stresses

The longitudinal, transverse and shear stresses are to be calculated using a weighted average approach. They are to be taken as:

$$\sigma_x = \frac{\sum_{i=1}^{n} A_i \sigma_{xi}}{\sum_{i=1}^{n} A_i}$$

$$\sigma_y = \frac{\sum_{i=1}^{n} A_i \sigma_{yi}}{\sum_{i=1}^{n} A_i}$$

$$\tau = \frac{\sum_{i=1}^{n} A_i \tau_i}{\sum_{i=1}^{n} A_i}$$

The edge stress ratios are to be taken as

$\psi_x = 1$

$\psi_y = 1$

Annex C32.2.3-4 GUIDANCE FOR CALCULATION OF SHEAR FLOW

1.1 General

1.1.1 General

This Guidance describes the procedures of direct calculation of shear flow which is working along a ship cross section due to hull girder vertical shear force. Shear flow q_v, at each location in the cross section, is calculated where considering the cross section is subjected to a unit vertical shear force, $1N$, in the direction of z coordinate. The unit shear flow per millimetre, q_v in N/mm, can be considered equal to:

$$q_v = q_D + q_I$$

q_D : Determinate shear flow, as defined in **1.2**.

q_I : Indeterminate shear flow which circulates around the closed cells, as defined in **1.3**.

In the calculation of the unit shear flow, q_v, the longitudinal stiffeners are to be taken into account.

1.2 Determinate Shear Flow

1.2.1 Determinate Shear Flow

The determinate shear flow, q_D in N/mm, at each location in the cross section can be obtained from the following line integration:

$$q_D(s) = -\frac{1}{10^6 I_y}\int_0^s (z - z_n)t\,ds$$

s : Coordinate value of running coordinate along the cross section, in m.

I_y : Moment inertia of the cross section, in m^4.

t : Thickness of plating.

z_n : Z coordinate of horizontal neutral axis from baseline, in m.

It is assumed that the cross section is composed of line segments as shown in **Fig. 1**: where each line segment has a constant plate net thickness. The determinate shear flow is obtained by the following equation.

$$q_{Dk} = -\frac{t\ell}{2\times 10^6 I_y}(z_k + z_i - 2z_n) + q_{Di}$$

q_{Dk}, q_{Di} : Determinate shear flow at node k and node i respectively , in N/mm.

ℓ : Length of line segments, in m.

y_k, y_i : Y coordinate of the end points k and i of line segment, in m, as defined in **Fig. 1**.

z_k, z_i: Z coordinate of the end points k and i of line segment, in m, as defined in **Fig. 1**.

Where the cross section includes closed cells, the closed cells are to be cut with virtual slits, as shown in **Fig. 2** in order to obtain the determinate shear flow. However, the virtual slits are not to be located at the walls by which the other closed cell is also bounded. Calculations of the determinate shear flow at bifurcation points can be calculated such as water flow calculations as shown in **Fig. 2**.

Fig. 1 Definition of Line Segment

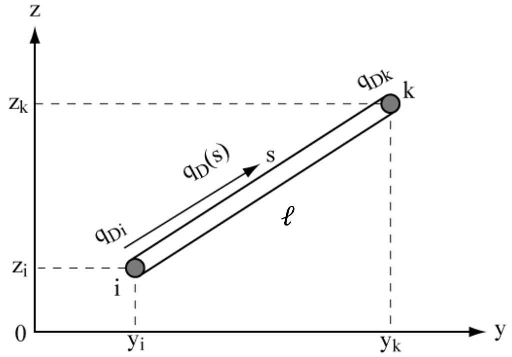
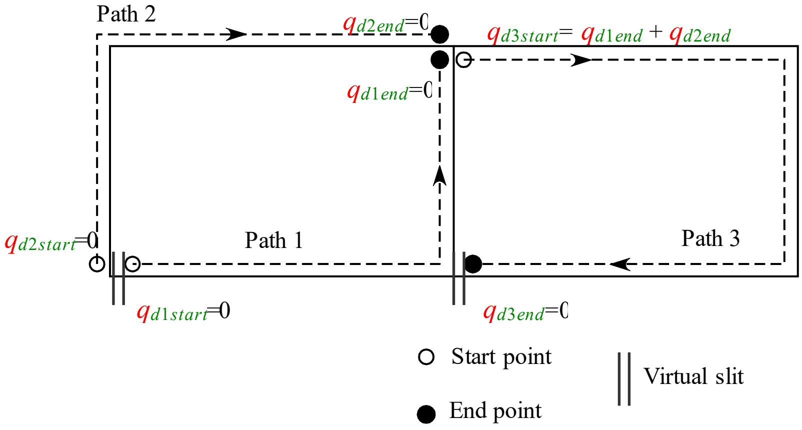


Fig. 2 Calculation of Determinate Shear Flow at Bifurcation



1.3 Indeterminate Shear Flow

1.3.1 Indeterminate Shear Flow

The indeterminate shear flow is working around the closed cells and can be considered as a constant value within the same closed cell. The following system of equation for determination of indeterminate shear flows can be developed. In the equations, contour integrations of several parameters around all closed cells are performed.

$$q_{Ic}\oint_{c}\frac{1}{t}ds-\sum_{m=i}^{Nw}q_{Im}\oint_{c\&m}\frac{1}{t}ds=-\oint_{c}\frac{q_D}{t}ds$$

Nw : Number of common walls shared by cell c and all other cells.

$c\&m$: Common wall shared by cells c and m.

q_{Ic}, q_{Im} : Indeterminate shear flow around the closed cell c and m respectively, in N/mm.

Under the assumption of the assembly of line segments shown in **Fig. 1** and constant plate thickness of each line segment, the above equation can be expressed as follows:

$$q_{Ic}\sum_{j=1}^{Nc}\left(\frac{\ell}{t}\right)_j-\sum_{m=1}^{Nw}\left\{q_{Im}\left[\sum_{j=1}^{Nm}\left(\frac{\ell}{t}\right)_j\right]_m\right\}=-\sum_{j=1}^{Nc}\phi_j$$

$$\phi_j=\left[-\frac{\ell^2}{6\times10^3 I_y}(z_k+2z_i-3z_n)+\frac{\ell}{t}q_{Di}\right]_j$$

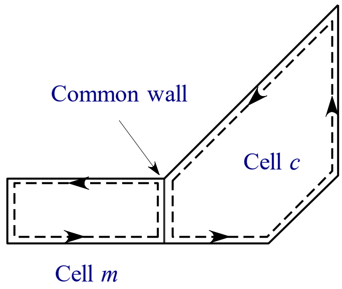
N_c : Number of line segments in cell c.

N_m : Number of line segments on the common wall shared by cells c and m.

q_{Di} : Determinate shear flow, in N/mm, calculated according to **1.2**.

The difference in the directions of running coordinates specified in **1.2** and in this section has to be considered.

Fig. 3 Closed Cells and Common Wall



1.4 Computation of Sectional Properties

1.4.1 Computation of Sectional Properties

Properties of the cross section are to be obtained by the following formulae where the cross section is assumed as the assembly of line segments:

$$\ell = \sqrt{(y_k - y_i)^2 + (z_k - z_i)^2}$$

$$a = 10^{-3}\ell t \qquad A = \sum a$$

$$s_y = \frac{a}{2}(z_k + z_i) \qquad S_y = \sum s_y$$

$$i_{y0} = \frac{a}{3}(z_k^2 + z_k z_i + z_i^2) \qquad I_{y0} = \sum i_{y0}$$

$a_{net} = 10^{-3} l t_{net} s_{y\text{-}net} = \frac{a_{net}}{2}(z_k + z_i) i_{y0\text{-}net} = \frac{a_{net}}{3}(z_k^2 + z_k z_i + z_i^2)$ a, A : Area of the line segment and the cross section respectively, in m^2.

s_y, S_y : First moment of the line segment and the cross section about the baseline, in m^3.

i_{y0}, I_{y0} : Moment of inertia of the line segment and the cross section about the baseline, in m^4.

The height of horizontal neutral axis, z_n, in m, is to be obtained as follows:

$$z_n = \frac{S_y}{A}$$

Inertia moment about the horizontal neutral axis, in m^4, is to be obtained as follows:

$$I_y = I_{y0} - z_n^2 A$$

Annex C32.2.7 GUIDANCE FOR BUCKLING STRENGTH ASSESSMENT

1.1 General

1.1.1 Definitions

1 Unless specified otherwise, the definitions of the symbols used in this Guidance are as specified in **Table 1**.

2 In this Guidance, compressive stresses are taken as positive stresses while tensile stresses are taken as negative stresses.

Table 1 Symbols

Symbol	Unit	Definition
x axis		Local axis of a rectangular buckling panel parallel to its long edge.
y axis		Local axis of a rectangular buckling panel perpendicular to its long edge.
σ_x	N/mm^2	Stress applied on the edge along *x* axis of the buckling panel.
σ_y	N/mm^2	Stress applied on the edge along *y* axis of the buckling panel.
τ	N/mm^2	Applied shear stress.
σ_a	N/mm^2	Axial stress in the stiffener, defined in **2.4.4-2**.
σ_b	N/mm^2	Bending stress in the stiffener, defined in **2.4.4-3**.
σ_w	N/mm^2	Warping stress in the stiffener, defined in **2.4.4-4**.
$\sigma_{cx}, \sigma_{cy}, \tau_c$	N/mm^2	Critical stress, defined in **2.2.1-1** for plates.
σ_{YS}	N/mm^2	Specified minimum yield stress of the stiffener, defined in **2.4.4-1**.
σ_{YP}	N/mm^2	Specified minimum yield stress of the plate.
a	*mm*	Length of the longer side of the plate panel. (See **Table 4**)
b	*mm*	Length of the shorter side of the plate panel. (See **Table 4**)
d	*mm*	Length of the side parallel to the axis of the cylinder corresponding to the curved plate panel as shown in **Table 5**.
σ_E	N/mm^2	Elastic buckling reference stress, to be taken as: For the application of plate limit state according to **2.2.1-2**: $\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{b}\right)^2$ $\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{b}\right)^2$ For the application of curved plate panels according to **2.2.2**: $\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{d}\right)^2$ $\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{d}\right)^2$
υ		Poisson's ratio, taken as 0.3.
$t_p t_p$	*mm*	Thickness of plate panel.
t_w	*mm*	Stiffener web thickness.
$t_f t_f$	*mm*	Flange thickness.

Table 1 Symbols (Continued)

Symbol	Unit	Definition
b_f	mm	Breadth of the stiffener flange.
h_w	mm	Depth of stiffener web.
e$_f$$e_f$	mm	Distance from attached plating to centre of flange, to be taken as follows: $e_f = h_w$ for flat bar profile. $e_f = h_w - 0.5\ t_f$ for bulb profile. $e_f = h_w + 0.5\ t_f$ for angle and Tee profiles.
α		Aspect ratio of the plate panel, to be taken as follows: $\beta = \frac{1\text{-}\psi}{\alpha}\alpha = \frac{a}{b}$
ββ		Coefficient taken as follows: $\beta = \frac{1-\psi}{\alpha}\beta = \frac{1\text{-}\psi}{\alpha}$
ψψ		Edge stress ratio to be taken as follows:$\psi = \frac{\sigma_2}{\sigma_1}\psi = \frac{\sigma_2}{\sigma_1}$
γ		Stress multiplier factor acting on loads. When the factor is such that the loads reach the interaction formulae, $\gamma = \gamma_c$.
γ_c		Stress multiplier factor at failure.
σ_1	N/mm^2	Maximum stress.
σ_2	N/mm^2	Minimum stress.
R	mm	Radius of curved plate panel.
E	N/mm^2	Young's modulus, to be taken as 2.06×10^5 (N/mm^2).
ℓ	mm	Span of stiffener equal to spacing between primary supporting members.
s	mm	Spacing of stiffener to be taken as the mean spacing between the stiffeners of the considered stiffened panel.

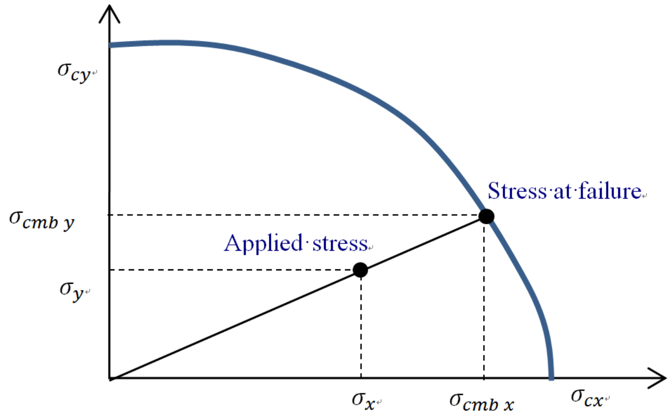
1.1.2 Buckling Utilisation Factor

The buckling utilisation factor is to be taken as follows:

$$\eta_{act} = \frac{1}{\gamma_c}$$

γ_c: Stress multiplier factor at failure. Buckling strength assessment for plate is to be in accordance with **2.2.1** or **2.2.2**, and buckling strength assessment for stiffener is to be in accordance with **2.3.1** and **2.4.4**. The concept to calculate the stress multiplier factor at failure for applied stress combination is to be as given in **Fig. 1**.

Fig. 1 Failure Limit State Curve



Notes:

σ_x,σ_y: Applied stress combination for buckling.

$\sigma_{cmb\ x}$,$\sigma_{cmb\ y}$: Critical buckling stresses for the stress combination for buckling.

2.1 Elementary Plate Panel (*EPP*)

2.1.1 Definition

An Elementary Plate Panel (*EPP*) is the part of the plating between stiffeners and/or primary supporting members. All the edges of the elementary plate panel are forced to remain straight (but free to move in the in-plane directions) due to the surrounding structure/neighbouring plates (usually longitudinal stiffened panels in deck, bottom, and inner-bottom plating, shell and longitudinal bulkheads).

2.1.2 *EPP* with Different Thickness

1 Longitudinally Stiffened *EPP* with Different Thicknesses

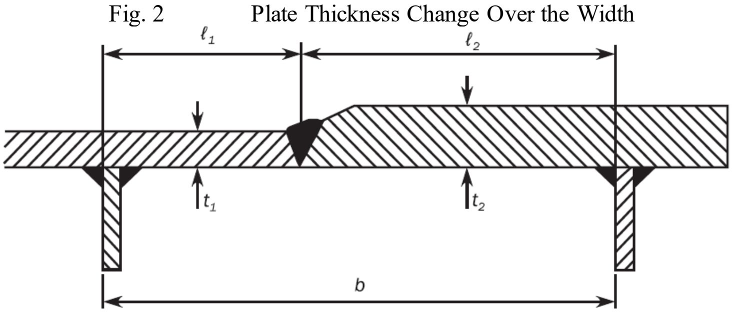
In longitudinal stiffening arrangement, when the plate thickness varies over the width, b, in mm, of a plate panel, the buckling capacity is calculated on an equivalent plate panel width, having a thickness equal to the smaller plate thickness, t_1. The width of this equivalent plate panel, b_{eq}, in mm, is defined by the following formula:

$$b_{eq} = \ell_1 + \ell_2 \left(\frac{t_1}{t_2}\right)^{1.5}$$

ℓ_1: Width of the part of the plate panel with the smaller plate thickness, t_1, in mm, as defined in **Fig. 2**.

ℓ_2: Width of the part of the plate panel with the greater plate thickness, t_2, in mm, as defined in **Fig. 2**.

Fig. 2 Plate Thickness Change Over the Width



2 Transversally Stiffened *EPP* with Different Thicknesses

In transverse stiffening arrangement, when an *EPP* is made of different thicknesses, the buckling check of the plate and stiffeners is to be made for each thickness considered constant on the *EPP*.

2.2 Buckling Capacity of Plates

2.2.1 Plate Panel

1 Plate Limit State

The plate limit state is based on the following interaction formulae:

$$\left(\frac{\gamma_{c1}\sigma_x}{\sigma_{cx}}\right)^{e_0} - B\left(\frac{\gamma_{c1}\sigma_x}{\sigma_{cx}}\right)^{e_0/2}\left(\frac{\gamma_{c1}\sigma_y}{\sigma_{cy}}\right)^{e_0/2} + \left(\frac{\gamma_{c1}\sigma_y}{\sigma_{cy}}\right)^{e_0} + \left(\frac{\gamma_{c1}|\tau|}{\tau_c}\right)^{e_0} = 1$$

$$\left(\frac{\gamma_{c2}\sigma_x}{\sigma_{cx}}\right)^{2/\beta_p^{0.25}} + \left(\frac{\gamma_{c2}|\tau|}{\tau_c}\right)^{2/\beta_p^{0.25}} = 1 \ \text{ for } \ \sigma_x \geq 0$$

$$\left(\frac{\gamma_{c3}\sigma_y}{\sigma_{cy}}\right)^{2/\beta_p^{0.25}} + \left(\frac{\gamma_{c3}|\tau|}{\tau_c}\right)^{2/\beta_p^{0.25}} = 1 \ \text{ for } \ \sigma_y \geq 0$$

$$\frac{\gamma_{c4}|\tau|}{\tau_c} = 1$$

$$\gamma_c = \min(\gamma_{c1}, \gamma_{c2}, \gamma_{c3}, \gamma_{c4})$$

σ_{cx}: Ultimate buckling stress in N/mm^2 in direction parallel to the longer edge of the buckling panel as defined in **-3**.

σ_{cy}: Ultimate buckling stress in N/mm^2 in direction parallel to the shorter edge of the buckling panel as defined in **-3**.

τ_c: Ultimate buckling shear stress, in N/mm^2 as defined in **-3**.

γ_{c1},γ_{c2},γ_{c3},γ_{c4}: Stress multiplier factors at failure for each of the above different limit states.$\gamma_{c2}$and $\gamma_{c3}$are only to be considered when$\sigma_x \geq 0$and$\sigma_y \geq 0$respectively.

B: Coefficient given in **Table 2**.

e_0: Coefficient given in **Table 2**.

β_p: Plate slenderness parameter taken as:

$$\beta_p = \frac{b}{t_p}\sqrt{\frac{\sigma_{YP}}{E}}$$

Table 2 Definition of Coefficients *B* and e_0

Applied Stress	*B*	e_0
$\sigma_x \geq 0$and$\sigma_y \geq 0$	$0.7 - 0.3\,\beta_p/\alpha^2$	$2/\beta_p^{0.25}$
$\sigma_x < 0$or$\sigma_y < 0$	1.0	2.0

2 Reference Degree of Slenderness

The reference degree of slenderness λ is to be taken as:

$$\lambda = \sqrt{\frac{\sigma_{YP}}{K\sigma_E}}$$

K: Buckling factor, as defined in **Table 4** and **Table 5**.

3 Ultimate Buckling Stresses

The ultimate buckling stress of plate panel σ_{cx} and σ_{cy}, in N/mm^2, is to be taken as:

$$\sigma_{cx} = C_x\sigma_{YP}$$

$$\sigma_{cy} = C_y\sigma_{YP}$$

The ultimate buckling stress of plate panels subject to shear τ_c, in N/mm^2, is to be taken as:

$$\tau_c = C_\tau\frac{\sigma_{YP}}{\sqrt{3}}$$

C_x,C_y,C_τ: Reduction factors, as defined in **Table 4**.

For the first equation of **-1** above, when$\sigma_x < 0$or$\sigma_y < 0$, the reduction factors are to be taken as:

C_x=C_y=C_τ= 1

For the other cases: For Method A (See **C32.9.9-3**), C_y is calculated according to **Table 4** by using

$$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

For the other cases: For Method B (See **C32.9.9-3**), C_y is calculated according to **Table 4** by using

$$c_1 = 1$$

The boundary conditions for plates are to be considered as simply supported (see cases 1, 2 and 15 of **Table 4**). If the boundary conditions differ significantly from simple support, a more appropriate boundary condition can be applied according to the different cases of **Table 4** subject to the approval by the Society.

4 Correction Factor F_{long}

The correction factor F_{long} depending on the edge stiffener types on the longer side of the buckling panel is defined in **Table 3**. An average value of F_{long} is to be used for plate panels having different edge stiffeners. For stiffener types other than those mentioned in **Table 3**, the value of c is to be agreed by the Society. In such a case, value of c higher than those mentioned in **Table 3** can be used, provided it is verified by buckling strength check of panel using non-linear FE analysis and deemed appropriate by Society.

Table 3 Correction Factor F_{long}

Structural element types			F_{long}	c
Unstiffened panel			1.0	N/A
Stiffened panel	Stiffener not fixed at both ends		1.0	N/A
	Stiffener fixed at both ends	Flat bar (1)	$F_{long} = c + 1$ for $\frac{t_w}{t_p} > 1$	0.10
		Bulb profile		0.30
		Angle profile	$F_{long} = c\left(\frac{t_w}{t_p}\right)^3 + 1$ for $\frac{t_w}{t_p} \leq 1$	0.40
		T profile		0.30
		Girder of high rigidity (e.g., bottom transverse)	1.4	N/A
(1) : t_w is the web thickness, in mm, without the correction defined in **2.4.3-5**.				

Table 4 Buckling Factor and Reduction Factor for Plane Plate Panels

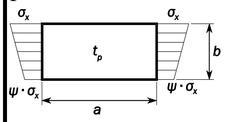
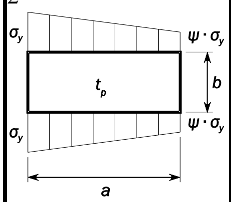
Case	Stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor C
1 	$1 \geq \psi \geq 0$		$K_x = F_{long}\dfrac{8.4}{\psi + 1.1}$	When $\sigma_x \leq 0$: $C_x = 1$ When $\sigma_x > 0$: $C_x = 1$ for $\lambda \leq \lambda_c$ $C_x = c\left(\dfrac{1}{\lambda} - \dfrac{0.22}{\lambda^2}\right)$ for $\lambda > \lambda_c$ Where: $c = (1.25 - 0.12\psi) \leq 1.25$ $\lambda_c = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0.88}{c}}\right)$
	$0 \geq \psi > -1$		$K_x = F_{long}[7.63 - \psi(6.26 - 10\psi)]$	
	$\psi \leq -1$		$K_x = F_{long}[5.975\,(1 - \psi)^2]$	
2 	$1 \geq \psi \geq 0$		$K_y = \dfrac{2\left(1 + \dfrac{1}{\alpha^2}\right)^2}{1 + \psi + \dfrac{(1-\psi)}{100}\left(\dfrac{2.4}{\alpha^2} + 6.9f_1\right)}$	When $\sigma_y \leq 0$: $C_y = 1$ When $\sigma_y > 0$: $C_y = c\left(\dfrac{1}{\lambda} - \dfrac{R + F^2(H - R)}{\lambda^2}\right)$ Where: $c = (1.25 - 0.12\psi) \leq 1.25$ $R = \lambda(1 - \lambda/c)$ for $\lambda < \lambda_c$ $R = 0.22$ for $\lambda \geq \lambda_c$ $\lambda_c = 0.5c(1 + \sqrt{1 - 0.88/c})$ $F = \left[1 - \left(\dfrac{K}{0.91} - 1\right)/\lambda_p^2\right]c_1 \geq 0$ $\lambda_p^2 = \lambda^2 - 0.5$ for $1 \leq \lambda_p^2 \leq 3$ c_1 as defined 2.2.1-3. $H = \lambda - \dfrac{2\lambda}{c(T + \sqrt{T^2 - 4})} \geq R$ $T = \lambda + \dfrac{14}{15\lambda} + \dfrac{1}{3}$
		$\alpha \leq 6$	$f_1 = (1 - \psi)(\alpha - 1)$	
		$\alpha > 6$	$f_1 = 0.6\left(1 - \dfrac{6\psi}{\alpha}\right)\left(\alpha + \dfrac{14}{\alpha}\right)$ but not greater than $14.5 - \dfrac{0.35}{\alpha^2}$	
	$0 > \psi \geq 1 - \dfrac{4\alpha}{3}$		$K_y = \dfrac{200(1 + \beta^2)^2}{(1 - f_3)(100 + 2.4\beta^2 + 6.9f_1 + 23f_2)}$	
		$\alpha > 6(1 - \psi)$	$f_1 = 0.6\left(\dfrac{1}{\beta} + 14\beta\right)$ but not greater than $14.5 - 0.35\beta^2$ $f_2 = f_3 = 0$	
		$3(1 - \psi) \leq \alpha \leq 6(1 - \psi)$	$f_1 = \dfrac{1}{\beta} - 1$ $f_2 = f_3 = 0$	

Table 4 Buckling Factor and Reduction Factor for Plane Plate Panels (Continued)

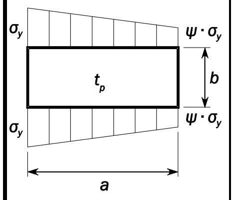
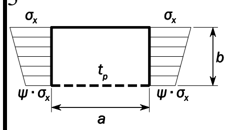
2 	$0 > \psi \geq 1 - \frac{4\alpha}{3}$	$1.5(1-\psi) \leq \alpha < 3(1-\psi)$	$f_1 = \frac{1}{\beta} - (2 - \omega\beta)^4 - 9(\omega\beta - 1)\left(\frac{2}{3} - \beta\right)$ $f_2 = f_3 = 0$	When $\sigma_y \leq 0$: $C_y = 1$ When $\sigma_y > 0$: $C_y = c\left(\frac{1}{\lambda} - \frac{R + F^2(H - R)}{\lambda^2}\right)$ $c = (1.25 - 0.12\psi) \leq 1.25$ $R = \lambda(1 - \lambda/c)$ for $\lambda < \lambda_c$ $R = 0.22$ for $\lambda \geq \lambda_c$ $\lambda_c = 0.5c(1 + \sqrt{1 - 0.88/c})$ $F = \left[1 - \left(\frac{K}{0.91} - 1\right)/\lambda_p^2\right] c_1 \geq 0$ $\lambda_p^2 = \lambda^2 - 0.5$ for $1 \leq \lambda_p^2 \leq 3$ c_1 as defined in 2.2.1-3. $H = \lambda - \frac{2\lambda}{c(T + \sqrt{T^2 - 4})} \geq R$ $T = \lambda + \frac{14}{15\lambda} + \frac{1}{3}$
		$1 - \psi \leq \alpha < 1.5(1-\psi)$	For $\alpha > 1.5$: $f_1 = 2\left(\frac{1}{\beta} - 16\left(1 - \frac{\omega}{3}\right)^4\right)\left(\frac{1}{\beta} - 1\right)$ $f_2 = 3\beta - 2$ $f_3 = 0$ For $\alpha \leq 1.5$: $f_1 = 2\left(\frac{1.5}{1 - \psi} - 1\right)\left(\frac{1}{\beta} - 1\right)$ $f_2 = \frac{\psi(1 - 16f_4^2)}{1 - \alpha}$ $f_3 = 0$ $f_4 = (1.5 - Min(1.5;\alpha))^2$	
		$0.75(1-\psi) \leq \alpha < 1 - \psi$	$f_1 = 0$ $f_2 = 1 + 2.31(\beta - 1) - 48\left(\frac{4}{3} - \beta\right) f_4^2$ $f_3 = 3f_4(\beta - 1)\left(\frac{f_4}{1.81} - \frac{\alpha - 1}{1.31}\right)$ $f_4 = (1.5 - Min(1.5;\alpha))^2$	
	$\psi < 1 - \frac{4\alpha}{3}$		$K_y = 5.972\frac{\beta^2}{1 - f_3}$ $f_3 = f_5\left(\frac{f_5}{1.81} + \frac{1 + 3\psi}{5.24}\right)$ $f_5 = \frac{9}{16}(1 + Max(-1;\psi))^2$	
3 	$1 \geq \psi \geq 0$		$K_x = \frac{4(0.425 + 1/\alpha^2)}{3\psi + 1}$	$C_x = 1$ for $\lambda \leq 0.7$ $C_x = \frac{1}{\lambda^2 + 0.51}$ for $\lambda > 0.7$
	$0 > \psi \geq -1$		$K_x = 4(0.425 + 1/\alpha^2)(1 + \psi) - 5\psi(1 - 3.42\psi)$	

Table 4 Buckling Factor and Reduction Factor for Plane Plate Panels (Continued)

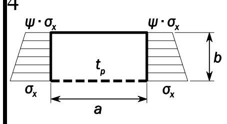
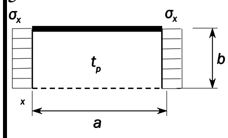
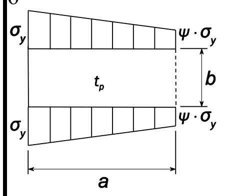
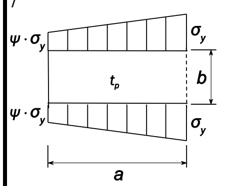
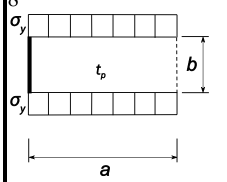
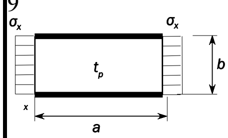
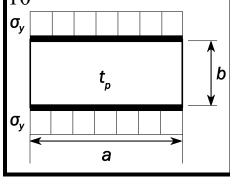
4 	$1 \ge \psi \ge -1$		$K_x = \left(0.425 + \frac{1}{\alpha^2}\right)\frac{3-\psi}{2}$	$C_x = 1$ for $\lambda \le 0.7$ $C_x = \frac{1}{\lambda^2+0.51}$ for $\lambda > 0.7$
5 	-	$\alpha \ge 1.64$	$K_x = 1.28$	
		$\alpha < 1.64$	$K_x = \frac{1}{\alpha^2} + 0.56 + 0.13\alpha^2$	
6 	$1 \ge \psi \ge 0$		$K_y = \frac{4(0.425+\alpha^2)}{(3\psi+1)\alpha^2}$	$C_y = 1$ for $\lambda \le 0.7$ $C_y = \left(\frac{1}{\lambda^2+0.51}\right)$ for $\lambda > 0.7$
	$0 > \psi \ge -1$		$K_y = 4(0.425+\alpha^2)(1+\psi)\frac{1}{\alpha^2}$ $-5\psi(1-3.42\psi)\frac{1}{\alpha^2}$	
7 	$1 \ge \psi \ge -1$		$K_y = 4(0.425+\alpha^2)\frac{(3-\psi)}{2\alpha^2}$	
8 	-		$K_y = 1 + \frac{0.56}{\alpha^2} + \frac{0.13}{\alpha^4}$	
9 	-		$K_x = 6.97$	$C_x = 1$ for $\lambda \le 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
10 	-		$K_y = 4 + \frac{2.07}{\alpha^2} + \frac{0.67}{\alpha^4}$	$C_y = 1$ for $\lambda \le 0.83$ $C_y = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$

Table 4 Buckling Factor and Reduction Factor for Plane Plate Panels (Continued)

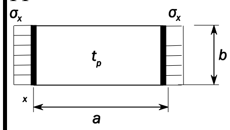
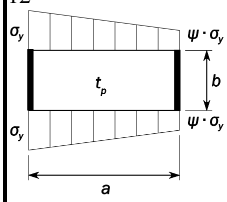
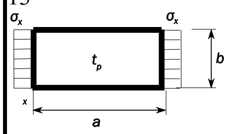
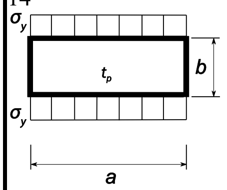
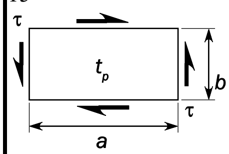
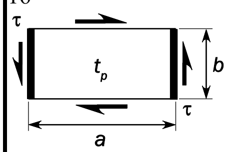
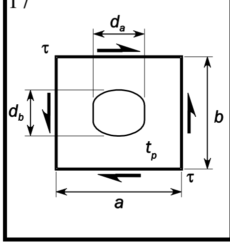
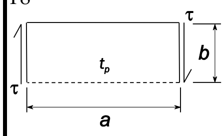
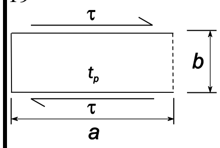
11 	-	$\alpha \geq 4$	$K_x = 4$	$C_x = 1$ for $\lambda \leq 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
		$\alpha < 4$	$K_x = 4 + 2.74\left[\frac{4-\alpha}{3}\right]^4$	
12 	-	$K_y = K_y$ determined as per case 2		For $\alpha < 2$: $C_y = C_{y2}$ For $\alpha \geq 2$: $C_y = \left(1.06 + \frac{1}{10\alpha}\right)C_{y2}$ where: C_{y2} : C_y determined as per case 2
13 	-	$\alpha \geq 4$	$K_x = 6.97$	$C_x = 1$ for $\lambda \leq 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
		$\alpha < 4$	$K_x = 6.97 + 3.1\left[\frac{4-\alpha}{3}\right]^4$	
14 	-	$K_y = \frac{6.97}{\alpha^2} + \frac{3.1}{\alpha^2}\left[\frac{4-1/\alpha}{3}\right]^4$		$C_y = 1$ for $\lambda \leq 0.83$ $C_y = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
15 	-	$K_\tau = \sqrt{3}\left[5.34 + \frac{4}{\alpha^2}\right]$		$C_\tau = 1$ for $\lambda \leq 0.84$ $C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$
16 	-	$K_\tau = \sqrt{3}\left\{5.34 + Max\left[\frac{4}{\alpha^2}; \frac{7.15}{\alpha^{2.5}}\right]\right\}$		
17 	-	$K_\tau = K_{\tau\ case15}r$ $K_{\tau\ case15}$:K_τ according to case 11 r: opening reduction factor taken as: $r = \left(1 - \frac{d_a}{a}\right)\left(1 - \frac{d_b}{b}\right)$ with $\frac{d_a}{a} \leq 0.7$ and $\frac{d_b}{b} \leq 0.7$		

Table 4 Buckling Factor and Reduction Factor for Plane Plate Panels (Continued)

18 	-	$K_\tau = \sqrt{3}(0.6 + 4/\alpha^2)$	$C_\tau = 1$ for $\lambda \le 0.84$ $C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$
19 	-	$K_\tau = 8$	
Edge boundary conditions: Plate edge free. Plate edge simply supported. Plate edge clamped.			
Notes: F_{long}: Coefficient, as defined in **2.2.1-4**. ω: Coefficient to be taken as : $\omega = \min(3;\alpha)$			
(1): Cases listed are general cases. Each stress component (σ_x,σ_y) is to be understood in local coordinates.			

2.2.2 Curved Plate Panels

This requirement for curved plate limit state is applicable when $R/t_p \le 2500$. Otherwise, the requirement for plate limit state given in **2.2.1-1** is applicable. The curved plate limit state is based on the following interaction formula:

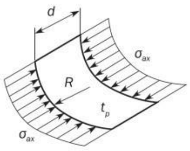
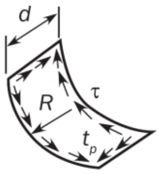
$$\left(\frac{\gamma_c \sigma_{ax}}{C_{ax}\sigma_{YP}}\right)^{1.25} + \left(\frac{\gamma_c \tau \sqrt{3}}{C_\tau \sigma_{YP}}\right)^2 = 1.0$$

σ_{ax}: Applied axial stress to the cylinder corresponding to the curved plate panel, in N/mm^2. In case of tensile axial stresses, σ_{ax}= 0.

C_{ax}, C_τ: Buckling reduction factor of the curved plate panel, as defined in **Table 5**.

The stress multiplier factor, γ_c , of the curved plate panel need not be taken less than the stress multiplier factor, γ_c , for the expanded plane panel according to **2.2.1-1**.

Table 5 Buckling Factor and Reduction Factor for Curved Plate Panels

Case	Aspect ratio	Buckling factor K	Reduction factor C
1 	$\frac{d}{R} \leq 0.5\sqrt{\frac{R}{t_p}}$	$K = 1 + \frac{2}{3}\frac{d^2}{Rt_p}$	For general application: $C_{ax} = 1$ for $\lambda \leq 0.25$ $C_{ax} = 1.233 - 0.933\lambda$ for $0.25 < \lambda \leq 1$ $C_{ax} = 0.3/\lambda^3$ for $1 < \lambda \leq 1.5$ $C_{ax} = 0.2/\lambda^2$ for $\lambda > 1.5$ For curved single fields, e.g. bilge strake, which are bounded by plane panels: $C_{ax} = \frac{0.65}{\lambda^2} \leq 1.0$
	$\frac{d}{R} > 0.5\sqrt{\frac{R}{t_p}}$	$K = 0.267\frac{d^2}{Rt_p}\left[3 - \frac{d}{R}\sqrt{\frac{t_p}{R}}\right]$ $\geq 0.4\frac{d^2}{Rt_p}$	
2 	$\frac{d}{R} \leq 8.7\sqrt{\frac{R}{t_p}}$	$K = \sqrt{3}\sqrt{28.3 + \frac{0.67d^3}{R^{1.5}t_p^{1.5}}}$	$C_\tau = 1$ for $\lambda \leq 0.4$ $C_\tau = 1.274 - 0.686\lambda$ for $0.4 < \lambda \leq 1.2$ $C_\tau = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$
	$\frac{d}{R} > 8.7\sqrt{\frac{R}{t_p}}$	$K = \sqrt{3}\frac{0.28d^2}{R\sqrt{Rt_p}}$	
Explanations for boundary conditions: ——— Plate edge free			

2.3 Buckling Capacity of Overall Stiffened Panel

2.3.1

The elastic stiffened panel limit state is based on the following interaction formula:

$$\frac{P_z}{c_f} = 1$$

where c_f, and P_z are defined in **2.4.4-3**.

2.4 Buckling Capacity of Longitudinal Stiffeners

2.4.1 Stiffener Limit States

The buckling capacity of longitudinal stiffeners is to be checked for the following limit states:

(1) Stiffener induced failure (*SI*)

(2) Associated plate induced failure (*PI*)

2.4.2 Lateral Pressure

The lateral pressure is to be considered as constant in the buckling strength assessment of longitudinal stiffeners.

2.4.3 Stiffener Idealization

1 Effective Length of the Stiffener ℓ_{eff}

The effective length of the stiffener ℓ_{eff}, in *mm*, is to be taken equal to:

$\ell_{eff} = \frac{\ell}{\sqrt{3}}$ for stiffener fixed at both ends.

$\ell_{eff} = 0.75\ell$ for stiffener simply supported at one end and fixed at the other.

$\ell_{eff} = \ell$ for stiffener simply supported at both ends.

2 Effective Width of the Attached Plating b_{eff1}

The effective width of the attached plating of a stiffener b_{eff1}, in *mm*, without the shear lag effect is to be taken equal to:

For $\sigma_x > 0$: For FE analysis: $b_{eff1} = C_x b$

For prescriptive assessment: $b_{eff1} = \dfrac{C_{x1}b_1 + C_{x2}b_2}{2}$

For $\sigma_x \le 0$: $b_{eff1} = b$

C_x: Reduction factor defined in **Table 4**.

C_{x1}, C_{x2}: Reduction factor defined in **Table 4** calculated for the *EPP*1 and *EPP*2 on each side of the considered stiffener according to case 1.

b_1, b_2: Width of plate panel on each side of the considered stiffener, in *mm*.

3 Effective Width of Attached Plating of Stiffeners b_{eff}

The effective width of attached plating of stiffeners, b_{eff}, in *mm*, is to be taken as:

For $\sigma_x > 0$: For FE analysis: $b_{eff} = \min(C_x b, \chi_s s)$

For prescriptive assessment: $b_{eff} = \min\left(\dfrac{C_{x1}b_1 + C_{x2}b_2}{2}, \chi_s s\right)$

For $\sigma_x \le 0$: $b_{eff} = \chi_s s$

C_x: Reduction factor defined in **Table 4**.

C_{x1}, C_{x2}: Reduction factor defined in **Table 4** calculated for the *EPP*1 and *EPP*2 on each side of the considered stiffener according to case 1.

b_1, b_2: Width of plate panel on each side of the considered stiffener, in *mm*.

χ_s: Effective width coefficient to be taken as:

$$\chi_s = \min\left[\frac{1.12}{1 + \frac{1.75}{\left(\frac{\ell_{eff}}{s}\right)^{1.6}}}; 1.0\right] \qquad \text{for } \frac{\ell_{eff}}{s} \ge 1$$

$$\chi_s = 0.407\frac{\ell_{eff}}{s} \qquad \text{for } \frac{\ell_{eff}}{s} < 1$$

ℓ_{eff}: Effective length of the stiffener, in *mm*, as specified in **-1**.

4 Thickness of Attached Plating

Thickness of attached plating t_p, in *mm*,to be taken as:

(1) For prescriptive assessment:

The mean of the two attached plating panels

(2) For FE analysis:

The thickness of the considered *EPP* on one side of the stiffener.

5 Effective Web Thickness of Flat Bar

For accounting the decrease of stiffness due to local lateral deformation, the effective web thickness of flat bar stiffener, in *mm*, is to be used for the calculation of the sectional area, A_s, the section modulus, Z, and the moment of inertia, I, of the stiffener and is taken as:

$$t_{w\_red} = t_w\left(1 - \frac{2\pi^2}{3}\left(\frac{h_w}{s}\right)^2\left(1 - \frac{b_{eff1}}{s}\right)\right)$$

6 Net Section Modulus of a Stiffener

The section modulus Z of a stiffener, in cm^3, including effective width of plating is to be taken equal to:

(1) For stiffener induced failure (*SI*)

The section modulus Z is to be calculated at the top of stiffener flange.

(2) For plate induced failure (*PI*)

The section modulus Z is to be calculated at the attached plating.

7 Moment of Inertia of a Stiffener

The moment of inertia I, in cm^4, of a stiffener including effective width of attached plating is to comply with the following requirement:

$$I \geq \frac{s t_p^3}{12 \times 10^4}$$

8 Idealisation of Bulb Profile

Bulb profiles may be considered as equivalent angle profiles. The dimensions of the equivalent built-up section are to be obtained from the following formulae.

$$h_w = h'_w - \frac{h'_w}{9.2} + 2(mm)$$

$$b_f = \alpha\left(t'_w + \frac{h'_w}{6.7} - 2\right)(mm)$$

$$t_f = \frac{h'_w}{9.2} - 2(mm)$$

$$t_w = t'_w(mm)$$

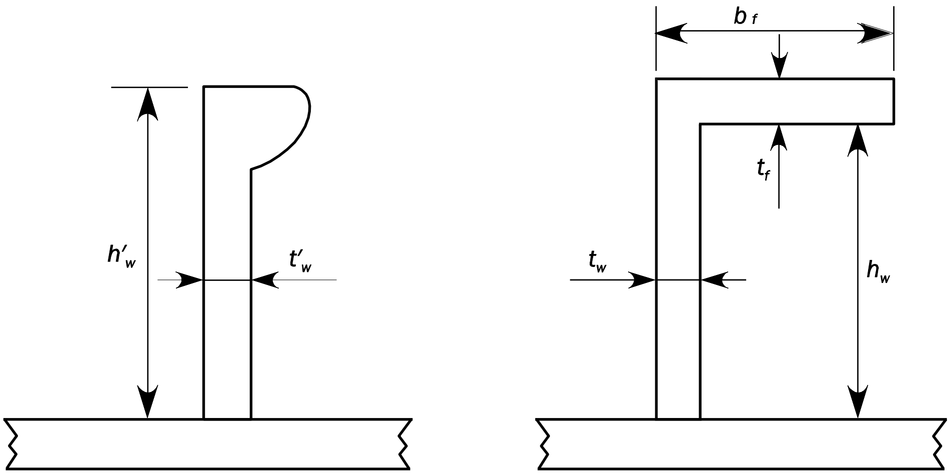
h'_w, t'_w: Height and thickness of a bulb section, in mm, as shown in **Fig. 3**.

α: Coefficient equal to:

$$\alpha = 1.1 + \frac{(120 - h'_w)^2}{3000} \quad \text{for } h'_w \leq 120$$

$$\alpha = 1.0 \quad \text{for } h'_w > 120$$

Fig. 3 Idealisation of Bulb Stiffener



Bulb Equivalent angle

2.4.4 Ultimate Buckling Capacity

1 Longitudinal Stiffener Limit State

When$\sigma_a + \sigma_b + \sigma_w > 0$, the ultimate buckling capacity for stiffener is to be checked according to the following interaction formula:

$$\frac{\gamma_c \sigma_a + \sigma_b + \sigma_w}{\sigma_Y} = 1$$

σ_a: Effective axial stress, in N/mm^2, at mid-span of the stiffener, defined in **-2**.

σ_b: Bending stress in the stiffener, in N/mm^2, defined in **-3**.

σ_w: Stress due to torsional deformation, in N/mm^2, defined in **-4**.

σ_Y: Specified minimum yield stress of the material, in N/mm^2.

$\sigma_Y = \sigma_{YS}$ for stiffener induced failure (*SI*)

$\sigma_Y = \sigma_{YP}$ for plate induced failure (*PI*)

2 Effective Axial Stress σ_a

The effective axial stress σ_a, in N/mm^2, at mid-span of the stiffener, acting on the stiffener with its attached plating is to be taken equal to:

$$\sigma_a = \sigma_x \frac{s\,t_p + A_s}{b_{eff1}\,t_p + A_s}$$

σ_x: Nominal axial stress, in N/mm^2, acting on the stiffener with its attached plating.

For FE analysis:σ_x is the FE corrected stress as defined in -5 in the attahed plating in the direction of the stiffener axis.

For prescriptive assessment:σ_x is the axial stress calculated at load calculation point of the stiffener.

b_{eff1}: The effective width of the attached plating of a stiffener without the shear lag effect, according to 2.4.3-2.

A_s: Sectional area, in mm^2, of the considered stiffener.

3 Bending Stress σ_b

The bending stress in the stiffener σ_b, in N/mm^2, is to be taken equal to:

$$\sigma_b = \frac{M_0 + M_1}{Z} 10^{-3}$$

Z: Section modulus of stiffener, in cm^3, including effective width of plating, according to 2.4.3-6.

M_1: Bending moment, in N-mm, due to the lateral load P:

$$M_1 = C_i \frac{|P| s \ell^2}{24} 10^{-3} \text{ for continuous stiffener}$$

$$M_1 = C_i \frac{|P| s \ell^2}{8} 10^{-3} \text{ for sniped stiffener}$$

P: Lateral load, in kN/m^2.

For FE analysis: P is the average pressure in the attached plating.

For prescriptive assessment: P is the pressure calculated at load calculation point of the stiffener.

C_i: Pressure coefficient:

$C_i = C_{SI}$ for stiffener induced failure (SI)

$C_i = C_{PI}$ for plate induced failure (PI)

C_{PI} : Plate induced failure pressure coefficient:

$C_{PI} = 1$ if the lateral pressure is applied on the side opposite to the stiffener.

$C_{PI} = -1$ if the lateral pressure is applied on the same side as the stiffener.

C_{SI} : Stiffener induced failure pressure coefficient

$C_{SI} = -1$ if the lateral pressure is applied on the side opposite to the stiffener.

$C_{SI} = 1$ if the lateral pressure is applied on the same side as the stiffener.

M_0: Bending moment, in N-mm, due to the lateral deformation w of the stiffener:

$$M_0 = F_E \left(\frac{P_z w}{c_f - P_z} \right) \quad \text{with } c_f - P_z > 0$$

F_E: Ideal elastic buckling force of the stiffener, in N.

$$F_E = \left(\frac{\pi}{\ell}\right)^2 EI\,10^4 \mathrm{F_E} = \left(\frac{\pi}{\mathrm{l}}\right)^2 \mathrm{EI}10^4$$

P_z: Nominal lateral load, in N/mm^2, acting on the stiffener due to stress,σ_x,$\sigma_y$and τ, in the attached plating in way of the stiffener mid span:

$$P_z = \frac{t_p}{s}\left(\sigma_{xl}\left(\frac{\pi s}{\ell}\right)^2 + 2c\gamma\sigma_y + \sqrt{2}\tau_1 \right)$$

$$\sigma_{xl} = \gamma\sigma_x\left(1 + \frac{A_s}{st_p}\right)\mathrm{\sigma_{xl}} = \mathrm{\gamma_c\sigma_x}\left(1 + \frac{\mathrm{A_s}}{\mathrm{st_p}}\right) \quad \text{but not less than 0}$$

$$\tau_1 = \gamma|\tau| - t_p\sqrt{\sigma_{YP} E\left(\frac{m_1}{a^2} + \frac{m_2}{s^2}\right)} \quad \text{but not less than 0}$$

σ_y: Stress applied on the edge along y axis of the buckling panel, in N/mm^2, but not less than 0.

For FE analysis: σ_y is the FE corrected stress as defined in -5 in the attached plating in the direction perpendicular to the stiffener axis.

For prescriptive assessment: $\sigma_y = 0$

τ: Applied shear stress, in N/mm^2

For FE analysis: τ is the reference shear stress in the attached plating.

For prescriptive assessment: τ is the shear stress calculated at load calculation point of the stiffener attached plating.

m_1, m_2: Coefficients taken equal to:

$m_1 = 1.47$, $m_2 = 0.49$ for $\alpha \geq 2$

$m_1 = 1.96$, $m_2 = 0.37$ for $\alpha < 2$

w: Deformation of stiffener, in mm:

$$w = w_0 + w_1$$

w_0: Assumed imperfection, in mm, to be taken as:

$w_0 = \ell 10^{-3}$ in general

$w_0 = -w_{na}$ for stiffeners sniped at both ends considering stiffener induced failure (SI)

$w_0 = w_{na}$ for stiffeners sniped at both ends considering plate induced failure (PI)

w_{na}: Distance from the mid-point of attached plating to the neutral axis of the stiffener calculated with the effective width of the attached plating.

w_1: Deformation of stiffener, in mm, at mid-point of stiffener span due to lateral load P. In case of uniformly distributed load, w_1 is taken as:

$w_1 = C_i \dfrac{|P| s \ell^4}{384 EI} 10^{-7}$ in general

$w_1 = C_i \dfrac{5|P| s \ell^4}{384 EI} 10^{-7}$ for stiffeners sniped at both ends

c_f: Elastic support provided by the stiffener, in N/mm^2.

$$c_f = F_E \left(\frac{\pi}{\ell}\right)^2 (1 + c_p) \mathrm{c_f} = \mathrm{F_E} \left(\frac{\pi}{\mathrm{l}}\right)^2 (1 + \mathrm{c_p})$$

c_p: Coefficient to be taken as :

$$c_p = \frac{1}{1 + \dfrac{0.91}{c_{xa}} \left(\dfrac{12 I}{s t_p^3} 10^4 - 1 \right)}$$

c_{xa}: Coefficient to be taken as :

$c_{xa} = \left(\dfrac{\ell}{2s} + \dfrac{2s}{\ell} \right)^2$ for $\ell \geq 2s$

$c_{xa} = \left(1 + \left(\dfrac{\ell}{2s} \right)^2 \right)^2$ for $\ell < 2s$

4 Stress Due to Torsional Deformation σ_w

The stress due to torsional deformation σ_w, in N/mm^2, is to be taken equal to:

$\sigma_w = E y_w \left(\dfrac{t_f}{2} + h_w \right) \Phi_0 \left(\dfrac{\pi}{\ell} \right)^2 \left(\dfrac{1}{1 - \frac{0.4 \sigma_{YS}}{\sigma_{ET}}} - 1 \right)$ for stiffener induced failure (SI)

$\sigma_w = 0$ for plate induced failure (PI)

y_w: Distance, in mm, from centroid of stiffener cross section to the free edge of stiffener flange, to be taken as:

$y_w = \frac{t_w}{2}$ for flat bar.

$y_w = b_f - \frac{h_w t_w^2 + t_f b_f^2}{2A_s}$ for angle and bulb profiles.

$y_w = \frac{b_f}{2}$ for T profile.

Φ_0:Coefficient to be taken as :

$$\Phi_0 = \frac{\ell}{h_w} 10^{-3}$$

σ_{ET}: Reference stress for torsional buckling, in N/mm^2.

$$\sigma_{ET} = \frac{E}{I_P}\left(\frac{\varepsilon\pi^2 I_\omega}{\ell^2}10^2 + 0.385 I_T\right) \sigma_{ET} = \frac{E}{I_P}\left(\frac{\varepsilon\pi^2 I_\omega}{l^2}10^2 + 0.385 I_T\right)$$

I_P: Polar moment of inertia of the stiffener about point C as shown in **Fig. 4**, as defined in **Table 6**, in cm^4.

I_T: St. Venant's moment of inertia of the stiffener, as defined in **Table 6**, in cm^4.

I_ω: Sectional moment of inertia of the stiffener about point C as shown in **Fig. 4**, as defined in **Table 6**, in cm^6.

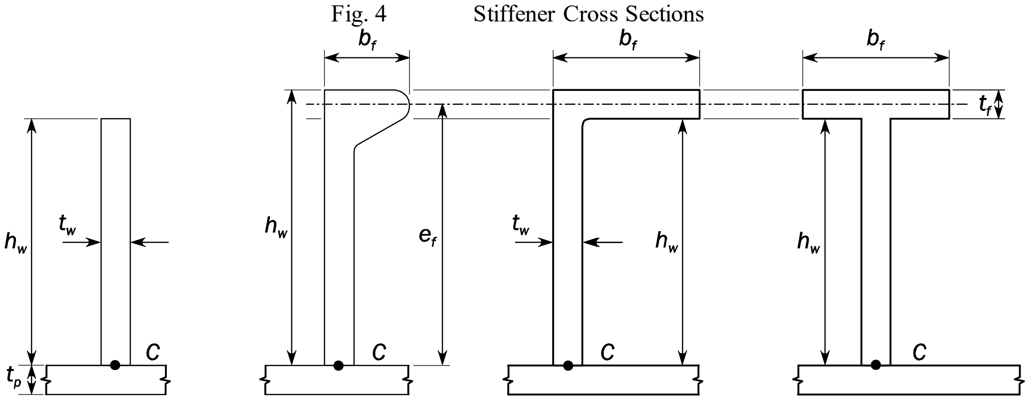
ε:Degree of fixation.

$$\varepsilon = 1 + \frac{\left(\frac{\ell}{\pi}\right)^2 10^{-3}}{\sqrt{I_\omega\left(\frac{0.75s}{t_p^3} + \frac{e_f - 0.5t_f}{t_w^3}\right)}}$$

Table 6 Moments of Inertia

	Flat bars	Bulb, angle and Tee profiles
I_P	$\frac{h_w^3 t_w}{3\times10^4}$	$\left(\frac{A_w(e_f-0.5t_f)^2}{3} + A_f e_f^2\right)10^{-4}$
I_T	$\frac{h_w t_w^3}{3\times10^4}\left(1-0.63\frac{t_w}{h_w}\right)$	$\frac{(e_f-0.5t_f)\,t_w^3}{3\times10^4}\left(1-0.63\frac{t_w}{e_f-0.5t_f}\right) + \frac{b_f t_f^3}{3\times10^4}\left(1-0.63\frac{t_f}{b_f}\right)$
I_ω	$\frac{h_w^3 t_w^3}{36\times10^6}$	$\frac{A_f e_f^2 b_f^2}{12\times10^6}\left(\frac{A_f+2.6A_w}{A_f+A_w}\right)$ for bulb and angle profiles $\frac{b_f^3 t_f e_f^2}{12\times10^6}$ for Tee profiles
A_w:	Web area, in mm^2.	
A_f:	Flange area, in mm^2.	

Fig. 4 Stiffener Cross Sections



5 FE Corrected Stress for Stiffener Capacity

When the reference stress σ_x and σ_y obtained by FE analysis are both compressive, they are to be corrected according to the following formulae:

(1) If $\sigma_x < 0.3\sigma_y$:

$\sigma_{xcor} = 0$

$\sigma_{ycor} = \sigma_y$

(2) If $\sigma_y<0.3\sigma_x$:

$\sigma_{xcor} = \sigma_x$

$\sigma_{ycor} = 0$

(3) If the other cases:

$\sigma_{xcor} = \sigma_x - 0.3\sigma_y$

$\sigma_{ycor} = \sigma_y - 0.3\sigma_x$

2.5 Primary Supporting Members

2.5.1 Web Plate in way of Openings

1 Web Plate In Way of Openings

The web plate of primary supporting members with openings is to be assessed for buckling based on the combined axial compressive and shear stresses.

The web plate adjacent to the opening on both sides is to be considered as individual unstiffened plate panels as shown in **Table 7**. The interaction formula of **2.2.1-1** is to be used with:

(1) $\sigma_x = \sigma_{av}$

(2) $\sigma_y = 0$

(3) $\tau = \tau_{av}$

σ_{av}: Weight average compressive stress, in N/mm^2, in the area of web plate being considered, i.e., $P1$, $P2$, or $P3$ as shown in **Table 7**.

τ_{av}: Weight average shear stress, in N/mm^2, in the area of web plate being considered.

For the application of the **Table 7**, the weighted average shear stress is to be taken as:

(1) Opening modelled in primary supporting members:

τ_{av}: Weight average shear stress, in N/mm^2, in the area of web plate being considered, i.e., $P1$, $P2$, or $P3$ as shown in **Table 7**.

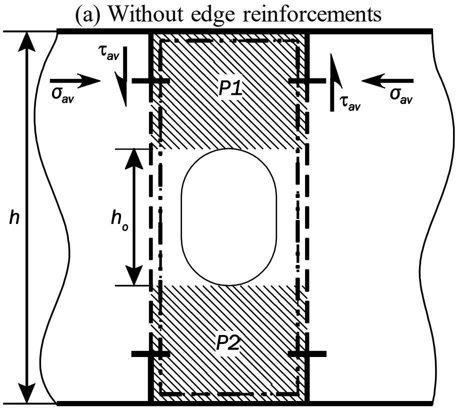
(2) Opening not modelled in primary supporting members:

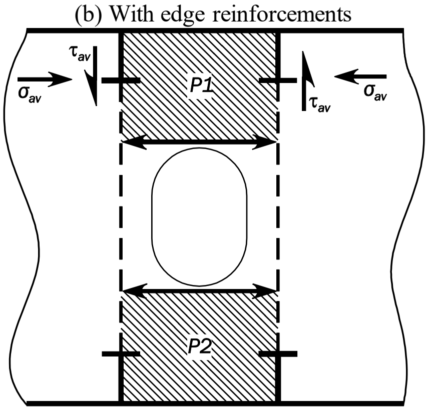
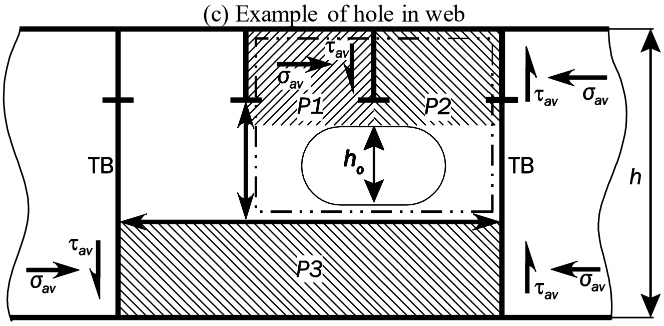
τ_{av}: Weighted average shear stress, in N/mm^2, given in **Table 7**.

2 Reduction Factor of Web Plate In Way of Openings

The reduction factors, C_x or C_y in combination with, C_τ of the plate panel(s) of the web adjacent to the opening is to be taken as shown in **Table 7**.

Table 7 Reduction Factor

<table>
<tr><th rowspan="2">Configuration</th><th rowspan="2">C_x, C_y</th><th colspan="2">C_τ</th></tr>
<tr><th>Opening modelled in PSM</th><th>Opening not modelled in PSM</th></tr>
<tr><td>(a) Without edge reinforcements

</td><td>Separate reduction factors are to be applied to areas $P1$ and $P2$ using case 3 or case 6 in Table 4, with edge stress ratio:
$\psi = 1.0$</td><td>Separate reduction factors are to be applied to areas $P1$ and $P2$ using case 18 or case 19 in Table 4.</td><td>When case 17 of Table 4 is applicable:
A common reduction factor is to be applied to areas $P1$ and $P2$ using case 17 in Table 4 with:
$\tau_{av} = \tau_{av}(web)$

When case 17 of Table 4 is not applicable:
Separate reduction factors are to be applied to areas $P1$ and $P2$ using case 18 or case 19 in Table 4 with:
$\tau_{av} = \tau_{av}(web)\ h/(h-h_0)$</td></tr>
<tr><td>(b) With edge reinforcements

</td><td>Separate reduction factors are to be applied to areas $P1$ and $P2$ using C_x for case 1 or C_y for case 2 in Table 4, with stress ratio:
$\psi = 1.0$</td><td>Separate reduction factors are to be applied for areas $P1$ and $P2$ using case 15 in Table 4.</td><td>Separate reduction factors are to be applied to areas $P1$ and $P2$ using case 15 in Table 4 with:
$\tau_{av} = \tau_{av}(web)\ h/(h-h_0)$</td></tr>
<tr><td colspan="2">(c) Example of hole in web

</td><td colspan="2">Panels $P1$ and $P2$ are to be evaluated in accordance with (a).
Panel $P3$ is to be evaluated in accordance with (b).</td></tr>
<tr><td colspan="4">Notes:
h: Height, in m, of the web of the primary supporting member in way of the opening.
h_0: Height, in m, of the opening measured in the depth of the web.
$\tau_{av}(web)$: Weighted average shear stress, in N/mm^2, over the web height h of the primary supporting member.</td></tr>
<tr><td colspan="4">(1): Web panels to be considered for buckling in way of openings are shown shaded and numbered $P1$, $P2$, etc.</td></tr>
</table>

Annex C32.2.8-1 GUIDANCE FOR THE HULL GIRDER ULTIMATE STRENGTH ASSESSMENT

1.1 General

1.1.1 Definitions

Unless specified otherwise, the definitions of the symbols used in this Guidance are as specified in **Table 1**.

Table 1 Definition of the Symbols

Symbol	Unit	Definition
I_y	m^4	Moment of inertia of the hull transverse section around its horizontal neutral axis
Z_B, Z_D	m^3	Section moduli at bottom and deck, respectively
σ_{YS}	N/mm^2	Minimum yield stress of the material of the considered stiffener
σ_{YP}	N/mm^2	Minimum yield stress of the material of the considered plate
A_S	cm^2	Sectional area of stiffener, without attached plating
A_P	cm^2	Sectional area of attached plating

2.1 General Assumptions

2.1.1

The method for calculating the ultimate hull girder capacity is to identify the critical failure modes of all main longitudinal structural elements.

2.1.2

Structures compressed beyond their buckling limit have reduced load carrying capacity. All relevant failure modes for individual structural elements, such as plate buckling, torsional stiffener buckling, stiffener web buckling, lateral or global stiffener buckling and their interactions, are to be considered in order to identify the weakest inter-frame failure mode.

2.2 Incremental-iterative Method

2.2.1 Assumptions

In applying the incremental-iterative method, the following assumptions are generally to be made:

(1) The ultimate strength is calculated at transverse sections between two adjacent transverse webs;

(2) The hull girder transverse section remains plane during each curvature increment;

(3) The hull material has an elasto-plastic behaviour; and

(4) The hull girder transverse section is divided into a set of elements which are considered to act independently. (See **2.2.2-2**)

According to the iterative procedure, the bending moment M_i acting on the transverse section at each curvature value χ_i is obtained by summing the contribution given by the stress σ acting on each element. The stress σ corresponding to the element strain ε is to be obtained for each curvature increment from the non-linear load-end shortening curves $\sigma - \varepsilon$ of the element.

These curves are to be calculated, for the failure mechanisms of the element, from the formulae specified in **2.2.3**. The stress σ is selected as the lowest among the values obtained from each of the considered load-end shortening curves $\sigma - \varepsilon$.

The procedure is to be repeated until the value of the imposed curvature reaches the value χ_F (m^{-1}) in hogging and sagging condition, obtained from the following formula:

$$\chi_F = \pm 0.003 \frac{M_Y}{EI_y}$$

M_Y: Lesser of the values M_{Y1} and M_{Y2}, in kN-m.

$M_{Y1} = 10^3 \sigma_Y Z_B$

$M_{Y2} = 10^3 \sigma_Y Z_D$

If the value χ_F is not sufficient to evaluate the peaks of the curve M-χ, the procedure is to be repeated until the value of the imposed curvature permits the calculation of the maximum bending moments of the curve.

2.2.2 Procedure

1 General

The curve $M - \chi$ is to be taken as follows:

(1) The curve $M - \chi$ is to be obtained by means of an incremental-iterative approach, summarised in the flow chart in **Fig. 1**.

(2) In this procedure, the ultimate hull girder bending moment capacity M_U is defined as the peak value of the curve with vertical bending moment M versus the curvature χ of the ship cross section as shown in **Fig. 1**. The curve is to be obtained through an incremental-iterative approach.

(3) Each step of the incremental procedure is represented by the calculation of the bending moment M_i which acts on the hull transverse section as the effect of an imposed curvature χ_i.

(4) For each step, the value χ_i is to be obtained by summing an increment of curvature $\Delta\chi$ to the value relevant to the previous step χ_{i-1}. This increment of curvature corresponds to an increment of the rotation angle of the transverse section around its horizontal neutral axis.

(5) This rotation increment induces axial strains ε in each hull structural element whose value depends on the position of the element. In hogging condition, the structural elements above the neutral axis are lengthened, while the elements below the neutral axis are shortened, and vice-versa in sagging condition.

(6) The stress σ induced in each structural element by the strain ε is to be obtained from the load-end shortening curve $\sigma - \varepsilon$

of the element, which takes into account the behaviour of the element in the non-linear elasto-plastic domain.

(7) The distribution of the stresses induced in all the elements composing the hull transverse section determines, for each step, a variation of the neutral axis position since the relationship $\sigma - \varepsilon$ is non-linear. The new position of the neutral axis relevant to the step considered is to be obtained by means of an iterative process, imposing the equilibrium among the stresses acting in all the hull elements on the transverse section.

(8) Once the position of the neutral axis is known and the relevant element stress distribution in the section is obtained, the bending moment of the section M_i around the new position of the neutral axis, which corresponds to the curvature χ_i imposed in the step considered, is to be obtained by summing the contribution given by each element stress.

(9) The main steps of the incremental-iterative approach described above are summarised as follows: (See **Fig. 1**)

(a) Step 1: Divide the transverse section of hull into stiffened plate elements.

(b) Step 2: Define stress-strain relationships for all elements as shown in **Table 2**.

(c) Step 3: Initialise curvature χ_i and neutral axis for the first incremental step with the value of incremental curvature (i.e. curvature that induces a stress equal to 1% of yield strength in strength deck) as follows:

$$\chi_1 = \Delta\chi = 0.01\frac{\sigma_Y}{E}\frac{1}{z_D - z_n}$$

z_D: Z-coordinate (m) of strength deck at side.

z_n: Z-coordinate (m) of horizontal neutral axis of the hull transverse section

(d) Step 4: Calculate for each element the corresponding strain $\varepsilon_i = \chi(z_i - z_n)$ and the corresponding stress σ_i

(e) Step 5: Determine the neutral axis z_{NA_cur} at each incremental step by establishing force equilibrium over the whole transverse section as:

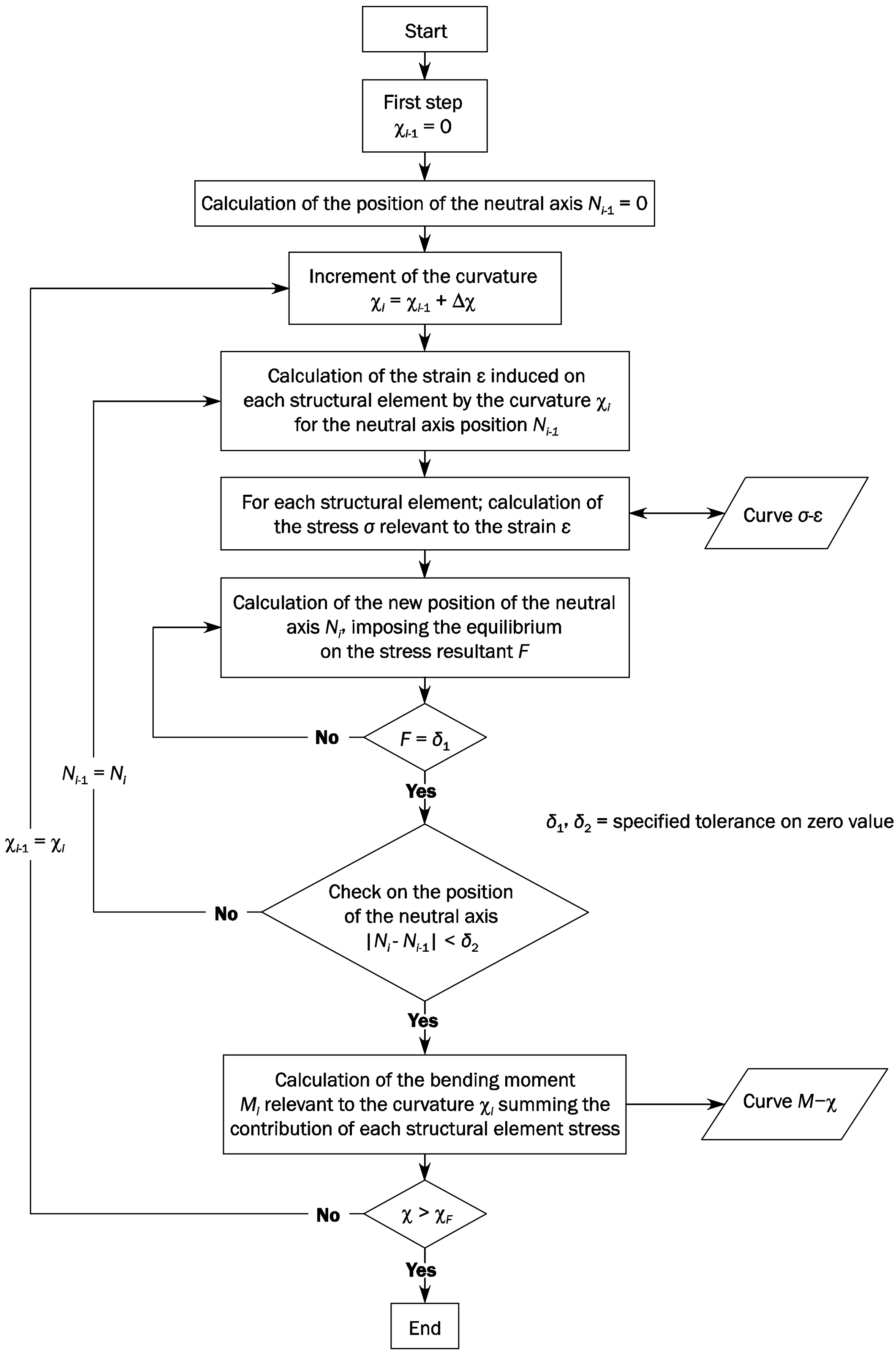
$$\sum A_i\sigma_i = \sum A_j\sigma_j$$ (i-th element is under compression, j-th element under tension)

(f) Step 6: Calculate the corresponding moment by summing the contributions of all elements as follows:

$$M_U = \sum \sigma_{Ui} A_i |(z_i - z_{NA\_cur})|$$

(g) Step 7: Compare the moment in the current incremental step with the moment in the previous incremental step. If the slope in $M - \chi$ relationship is less than a negative fixed value, terminate the process and define the peak value of M_U. Otherwise, increase the curvature by the amount of $\Delta\chi$ and go to Step 4.

Fig. 1 Flow Chart of the Procedure for the Evaluation of the Curve $M - \chi$


Start
First step
$\chi_{i-1} = 0$
Calculation of the position of the neutral axis $N_{i-1} = 0$
Increment of the curvature
$\chi_i = \chi_{i-1} + \Delta\chi$
Calculation of the strain ε induced on each structural element by the curvature χ_i for the neutral axis position N_{i-1}
For each structural element; calculation of the stress σ relevant to the strain ε
Curve σ-ε
Calculation of the new position of the neutral axis N_i, imposing the equilibrium on the stress resultant F
No
$F = \delta_1$
Yes
$N_{i-1} = N_i$
δ_1, δ_2 = specified tolerance on zero value
$\chi_{i-1} = \chi_i$
No
Check on the position of the neutral axis
$|N_i - N_{i-1}| < \delta_2$
Yes
Calculation of the bending moment M_i relevant to the curvature χ_i summing the contribution of each structural element stress
Curve $M-\chi$
No
$\chi > \chi_F$
Yes
End

2 Classification of the structural members

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder ultimate strength.

Sniped stiffeners are also to be modelled, taking account that they do not contribute to the hull girder strength.

The structural members are categorised into a stiffener element, a transversely stiffened plate element or a hard corner element.

The plate panel including web plate of girder or side stringer is idealised into either a transversely stiffened plate element, an attached plate of a stiffener element or a hard corner element.

The plate panel is categorised into the following two kinds:

- Longitudinally stiffened panel of which the longer side is in the longitudinal direction; or
- Transversely stiffened panel of which the longer side is in the perpendicular direction to the longitudinal direction.

(1) Hard corner element:

Hard corner elements are sturdier elements composing the transverse section, which collapse mainly according to an elasto-plastic mode of failure (material yielding); they are generally constituted by two plates not lying in the same plane.

The extent of a hard corner element from the point of intersection of the plates is taken equal to $20t$ on a transversely stiffened panel and to $0.5s$ on a longitudinally stiffened panel. (See **Fig. 2**)

t: Thickness of the plate (mm)

s: Spacing of the adjacent longitudinal stiffener (m)

Bilge, sheer strake-deck stringer elements, girder-deck connections and face plate-web connections on large girders are typical hard corners.

(2) Stiffener element:

The stiffener constitutes a stiffener element together with the attached plate.

The attached plate width is in principle:

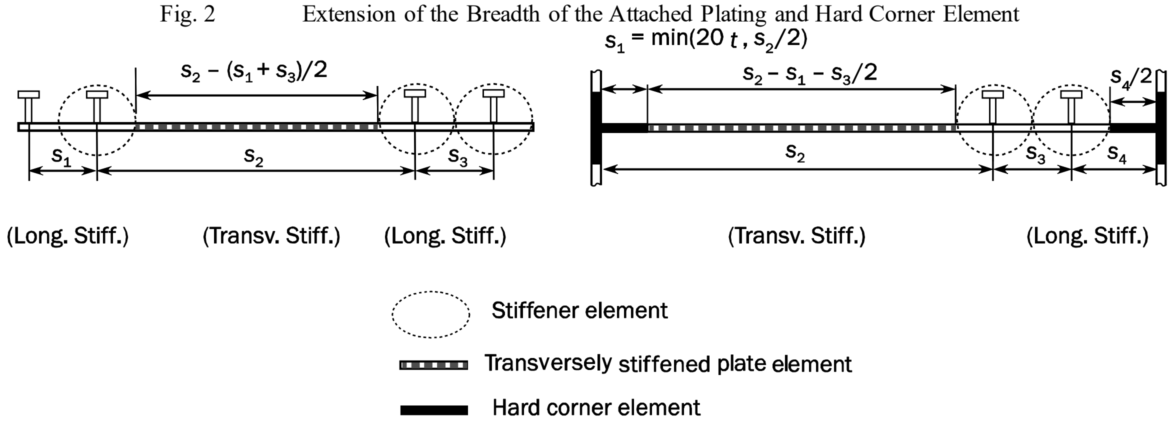
(a) Equal to the mean spacing of the stiffener when the panels on both sides of the stiffener are longitudinally stiffened, or

(b) Equal to the width of the longitudinally stiffened panel when the panel on one side of the stiffener is longitudinally stiffened and the other panel is of the transversely stiffened. (See **Fig. 2**)

(3) Transversely stiffened plate element

The plate between stiffener elements, between a stiffener element and a hard corner element or between hard corner elements is to be treated as a transversely stiffened plate element (See **Fig. 2**)

Fig. 2 Extension of the Breadth of the Attached Plating and Hard Corner Element



3 Modelling of the hull girder cross section

The typical examples of modelling of hull girder section are illustrated in **Fig. 3**. Notwithstanding the principle of **-2** above, these figures are to be applied to **Fig. 3** in the modelling in the vicinity of upper deck, sheer strake and hatch side girder.

(1) In case of the knuckle point as shown in **Fig. 4**, the plating area adjacent to knuckles in the plating with an angle greater than 30 degrees is defined as a hard corner. The extent of one side of the corner is taken equal to $20t$ on transversely framed panels and to $0.5s$ on longitudinally framed panels from the knuckle point.

(2) Where the plate members are stiffened by non-continuous longitudinal stiffeners, the non-continuous stiffeners are considered only as dividing a plate into various elementary plate panels.

(3) Where attached plating is made of steels having different thicknesses and/or yield stresses, an average thickness or average yield stress obtained from the following formula is to be used for the calculation.

$$t = \frac{t_1 s_1 + t_2 s_2}{s} \quad t_{net} = \frac{t_{1\text{-}net} s_1 + t_{2\text{-}net} s_2}{s}$$

$$\sigma_{YP} = \frac{\sigma_{YP1} t_1 s_1 + \sigma_{YP2} t_2 s_2}{ts} \quad R_{eH\_P} = \frac{R_{eH\_P1} t_{1\text{-}net} s_1 + R_{eH\_P2} t_{2\text{-}net} s_2}{t_{net} s}$$

σ_{YP1}, σ_{YP2}, t_1, t_2, s_1, s_2 and s: As defined in **Fig. 5**.

Fig. 3 Examples of the Configuration of Stiffened Plate Elements, Stiffener Elements and Hard Corner Elements on a Hull Section

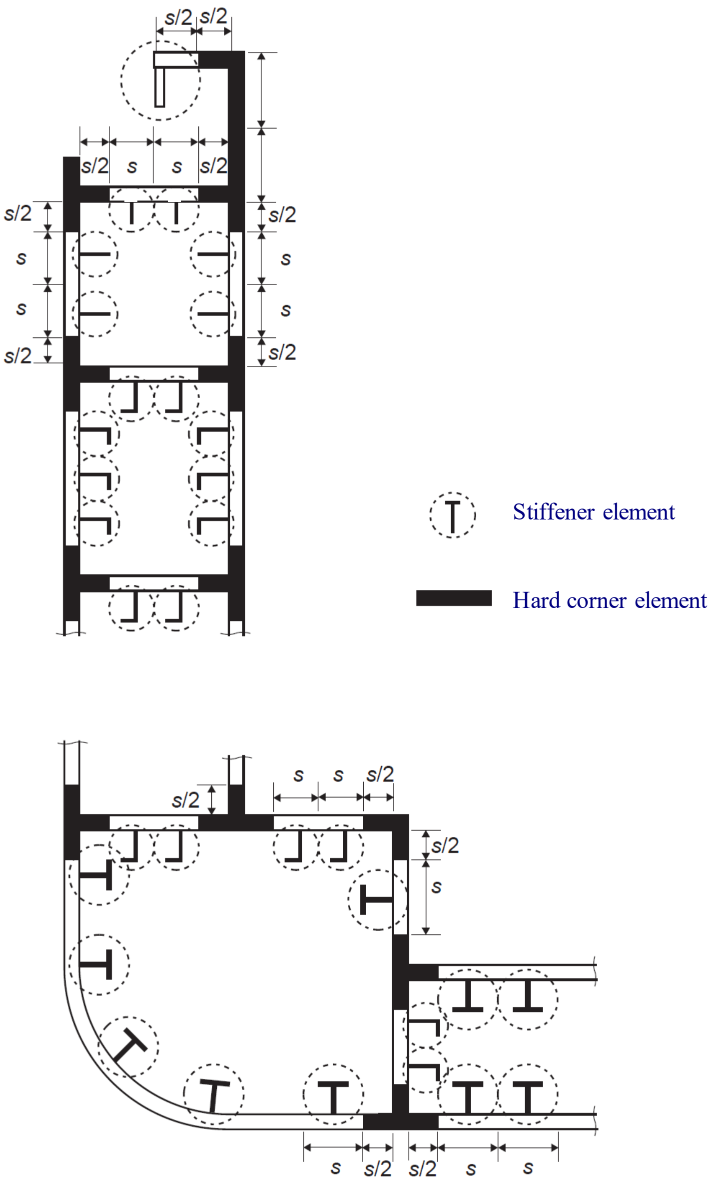


Fig. 4 Plating with Knuckle Point

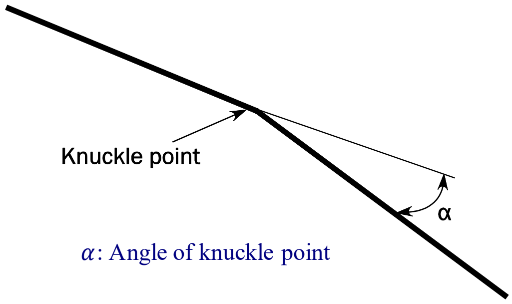
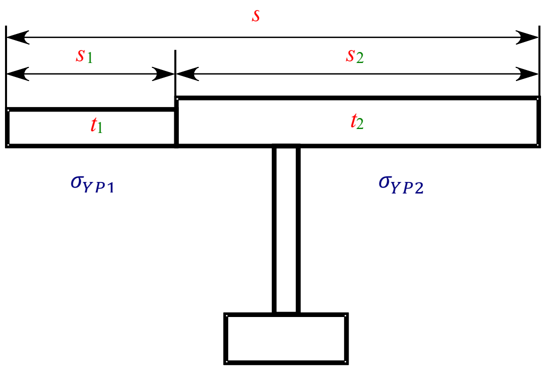


Fig. 5 Element with Different Thickness and Yield Strength



2.2.3 Load-end Shortening Curves

1 Transversely stiffened plate element and stiffener element

Transversely stiffened plate element and stiffener element composing the hull girder transverse sections may collapse following one of the modes of failure specified in **Table 2**.

(1) Where the plate members are stiffened by non-continuous longitudinal stiffeners, the stress of the element is to be obtained in accordance with **-2** to **-7**, taking into account the non-continuous longitudinal stiffener. In calculating the total forces for checking the hull girder ultimate strength, the area of non-continuous longitudinal stiffener is to be assumed as 0.

(2) Where the opening is provided in the transversely stiffened plate element, the considered area of the transversely stiffened plate element is to be obtained by deducting the opening area from the plating in calculating the total forces for checking the hull girder ultimate strength.

(3) For transversely stiffened plate element, the effective width of plate for the load shortening portion of the stress-strain curve is to be taken as full plate width, i.e. to the intersection of other plate or longitudinal stiffener – neither from the end of the hard corner element nor from the attached plating of stiffener element, if any. In calculating the total forces for checking the hull girder ultimate strength, the area of the transversely stiffened plate element is to be taken between the hard corner element and the stiffener element or between the hard corner elements, as applicable.

Table 2 Modes of Failure of Transversely Stiffened Plate Element and Stiffener Element

Element	Mode of failure	Curve $\sigma - \varepsilon$ defined in
Lengthened stiffened plate element or stiffener element	Elasto-plastic collapse	2.2.3-2
Shortened stiffener element	Beam column buckling Torsional buckling Web local buckling of flanged profiles Web local buckling of flat bars	2.2.3-3 2.2.3-4 2.2.3-5 2.2.3-6
Shortened stiffened plate element	Plate buckling	2.2.3-7

2 Elasto-plastic collapse of structural elements (hard corner element)

The equation describing the load-end shortening curve $\sigma - \varepsilon$ for the elasto-plastic collapse of structural elements composing the transverse section is to be obtained from the following formula:

$$\sigma = \Phi \sigma_{YA}$$

σ_{YA}: Equivalent minimum yield stress (N/mm^2) of the considered element obtained by the following formula:

$$\sigma_{YA} = \frac{\sigma_{YP} A_P + \sigma_{YS} A_S}{A_P + A_S}$$

Φ : Edge function, equal to the following:

$\Phi = -1$ for $\varepsilon < -1$

$\Phi = \varepsilon$ for $-1 \leq \varepsilon \leq 1$

$\Phi = 1$ for $\varepsilon > 1$

ε: Relative strain, equal to the following:

$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_Y}$$

ε_E: Element strain.

ε_Y: Strain at yield stress in the element, equal to the following:

$$\varepsilon_Y = \frac{\sigma_{YA}}{E}$$

3 Beam column buckling

The positive strain portion of the average stress – average strain curve $\sigma_{CR1} - \varepsilon$ based on beam column buckling of plate-stiffener combinations is described according to the following:

$$\sigma_{CR1} = \Phi \sigma_{C1} \frac{A_{PE} + A_S}{A_P + A_S}$$

Φ: Edge function, as defined in **-2**.

σ_{C1}: Critical stress (N/mm^2), equal to the following:

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon} \qquad \text{for } \sigma_{E1} \leq \frac{\sigma_{YB}}{2}\varepsilon$$

$$\sigma_{C1} = \sigma_{YB}\left(1 - \frac{\sigma_{YB}\varepsilon}{4\sigma_{E1}}\right) \qquad \text{for } \sigma_{E1} > \frac{\sigma_{YB}}{2}\varepsilon$$

σ_{YB}: Equivalent minimum yield stress (N/mm^2) of the considered element obtained by the following formula:

$$\sigma_{YB} = \frac{\sigma_{YP} A_{PE1} \ell_{PE} + \sigma_{YS} A_S \ell_{SE}}{A_{PE1} \ell_{PE} + A_S \ell_{SE}} R_{eHB} = \frac{R_{eH\_P} A_{pEI\text{-}net} l_{pE} + R_{eH\_S} A_{s\text{-}net} l_{sE}}{A_{pEI\text{-}net} l_{pE} + A_{s\text{-}net} l_{sE}}$$

A_{PE1}: Effective area (cm^2), equal to the following:

$$A_{PE1} = 10 b_{E1} t A_{pEI\text{-}net} = 10 b_{E1} t_{net}$$

ℓ_{PE}: Distance (mm) measured from the neutral axis of the stiffener with attached plate of width b_{E1} to the bottom of the attached plate

ℓ_{SE}: Distance (mm) measured from the neutral axis of the stiffener with attached plate of width b_{E1} to the top of the stiffener

ε: Relative strain, as defined in **-2**.

σ_{E1}: Euler column buckling stress (N/mm^2), equal to the following:

$$\sigma_{E1} = \pi^2 E \frac{I_E}{A_E \ell^2} 10^{-4} \sigma_{E1} = \pi^2 E \frac{I_{E\text{-net}}}{A_{E\text{-net}} l^2} 10^{-4}$$

I_E: Moment of inertia of stiffeners (cm^4) with attached plating of width b_{E1}.

A_E: Area (cm^2) of stiffeners with attached plating of width b_E.

b_{E1}: Effective width corrected for relative strain (m) of the attached plating, equal to the following:

$$b_{E1} = \frac{s}{\beta_E} \quad \text{for } \beta_E > 1.0$$

$$b_{E1} = s \quad \text{for } \beta_E \leq 1.0$$

β_E: Coefficient, given as follow:

$$\beta_E = 10^3 \frac{s}{t} \sqrt{\frac{\varepsilon \sigma_{YP}}{E}}$$

A_{PE}: Area (cm^2) of attached plating of width b_E, equal to the following:

$$A_{PE} = 10 b_E t$$

b_E: Effective width (m) of the attached plating, equal to the following:

$$b_E = \left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2} \right) s \quad \text{for } \beta_E > 1.25$$

$$b_E = s \quad \text{for } \beta_E \leq 1.25$$

4 Torsional buckling

The load-end shortening curve $\sigma_{CR2} - \varepsilon$ for the flexural-torsional buckling of stiffeners composing the hull girder transverse section is to be obtained according to the following formula:

$$\sigma_{CR2} = \Phi \frac{A_P \sigma_{CP} + A_S \sigma_{C2}}{A_P + A_S}$$

Φ: Edge function, as defined in **-2**.

σ_{C2}: Critical stress (N/mm^2), equal to the following:

$$\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon} \quad \text{for } \sigma_{E2} \leq \frac{\sigma_{YS}}{2} \varepsilon$$

$$\sigma_{C2} = \sigma_{YS} \left(1 - \frac{\sigma_{YS} \varepsilon}{4 \sigma_{E2}} \right) \quad \text{for } \sigma_{E2} > \frac{\sigma_{YS}}{2} \varepsilon$$

ε:Relative strain, as defined in **-2**.

σ_{E2}: Euler torsional buckling stress (N/mm^2), taken as σ_{ET} specified in **2.4.4-4 Annex C32.2.7 "GUIDANCE FOR BUCKLING STRENGTH ASSESSMENT"**.

σ_{CP}: Buckling stress of the attached plating (N/mm^2), equal to the following:

$$\sigma_{CP} = \left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2} \right) \sigma_{YP} \quad \text{for } \beta_E > 1.25$$

$$\sigma_{CP} = \sigma_{YP} \quad \text{for } \beta_E \leq 1.25$$

β_E: Coefficient, as defined in **-3**.

5 Web local buckling of stiffeners made of flanged profiles

The load-end shortening curve $\sigma_{CR3} - \varepsilon$ for the web local buckling of flanged stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi \frac{10^3 b_E t \sigma_{YP} + (h_{we} t_w + b_f t_f) \sigma_{YS}}{10^3 s t + h_w t_w + b_f t_f}$$

Φ: Edge function, as defined in **-2**.

b_E: Effective width (m) of the attached shell plating, as defined in -3.

h_{we}: Effective height (mm) of the web, equal to the following:

$$h_{we} = \left(\frac{2.25}{\beta_w} - \frac{1.25}{\beta_w^2}\right) h_w \quad \text{for } \beta_w > 1.25$$

$$h_{we} = h_w \qquad \text{for } \beta_w \leq 1.25$$

β_w: Coefficient, given as follow:

$$\beta_w = \frac{h_w}{t_{w\text{-}net}} \sqrt{\frac{\varepsilon R_{eH\_S}}{E}} \beta_w = \frac{h_w}{t_w} \sqrt{\frac{\varepsilon \sigma_{YS}}{E}}$$

ε: Relative strain, as defined in -2.

6 Web local buckling of stiffeners made of flat bars

The load-end shortening curve $\sigma_{CR4} - \varepsilon$ for the web local buckling of flat bar stiffeners composing the transverse section is to be obtained from the following formula:

$$\sigma_{CR4} = \Phi \frac{A_P \sigma_{CP} + A_S \sigma_{C4}}{A_P + A_S}$$

Φ: Edge function, as defined in -2.

σ_{CP}: Buckling stress of the attached plating (N/mm^2), as defined in -4.

σ_{C4}: Critical stress (N/mm^2), equal to the following:

$$\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon} \qquad \text{for } \sigma_{E4} \leq \frac{\sigma_{YS}}{2} \varepsilon$$

$$\sigma_{C4} = \sigma_{YS}\left(1 - \frac{\sigma_{YS}\,\varepsilon}{4\,\sigma_{E4}}\right) \qquad \text{for } \sigma_{E4} > \frac{\sigma_{YS}}{2} \varepsilon$$

σ_{E4}: Local Euler buckling stress (N/mm^2), equal to the following:

$$\sigma_{E4} = 160000\left(\frac{tw}{hw}\right)^2 \sigma_{E4} = 160000\left(\frac{t_{w\text{-}net}}{h_w}\right)^2$$

ε: Relative strain, as defined in -2.

7 Plate buckling

The load-end shortening curve $\sigma_{CR5} - \varepsilon$ for the buckling of transversely stiffened panels composing transverse section is to be obtained from the following formula:

$$\sigma_{CR5} = \min \begin{cases} \sigma_{YP}\Phi \\ \Phi \sigma_{YP}\left[\frac{s}{\ell}\left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2}\right) + 0.1\left(1 - \frac{s}{\ell}\right)\left(1 + \frac{1}{\beta_E^2}\right)^2\right] \end{cases}$$

Φ: Edge function, as defined in -2.

β_E: Coefficient, as defined in -3.

s: Plate breadth (m), taken as the spacing between the stiffeners.

ℓ: Longer side of the plate (m).

2.3 Alternative Methods

2.3.1 General

1 Application of alternative methods is to be agreed by the Society prior to commencement. Documentation of the analysis methodology and detailed comparison of its results are to be submitted for review and approval. The use of such methods may require the partial safety factors to be recalibrated.

2 The bending moment-curvature relationship, M-χ, may be established by alternative methods. Such models are to consider all the relevant effects important to the non-linear response with due considerations of:

(1) Non-linear geometrical behaviour.

(2) Inelastic material behaviour.

(3) Geometrical imperfections and residual stresses (geometrical out-of-flatness of plate and stiffeners).

(4) Simultaneously acting loads:

(a) Bi-axial compression.

(b) Bi-axial tension.

(c) Shear and lateral pressure.

(5) Boundary conditions.

(6) Interactions between buckling modes.

(7) Interactions between structural elements such as plates, stiffeners, girders, etc.

(8) Post-buckling capacity.

(9) Overstressed elements on the compression side of hull girder cross section possibly leading to local permanent sets/buckle damages in plating, stiffeners, etc. (double bottom effects or similar).

2.3.2 Non-linear Finite Element Analysis

1 Advanced non-linear finite element analyses models may be used for the assessment of the hull girder ultimate bending moment capacity. Such models are to consider the relevant effects important to the non-linear responses with due consideration of the items listed in **2.3.1-2**.

2 Particular attention is to be given to modelling the shape and size of geometrical imperfections. It is to be ensured that the shape and size of geometrical imperfections trigger the most critical failure modes.

Annex C34.1.2 GUIDANCE FOR PREPARATION OF LOADING MANUAL

1.1 Composition of Loading Manual

1.1.1 General

1 The Loading Manual is to be composed of the following three parts:

(1) Introduction

This part is to contain explanatory notes for making the ship master familiar with the general features of the ship so that he will be able to grasp the general relationship between loading and hull strength and thus, to obtain general guidance for loading.

(2) Standard loading conditions

This part is to give descriptions on the standard loading conditions.

(3) Methods of calculation of longitudinal strength for loading conditions different from the standard loading conditions.

2 Furthermore, the following is to be added for those ships to which the requirements in **Chapter 32, Part C of the Rules** apply and those ships specified in **C15.1.1(2)**.

(1) Methods of calculation of torsional moment of hull due to uneven cargo stowage

The methods of calculation to verify that the torsional moment generated in the hull due to uneven cargo stowage under the loaded condition is within the allowable range.

3 For ships with a freeboard length L_f which is not more than 100 m, the requirements in **1.1.1-1(3)** above may be exempted.

Note: Refer to **Appendix C2**, "**APPENDIX to ANNEX C34.1.2 DETAIL GUIDE FOR PREPARATION OF LOADING MANUAL**"

1.2 Contents to be Included in the Introduction

1.2.1 Principal Dimensions

1 General explanatory notes on the construction, arrangement and characteristics of the ship including the principal dimensions.

1.2.2 Precautions for Loading

1 The following precautions regarding loading are to be specified in the Loading Manual.

(1) For standard loading conditions, the analysis results of structural strength including transverse strength and local strength and the operational precautions based on the analysis results of the strength

(2) For loading conditions different from standard loading conditions, precautions regarding the prevention of excessive stress on the hull strength

(3) Precautions regarding weight shifting involving the transfer of ballast water and cargo when loading under standard loading conditions or any other arbitrary loading conditions

(4) Precautions related to the filling level of ballast tanks according to the provisions of **C15.2.1(6)**

2 Although specific contents may differ on each ship, precautions must be generally taken on the following points in preparing the Loading Manual:

(1) The minimum bow draught required for the structural strength of the strengthened bottom forward

(2) Limitation to apparent specific gravity of cargo (γ) and/or loading height in cargo holds

(3) Acceptability of alternate loading, two-port loading, etc.

(4) Limitation to liquid levels in tanks

(5) Limitation to loading with respect to local strength and transverse strength (e.g. limitations to the maximum design cargo weight on deck or hatch cover)

(6) Limitation to loading with respect to longitudinal hull strength

(7) Precautions for ballasting/deballasting and dry-docking

1.2.3 Allowable Values for Longitudinal Still Water Bending Moment and Still Water Shearing Force

1 Allowable values of longitudinal still water bending moment and still water shearing force calculated in accordance with the requirements in **1.4** of the Annex are to be specified following the descriptive examples **1.2** and **1.3 of Appendix C2**. Furthermore, the sign convention of bending moment and shearing force is to be specified. (*See* in **15.2.1-1** and **15.3.1-1, Part C of the Rules** and **32.1.2, Part C of the Rules** for ships to which the requirements in **Chapter 32, Part C of the Rules** apply)

2 The stress levels of longitudinal strength of the ship are to be specified following the descriptive example **1.4 of Appendix C2**.

1.2.4 Allowable Values for Torsional Moment of Hull due to Uneven Cargo Stowage

1 For ships to which the requirements in **32.3.1-1, Part C of the Rules** apply, the values of torsional moment of hull due to uneven cargo stowage are to be specified as the allowable value in the manual. In cases where the values of torsional moments of hull due to uneven cargo stowage are to be considered for ships subject to the requirements in **C32.3.1**, the torsional moments are to be taken as the allowable values in the manual.

1.3 Standard Loading Conditions

1.3.1 Standard Loading Conditions

1 The Loading Manual is to contain the following loading conditions, upon which the approval of the scantlings of the hull structural members is based.

(1) Cargo ships, container ships, roll-on/roll-off ships, refrigerated cargo ships, bulk carriers, ore carriers, etc.
- (a) Light load condition
- (b) Ballast conditions (at arrival and departure)
- (c) Homogeneous loading conditions of cargo (at arrival and departure)
- (d) All non-homogeneous loading conditions as given in the Specifications (at arrival and departure)
- (e) Specially approved loading conditions for short voyage or in smooth water, where necessary
- (f) Temporary severe loading conditions during cargo loading or unloading, where necessary
- (g) Conditions for entering dry-dock while afloat

(2) Tankers
- (a) Light load condition
- (b) Ballast conditions (at arrival and departure)
- (c) Homogeneous loading conditions (at arrival and departure)
- (d) All non-homogeneous loading conditions as given in the Specifications (at arrival and departure)
- (e) Conditions which largely differ from the standard ballast condition due to tank cleaning or other work whilst the ship is at sea
- (f) Temporary severe loading conditions during cargo loading or unloading where necessary
- (g) Conditions for entering dry dock while afloat

(3) Ships carrying dangerous chemicals in bulk
- (a) The same conditions as specified in **(2)** above for tankers, and the loading conditions specified in the Operation Manual
- (b) Loading conditions for cargo items included in the approved list of cargoes, which are of a high density, or require heating or isolated stowage.

(4) Ships carrying liquefied gases in bulk
- (a) Light load condition
- (b) Ballast conditions (at arrival and departure)
- (c) Homogeneous loading conditions (at arrival and departure)
- (d) Loading conditions involving empty or partially loaded tanks
- (e) Loading conditions where two or more kinds of cargoes with largely different specific gravity are loaded in different tanks
- (f) Loading in smooth water where an increased vapour pressure is approved
- (g) Temporary severe loading conditions during cargo loading or unloading, where necessary.
- (h) Conditions for entering dry-dock while afloat

(5) Combination carriers
- (a) The same conditions as specified respectively in **(1)** and **(2)** above for cargo ships and oil tankers

2 Where any ballasting and/or deballasting is intended during the voyage in design loading conditions, conditions just before and just after ballasting and/or deballasting any ballast tanks are to be included in the standard loading conditions specified in **-1** above as intermediate conditions between departure and arrival conditions. Such intermediate conditions are to generally take into account the ballasting and/or deballasting of each ballast tank. For determining intermediate conditions and notes to be mentioned in the ship's loading manuals, refer to **Annex C15.2.1**.

3 Where the amount and dispositions of consumables at any intermediate stage of the voyage are considered more severe in regards to longitudinal strength, such conditions are to be included in the standard loading conditions specified in **-1** above as intermediate stages.

1.3.2 Graphical Illustration for Standard Loading Conditions

1 To enable the ship master to readily grasp the relationships between loading conditions and hull strength under the standard loading conditions and to facilitate the planning of the loading operation, the results of calculations of longitudinal still water bending moment (M_S) and still water shearing force (F_S) at each condition are to be projected into graphical illustration together with the respective allowable values. In this case, the directions of positive and negative are also to be specified for F_S and M_S.

2 The results of calculations specified in **1** above on each condition are to be shown on a single or double page as far as practicable together with the arrangement plan of compartments (tanks and cargo holds), cargo stowage table, and the results of trim and stability calculations.

3 Descriptive examples specified in **1** and **2** above are shown in **1.5 of Appendix C2**. Restrictions imposed for operation of the ship in standard loading conditions if any, are to be specified.

1.4 Allowable Values for Longitudinal Strength

1.4.1 General

1 For ships to which the requirements in **Chapter 32, Part C of the Rules** do not apply, the allowable values for longitudinal still water bending moment and still water shearing force which are to be specified in the Loading Manual are to be determined with due consideration of the design condition of the ship. These values, however, are not to exceed the values obtained from the requirements in the following **(1)** to **(3)**, at positions of the transverse section of the hull where deemed necessary by the Society.

(1) Allowable Values for Vertical Still Water Bending Moment

The values obtained from the following formulae are to be taken as the allowable value for each positive and negative moment at the transverse section of the ship under consideration. However, these values are to satisfy the requirements in **15.4, Part C of the Rules**.

Value determined by longitudinal bending strength

For positive values: $\dfrac{fZ}{5.72C} - M_w(+)$ $(kN\text{-}m)$

For negative values: $-\dfrac{fZ}{5.72C} - M_w(-)(kN\text{-}m)$

f: As specified in the following **(a)** or **(b)**:

(a) 1.0 for ships to which the requirements in **1.1.7-2(1), Part C** and **1.3.1-2(1), Part CS of the Rules** do not apply
However, for ships to which the requirements with f_B or f_D in **Part C of the Rules** or **Part C of the Guidance** apply, the value of f is to be taken as f_B or f_D.

(b) The value of f_{BH} or f_{DH} determined by the requirements in **1.2.1-2(1)** of **Annex C1.1.7-1** "**GUIDANCE FOR HULL CONSTRUCTION CONTAINING HIGH TENSILE STEEL MEMBERS**" for ships to which the requirements in **1.1.7-2(1), Part C** or **1.3.1-2(1), Part CS of the Rules** is applied

Z: Section modulus (cm^3) of transverse section of the ship with respect to the ship's bottom or strength deck at the position under consideration

C: Coefficient specified in **C15.1.1(3), PartC of the Guidance**
However, where
$C'_b \geq 0.65$, $C = 1.0$.
C'_b: As specified in **15.2.1-1, Part C of the Rules**

$M_w(+)$ and $M_w(-)$: As specified in **15.2.1-1, Part C of the Rules**

(2) Allowable Values for Still Water Shearing Force

(a) The allowable values for still water shearing forces for ships without longitudinal bulkheads are to be obtained from the following formula:

For positive values: $\frac{t_S I}{0.455mK} - F_w(+)$ (kN)

For negative values: $-\frac{t_S I}{0.455mK} - F_w(-)$ (kN)

t_S: Plate thickness (mm) of side shell plating at positions under consideration

I, m, $F_w(+)$ and $F_w(-)$: As specified in **15.3.1-1, Part C of the Rules**

K: Coefficient corresponding to the kind of steel

e.g., 1.0 for mild steel, the values specified in **1.1.7-2(1) of the Rules** for high tensile steel

(b) For ships which have the plate thickness of side shell plating determined according to the requirements in **C15.3.1-1 of the Guidance**, the value of **(a)** above or the value obtained from the following formula is to be taken, whichever is smaller.

For positive values: $F\frac{\tau_p}{\tau} - F_w(+)$ (kN)

For negative values: $-F\frac{\tau_p}{\tau} - F_w(-)$ (kN)

F: Shearing force (kN) acting on the transverse section of the ship used in the direct calculation which is given by the formulae specified in **C15.3.1-1(1)**

$F_w(+)$ and $F_w(-)$: Wave induced longitudinal shearing force (kN) as specified in **15.3.1-1, Part C of the Rules**

τ_p: Allowable stress (N/mm^2) as specified in **C15.3.1-1(2)**

τ: The largest of the shearing stresses (N/mm^2) determined by direct calculation occurring in side shell plating, bilge hopper tanks and top side tanks

(c) For ships with one to four rows of longitudinal bulkheads, the allowable value for still water shearing force is to be as specified in the following requirements in **i)** and **ii)**:

i) The allowable value for still water shearing force is to be obtained from the following formula:

For positive values: $\frac{\sum tI}{0.455mK} - F_w(+)$ (kN)

For negative values: $-\frac{\sum tI}{0.455mK} - F_w(-)$ (kN)

I, m, $F_w(+)$ and $F_w(-)$: As specified in **15.3.1-1, Part C of the Rules**

$\sum t$:Sum of the plate thickness (mm) of each longitudinal bulkhead at positions under consideration

K: As specified in **(a)** above

ii) The allowable value for shearing force (F_L) acting on the longitudinal bulkheads on one side is to be obtained from the following formula:

For positive values: $\frac{tI}{0.910mK} - \alpha F_w(+)$ (kN)

For negative values: $-\frac{tI}{0.910mK} - \alpha F_w(-)$ (kN)

I, m, $F_w(+)$ and $F_w(-)$: As specified in **15.3.1-1, Part C of the Rules**

t: Plate thickness (mm) of the each longitudinal bulkhead at positions under consideration

α: Rate of distribution of shearing force in each longitudinal bulkhead as specified in **15.3.2, Part C of the Rules**

K: As specified in **(a)** above

(d) The allowable values for F_s determined from **(a)** to **(c)** above are to comply with the requirements in **15.4.1, Part C of the Rules**.

(3) Allowable Values for Longitudinal Still Water Bending Moment and Shearing Force in Harbour Condition

The allowable values for the longitudinal still water bending moment and shearing force in harbour water free from the effects of waves may be obtained by taking half the values of the wave induced longitudinal bending moment and shearing force as specified in **(1)** and **(2)** respectively.

2 For ships to which the requirements in **Chapter 32, Part C of the Rules** apply, the allowable values for the vertical still water bending moment and vertical still water shear force which are to be specified in the loading manual are to be the permissible vertical still water bending moment and vertical still water shear force specified in **32.2.3-4, Part C of the Rules**.
The allowable values for the vertical still water bending moment and vertical still water shear force in the harbour condition may be the values of the above allowable values for the vertical still water bending moment and vertical still water shear force plus half the value of the vertical wave induced bending moment and vertical wave induced shear force as specified in **32.2.9-6** and **-7, Part C of the Rules**.

3 References to the ship's loading computer and the operation manual are to be made, if provided with a computer according to the provisions of **34.1.1-2, Part C of the Rules**.

Annex C35.2.4 GUIDANCE FOR DECISION OF ALTERNATIVE MEANS OF ACCESS

1 General

1.1 General

1.1.1 Application

This Annex provides guidance for the selection of alternative means of access for compliance with **35.2, Part C of the Rules**. This Annex also covers means of access used independently or in combination with provided permanent means of access to areas to be surveyed and measured in accordance with the Rules.

1.1.2 Definitions

For the purpose of this Annex, definitions of terms are as specified in the following.

(1) "Approved" means that the construction and materials of the means of access and any attachment to the ship's structure should be to the satisfaction of the Society. Compliance with the procedures in this Annex will satisfy the requirements of an administration in the absence of any specific instructions from a specific administration.

(2) "Acceptance" means that it should be demonstrated to the satisfaction of the Owner that the equipment provided has been maintained and is, where applicable, provided with operators who are trained to use such equipment. This should be demonstrated to the surveyors by the production of documents, prior to the equipment being used, which demonstrate that the equipment has been maintained and which indicate any limitations of the equipment.

(3) "Initial survey" means a survey carried out prior to the delivery of the ship. The means of access should be subject to an initial survey and it should be demonstrated that the means of access specified in plans required by **35.2.6, Part C of the Rules** are obtainable.

(4) "Alternative means of access" are portable or movable means of access provided for the survey and thickness measurements of hull structure in areas otherwise not accessible by permanent means of access. For the purpose of this Annex, alternative means of access include supplementary or additional means to provide necessary access for surveys and thickness measurements in accordance with the provisions of **35.2, Part C of the Rules**.

(5) "Portable means of access" are means that generally may be hand carried or arranged by the crew, *e.g.* ladders, small platforms and staging. Portable means specified as part of the Ship Structure Access Manual as specified in **35.2.6, Part C of the Rules** should be carried onboard the ship throughout the duration of the validity of the relevant access manual.

(6) "Movable means of access" may include devices like "cherry pickers", wire lift platforms, rafts or other means. Unless otherwise specified in **35.2, Part C of the Rules**, such means need not necessarily be kept on board or be capable of being operated by the ship's crew. However arrangements for the provision of such means should be addressed during survey planning. Movable means of access should be included in the Ship Structure Access Manual as specified in **35.2.6, Part C of the Rules** to designate the extent of access to the structural members to be surveyed and measured.

(7) "Authorized person" is a person specified by the Company who uses the means of access and that should assume the role of inspector for checking the access arrangements for obvious damage prior to use. Whilst using the means of access, the inspector should verify the condition of the sections used by close up examination of those sections and note any deterioration in the provisions. Should any damage or deterioration be found, the effect of such deterioration should be assessed as to whether the damage or deterioration affects the safety for continued use of the means of access. Deterioration found that is considered to affect safe use should be determined and measures should be put in place to ensure that the affected section(s) should not be further used prior to effective repair.

1.2 General Provisions

1.2.1 General

1 It is recognized that permanent means of access specified in **35.2, Part C of the Rules** will not give access to all areas required to be surveyed and measured. Therefore, it is necessary that all areas outside of reach (*i.e.*, normally beyond hand's reach) of the permanent means of access should be accessed by alternative means in combination with the permanent means of access.

2 Means of access, including alternative means of access, specified in the Ship Structure Access Manual should be approved by the Society. For the selection of each means of access, refer to **Chapter 2**. Innovative means of access may be allowed, based on a case by case acceptance. Refer to **2.7**.

3 When an alternative means of access is supplied by the builder for compliance with the provisions of **35.2, Part C of the Rules**, such means of access should comply with an appropriate safety standard such as recognized National or International Standards or equivalent. In this case, such means can be approved by the Society as part of the Ship Structure Access Manual. Any limitations to the use of the equipment at sea or in port should be described in the approved Ship Structure Access Manual.

4 Where movable means of access are supplied by a shore-based provider, then the confirmation of its safe and adequate use should be made by the Owner based on recorded maintenance and inspection regime by the provider of the equipment. Cognizance should be taken of the complexity of the equipment when making the judgement on the periodicity of inspections and thoroughness of maintenance by the provider of equipment. The surveyor has the right to reject movable means of access if not satisfied with the documentation or condition of the equipment.

5 It should be demonstrated as part of the initial survey, that the means of access identified in the Ship Structure Access Manual provides the required access, prior to delivery for the first ship in the series, or prior to initial use of a Ship Structure Access Manual where an existing means of access is amended, or a new means of access is added.

6 It should be demonstrated by the Owner that the equipment provided has been maintained and a person operating the equipment is trained in the safe use of such equipment. These should be demonstrated to the surveyors by the production of documents, prior to the equipment being used, which demonstrate that the equipment has been maintained and which indicate any limitations of the equipment.

7 The records of training, inspections and maintenance should be established in accordance with requirements of the Ships Safety Management System.

8 All surveyors should apply appropriately safe methods of working requirements. See also the relevant provisions of **1.4.2-1, Part B of the Rules** for Access to Structures.

2 Alternative Means of Access

2.1 General

2.1.1 General

1 The Owners are responsible for ensuring that alternative means of access are suitable for the purpose of the appropriate use. The equipment where applicable should be operated by qualified personnel and evidence should be provided that the equipment has been properly maintained by a shore-based provider. The standing platform should be fitted with anchor points for attaching fall arrest systems. For equipment provided with a self levelling platform, care should be taken that the locking device is engaged after completion of manoeuvring to ensure that the platform is fixed.

2.2 Hydraulic Arm Vehicles ("Cherry Pickers")

2.2.1 Application

Hydraulic arm vehicles or aerial lifts ("Cherry Pickers") may be used to enable the examination of the cargo hold structure on bulk carriers not accessible by permanent ladders fitted in accordance with **35.2.4-4(1), Part C of the Rules**. In the Ship Structural Access Manual, Cherry Pickers may be accepted as movable means, for use up to 17*m* above the tank top.

2.2.2 Safety Routines

1 Safety measures, including the following, should be taken by an authorised person prior to survey to the satisfaction of the attending surveyor(s):

(1) Lift controls, including safety devices should be serviceable and should be operated throughout the range prior to use. Operators should be trained.

(2) The operating range of the equipment should be agreed with the operator before using the equipment.

(3) Operators should work within the basket.

(4) Body belts (such as harnesses) with lanyards should be used.

(5) Permissible load and reach limitations should not be exceeded.

(6) Brakes should be set; outriggers used, if so equipped; and wheels chocked; if on an incline.

(7) Unless designed otherwise, aerial lift trucks should not be moved when the boom is elevated in a working position with workers in the basket.

(8) Upper and lower controls should be required and should be plainly marked. Lower controls should be capable of overriding the upper controls.

(9) Special precautions should be made to ensure that the vessel and the lifting device are stable when aerial lifts are used aboard other vessels (for example barges, floats).

(10) Personal flotation devices (*PFD*) should be used when working over water.

(11) Caution should be taken for potential crushing hazards (for example booming into the overhead, pinch point).

2 The operation and training in the use of this type of equipment should be addressed by the Ships Safety Management System.

2.3 Wire Lift Platform

2.3.1 Application

1 Wire lift platforms may be used for inspection of structural members of ballast tanks, cargo oil tanks and cargo holds. Such equipment should be rated for more than one person and be operated by suitably authorised personnel. If carried on board and included in the Ship Structure Access Manual, the designer will have to take into consideration safety aspects associated with deployment and use of such means of access. The platform and equipment, including fixed points to the ships structure should be approved on behalf of the Administration being based on a recognized International or National Standard.

2 The following should be addressed for approval of the wire lift platform:

(1) Accidental loss of balance

(2) Protection against overload

(3) Secondary means of escape

(4) Guard rails

(5) Permissible loads

(6) Permanent markings of the loads

(7) Recovery in the event of power loss

2.3.2 Safety Routines

1 Safety measures, including the following, should be taken by an authorised person prior to survey to the satisfaction of the attending surveyor(s):

(1) Lift controls, including safety devices and brakes should be serviceable and should be operated throughout the range prior to use. Operators should be trained.

(2) Rigging of wires should be in accordance with manufacturer's recommendations and conducted by qualified personnel.

(3) Fix points to which the wires will be connected should be examined before each use and verified as in good condition (free of wastage, fractures).

(4) Permissible load limitations should not be exceeded.

(5) Personnel should work from within the lift basket.

(6) Body belts (such as harnesses) with lanyards should be used.

(7) Means should be provided for using fall protection with a lifeline that can be tended from above the platform.

2 The maintenance of all equipment, the rigging of the equipment, its operation and training in use should be addressed by the Ships Safety Management System.

2.4 Portable Platforms

2.4.1 Application

1 Portable platforms not more that 3 *m* in length may be used for access between longitudinal permanent means of access and the structural member to be accessed. (Refer to **Fig.1**) Handrails should be provided, unless a safety harness is used in conjunction with the prearranged handgrips in way of the structure being accessed.

2 Portable platforms may be used as a portable means of access, provided that the platform and equipment, including fixed points to the ship's structure are specifically designed for the task and approved on behalf of the Administration based on a recognized International or National Standard.

3 Where portable platforms are included in the approved Ship Structure Access Manual, then the following should be considered prior to approval:

(1) Permissible loads

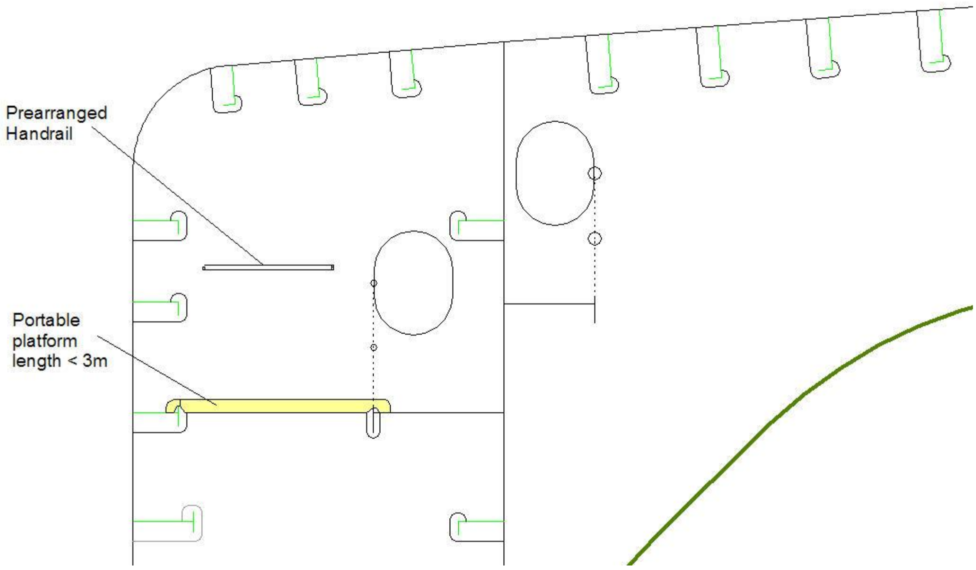
(2) Permanent markings of the loads

(3) Fixing arrangements

(4) Guard rails

(5) Non skid construction

Fig. 1 Portable Platform



2.4.2 Safety Routines

1 Safety measures should be taken by the authorised person prior to survey to the satisfaction of the attending surveyor(s). This includes ensuring that portable platforms are safely secured and supported prior to use.

2 The maintenance of all equipment, the fixing of the equipment, its operation and training in its use should be addressed by the Ships Safety Management System.

2.5 Staging

2.5.1 Application

1 Staging is the most common means of access provided especially where repairs or renewals are being carried out. Staging is generally an option for access to any structural members to be surveyed and measured in tanks, holds and spaces but is not considered as an alternative to permanent means of access as required in **35.2.4-1(1)(d)** and **-4(3)**, **Part C of the Rules**. Staging not carried on board is not subject to approval as part of the means of access as specified in **35.2, Part C of the Rules**. In this case, Owner and/or provider of equipment are responsible for ensuring safe use.

2 Where staging and the associated equipment including its attachments to the ship's structure are specifically designed for survey and thickness measurement in accordance with **35.2, Part C of the Rules**, such staging should be approved on behalf of the Administration based on a recognized International or National Standard and necessary consideration is taken for safe use.

2.5.2 Safety Routines

1 Safety measures should be taken by an authorised person prior to survey to the satisfaction of the attending surveyor(s). The following conditions should be ensured before any work is commenced on or near any staging:

(1) For suspended scaffolds, a minimum of 6 evenly spaced suspension points – steel wire ropes or chains evenly spaced and as near vertical as possible are provided.

(2) Scaffold tubes are linked by right-angle couplers.

(3) An adequate working platform, fully boarded with toe boards and guard rails is provided. Platform transforms (at not greater than 1.2 m intervals) resting on ledgers (at not greater than 2.5 m intervals) and double transforms at platform board overlaps

(4) The staging is level and provided with safe access (such as ladders),

(5) The staging is adequately decked (for example have a work surface and platform), and provided with guardrails,

(6) The staging is adequate for the work performed taking into account that falls are significant hazard in site.

2 Where staging is approved as a part of the Ship Structure Access Manual and carried on board, the maintenance of all equipment, the rigging of the equipment, its operation and training in its use should be addressed by the Ships Safety Management System.

2.6 Rafting

2.6.1 Application

1 Rafting is generally used as a term for surveys carried out by means of boats or rafts. Rafting may be an option for use in tanks, holds and spaces which may be filled with water provided the arrangement of the internal structure is as described here in **2.6.1**.

2 When rafting is specified for use in the Ship Structure Safe Access Manual as movable means of access, inflatable rafts or boats, having satisfactory residual buoyancy and stability even if one chamber is ruptured, should be used.

3 The structural arrangement should allow easy escape to the deck from any position being rafted. At least 1.0 *m* clearance above and 0.5 *m* clearance beyond the breadth of the raft should be allowed for safe passage past any internal obstructions.

4 For bulk cargo holds designed for filling with water (*e.g.* ballast holds) and where the water is permitted to be filled up to a height not less than 2 *m* below the top of side frames (*e.g.* air draft holds), rafting may be utilized in lieu of permanent means of access to side frames (refer to **35.2.4-4(3), Part C of the Rules**) provided the structural capacity of the hold is sufficient to withstand static loads at all levels of water needed to survey the side shell frames. (Refer to **B1.4.2-4**)

5 Rafting of cargo oil tanks is subject to restrictions on discharging water in the harbour and weather conditions at voyage. Rafting as alternative means of access should therefore not be considered as "readily accessible" in oil cargo tanks and do not provide an alternative to fitting longitudinal permanent means of access as required by **35.2.4-1(1)(d), Part C of the Rules**.

2.6.2 Safety Routines

1 Safety measures, including the following, should be taken by an authorised person prior to survey to the satisfaction of the attending surveyor(s):

(1) The surface of the water in the tank should be calm (under all foreseeable conditions the expected rise of water within the tank should not exceed 0.25 *m*) and the water level stationary. On no account should the level of the water be rising while the boat or raft is in use.

(2) Except where permanent means of access is provided in each bay to allow safe entry and exit in accordance with **C35.2.4-3(2)**, at no time should the upside of the boat or raft be allowed to be within 1 *m* of the deepest under deck web face flat.

(3) The tank or space in which the boat or raft will be used should contain clean ballast water only. When a thin sheen of oil on the water is observed, further testing of the atmosphere should be done to ensure that the tank or space is safe for entering.

(4) If the tanks (or spaces) are connected by a common venting system, or inert gas system, the tank in which the boat or raft will be used should be isolated to prevent a transfer of gas from other tanks (or spaces).

(5) Appropriate lifejackets should be available for all participants.

(6) The boat or raft should be tethered to the access ladder and an additional person should be stationed down the access ladder with a clear view of the boat or raft.

(7) A communication system should be arranged between the survey party in the tank or space being examined, the responsible officer on deck, the navigation bridge and the personnel in charge of handling the ballast pump(s) in the pump control room.

(8) Adequate and safe lighting should be provided for the safe and efficient conduct of the survey.

2 It is responsibility of the Owners to provide a raft that meets the requirements of **2.6.1**.

3 The organization for the surveys by means of rafting, its operation and training in use should be addressed by the Ships Safety Management System.

2.7 Portable Ladders

2.7.1 Application

1 Portable ladders may be used for access to any structural members as supplementary and/or additional means to permanent means of access in accordance with **35.2, Part C of the Rules** and should be included in the Ship Structure Access Manual.

2 When specified for use in the Ship Structure Safe Access Manual as a portable means of access, such ladders should comply with the following:

(1) Portable ladders should be designed based on a recognized International or National Standard.

(2) Non-self supporting and self-supporting portable ladders not according to **(1)** above should support at least four times the maximum intended load.

(3) The rungs and steps of portable ladders should be designed to minimize slipping, *e.g.* corrugated, knurled, dimpled or coated with skid resistance material.

(4) Step ladders, hanging ladders and ladders more than 5 *m* long may only be utilized if fitted with a mechanical device to secure the upper end of the ladder.

(5) The manner is which portable ladders can most safely be used by workers should be specified.

3 In accordance with **B1.4.2-10(3)(a), Part B of the Guidance**, portable ladders may be used for close-up surveys of the cargo hold shell frames of bulk carriers.

2.7.2 Safety Routines

1 Safety measures, including the following, should be taken by an authorised person prior to survey to the satisfaction of the attending surveyor(s):

(1) Portable ladders should rest on a stable, strong, suitably sized, immobile footing so that the rungs remain horizontal. Suspended ladders should be attached in a manner so that they can not be displaced and do not swing.

(2) The feet of portable ladders should be prevented from slipping during use by securing the stiles at or near their upper and lower ends, by any anti-slip device or by other arrangements of equivalent effectiveness. Unless specified in the specifications of each portable ladder or relevant safety standards, the ladder should be raised at an angle of around 70 degrees to the horizontal.

(3) Portable ladders should be used only on the bottom or on a deep stringer platform so that the free falling height does not exceed 6 *m*. If it is necessary to exceed this height, there should be at least 3 *m* of water above the highest structural element in the bottom to provide a "cushion" or a safety harnesses is to be used. The free falling height above the water surface should not exceed 6 *m*.

(4) When climbing ladders in tanks containing water, the surveying personnel should wear "flotation" aids. A flotation aid is a simple form of lifejacket which does not impede climbing or a self-inflatable lifejacket.

(5) Aluminium ladders may be used in cargo tanks, but can not be stored in the cargo area or other gas dangerous spaces.

(6) Ladders should be maintained free of oil, grease and other slipping hazards.

2 The maintenance of all equipment, the securing of the equipment, its operation and training in use should be addressed by the Ships Safety Management System.

2.8 Innovative Approach

2.8.1 General

1 Any proposal for innovative means of access should be tested outside the requirements of the **35.2, Part C of the Rules** and should not be accepted as meeting this regulation until accepted by the Society.

2 Where accepted by the Society, then the arrangements may be accepted as an alternative means of access provided that all the criteria from the trials are included into the design.

Appendix C1 REFERENCE DATA FOR DESIGN

1.1 (Deleted)

1.2 Connection of Rudder Stock and Rudder Main Piece Using Cone Coupling with Key (3.8.3, Part C of the Rules)

1.2.1

Where the rudder stock is connected to the main piece using the cone coupling with a slugging nut and key and all of the rudder torque is transmitted by the key, the standard necessary push-up force and the push-up length are as determined by the following formulae;

Push-up force (F):

$$F = \frac{2T_R f_{s1}}{\mu_2 d_m}\left(\mu_1 + \frac{1}{2k}\right) \ (kN)$$

Push-up length (Δl):

$$\Delta l = 4k\left(\frac{T_R f_{s1} \times 10^3}{\pi E \mu_2 d_m l\left(1-c^2\right)} + R_t\right) \ (mm)$$

Permissible push-up length (Δl_{perm}):

$$\Delta l_{perm} = 2k\left(\frac{d_m \sigma_Y}{E\sqrt{3+c^4} f_{s2}} + 2R_t\right) \ (mm)$$

Where:

$c = d_m/d_c$

d_m: Mean diameter (mm) of cone

d_c: Outer diameter (mm) of gudgeon at middle height of cone

μ_1: Coefficient of friction against push-up, may normally be taken as 0.14

μ_2: Coefficient of friction against slip, may normally be taken as 0.15

R_t: Mean roughness of the contact surface, may normally be taken as 0.01 mm

k: Inverse number of cone taper on diameter (12～20)

E: Young's modulus of the materials of rudder stock and gudgeon, be taken as 2.06×10^5 (N/mm^2) for steel

σ_Y: Yield stress (N/mm^2) of the material of gudgeon

f_{s1}: Coefficient, to be taken as 0.5 or over

f_{s2}: Safety factor against strength of the gudgeon, to be taken as not less than 1.25
Special consideration is to be made for couplings that are under a large bending moment in addition to the rudder torque such as those of rudder type C.

l: Taper length (mm) of cone

1.3 Thickness of Sleeves and Bushes (3.10, Part C of the Rules)

1.3.1

As for the thickness of sleeves and bushes at the pintle bearing part and neck bearing part, their standard thicknesses are to be as obtained from the following formulae, where sleeves are metallic and bushes are of lignum vitae or synthetic resin. The thicknesses of sleeves and bushes are as in 3.10.1, Part C of the Rules.

(1)

(a) Thickness of pintle sleeve

$0.03d_{po} + 5 \ (mm)$

Where:

d_{po}: Diameter (mm) of pintle measured at outside of sleeve

(b) Thickness of bush of pintle bearing

$d_{po} < 300$: $0.05d_{po} + 5$ (mm)

$d_{po} \geq 300$: $0.03d_{po} + 11$ (mm)

Where:

d_{po}: As per **(1)(a)** above

(2)

(a) Thickness of rudder stock sleeve at neck bearing

$0.03d_l + 3$ (mm)

Where:

d_l: Diameter of lower stock (mm)

(b) Thickness of bush of neck bearing

$d_l < 300$: $0.05d_l + 2$ (mm)

$d_l \geq 300$: $0.03d_l + 8$ (mm)

Where:

d_l: As per **(2)(a)** above

1.4 (Deleted)

1.5 Prevention of Vibrations of Tanks in Aft Part (14.2, Part C of the Rules)

1.5.1

Panels with stiffeners in tanks in the aft part are to be so constructed that both the natural frequencies calculated by the following two formulae are greater than $2.2n_pN$.

$$\frac{725}{\alpha_s}\sqrt{\frac{t^3}{24.65t+C\sqrt{\alpha_s}}}\ (rpm)$$

$$\frac{4825K}{l^2\sqrt{1+\frac{Cl\beta_n}{24.65te\sqrt{1+\beta_n^2}}}}\ (rpm)$$

Where:

$$\alpha_s = \frac{\beta^2 S^2}{1+\beta^2}$$

S: Stiffener spacing (m)

$$\beta = \frac{l}{S}$$

t: Plate thickness (mm)

C: Coefficient, to be equal to 1,000 if only one side is in contact with water or 2,000 if both sides are in contact with water

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

I: Moment of inertia (cm^4) of section of a stiffener with attached plate

A: Sectional area (cm^2) of a stiffener with attached plate

l: Length (m) of side of panel in parallel with stiffeners

$$\beta_n = \frac{(n+1)S}{l}$$

n: Number of stiffeners

t_e: Apparent thickness (mm) of plating to be obtained from the following formula:

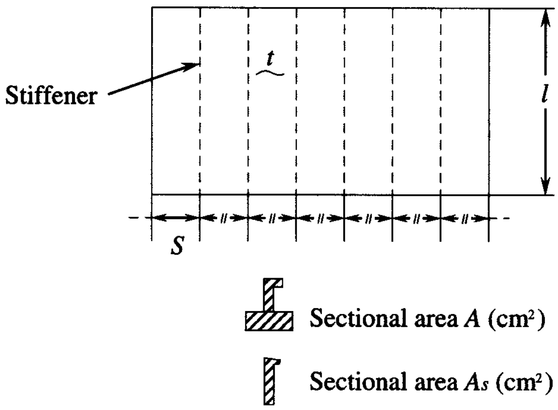
$$t_e = t + \frac{A_s n}{10(n+1)S}$$

A_s: Sectional area (cm^2) of a stiffener not including attached plate

n_p: Number of blades of propeller

N: Rate of revolutions (rpm) of propeller

Fig. 5.1



1.6 (Deleted)

1.7 Standard Value of Torsional Moment of Hull due to Uneven Cargo Stowage in Container Carriers (C32.3.1 of the Guidance)

1.7.1

"The torsional moment generated in the hull due to uneven cargo stowage" to be considered in applying the requirements of **C32.3.1 of the Guidance** may be the following M_{TC} value, as a standard:

$M_{TC} = 0.23 L N_R W_C$ (kN-m)

Where:

N_R: Maximum number of rows of containers loaded in a cargo hold

W_C: Mean weight per 20 ft container which is normally taken as 100 kN

The warping stress (N/mm^2) acting on the hull due to M_{TC} may be obtained from the following formula:

$$\sigma_{\omega C} = 0.000318 \frac{\omega\, l_C M_{TC}}{I_\omega + 0.04 l_C^2 J}$$

Where:

ω, l_C, I_ω and J: As specified in **C32.3.1 of the Guidance**

1.8 (Deleted)

1.9 Minimum Thickness of Face Plates of Girders (29.6, Part C of the Rules)

1.9.1

The thickness of face plates having a free edge or edges is not to be less than that obtained from the following formula:

$$\frac{\bar{b}}{15\sqrt{1+\frac{2.4}{\alpha^2}}}\ (mm)$$

Where:

$\alpha = \frac{S_t}{\bar{b}}$

$\bar{b}$: Width (mm) of free flange of face plate

S_t: Distance (mm) between supports of face plate of girder

Where the free flange of the face plate is reinforced by an effective stiffener as stipulated below, the thickness may be reduced to the value not less than that obtained from the following formulae:

$1.0 > \alpha$: $\frac{\bar{b}}{24\left(\alpha+\frac{1}{\alpha}\right)}\ (mm)$

$\alpha \geq 1.0$: $\frac{\bar{b}}{48}\ (mm)$

The above-mentioned effective stiffeners are to be such that they satisfy the following relationship:

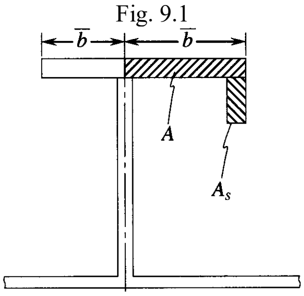
$A_s \geq \frac{1}{9}A$

Where:

A_s: Sectional area (mm^2) of stiffener

A: Sectional area (mm^2) of free flange of face plate (*See* **Fig. 9.1**)

Fig. 9.1



1.10 (Deleted)

1.11 Change-over of Ore/Oil Carriers (30.7, Part C of the Rules)

1.11.1

This clause gives an example of precautions to be taken in preparing a Check List for the work and equipment necessary for change-over from oil carrier to ore carrier or vice versa for ships intended to carry cargo oils with a flash point not exceeding 60°C or alternatively bulk cargoes such as ore.

(1) The Check List is to be prepared with due attention paid to the following matters, as set forth in the attached “Example.”

(a) As the work for change-over of ore/oil carrier is usually carried out by the ship’s crew members during navigation and, further, it contains an enormous quantity of items which must be finished in a limited time, the Check List is to be prepared in such a way that it is clear when all the items of work have been finished without omission and mistake.

(b) The Check List is to contain details of necessary information such as precautions, so that the check list can be filled in without reference to any other documents in the course of change-over work.

(c) The descriptions of the completed state of change-over of piping systems is to contain, in addition to the states of blank flanges, the states of stop valves installed as substitutes for blank flanges and the stop valves in the systems which are not to be used according to the type of cargo (ore or oil).

An example of such stop valves is given below.

i) Stop valves installed as substitutes for blank flanges on the cargo stripper lines that lead to the slop tanks

ii) Stop valves on the cargo suction lines without blank flanges that lead to slop tanks (*See* **4.5.1-4(2), Part R** of the Rules)

iii) Stop valves on branches that lead to wing tanks (cargo oil tanks) of stripper lines when they are used as bilge suction lines of ore holds while the ship is used as an ore carrier

(d) The compartments and installations to be contained in the Check List are generally as follows:

i) Cargo oil tanks and compartments adjacent to cargo oil tanks

ii) Combined oil/ore holds and compartments adjacent to combined oil/ore holds

iii) Combined ore holds and water ballast tanks

iv) Wells, piping systems, sounding systems, closing appliances, etc. installed for the compartments for dual use

v) Cargo oil pipe system and vent pipe system (if the bilge system and the ballast system need change-over, they are to be included in the Check List)

vi) Installations needing change-over at every change-over from/to oil carrier to/from ore carrier

(e) Details of work contained in the Check List are to be described in the related manuals.

(f) Though the Check List shown as an example contains, to some extent, various indications as to the contents of work, they are for the purpose of confirming completion of the work and not for giving instructions of the work.

(g) Refer to the example for further information.

(2) An example of the Check List and some precautions to be taken when filling it in are given below.

Check List for Ore/Oil Change-Over (Hull Part)

Oil Carrier → Ore Carrier

Ore Carrier → Oil Carrier

Commencement of work:

Completion of work:

Officer in Charge:

(Precautions to be taken when filling in the Check List)

(a) The Check List is to be filled in at every change-over from/to ore to/from oil. The items of work which are not necessary to be carried out are to be crossed out. (Accordingly, the whole work is finished when all the blank columns have been marked up.)

(b) For details of the work contained in the Check List, refer to the "Manual for Handling Special Installations of Ore/Oil Carrier".

(c) "Confirmation of gas-freeing in compartments adjacent to cargo oil tanks" means the work of confirming the absence of leakage of dangerous gases into these compartments.

(d) Where there are special indications given to valves relating to the piping systems, they are to be treated in the same manner as for the blank flanges. For example, "ore-close" indicates that the valves must never be opened while the ship is used as an ore carrier.

1.12 Change-over of Bulk/Oil Carriers (31.8.1, Part C of the Rules)

1.12.1

Combined bulk/oil carriers are designed to be operated as bulk carriers for a certain period and alternatively as oil tankers in other periods for the transport of oils with a flash point not exceeding 60°C. Accordingly, several installations on board are to be changed-over to comply with the use of the ship.

The ships of this category are approved by the Society on the basis that such change-over work is carried out in a reliable manner. Accordingly, in order to assure reliable performance of such change-over work, it is recommended to prepare a Check List as described under Article **1.11 Change-over of Ore/Oil Carriers**.

1.13 Simplified Method of Calculating Periods of Natural Vibration/Oscillations of Hull and Liquid Cargo (31.8.2, Part C of the Rules)

1.13.1

When a hold is half-filled with cargo oil, the periods of longitudinal and transverse oscillations of cargo oil and the pitching and rolling of the hull are approximately given by the following formulae:

(1) Periods of oscillations of cargo oil

(a) Period of longitudinal oscillation

$$\frac{2\pi}{\sqrt{\frac{\pi}{l}g\ \tanh\frac{\pi}{l}h_1}}\ (sec)$$

(b) Period of transverse oscillation

$$\frac{2\pi}{\sqrt{\frac{\pi}{b}g\ \tanh\frac{\pi}{b}h_1}}\ (sec)$$

Where:

b: Breadth (*m*) of compartment (distance between longitudinal bulkheads)

l: Length (*m*) of compartment (distance between transverse bulkheads)

h_1: Height (*m*) of level measured from the top of inner bottom

g: Acceleration due to gravity (m/sec^2)

(2) Periods of oscillations of hull

(a) Period of pitching $0.6\sqrt{L}$ (*sec*)

(b) Period of rolling $\frac{0.8B}{\sqrt{GM}}$ (*sec*)

Where:

GM: Metacentric height (*m*)

Where a free surface exists as is the case of halfballasting, the observed value of *GM* is to be obtained from the following formula:

$$GM - \frac{1}{12}\frac{lB^2}{V}$$

V: Displacement (*ton*) of the ship under the loading condition considered

l: Length (*m*) of the hold (distance between transverse bulkheads)

Fig. 11.1

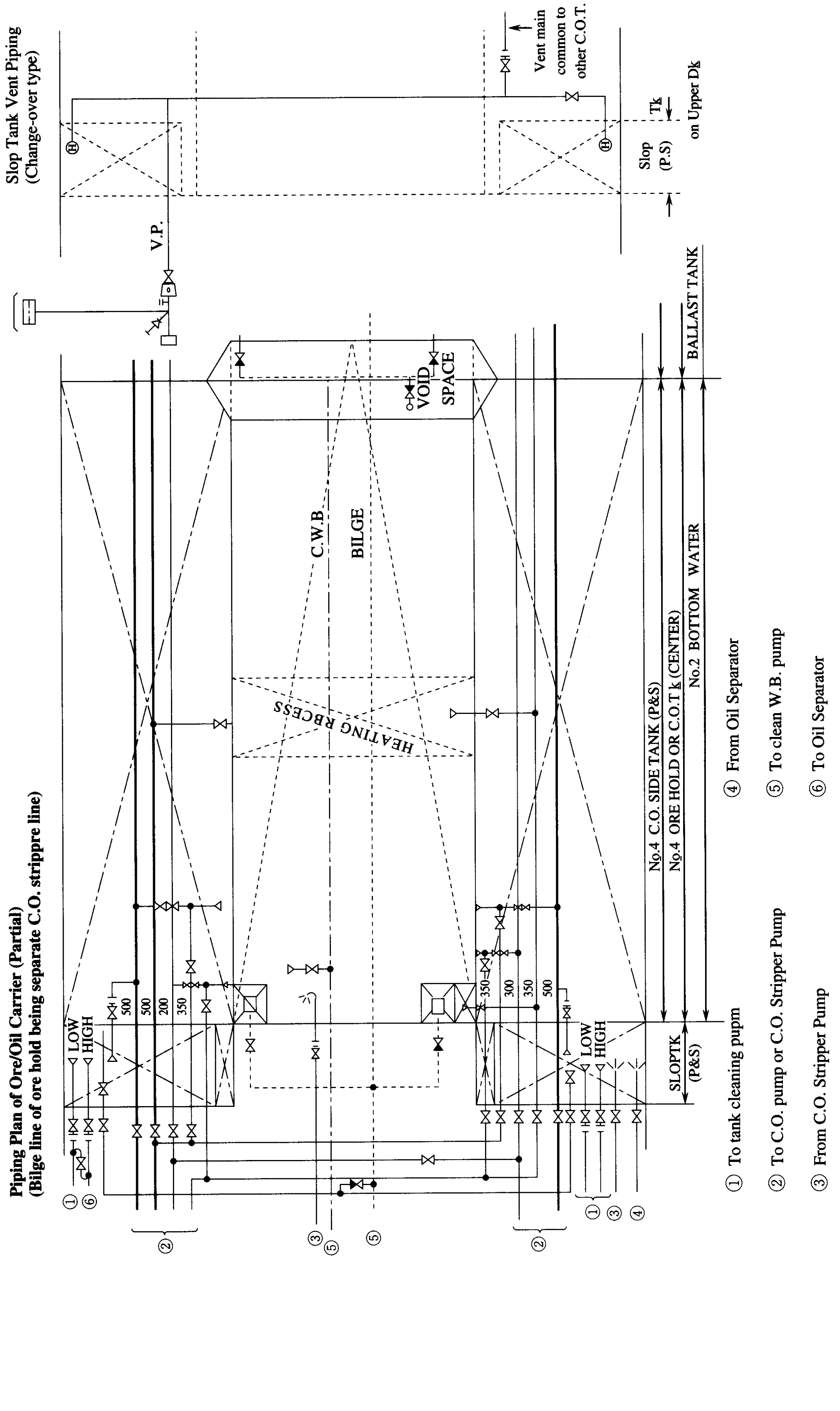

Piping Plan of Ore/Oil Carrier (Partial)
(Bilge line of ore hold being separate C.O. strippre line)
Slop Tank Vent Piping
(Change-over type)
V.P.
Vent main
common to
other C.O.T.
Slop
(P.S)
Tk
on Upper Dk
BALLAST TANK
VOID
SPACE
C.W.B.
BILGE
HEATING RECESS
No.4 C.O. SIDE TANK (P&S)
No.4 ORE HOLD OR C.O.T k (CENTER)
No.2 BOTTOM WATER
SLOPTK
(P&S)
LOW
HIGH
500
500
200
350
350
300
350
500
① To tank cleaning pupm
② To C.O. pump or C.O. Stripper Pump
③ From C.O. Stripper Pump
④ From Oil Separator
⑤ To clean W.B. pump
⑥ To Oil Separator

Table 11.1 Example of Check List

Compartment		Location work	Oil→Ore (Note 1)		Ore→Oil (Note 1)	
			Work	Signature	Work	Signature
Omitted						
No.2 Ore Hold or W.B.T (Centre)		Hold (Note 2)	Cleaning, gas freeing confirmed		Cleaning	
		Ballast well (S)	Tight cover fitted		Tight cover removed	
		Bilge well (P)	Tight cover removed Perforated plate fitted		Perforated plate removed Tight cover fitted	
		Bilge well (S)	Same as above		Same as above	
		Float gauge	Removed		Fitted	
Omitted						
No.4 Ore Hold or C.O.T.(Centre)		Hold (Note 2)	Cleaning, Gas freeing		Cleaning	
		Heating recess (Note 3)	Tight cover fitted		Tight cover removed	
		Stripper well (S)	Tight cover fitted		Tight cover removed	
		Bilge well (P)	Tight cover removed Perforated plate fitted		Perforated plate removed, Tight cover fitted	
		Float gauge	Removed		Fitted	
Aux. Pumproom (Forward of C.O.T.)		Pumproom	Gas freeing confirmed			
Omitted						
No.4 C.O.S.TK	P	Inside the Tank	Cleaning, Gas freeing		Blank flange removed	
		Cargo main branch to slop tank	Blank flange fitted		Blank flange removed	
	S	Inside the Tank	Cleaning, Gas freeing			
		Cargo main branch to slop tank	Blank flange fitted		Blank flange removed	
Omitted						
Pumproom		Inside the Compartment	Gas freeing			
		Low suction line in P-side slop tank	Blank flange fitted		Blank flange removed	
		High suction line in P-side stop tank	Same as above		Same as above	
		Centre hold return line	Same as above		Same as above	
		Low suction line in S-side slop tank	Same as above		Same as above	
		High suction line in S-side slop tank	Same as above		Same as above	
Omitted						
Hatches on upper deck		No.1 Hatch cover (Note 4)	Gas freeing confirmed (Note 4)		Tightening bolts checked (Note 5)	
		Omitted				
Cargo main lines (Note 6)		No.1 Line system to No.1 cargo pump; S-side wing tank group	Cleaning, Gas freeing			
		Omitted				
Omitted						
Vent line		Forward vent lines	Cleaning of Gas freeing			
		Omitted				
		Changing-over part of vent line (aft) of slop tank (Note 7)	Blank flange closed, Stop valve of stern vent line opened		Blank flange (and stop valve) opened Stop valve of stern vent line closed	
Omitted						

Notes :

1. The column not in use is to be crossed out.
2. Including wells, recess, etc.
3. Same work is to be carried out even when heating coils are not used under oil tanker service (compartment common with cargo well).
4. Hatch covers of this ship are doubleplated.
5. Bolts must be tightened during navigation. Dangerous if loosened after oil unloading is finished.
6. Including deck lines.
7. The vent line of the slop tank is of a change-over type.

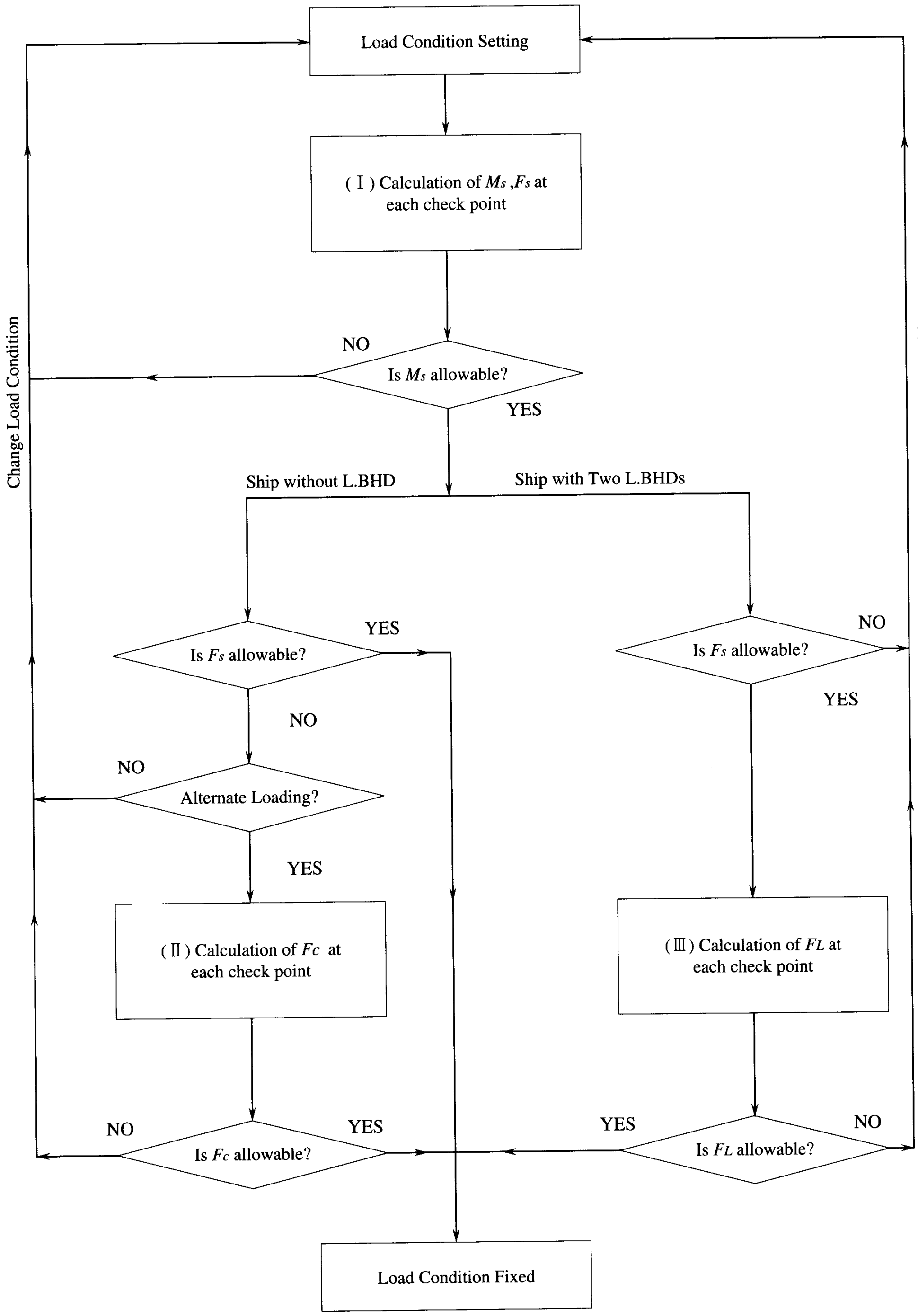
Appendix C2 APPENDIX to ANNEX C34.1.2 DETAIL GUIDE FOR PREPARATION OF LOADING MANUAL

1.1 Method of Calculation of Longitudinal Strength for Loading Conditions Different from Standard Loading Conditions

1.1.1 Check Items for Longitudinal Strength

Calculation and confirmation of longitudinal strength for loading conditions different from the standard loading conditions are to be made on the following items in accordance with the procedures given in the flow chart below (*See* **Fig. 1**) for each point of output.

Fig. 1 Flow Chart for Checking Longitudinal Strength



(1) Ships without longitudinal bulkheads
  (a) Longitudinal still water bending moment (M_S)
  (b) Still water shearing force (F_S)
  (c) Still water shearing force for alternate loading (F_C: F_S corrected for alternate loading)
  However, where the ship's design does not take into account load sharing by the double bottom, the shearing force for alternate loading does not need to be checked.

(2) Ships with one or four rows of longitudinal bulkhead
  (a) Longitudinal still water bending moment (M_S)
  (b) Still water shearing force (F_S)
  (c) Shearing force of longitudinal bulkhead (F_L: shearing force acting on the longitudinal bulkhead taking into account the local load)

1.1.2 Point of Output for Checking Longitudinal Strength

1 At least six points of output of longitudinal still water bending moment are to be properly arranged along the length of the ship (including the midship $0.5L$).

2 The points of output of still water shearing force are to be arranged at fore and aft bulkheads of cargo loaded compartments, the transverse bulkheads between these bulkheads, and/or similar spaces. However, where the distance between transverse bulkheads is small, such as with cofferdams, the strength check of one of the bulkheads may be omitted. Also, the strength check may be omitted where the shearing force is considered to be small.

1.1.3 Grouping of Loads in Calculation

1 Loads in those tanks symmetrically arranged on both sides of a ship may be summarized in the same group in calculation.

2 Where multiple hatch openings are provided for one cargo hold, calculation is to be made for each hatch opening. However, where separation according to the type of cargo is unnecessary, the calculation may be made by hold.

1.1.4 Procedure for Checking Longitudinal Strength

1 In order to easily check the allowable cargo load, the relation between loading and longitudinal strength, and the procedure for checking longitudinal strength are to be explained by using a flow chart or other suitable means. Descriptive examples are shown in **1.6** and **1.7**.

2 The following allowable values corresponding to the values calculated in **1.1.1** above are to be clearly specified so that the ship master can judge the adequacy of cargo loading without making mistakes.

(1) Allowable value for longitudinal still water bending moment (allowable value of M_S)

(2) Allowable value for still water shearing force (allowable value of F_S)

(3) Allowable value for shearing force of longitudinal bulkhead (allowable value of F_L)

These allowable values are to be those calculated in accordance with the requirements of **1.4, Annex C34.1.2** "Allowable Values for Longitudinal Strength" at each point of output. The allowable values for ships in port are not to be included in the calculation form.

3 Terms and expressions used for describing the calculated values and allowable values are to be the same as used in **1.1.1(1)**, **(2)** and **1.1.4-2**.

1.1.5 Method of Calculation

1 Calculation of longitudinal still water bending moment (M_S) and still water shearing force (F_S)

Longitudinal still water bending moment and still water shearing force are to be determined based upon direct calculation as far as possible.

2 Calculation of still water shearing force for alternate loading (F_C)

Corrective calculations for where the adjoining holds are alternately loaded are to be made according to the method given in **1.9**.

3 Calculation of shearing force on longitudinal bulkheads (F_L)

Calculations of still water shearing force to be shared by the longitudinal bulkhead for ships with one or four rows of longitudinal bulkheads are to be made according to the method given in **1.10**.

4 The Loading Manual is to be appended with these examples of calculation.

1.2 Descriptive Example 1 of Allowable Values for Longitudinal Still Water Bending Moment and Still Water Shearing Force (Ships without Longitudinal Bulkheads)

1.2.1

The allowable values for longitudinal still water bending moment and still water shearing force of the ship at sea and in port are shown in the following **Table 1**, **Table 2** and **Fig 2**.

Table 1 For Conditions at Sea

Point of output	Allowable value of longitudinal still water bending moment (*kN-m*)		Allowable value of still water shearing force (*kN*)	
	Positive	Negative	Positive	Negative

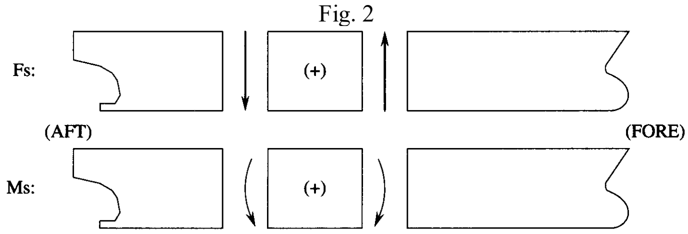
Table 2 For Conditions in Port

Point of output	Allowable value of longitudinal still water bending moment (*kN-m*)		Allowable value of still water shearing force (*kN*)	
	Positive	Negative	Positive	Negative

Note:

The positive allowable value is shown in the following figure.

Fig. 2



1.3 Descriptive Example 2 of Allowable Values for Longitudinal Still Water Bending Moment and Still Water Shearing Force (Ships with One or Four Rows of Longitudinal Bulkheads)

1.3.1

The allowable values for longitudinal still water bending moment and still water shearing force of the ship at sea and in port are shown in the following **Table 3**, **Table 4** and **Fig.3**.

Table 3 For conditions at sea

Point of output	Allowable value of longitudinal still water bending moment(kN-m)		Allowable value of still water shearing force(kN)		Allowable value of still water shearing force for longitudinal bulkhead (kN)	
	Positive	Negative	Positive	Negative	Positive	Negative

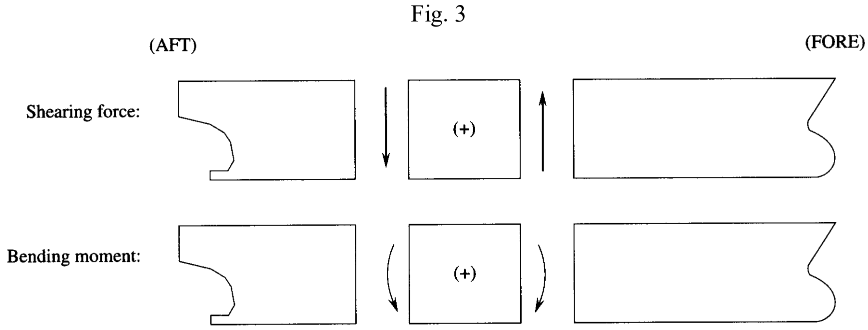
Table 4 For conditions in port

Point of output	Allowable value of longitudinal still water bending moment(kN-m)		Allowable value of still water shearing force(kN)		Allowable value of still water shearing force for longitudinal bulkhead (kN)	
	Positive	Negative	Positive	Negative	Positive	Negative

Note:

The positive allowable value is shown in the following figure.

Fig. 3



1.4 Descriptive Example of Stresses

1.4.1 Stress on Hull

1 Longitudinal bending stress (σ)

The section modulus (Z) of the midship point of L calculated on the basis of the original as-built scantlings is as follows:

$$Z_{act(deck\ side)} = 86.642\ (m^3)$$

Longitudinal bending stresses (σ) under various conditions of the ship on the basis of the above section modulus are as follows:

$$\sigma = \frac{M(kN\cdot m)}{Z(cm^3)} \times \frac{1}{1000} = \frac{M}{86{,}642}\ (N/mm^2)$$

(1) The positive allowable value for longitudinal still water bending moment of the ship (M_S) is 5,750,000 (kN-m), and its corresponding longitudinal bending stress (σ_S) is as follows:

$$\sigma_S = \frac{5{,}750{,}000}{86{,}642} = 66\ (N/mm^2)$$

In other words, the bending stress in calm seas is 66 N/mm^2 or less providing that loading is properly done.

(2) Where the ship is in open seas, the wave induced bending moment acts on the ship and the corresponding bending stress is added to **(1)** above. Where the longitudinal wave bending moment (M_w= (+) 9,410,000 *kN-m*) specified in the Rules is added to the bending stress becomes as follows:

$$\sigma = \frac{M_S + M_W(+)}{86{,}642} = \frac{15{,}160{,}000}{86{,}642} = 175 \ (N/mm^2)$$

(3) The bending stress (σ_{port}) corresponding to the allowable longitudinal still water bending moment in harbour conditions (10,455,000 *kN-m*) is as follows:

$$\sigma_{port} = \frac{10{,}455{,}000}{86{,}642} = 121 \ (N/mm^2)$$

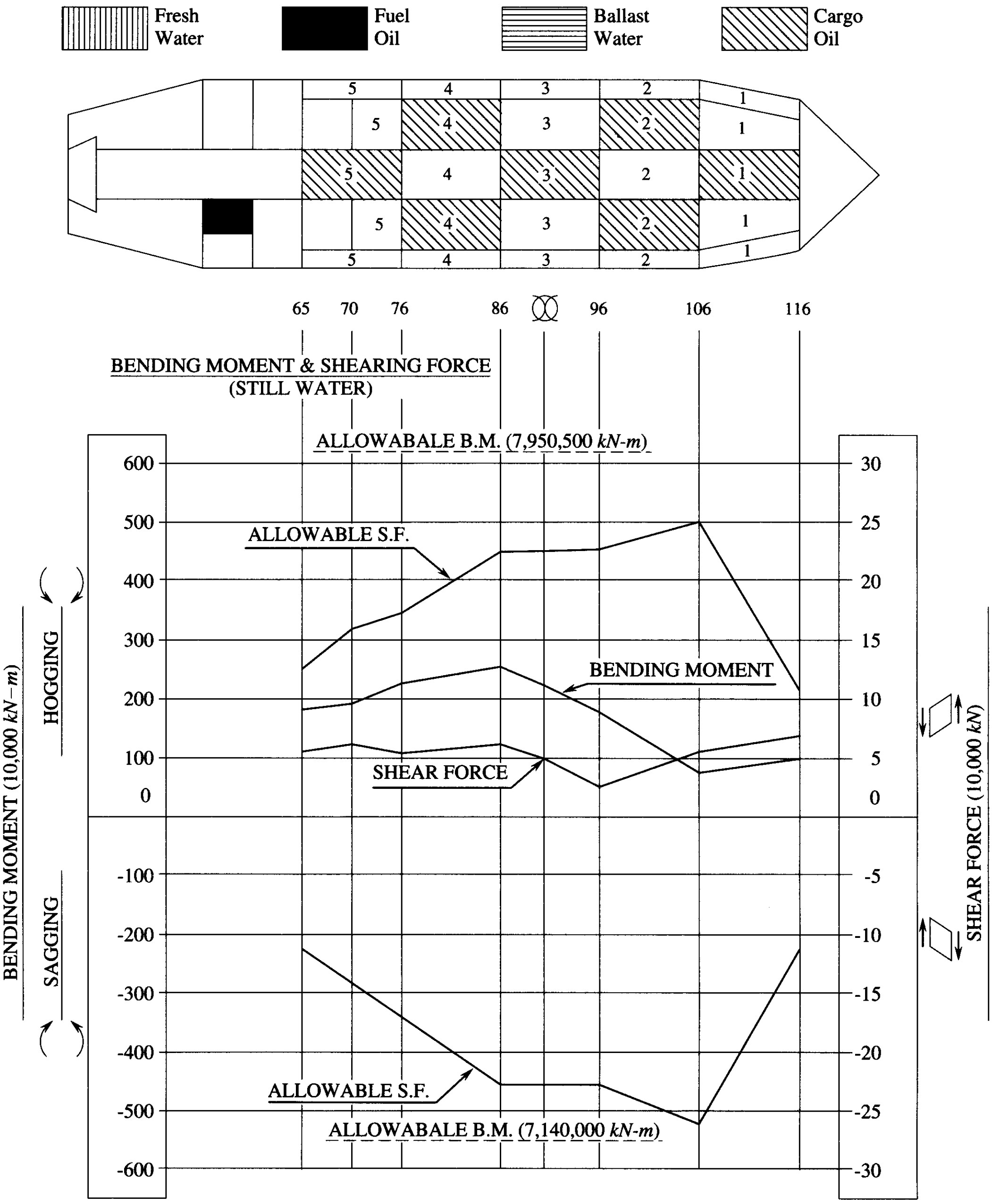
2 Shearing stress (τ)

The shearing stress (τ), where the wave induced shearing force specified in the Rules acts on the ship is 110 N/mm^2 or below provided that loading is properly done.

1.5 Descriptive Example of Standard Loading Conditions

Descriptive examples of standard loading conditions are shown in **Table 5**, **Table 6** and **Fig 4**.

Fig. 4



Fresh Water
Fuel Oil
Ballast Water
Cargo Oil
65 70 76 86 96 106 116
BENDING MOMENT & SHEARING FORCE
(STILL WATER)
ALLOWABALE B.M. (7,950,500 kN-m)
ALLOWABLE S.F.
BENDING MOMENT
SHEAR FORCE
ALLOWABLE S.F.
ALLOWABALE B.M. (7,140,000 kN-m)
HOGGING
SAGGING
BENDING MOMENT (10,000 kN−m)
SHEAR FORCE (10,000 kN)

Table 5 CONDITION NO. 20 (PARTIAL LOADING CONDITION)

CONDITION NO. 20
PARTIAL LOADING CONDITION

DISPLACEMENT		t	170000
DRAFT AT C. F.		m	11.54
DRAFT	FORE	m	9.76
	AFT	m	13.69
	MEAN	m	11.73
TRIM		m	3.93
⊠G		m	13.50
⊠B		m	20.20
⊠F		m	17.00
MTC		$t-m$	2933.1
KM		m	29.92
KG		m	15.88
GM		m	14.04
GG_0		m	0.91
G_0M		m	13.13
PROPELLER IMMERSION (I/D)		%	132
DETAIL OF DEADWEIGHT			
CARGO OIL		t	130750
BALLAST WATER		t	0
FUEL OIL		t	408
DIESEL OIL		t	334
FRESH WATER		t	490
CONSTANT		t	508
OTHERS PROVISIONS		t	0
DEADWEIGHT TOTAL		t	132490
LONGITUDINAL STRENGTH			
MAX. BENDING MOMENT (at FR 86)		$kN-m$	149334
MIN. BENDING MOMENT (at FR 106)		$kN-m$	− 22038
MAX. SHEAR. FORCE (at FR 96)		kN	1857
MIN. SHEAR. FORCE (at FR 51)		kN	− 3539
STABILITY			
GZ MAX.		m	7.68
ANGLE OF GZ (MAX.)		$deg.$	38.2

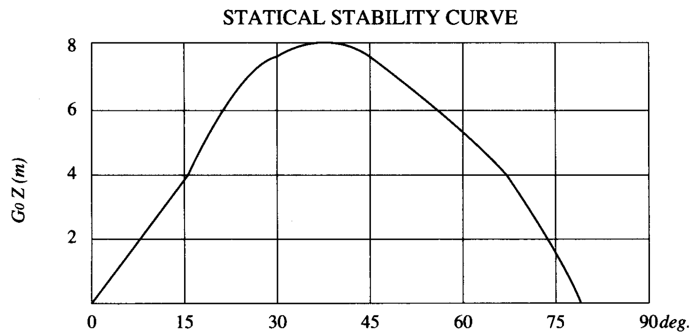


Table 6 Weight Conditions

Tank	Weight (*ton*)	VOL/CAP (%)
Cargo Oil		
NO 1 CT (C)	20681	98
NO 2 CT (C)	0	0
NO 3 CT (C)	24642	98
NO 4 CT (C)	0	0
NO 5 CT (C)	23885	98
NO 1 CT (P/S)	0	0
NO 2 CT (P/S)	30771	98
NO 3 CT (P/S)	0	0
NO 4 CT (P/S)	30771	98
NO 5 CT (P/S)	0	0
SLOPT	0	0
Ballast Water		
FPT	0	0
NO 1 WBT	0	0
NO 2 WBT	0	0
NO 3 WBT	0	0
NO 4 WBT	0	0
NO 5 WBT	0	0
E/R WBT	0	0
APT	0	0
Fresh Water		
DRWT	245	96
FRWT	245	96
Fuel Oil		
NO 1 FOT	408	12
NO 2 FOT	0	0
Diesel Oil		
NO 1 DOT	167	96
NO 2 DOT	167	96

1.6 Descriptive Example 1 on the Procedure of Calculation of Longitudinal Still Water Bending Moment and Still Water Shearing Force (Ships without Longitudinal Bulkheads)

1.6.1 Adjustments in Loading and Judging Procedure

Where the loading condition differs from the standard loading condition, longitudinal still water bending moment (M_S) and still water shear force (F_S, F_C) are to be obtained by the procedures stated below, and the loading condition is to be adjusted so that the values obtained above do not exceed the respective allowable values. The allowable values incorporate the tolerances of the structural strength of each part of the hull in regards to stresses due to foreseen longitudinal bending moments and shearing forces for voyages in open seas. Therefore, the strength of the ship at sea can be ensured so far as the values of M_S, F_S and F_C at each point of output do not exceed the corresponding allowable values.

The longitudinal bending moment and shearing force to be checked are as follows:

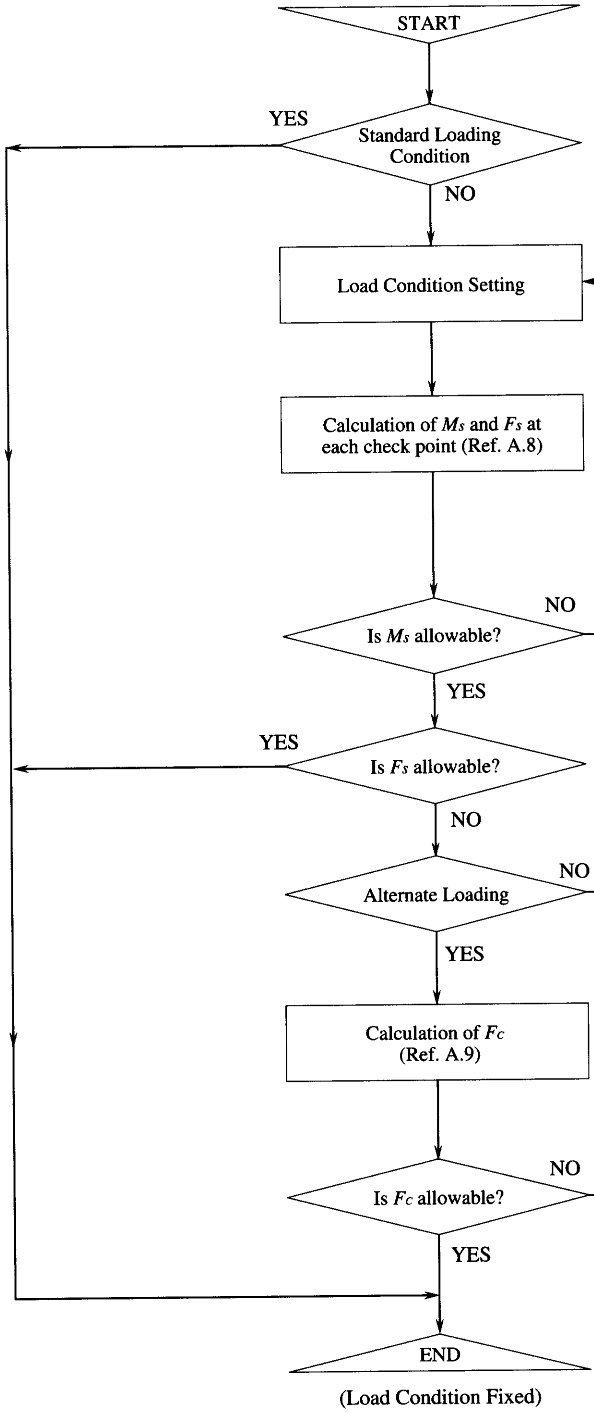
Still water bending moment (M_S)

Still water shearing force (F_S)

Still water shearing force in alternate loading (F_C)

Details of the procedure to obtain the values of F_S, F_C and M_S will be explained in **1.8** and **1.9**, and the method for checking these values is to be made according to the following procedure (*See* Flow Chart in **Fig. 5**).

Fig. 5



(1) Calculate the values of M_S and F_S at each point of output through the use of the form as shown in **1.8** by giving the loads in each cargo hold and tank.

(2) Check if the values of M_S at each point of output exceed the allowable value of M_S shown in **1.2**. If they are verified to be in the range between the positive and negative allowable values, proceed to the next step. Where they exceed the allowable values, the loading condition requires adjustment.

(3) Check if the values of F_S at each point of output obtained in **-1** exceed the allowable value of F_S shown in **1.2**. If they are

verified to be in the range between the positive and negative allowable values, the loading condition may be acceptable. Where they exceed the allowable values, proceed to the next step.

(4) Check if the point of output exceeding the allowable value of F_S is where the cargo is an alternate loading condition. If not, the loading condition requires adjustment. If so, proceed to the next step.

(5) On points of output exceeding the allowable value of F_S, calculate F_C through the use of the form shown in **1.9**.

(6) Where values of F_C are in the range between the positive and negative allowable value of F_S, the loading condition may be accepted. When F_C exceeds the allowable value of F_S, loading condition requires adjustment.

1.7 Descriptive Example 2 on the Procedure of Calculation of Longitudinal Still Water Bending Moment and Still Water Shearing Force (Ships with One or Four Rows of Longitudinal Bulkheads)

1.7.1 Adjustments in Loading and Judging Procedure

Where the loading condition differs from the standard loading condition, the longitudinal still water bending moment (M_S) and still water shearing force (F_S, F_L) are to be obtained by the procedures stated below, and the loading condition is to be adjusted so that the values obtained above do not exceed the respective allowable values. The allowable values incorporate the tolerances of the structural strength of each part of the hull in regards to stresses due to foreseen longitudinal bending moments and shearing forces for voyages in open seas. Therefore, the strength of the ship at sea can be ensured so far as the values of M_S, F_S and F_L at each point of output do not exceed the corresponding allowable values.

The longitudinal bending moment and shearing force to be checked are as follows:

Still water bending moment (M_S)

Still water shearing force (F_S)

Still water shearing force acting on longitudinal bulkhead (F_L)

Explanatory notes on details of calculation procedures will be given in **1.8** and **1.10**, but the method for calculation and its verification are to be made according to the following procedures (*See* Flow Chart in **Fig. 6**)

(1) Calculate values of M_S and F_S at each point of output through the use of the form as shown in **1.8** by giving the loads in each cargo hold and tank.

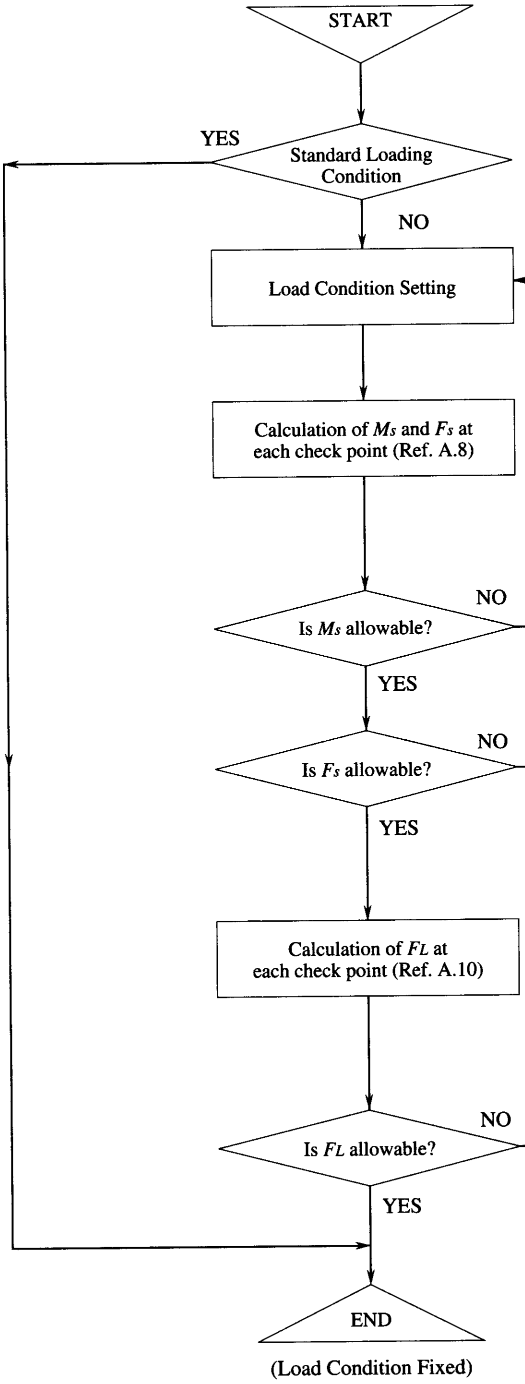
(2) Check if the values of M_S at each point of output exceed the allowable value of M_S shown in **1.3**. If they are verified to be in the range between the positive and negative allowable values, proceed to the next step. Where they exceed the allowable values, the loading condition requires adjustment.

(3) Check if the values of F_S at each point of output obtained in **1** exceed the allowable value of F_S shown in **1.3**. If they are verified to be in the range between the positive and negative allowable values, proceed to the next step. Where they exceed the allowable values, the loading condition requires adjustment.

(4) According to the form shown in **1.10**, calculate F_L at each point of output.

(5) Check if the values obtained in **(4)** above exceed the allowable value of F_L shown in **1.3**. If they are verified to be in the range between the positive and negative allowable values, the loading condition may be accepted. Where they exceed the allowable values, the loading condition requires adjustment.

Fig. 6



1.8 Method of Calculation of Longitudinal Still Water Bending Moment and Still Water Shearing Force

1.8.1 General explanation

With this method of longitudinal strength calculation, the longitudinal still water bending moment and still water shearing force at various locations on the hull for actual loading conditions can be obtained.

The method of longitudinal strength calculation and expressions used are as follows:

$\sum W$: Integral value of deadweight from the fore end of L to each point of output (shearing force due to dead-weight (unit: kN))

SS: Integral value of 'buoyancy-light weight' from the fore end of L to each point of output (shearing force due to 'buoyancy-light weight' (unit: kN))

$\sum M$: Double integral value of deadweight from the fore end of L to each point of output (bending moment due to deadweight (unit: *kN*-*m*))

SB :Double integral value of buoyancy and the ship's weight from the fore end of L to each point of output (bending moment due to buoyancy and the ship's light weight (unit: *kN*-*m*))

The longitudinal still water shearing force (F_S) and still water bending moment (M_S) at each point of output can be calculated by the following formulae:

$$F_S = \left(SS - \sum W\right) \times 9800 \ (kN)$$

$$M_S = \left(\sum W - SB\right) \times 9800 \ (kN\text{-}m)$$

F_S and M_S are positive/negative according to each allowable value, as shown in **Fig. 7**.

In this method of longitudinal strength calculation, the shearing forces (*SS*) and the bending moments (*SB*) due to buoyancy and the ship's light weight are calculated for every metre of draught and the longitudinal strength data (a list of shearing forces and bending moments for respective set-up draughts) is prepared. In **Table 8**, an example of the numerical table for one set of specific draughts is given.

Accordingly, by calculating only the shearing force and bending moment due to deadweight, the longitudinal still water shearing force (F_S) and still water bending moment (M_S) for each point of output can easily be obtained on board the ship.

Fig. 7

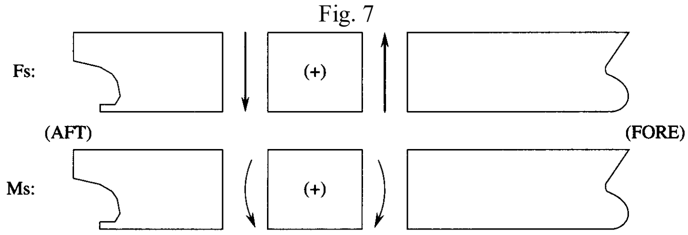


Table 7 Shearing Force and Bending Moment Calculation in Still Water

AFT DRAFT	(DA)	:	(m)
BASE DRAFT	(DB)	:	(m)
DIFFERENCE (ΔD) = DA − DB		:	(m)
TRIM		:	(m)

i	D. W. ITEM	WEIGHT 1/1,000	RATIO	LOAD (W_i)	⊗ G	MOMENT (M_i)
1	FORE PEAK TANK		1.000		152.29	
	FR. 116	$\Sigma W_i =$ ( ) $i = 1$			$\Sigma M_i =$ ( ) $i = 1$	
2	No. 1 C. O. T. (C)		1.000		118.64	
3	No. 1 C. O. T. (P/S)		1.000		118.03	
4	No. 1 W. B. T. (P/S)		1.000		121.5	
	FR. 106	$\Sigma W_i =$ ( ) $i = 1 \sim 4$			$\Sigma M_i =$ ( ) $i = 1 \sim 4$	
5	No. 2 C. O. T. (C)		1.000		71.20	
6	No. 2 C. O. T. (P/S)		1.000		71.20	
7	No. 2 W. B. T. (P/S)		1.000		71.09	
	FR. 96	$\Sigma W_i =$ ( ) $i = 1 \sim 7$			$\Sigma M_i =$ ( ) $i = 1 \sim 7$	
8	No. 3 C. O. T. (C)		1.000		21.20	
9	No. 3 C. O. T. (P/S)		1.000		21.20	
10	No. 3 W. B. T. (P/S)		1.000		21.20	
	FR. 86	$\Sigma W_i =$ ( ) $i = 1 \sim 10$			$\Sigma M_i =$ ( ) $i = 1 \sim 10$	
11	No. 4 C. O. T. (C)		1.000		−28.80	
12	No. 4 C. O. T. (P/S)		1.000		−28.80	
13	No. 4 W. B. T. (P/S)		1.000		−28.32	
	FR. 76	$\Sigma W_i =$ ( ) $i = 1 \sim 13$			$\Sigma M_i =$ ( ) $i = 1 \sim 13$	
14	No. 5 C. O. T. (C)		0.624		−68.13	
15	No. 5 C. O. T. (P/S)		1.000		−68.13	
16	No. 5 W. B. T. (P/S)		0.588		−68.13	
	FR. 70	$\Sigma W_i =$ ( ) $i = 1 \sim 16$			$\Sigma M_i =$ ( ) $i = 1 \sim 16$	
17	No. 5 C. O. T. (C)		0.376		−91.95	
18	SLOP TANK (P/S)		1.000		−93.63	
19	No. 5 W. B. T. (P/S)		0.412		−93.79	
	FR. 65	$\Sigma W_i =$ ( ) $i = 1 \sim 19$			$\Sigma M_i =$ ( ) $i = 1 \sim 19$	

	ITEM	SHEARING FORCE (F_S)			BENDING MOMENT (M_S)		
FR.116	BASE VALUE		①			①	
	DRAFT CORRECTION	CD ( ) × Δ D	②		CD ( ) × Δ D	②	
	TRIM CORRECTION	CT ( ) × TRIM	③		CT ( ) × TRIM	③	
	BUOYANCY & L. W.	① + ② + ③	SS		① + ② + ③	SS	
	DEADWEIGHT	Σ W i	ΣW		Σ W i	ΣM	
	CALCULATED VALUE	(SS − ΣW) × 9,800			(SS − ΣW) × 9,800		
	ALLOWABLE VALUE	ALLOWABLE SHEARING FORCE	105,800 ~ −107,800		ALLOWABLE BENDING MOMENT	2,406,600~ − 2,309,400	
FR.106	BASE VALUE		①			①	
	DRAFT CORRECTION	CD ( ) × Δ D	②		CD ( ) × Δ D	②	
	TRIM CORRECTION	CT ( ) × TRIM	③		CT ( ) × TRIM	③	
	BUOYANCY & L. W.	① + ② + ③	SS		① + ② + ③	SS	
	DEADWEIGHT	Σ W i	ΣW		Σ W i	ΣM	
	CALCULATED VALUE	(SS − ΣW) × 9,800			(SS − ΣW) × 9,800		
	ALLOWABLE VALUE	ALLOWABLE SHEARING FORCE	251,900 ~ −259,000		ALLOWABLE BENDING MOMENT	5,477,200~ −3,339,000	
FR.96	BASE VALUE		①			①	
	DRAFT CORRECTION	CD ( ) × Δ D	②		CD ( ) × Δ D	②	
	TRIM CORRECTION	CT ( ) × TRIM	③		CT ( ) × TRIM	③	
	BUOYANCY & L. W.	① + ② + ③	SS		① + ② + ③	SS	
	DEADWEIGHT	Σ W i	ΣW		Σ W i	ΣM	
	CALCULATED VALUE	(SS − ΣW) × 9,800			(SS − ΣW) × 9,800		
	ALLOWABLE VALUE	ALLOWABLE SHEARING FORCE	223,200 ~ −226,400		ALLOWABLE BENDING MOMENT	7,013,600~ −5,095,800	
FR.86	BASE VALUE		①			①	
	DRAFT CORRECTION	CD ( ) × Δ D	②		CD ( ) × Δ D	②	
	TRIM CORRECTION	CT ( ) × TRIM	③		CT ( ) × TRIM	③	
	BUOYANCY & L. W.	① + ② + ③	SS		① + ② + ③	SS	
	DEADWEIGHT	Σ W i	ΣW		Σ W i	ΣM	
	CALCULATED VALUE	(SS − ΣW) × 9,800			(SS − ΣW) × 9,800		
	ALLOWABLE VALUE	ALLOWABLE SHEARING FORCE	229,500 ~ −229,500		ALLOWABLE BENDING MOMENT	7,013,600~ −5,095,800	
FR.76	BASE VALUE		①			①	
	DRAFT CORRECTION	CD ( ) × Δ D	②		CD ( ) × Δ D	②	
	TRIM CORRECTION	CT ( ) × TRIM	③		CT ( ) × TRIM	③	
	BUOYANCY & L. W.	① + ② + ③	SS		① + ② + ③	SS	
	DEADWEIGHT	Σ W i	ΣW		Σ W i	ΣM	
	CALCULATED VALUE	(SS − ΣW) × 9,800			(SS − ΣW) × 9,800		
	ALLOWABLE VALUE	ALLOWABLE SHEARING FORCE	165,700 ~ −161,200		ALLOWABLE BENDING MOMENT	7,950,500~ −7,140,000	
FR.70	BASE VALUE		①			①	
	DRAFT CORRECTION	CD ( ) × Δ D	②		CD ( ) × Δ D	②	
	TRIM CORRECTION	CT ( ) × TRIM	③		CT ( ) × TRIM	③	
	BUOYANCY & L. W.	① + ② + ③	SS		① + ② + ③	SS	
	DEADWEIGHT	Σ W i	ΣW		Σ W i	ΣM	
	CALCULATED VALUE	(SS − ΣW) × 9,800			(SS − ΣW) × 9,800		
	ALLOWABLE VALUE	ALLOWABLE SHEARING FORCE	151,800 ~ −145,300		ALLOWABLE BENDING MOMENT	4,432,200~ −2,590,400	
FR.65	BASE VALUE		①			①	
	DRAFT CORRECTION	CD ( ) × Δ D	②		CD ( ) × Δ D	②	
	TRIM CORRECTION	CT ( ) × TRIM	③		CT ( ) × TRIM	③	
	BUOYANCY & L. W.	① + ② + ③	SS		① + ② + ③	SS	
	DEADWEIGHT	Σ W i	ΣW		Σ W i	ΣM	
	CALCULATED VALUE	(SS − ΣW) × 9,800			(SS − ΣW) × 9,800		
	ALLOWABLE VALUE	ALLOWABLE SHEARING FORCE	118,400 ~ −112,800		ALLOWABLE BENDING MOMENT	2,282,900~ −1,728,000	

Table 8 Longitudinal Strength Data (For Buoyancy & Light Ship Weight)

Each Value Shows (Actual Value (ton)/1000) Base Draft 12.000 Metres

	Shearing Force (UNIT MT)			Bending Moment (UNIT MT-M)		
Calculation Position	Base Value (S.F.)	Draft Correction (CD)	Trim Correction (CT)	Base Value (B.M.)	Draft Correction (CD)	Trim Correction (CT)
FRAME (116)	2.853	0.022	-0.153	20.084	0.166	-1.048
FRAME (106)	31.976	0.196	-1.063	876.054	5.700	-34.254
FRAME (96)	61.970	0.355	-1.536	2871.544	17.445	-90.924
FRAME (86)	100.459	0.559	-1.653	7322.246	42.534	-181.031
FRAME (76)	130.269	0.719	-1.362	12252.008	69.816	-246.525
FRAME (70)	157.848	0.889	-0.678	18944.238	107.158	-295.168
FRAME (65)	164.621	0.946	-0.365	21784.430	123.139	-304.240

1.8.2 Procedure for Calculation of Longitudinal Strength

The calculation of longitudinal strength may be conducted by filling up the spaces given in **Table 7**. The procedure is given as follows:

(1) After draught (D_A) and trim

The after draught and trim are to be entered into the relevant spaces when calculating the longitudinal strength.

Where there is a trim by the bow, it is to be noted with a negative sign (-).

(2) Base draught (D_B) and difference of draught (ΔD)

The base draft closest to but not greater than the after draft is to be selected from the longitudinal strength data and entered in the space for the base draught, and the difference between the after draught and the selected base draught is to be entered in the space for the difference (ΔD).

(3) Column for Weight

One-thousandth of the deadweight (*ton*) for each compartment is to be entered in this column.

(4) Column for W_i

This column is for indicating the deadweight in the respective compartments exerted on points of longitudinal strength output, which is obtained by multiplying the deadweight by the ratio (compartment ratio included in each point of output).

(5) Column for M_i

This column is for indicating the moment around the midship which is created by the deadweight in the respective compartments, and here the value of W_i × ⊗ G is to be entered.

(6) $\sum W_i$ and $\sum M_i$

The accumulations of W_i and M_i included between the fore end and each point of output are to be entered here.

(7) *SS* and *SB*

SS and *SB* indicate the shearing force and the bending moment due to buoyancy and the ship's light weight, and they are to be calculated according to the following procedures:

(a) Correction factors (*CD* and *CT*) based on base value, difference of draught and trim

Enter the value from the space for the base draft (on the longitudinal strength data sheet) in the space for the base value (column **1**) for each point of output, as well as the respective correction factors (*CD* and *CT*).

(b) Correction for difference of draught (ΔD) (column **2**)

This is to correct the difference between the base draught and the actual draught. The correction is to be made by multiplying the correction factor (*CD*) by the difference of draught (ΔD).

(c) Correction for trim (column **3**)

Where the ship has trim, the correction for trim is to be made by multiplying the correction factor (*CT*) by the value of trim (*m*).

(d) Summation

The base value **1**, corrected value for the difference of draught **2** and the corrected value for trim **3** are to be summed up and the sums are to be entered in the spaces for *SS* and *SB*.

(8) $\sum W$ and $\sum M$

$\sum W$ and $\sum M$ indicate the shearing force and bending moment due to deadweight respectively which are obtained by the following procedure:

(a) Column for $\sum W$

$\sum W$ is the accumulation of deadweight at each point of output ($\sum W_i$) which is to be entered in this column.

(b) Column for $\sum M$

$\sum M$ is the bending moment at each point of output converted from the bending moment ($\sum M_i$) around the midship due to deadweight at each point of output, and the values obtained from the following formula are to be entered:

$$\sum W \times (corrected\ lever) + \sum M_i$$

(9) Still water shearing force (F_S)

F_S indicates the actual still water shearing force under loading condition at each point of output and is obtained from by the following formula:

$$F_S = \left(SS - \sum W\right) \times 9800 \ (kN)$$

(10) Longitudinal still water bending moment (M_S)

M_S indicates the actual longitudinal still water bending moment under loading condition at each point of output, and is obtained from the following formula:

$$M_S = \left(\sum M - SB\right) \times 9800 \ (kN\text{-}m)$$

1.9 Method of Calculation of Shearing Force in Alternate Loading

1.9.1

Where the adjoining holds are loaded alternately, the shearing force is to be corrected in accordance with the calculation form shown in **Table 9**.

(1) Method of calculation (*See* **Fig.8**)

(a) Still water shearing force (F_S) (column **1**) (*kN*)

Still water shearing force obtained in **1.8** is to be entered in column **1**.

(b) Load between transverse bulkheads (F_{SF}-F_{SA}) (column **2**) (*kN*)

For each hold, the still water shearing force (F_S) at the aft end bulkhead of the hold is F_{SA}, and the shearing force (F_S) at the fore end bulkhead of the hold is F_{SF}, and the difference, F_{SF}-F_{SA}, is entered in column **2**.

(c) Ballast weight of topside tank (column **3**) (*kN*)

Where the topside tank is loaded with ballast, the weight of the load (*tons*) is multiplied by 9.8 and the corresponding value (*kN*) is entered in column **3**.

(d) Ballast weight of topside tank between bulkheads (F_T) (column **5**) (*kN*)

This column represents, for each hold, ballast (F_T) of the topside tank supported by transverse bulkheads at fore and aft ends of the hold, and a value (*kN*) derived by multiplying the ballast weight of the topside tank (column **3**) by the load ratio *C* (proportion of topside tank included between transverse bulkheads) is entered.

(e) Load acting on double bottoms (F_{SF}-F_{SA}-F_T) (column **6**) (*kN*)

This column represents, for each hold, the load (*kN*) which acts on the double bottoms of the holds, and the difference between the value in column **2** and the value in column **5** is entered.

(f) Shearing force modifier (ΔF_C) (column **8**) (*kN*)

This column represents, for each hold, the shearing force modifier (ΔF_C) which modifies the shearing force at fore and aft end bulkheads of the hold, and the value obtained by multiplying the load in column **6** by a coefficient *C* determined at each hold (value established in accordance with the requirements in **C15.3.1-2 of the Guidance** and entered beforehand in column **7**) is entered.

(g) Shearing force at fore and aft of transverse bulkhead (F_{CA} and F_{CF}) (column **9**) (kN)

This column represents shearing force at fore side of aft end bulkhead of hold (F_{CA}) or shearing force at aft side of fore end bulkhead of hold, and is given in the following **i)** and **ii)**.

i) The shearing force at the fore side of aft end bulkhead of hold is to be given as F_{CA} as defined as follows:

$$F_{CA} = F_{SA} + \Delta F_C$$

Where:

F_{SA}: Shearing force at aft end bulkhead of hold under consideration, whose value is entered in column **1**

ΔF_C: Shearing force modifier at the hold under consideration, whose value is recorded in column **8**

ii) The shearing force at the aft side of fore end bulkhead of hold is to be given as F_{CF} as defined as follows:

$$F_{CF} = F_{SF} - \Delta F_C$$

Where:

F_{SF}: Shearing force at fore end bulkhead of hold under consideration, whose value is entered in column **1**

ΔF_C: As given in **i)** above

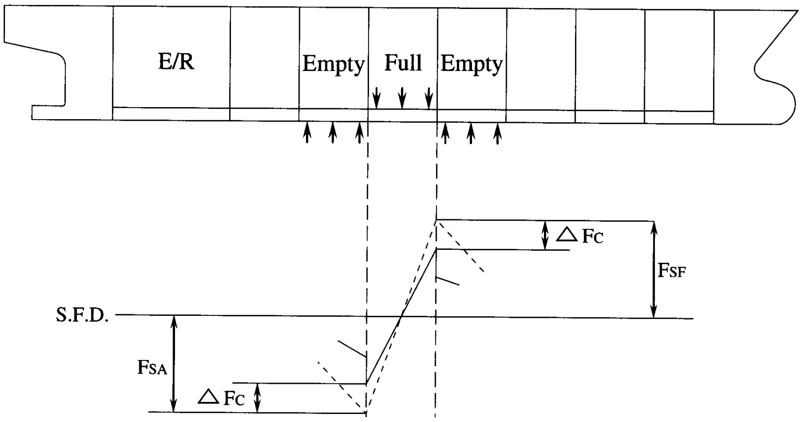
(h) Allowable values of shearing force

The allowable values of shearing force are indicated in the last column, and thus the value of shearing force in alternate loading condition (value in column **9**) is to be in the range between these two allowable values.

Table 9 Calculation Form for Shearing Force in Alternate Loading Condition

FR. No.			FR. 37	FR. 70		FR. 102		FR. 125		FR. 158		FR. 181		FR. 205
1	Still Water Shearing Force (F_s) (kN)													
Cargo Hold No.			No. 6 Cargo Hold		No. 5 Cargo Hold		No. 4 Cargo Hold		No. 3 Cargo Hold		No. 2 Cargo Hold		No. 1 Cargo Hold	
2	$F_{SF} - F_{SA}$ (kN)													
No. of Top Side Tank			No. 4 Top Side Tank				No. 3 Top Side Tank				No. 2 Top Side Tank		No. 1 Top Side Tank	
3	Ballast Weight of TST (kN)													
4	Load Ratio C		0.5		0.5		0.5		0.5		1.0		1.0	
5	F_T (3 × 4)													
6	Load acting on Double Bottom ($F_{SF} - F_{SA} - F_T$) (2 − 5)													
7	Hold Coefficient C		0.305		0.264		0.264		0.250		0.264		0.302	
8	Shearing Force Modifier ΔFc (6 × 7)													
9	Shearing force at Aft and Fore Bulkhead of Hold (F_{CA} & F_{CF})		F_{CA} 1 + 8	F_{CF} 1 − 8	F_{CA} 1 + 8	F_{CF} 1 − 8	F_{CA} 1 + 8	F_{CF} 1 − 8	F_{CA} 1 + 8	F_{CF} 1 − 8	F_{CA} 1 + 8	F_{CF} 1 − 8	F_{CA} 1 + 8	F_{CF} 1 − 8
Allowable Value of Shearing Force (kN)		+	30,200	25,500		26,300		27,600		27,600		25,200		29,300
		−	−28,100	−25,200		−25,200		−27,600		−28,700		−28,500		−30,400

Fig. 8



1.10 Method of Calculation of Longitudinal Bulkhead Shearing Force

1.10.1

The longitudinal bulkhead shearing force (the still water shearing force shared by the longitudinal bulkhead) is to be calculated by the calculation form in **Table 10**.

(1) Method of calculation

(a) Still water shearing force (F_S) (column **1**) (kN)

The shearing force obtained in **Chapter 8, Part C** of the Guidance is to be entered in column **1**).

(b) Sharing of shearing force in longitudinal direction (column **2**)

Longitudinal shearing force to be shared by the longitudinal bulkhead is to be obtained by multiplying the shearing force obtained in **1** by the sharing rate (α_j).

(c) Cargo weight loaded in centre tank, wing tank, side ballast tank and double bottom ballast tank (columns **3**, **6** ,**9**, and **12**) (kN)

The cargo weight loaded in the centre tank (*tons*) is multiplied by 9.8 and the corresponding force (kN) is entered in column **3**. The total cargo weight loaded in both side wing tanks, side ballast tanks and double bottom ballast tanks (*tons*) are multiplied by 9.8 and the corresponding forces (kN) are entered in columns **6**, **9** and **12**. However, where the weight loaded on one side greatly differs from that of the other side, double the loading weight on one side and enter them into columns **6**, **9** and **12**. The loading weight in the other tanks is entered in the same way.

(d) Sharing of shearing force due to loading weight (column **5**, **8**, **11** and **14**)

Sharing of shearing force due to loading weight is obtained by multiplying the loading weight of each tank obtained in columns **3**, **6**, **9**, **12** and the coefficient C_1 (given in column **4**), C_2 (given in column **7**), C_3 (given in column **10**), and C_4 (given in column **13**).

(e) Draught d' (column **15**)

The draught corresponding to each point of output obtained from **Fig. 9** is to be entered in column **15**.

(f) Sharing of shearing force due to draught (column **17**)

Shearing force due to draught shared by longitudinal bulkheads is to be obtained by multiplying the draught obtained in column **15** by the correction factor C_5 (given in column **14**).

(g) Local shearing force (ΔF_L) (column **18**) (kN)

Local shearing force is to be obtained by summing up the values obtained in columns **5**, **8**, **11**, **14** and **17**.

(h) Longitudinal bulkhead shearing force (F_L) (column **19**) (kN)

Longitudinal bulkhead shearing force is to be obtained by increasing/reducing the shearing force shared by the longitudinal bulkhead in the longitudinal direction in column **2** by the local shearing force in the transverse direction in column **18**. Attention is to be paid regarding positive/negative values in the calculation form in **Table 10**.

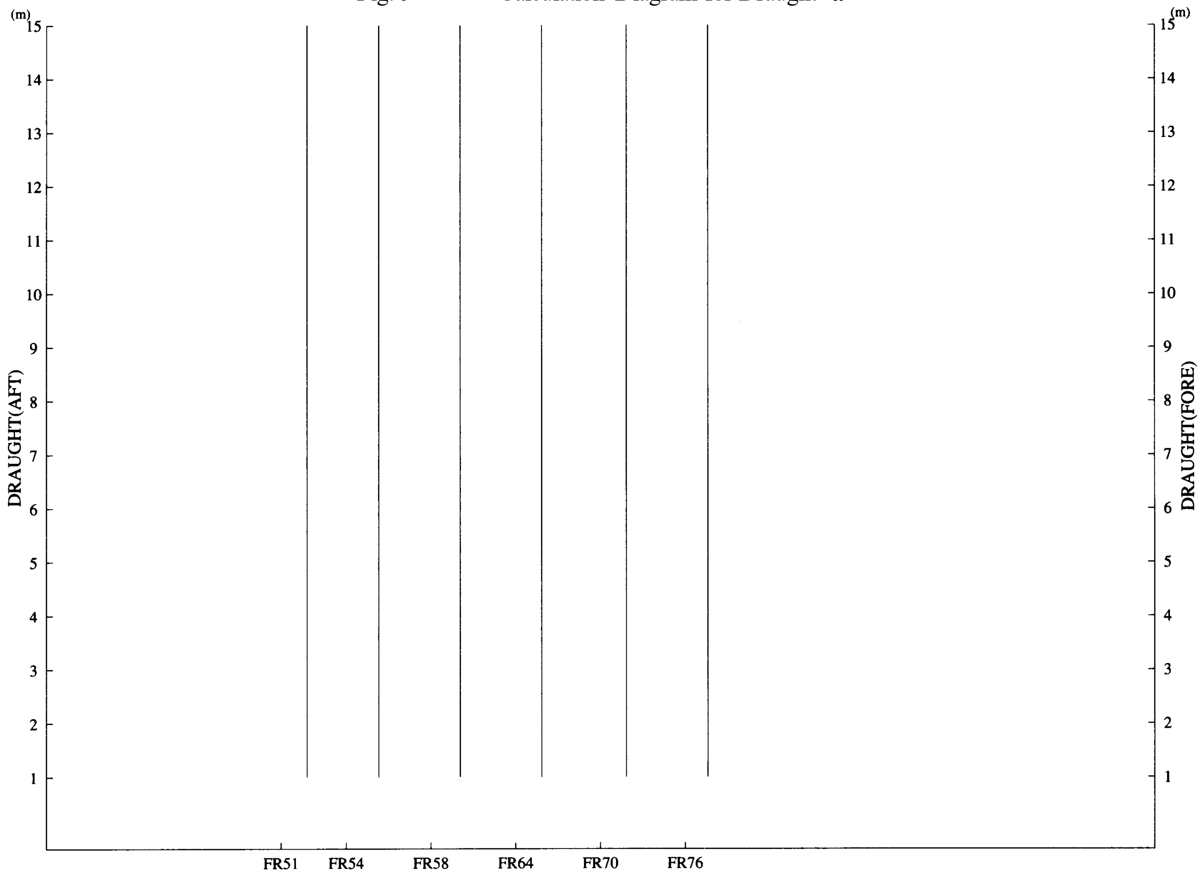
(i) Allowable value for longitudinal bulkhead shearing force (allowable value of F_L) (column **20**)

The longitudinal bulkhead shearing force in column **19** is not to exceed the allowable value of F_L.

Table 10 Calculation Form for Shearing Force of Longitudinal Bulkhead

	FR. *No.* of Transverse Bulkhead	FR. 65	FR. 70		FR. 76		FR. 86		FR. 96	
		FORE	AFT	FORE	AFT	FORE	AFT	FORE	AFT	FORE
1	Shearing force in Still Water (F_s)									
2	1 × 0.201 (α_L)									
3	CENTER TANK Loading Weight (*kN*)	*No.* 5 C.O.T.				*No.* 4 C.O.T.		*No.* 3 C.O.T.		
4	C_1	+0.1199		+0.1246		+0.1346		+0.1346		
5	3 × 4									
6	INNER SIDE TANK Loading Weight (*kN*)	SLOP T.		*No.* 5 C.O.T.		*No.* 4 C.O.T.		*No.* 3 C.O.T.		
7	C_2	−0.0209		−0.0174		+0.0055		+0.0055		
8	6 × 7									
9	OUTER SIDE TANK Loading Weight (*kN*)	*No.* 5 W.B.T.				*No.* 4 W.B.T.		*No.* 3 W.B.T.		
10	C_3	−0.0804		−0.0838		−0.0905		−0.0905		
11	9 × 10									
12	DOUBLE BOTTOM Loading Weight (*kN*)	*No.* 5 W.B.T.				*No.* 4 W.B.T.		*No.* 3 W.B.T.		
13	C_4	+0.0384		+0.0400		+0.0432		+0.0432		
14	12 × 13									
15	Draught d' (m)									
16	C_5	−564.48		−705.60		−1270.08		−1270.08		
17	15 × 16									
18	F_L = 5 + 8 + 11 + 14 + 17									
19	F_L = 2 ± 18	(−)	(+)	(−)	(+)	(−)	(+)	(−)	(+)	
20	Allowable F_L (*kN*) +	23,200	29,700		43,400		44,900			
	−	22,100	28,400		42,500		44,900			

Fig. 9 Calculation Diagram for Draught d'



(2) Guidance for calculation of C_1, C_2, C_3, C_4 and C_5

Where there are more than one row of longitudinal bulkheads, it is necessary to obtain both the shearing forces on the side shell plating as well as the longitudinal bulkhead. Where, however, it is obvious, that due to the design, one of them is under severer stress than the other (this example shows that the shearing force on the longitudinal bulkhead is severer than the one on the side shall plating), it is satisfactory to only check the severer one.

Although only the case of the longitudinal bulkhead (not at the double hull sides) of type E is shown in **Fig. C15.6** and **15.3.2, Part C** of the Rules is described in the example, a similar procedure is to be taken for the side shell plating, longitudinal bulkheads of double hull side, and side shell plating and longitudinal bulkheads of other types. The expressions used here are the same as those specified in **15.3.2, Part C** of the Rules unless otherwise expressly shown.

Shearing force acting on longitudinal bulkhead

$F_L = \alpha F_S + \Delta F$ (kN)

Substituting the following into the above formula,

$\Delta F = n_i(R - \alpha f)$

$R = 9.8(\beta W_a a + 0.5 W_b b_2)S$

$f = 19.6(W_a a + W_b b + W_c c)S$

$W_a = h_a + h_d - d'$

$W_b = h_b + h_d - d'$

$W_c = h_c + h_d - d'$

$B = 2(a + b + c)$

The following formula is obtained:

$F_L = \alpha F_S + 9.8 n_i S\{(\beta - 2\alpha) a h_a$

$+(0.5 b_2 - 2\alpha b) h_b - 2\alpha c h_c$

$+(\beta a + 0.5 b_2 - \alpha B) h_d$

$-(\beta a + 0.5 b_2 - \alpha B) d'\}$ (kN)

Now, let $\nabla a, l_a$ be the loading weight (kN) in the centre tank and the length (m) of the tank respectively, and $\nabla b, l_b$ be the total loading weight (*kN*) in the wing tanks on both sides and the length (m) of the tank respectively, and $\nabla c, l_c$ be the total loading weight (*kN*) in the side ballast tanks on both sides except for the double bottom ballast tank and the length (m) of the tank respectively, and $\nabla d, l_d$ be the loading weight (*kN*) of double bottom ballast tank and length (m) of the tank respectively, such that:

$$h_a \approx \frac{\nabla a}{19.6 a l_a}$$

$$h_b \approx \frac{\nabla b}{19.6 b l_b}$$

$$h_c \approx \frac{\nabla c}{19.6 c l_c}$$

$$h_d \approx \frac{\nabla d}{9.8 B l_d}$$

If the number of bottom transverse girders between transverse bulkheads is N, then $n_i = \pm N/2$ at the transverse bulkhead position. Thus, the shearing force (F_L) on longitudinal bulkhead at transverse bulkhead positions is presented by the following formula:

$$F_L = \alpha F_S \pm (C_1 \nabla a + C_2 \nabla b + C_3 \nabla c + C_4 \nabla d + C_5 d')$$

Where,

$$C_1 = \frac{NS}{4 l_a}(\beta - 2\alpha)$$

$$C_2 = \frac{NS}{4 b l_b}(0.5 b_2 - 2\alpha b)$$

$$C_3 = -\frac{NS\alpha}{2 l_c}$$

$$C_4 = \frac{NS}{2 B l_d}(\beta a + 0.5 b_2 - \alpha B)$$

$$C_5 = -\frac{NS}{2}(\beta a + 0.5 b_2 - \alpha B) \times 9.8$$

Therefore, by multiplying the coefficients C_1, C_2, C_3, C_4 and C_5 by the still water shearing force (F_S), loading weight in centre tank (∇a), total loading weight in the wing cargo tanks on both sides (∇b), total loading weight in the side ballast tanks on both sides except for the double bottom ballast tank (∇c), total loading weight of double bottom ballast tank (∇d) and draught at the corresponding position (d') respectively, and by combining them together, the shearing force on the longitudinal bulkhead can be obtained.

Appendix C3 SAMPLE OF SHIP STRUCTURAL ACCESS MANUAL

This appendix gives a reference sample for the preparation of a Ship Structure Access Manual as required in **35.2.6, Part C of the Rules.** This includes items specified in the Rules and also general notices for ensuring the maintenance of a minimum level of safety in the use of means of access, with examples. It should be noted that when preparing the manual for each ship, factors such as the specifications of means of access and the type of ship safety management system onboard that ship are taken into consideration.

Ship Structure Access Manual

Foreword

This access manual provides for safe conduct of overall and close-up inspections and thickness measurements on a regular basis throughout the ship's operational life, and gives necessary information and instructions for that purpose, under the provisions of *SOLAS* regulation II-1/3-6 adopted by resolution *MSC*.134(76) as amended by resolution *MSC*.151(78) and the Technical provisions for means of access for inspections adopted by resolution *MSC*.133(76) as amended by resolution *MSC*.158(78).

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Ship Structure Access Manual

Preamble

It has long been recognized that the only way of ensuring that the condition of a ship's structure is maintained to conform to the applicable requirements is for all its components to be surveyed on a regular basis throughout their operational life. This will ensure that they are free from damage such as cracks, buckling or deformation due to corrosion, overloading, or contact damage and that thickness diminution is within established limits. The provision of suitable means of access to the hull structure for the purpose of carrying out overall and close-up surveys and inspections is essential and such means should be considered and provided for at the ship design stage.

Ships should be designed and built with due consideration as to how they will be surveyed by flag State inspectors and classification society surveyors during their in-service life and how the crew will be able to monitor the condition of the ship. Without adequate access, the structural condition of the ship can deteriorate undetected and major structural failure can arise. A comprehensive approach to design and maintenance is required to cover the whole projected life of the ship.

Part I Manual for Safe Access

1 General Information

1.1 Ship Particulars

[*Prepared for each ship appropriately*]

1.2 Tank Arrangement

[*Prepared for each ship appropriately*]

2 Scope of Access Manual

2.1 General

2.1.1 Permanent means of access provided for the ship do not give access to all areas required to be surveyed and measured. It is necessary that all areas outside of reach (*i.e.*, normally beyond hand's reach) of the permanent means of access can be accessed by alternative means in combination with the permanent means of access, including those specified by the *ESP* code, as amended. Critical structural areas, if necessary, also can be accessed by appropriate means of access.

2.1.2 Such means of access are described as shown in section 4. However other access arrangements including innovative means may be accepted in lieu of the arrangement described in the manual, based on a case-by-case acceptance with the Classification Society prior to the survey.

2.1.3 Where movable means of access are supplied by a shore-based provider, it should be noted that the confirmation of suitability for the purpose and its safe and adequate use should be made by the Owner based on recorded maintenance and an inspection regime by the provider of the equipment. It should be also noted that the surveyor has the right to reject movable means of access if not satisfied with the documentation or condition of the equipment.

2.1.4 Where the Ship Safety Management System specifies handling/operation of means of access, reference to these documents should be made in the access manual.

2.2 Critical Structural Areas

2.2.1 Critical structural areas are locations which have been identified from calculations to require monitoring or from the service history of similar or sister ships to be sensitive to cracking, buckling or corrosion which would impair the structural integrity of the ship, and, for this ship, are listed as follows:

[*Prepared for each ship appropriately*]

2.2.2 Where monitoring other locations are deemed as necessary from the service history of this ship, or similar or sister ships, such locations should be added to the above list.

2.3 Relevant Rules and Regulations

Reference is to be made to the following publications:

(a) *SOLAS* regulation II-1/3-6 adopted by resolution *MSC*.134(76), as amended
(b) Technical Provisions adopted by resolution *MSC*.133(76), as amended
(c) The *ESP* code, as amended
(d) *IACS* Unified Requirements Z10.1, Z10.2, Z10.4 and Z10.5, as appropriate
(e) *IACS* Unified Interpretation SC191, as amended
(f) The relevant Class Rules for Vessels of the concerned Classification Society
(g) *IACS* Recommendation No.39 "Safe Use of Rafts or Boats for Survey"

(h) *IACS* Recommendation No.78 "Safe Use of Portable Ladders for Close-Up Surveys"

(i) *IACS* Recommendation No.91 "Guidelines for Approval/Acceptance of Alternative Means of Access"

2.4 Approval / Re-approval

2.4.1 Any changes of the permanent, portable, movable or alternative means of access within the scope of this manual are subject to review and approval / re-approval by the Administration or by the organization recognized by the Administration. An updated copy of the approved manual is to be kept on board. For the approval / re-approval, it should be demonstrated that such means of access provides the required access.

2.4.2 Notwithstanding the provisions of 2.4.1, replacing portable means of access with similar portable means which would give equivalent safety and accessibility, might not require the approval / re-approval, subject to being recorded in the access manual and reviewed by the Administration or by the organization recognized by the Administration at a periodical survey after such a change.

3 Definitions

3.1 *Portable means of access* are means that generally may be hand carried by the crew *e.g.* ladders, small platforms and staging. Portable means specified as part of the Ship Structure Access Manual should be carried onboard the ship throughout the duration of the validity of the relevant access manual.

3.2 *Movable means of access* may include devices like cherry pickers, wire lift platforms, rafts or other means. Unless otherwise specified in the Technical Provisions (TP) or UI SC191, as amended, such means need not necessarily be kept on board or be capable of being operated by the ship's crew. However arrangements for the provision of such means should be addressed during survey planning. Movable means of access should be included in the Ship Structure Access Manual to designate the extent of access to the structural members to be surveyed and measured.

3.3 *Alternative means of access* is a term within *SOLAS* II-1/3-6 and TP for portable or movable means of access provided for the survey and thickness measurements of hull structure in areas otherwise not accessible by permanent means of access. For the purpose of this manual, alternative means of access include supplementary or additional means to provide necessary access for surveys and thickness measurements in accordance with *SOLAS* II-1/3-6.

3.4 *Approved* means that the construction and materials of the means of access and any attachment to the ship's structure should be to the satisfaction of the Administration. Compliance with the procedures in *IACS* Recommendation No.91 should be used in the absence of any specific instructions from a specific administration

3.5 *Acceptance:* it should be demonstrated to the satisfaction of the Owner that the equipment provided has been maintained and is, where applicable, provided with operators who are trained to use such equipment. This should be demonstrated to the surveyors by the production of documents, prior to the equipment being used, which demonstrate that the equipment has been maintained and which indicate any limitations of the equipment.

3.6 *Authorized person* is a person specified by the Company who uses the means of access and that should assume the role of inspector for checking the access arrangements for obvious damage prior to use. Whilst using the means of access, the inspector should verify the condition of the sections used by close up examination of those sections and note any deterioration in the provisions. Should any damage or deterioration be found, the effect of such deterioration should be assessed as to whether the damage or deterioration affects the safety for continued use of the means of access. Deterioration found that is considered to affect safe use should be determined and measures should be put in place to ensure that the affected section(s) should not be further used prior to effective repair.

3.7 *Rung* means the step of a vertical ladder or step on the vertical surface.

3.8 *Tread* means the step of an inclined ladder or step for the vertical access opening.

3.9 *Spaces* are separate compartments including holds and tanks.

3.10 *Ballast tank* is a tank which is used for water ballast and includes side ballast tanks, ballast double bottom spaces, topside tanks, hopper side tanks and peak tanks.

3.11 An *overall survey* is a survey intended to report on the overall condition of the hull structure and determine the extent of close-up surveys.

3.12 A *close-up survey* is a survey where the details of structural components are within the close visual inspection range of the surveyor, *i.e.*, normally within reach of hand.

3.13 *Transverse section* includes all longitudinal members such as plating, longitudinals and girders at the deck, side and bottom, inner bottom and hopper side plating, longitudinal bulkheads, and bottom plating in top wing tanks.

3.14 *Representative spaces* are those, which are expected to reflect the condition of other spaces of similar type and service and with similar corrosion prevention systems. When selecting representative spaces account should be taken of the service and repair history on board and identifiable critical and/or suspect areas.

3.15 *Suspect areas* are locations showing substantial corrosion and/or are considered by the surveyor to be prone to rapid wastage.

3.16 *Substantial corrosion* is an extent of corrosion such that assessment of corrosion pattern indicates wastage in excess of 75% of allowable margins, but within acceptable limits.

3.17 A *corrosion prevention system* is normally considered a full hard coating.

Hard protective coating should be epoxy coating or equivalent. Other coating systems may be considered acceptable as alternatives provided that they are applied and maintained in compliance with the manufacturer's specifications.

3.18 *Coating condition* is defined as follows:

GOOD	condition with only minor spot rusting;
FAIR	condition with local breakdown of coating at edges of stiffeners and weld connections and/or light rusting over 20% or more of areas under consideration, but less than as defined for *POOR* condition;
POOR	condition with general breakdown of coating over 20% or more of areas or hard scale at 10% or more of areas under consideration.

3.19 *Critical structural areas* are locations, which have been identified from calculations to require monitoring or from the service history of the subject ship or from similar or sister ships to be sensitive to cracking, buckling or corrosion, which would impair the structural integrity of the ship.

4 Access Plans

[*Prepared appropriately*]

4.1 Plans showing the means of access to spaces (including openings for introducing portable means), with appropriate technical specifications and dimensions as shown in appendixes X.

4.2 Plans showing the means of access within each space to enable an overall inspection to be carried out, with appropriate technical specifications and dimensions as shown in appendixes X.

4.3 Plans showing the means of access within the space to enable close-up inspections to be carried out and necessary alternative means to be deployed. For any alternative means carried on board, appropriate technical specifications and dimensions are as shown in appendixes X.

5 Instructions

5.1 Instructions for Use of Means of Access

5.1.1 All persons using the means of access arrangements should study the instructions for safety in the access manual so as to gain adequate knowledge of the arrangements for the space(s) to be inspected prior to their use. Appropriate personal protective equipment must be available, if required.

5.1.2 Any recorded deficiencies to the means of access for the space(s) to be inspected should be considered. Any section with significant damage is not to be used.

5.1.3 It is recognized that climbing may be used by surveyors during surveys but is not accepted as an alternative means of access. When climbing the structures within tanks is necessary during surveys, the surface of the structures should be free of oil, sludge and mud and relatively dry to the satisfaction of the surveyor so that a good firm, non-slip footing maybe obtained.

5.2 Instructions for Inspection and Maintenance of Means of Access

5.2.1 Verification of means of access including portable equipment and their attachments is part of periodical surveys for continued effectiveness of the means of access in that space which is subject to the survey. After a space has been ventilated, cleaned and illuminated for the survey, an inspection of means of access should be carried out by the crew and/or an authorized person.

5.2.2 Periodical inspections of means of access should be carried out by the crew and/or an authorized person as a part of regular inspection and maintenance, at intervals, which are determined taking into account any corrosive atmosphere that may be within the space.

5.2.3 Any authorized person using the means of access should assume the role of inspector and check for obvious damage prior to using the access arrangements. Whilst using the means of access, the inspector should verify the condition of the sections used by close up examination of those sections and note any deterioration in the provisions. Should any damage or deterioration be found, the effect of such deterioration should be assessed as to whether the damage or deterioration affects the safety for continued use of the access. Deterioration found that is considered to affect safe use should be determined as "substantial damage" and measures should be put in place to ensure that the affected section(s) are not to be further used prior to completing effective repair.

5.2.4 Periodical surveys of any space that contains means of access should include verification of the continued effectiveness of the means of access in that space. Usually, survey of the means of access is not expected to exceed the scope and extent of the survey being undertaken. If the means of access is found deficient the scope of survey should be extended if this is considered appropriate.

5.2.5 Records of all inspections should be established based on the requirements detailed in the ships Safety Management System. The records should be readily available to persons using the means of access and a copy attached to the access manual. The latest record for the portion of the means of access inspected should include as a minimum the date of the inspection, the name and title of the inspector, a confirmation signature, the sections of means of access inspected, verification of continued serviceable condition or details of any deterioration or substantial damage found. A file of permits issued should be maintained for verification.

5.2.6 Where movable means of access are supplied by a shore-based provider, the confirmation of its safe and adequate use should be made based on recorded maintenance and inspection regime by the provider of the equipment. Cognizance should be taken of the complexity of the equipment when making the judgment on the periodicity of inspections and thoroughness of maintenance by the provider of equipment.

5.2.7 The maintenance of all means of access should be in accordance with the Ships Safety Management System.

5.3 Instructions for the Rigging and Use of Portable Means of Access

5.3.1 Portable ladders should rest on a stable, strong, suitably sized, immobile footing so that the rungs remain horizontal. Suspended ladders should be attached in a manner so that they cannot be displaced and do not swing. Step ladders, hanging ladders and ladders more than 5 *m* long may only be utilized if fitted with a mechanical device to secure the upper end of the ladder. Portable ladders should be maintained free of oil, grease and other slipping hazards.

5.3.2 The feet of portable ladders should be prevented from slipping during use by securing the stiles at or near their upper and lower ends, by any anti-slip device or by other arrangements of equivalent effectiveness. Unless otherwise stated in its specification or unless provided with appropriate securing means, the ladder should be raised at an angle of approximately 70 degrees.

5.3.3 When portable ladders are used on top of the inner bottom or on deep stringers, the falling height should generally not exceed 6 *m*. Suitable attachment points for securing safety harnesses should be provided. If it is necessary to exceed this height:

- There should be at least 3 *m* of water above the highest structural element in the bottom to provide a "cushion"
- A suitable safety harnesses or safety rafting should be considered
- Personal floating devices (*PFD*) should be used

The free falling height above the water surface should not exceed 6 *m*.

5.3.4 Portable ladders should be arranged and rigged to support at least four *times* the maximum intended load.

5.3.5 When climbing ladders in tanks containing water, personnel should wear flotation aids. A floatation aid is a simple form of lifejacket, which does not impede climbing, or a self-inflatable lifejacket.

5.3.6 Aluminium ladders may be used in cargo tanks, but should not be stored in the cargo area or other gas dangerous spaces.

5.3.7 The securing of the equipment, its operation and training in its use should be in accordance with the Ships Safety Management System.

5.4 Instructions for Safety Rafting (If Applicable)

5.4.1 Surveys of tanks or spaces by means of rafts or boats may only be undertaken with the agreement of the attending surveyor(s), who is to take into account the safety arrangements provided, including weather forecasting and ship response in reasonable sea conditions. Appropriate safety measures, including the following, should be taken by the authorized person prior to survey to the satisfaction of the attending surveyor(s).

5.4.2 When rafts or boats will be used for close-up survey the following conditions should be observed:

(1) Only rough duty, inflatable rafts or boats, having satisfactory residual buoyancy and stability even if one chamber is ruptured, should be used.

(2) The boat or raft should be tethered to the access ladder and an additional person should be stationed down the access ladder with a clear view of the boat or raft.

(3) Appropriate lifejackets should be available for all participants.

(4) The surface of the water in the tank should be calm (under all foreseeable conditions the expected rise of water within the tank should not exceed 0.25 *m*) and the water level stationary. On no account should the level of the water be rising while the boat or raft is in use.

(5) The tank or space must contain clean ballast water only. When a thin sheen of oil on the water is observed, further testing of the atmosphere should be done to ensure that the tank or space is safe for entering.

(6) For rafting of cargo tanks, at no time should the upside of the boat or raft be allowed to be within 1 *m* of the deepest under deck web face flat so that the survey team is not isolated from a direct escape route to the tank hatch. Filling to levels above the deck transverses should only be contemplated if a permanent means of access, as per paragraph 5.4.3.2, below, is provided. For bulk cargo holds designed to be filled with water (*e.g.* ballast holds) and where the water is permitted to be filled up to a height not less than 2 *m* below the top of side frames (*e.g.* air draft holds), rafting may be utilized in lieu of permanent means of access to side frames (ref. TP Table 2 - 1.8) provided the structural capacity of the hold is sufficient to withstand static loads at all levels of water needed to survey the side shell frames

(7) If the tanks (or spaces) are connected by a common venting system, or inert gas system, the tank in which the boat or raft is to be used should be isolated to prevent a transfer of gas from other tanks (or spaces).

5.4.3 In addition to the above, rafts or boats alone may be allowed for close-up survey of the under deck areas for tanks or spaces if the depth of the webs are 1.5 *m* or less. If the depth of the webs is more than 1.5 *m*, rafts or boats alone may be allowed only under either of the following conditions:

(1) When the coating of the under deck structure, as evaluated from a safe distance (see **5.4.2(6)**, is in *GOOD* condition and there is no evidence of wastage

(2) If a permanent means of access is provided in each bay to allow safe entry and exit. This means either of the following:

(a) Access direct from the deck via a vertical ladder and a small platform about 2 *m* below the deck

(b) Access to the deck from a longitudinal permanent platform having ladders to the deck in each end of the tank

The platform should, for the full length of the tank, be arranged in level with, or above, the maximum water level needed for rafting of under deck structures. For this purpose, the ullage corresponding to the maximum water level should be assumed to be not more than 3 *m* from the deck plate measured at the midspan of deck transverses and in the middle of the length of the tank.

5.4.4 Safety Meetings should be held prior to entering the tank or space and regularly during the survey on board for ensuring the following:

(1) The establishment of proper preparation and the close co-operation between the attending surveyor(s) and the company's representatives onboard prior to and during the survey are an essential part in the safe and efficient conduct of the survey.

(2) Applicable safety procedures and responsibilities should be discussed and agreed to ensure that the survey is carried out under controlled conditions.

5.4.5 Adequate communication arrangements and equipment should be prepared for ensuring the following:

(1) The attending surveyor(s) is always accompanied by at least one responsible person assigned by the company experienced in tank and enclosed spaces inspection. In addition a backup team of at least two experienced persons should be stationed at the hatch opening of the tank or space that is being surveyed. The back-up team should continuously observe the work in the tank or space and should keep lifesaving and evacuation equipment ready for use.

(2) A communication system should be arranged between the survey party in the tank or space being examined and the responsible officer on deck, the navigation bridge and the personnel in charge of handling the ballast pump(s) in the pump control room. These communication arrangements should be maintained throughout the survey.

(3) Adequate and safe lighting should be provided for the safe and efficient conduct of the survey.

(4) Adequate protective clothing should be made available and used (*e.g.* safety helmet, gloves, safety shoes, etc) during the survey.

5.4.6 The organization for the surveys by means of rafting, its operation and training in its use should be in accordance with the Ships Safety Management System.

5.5 Instructions for Use of Portable Platforms (If Applicable)

5.5.1 Portable platforms should not be more than 3 *m* in length.

5.5.2 Safety measures, including ensuring that portable platforms are safely secured and supported prior to use, should be taken by the authorized person prior to survey to the satisfaction of the attending surveyor(s).

5.5.3 The rigging of the equipment, its operation and training in its use should be in accordance with the Ships Safety Management System.

5.6 Instructions for Use of Staging (If Applicable)

5.6.1 Appropriate safety measures should be taken by the authorized person prior to survey to the satisfaction of the attending surveyor(s).

5.6.2 Before working on or near any staging it should be ensured that:

(1) A minimum of 6 evenly spaced suspension points – steel wire ropes or chains evenly spaced and as near vertical as possible are provided.

(2) Scaffold tubes are linked by rigid-angle couplers.

(3) An adequate working platform, fully boarded with toe boards and guardrails is provided. Platform transforms (at 1.2 *m* intervals) resting on ledgers (at 2.5 *m* interval) and double transforms at platform board overlaps.

(4) The staging is level and provided with safe access (such as ladders).

(5) The staging is adequately decked (for example have a work surface and platform), and provided with guardrails.

(6) The staging is adequate for the work performed taking into account that falls are a significant hazard in site.

5.6.3 Where specifically designed staging is carried on board as a part of the means of access listed in the Ship Structure Access Manual, the rigging of the equipment, its operation and training in its use should be in accordance with the Ships Safety Management System.

5.7 Instructions for Use of Wire Lift Platforms (If Applicable)

5.7.1 Safety measures, including the following, should be taken by an authorized person prior to survey to the satisfaction of the attending surveyor(s):

(1) Rigging of wires should be in accordance with manufacturer's recommendations and conducted by suitably qualified riggers.

(2) Fix points to which the wires will be connected should be examined before each use and verified as in good condition (free of wastage, fractures, etc.).

(3) Means should be provided for using fall protection with a lifeline that can be tended from above the platform.

5.7.2 The rigging of the equipment, its operation and training in its use should be in accordance with the Ships Safety Management System.

5.8 Instructions for Use of Hydraulic Arm Vehicles (If Applicable)

5.8.1 The vehicle should be operated by qualified personnel and evidence should be provided that the vehicle has been properly maintained by a shore-based provider. The standing platform should be fitted with anchor points for attaching fall arrest systems. For those vehicles provided with a self-levelling platform, care should be taken that the locking device is engaged after completion of manoeuvring to ensure that the platform is fixed.

5.8.2 Safety measures, including the following, should be taken by an authorized person prior to survey to the satisfaction of the attending surveyor(s):

(1) Lift controls, including safety devices should be serviceable and should be operated throughout the range prior to use.

(2) Operators should be trained.

(3) The operating range of the equipment should be agreed with the operator before using the equipment.

(4) Operators should work within the basket.

(5) Body belts (such as harnesses) with lanyards should be used.

(6) Permissible load and reach limitations should not be exceeded.

(7) Brakes should be set; outriggers used, if so equipped; and wheels chocked; if on incline.

(8) Unless designed otherwise, aerial lift trucks should not be moved when the boom is elevated in a working position with workers in the basket.

(9) Upper and lower controls should be required and should be plainly marked. Lower controls should be capable of overriding the upper controls.

(10) Special precautions should be made to ensure the vessel and the lifting device are stable when aerial lifts are used aboard vessels (for example barges, floats).

(11) Personal flotation devices (*PFD*) should be used when working over water.

(12) Caution should be taken for potential crushing hazards (for example booming into the overhead, pinch point).

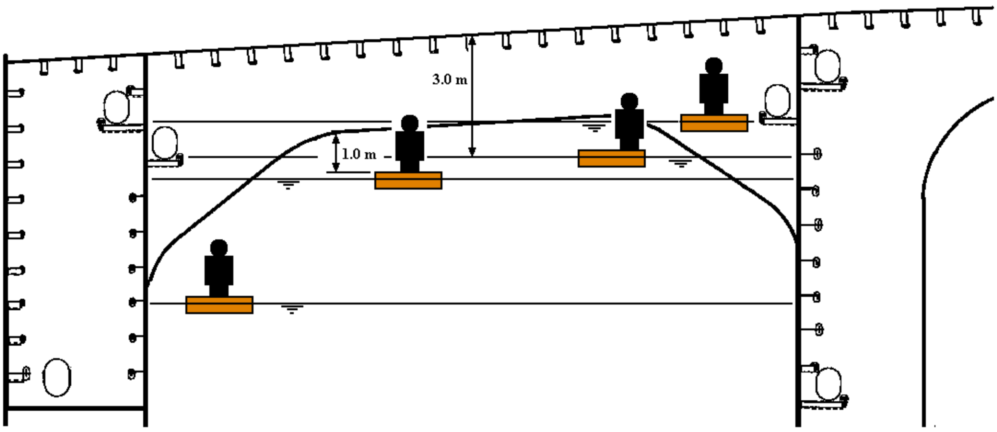
5.8.3 The operation and training in the use of this type of equipment should be in accordance with the Ships Safety Management System.

6 Inventory of Portable Means of Access

All portable means of access are listed as shown in appendix xx.

Appendix 1

Plans for Access to the Under Deck Structures within No.x Cargo Tanks (P/S)
(*example*)

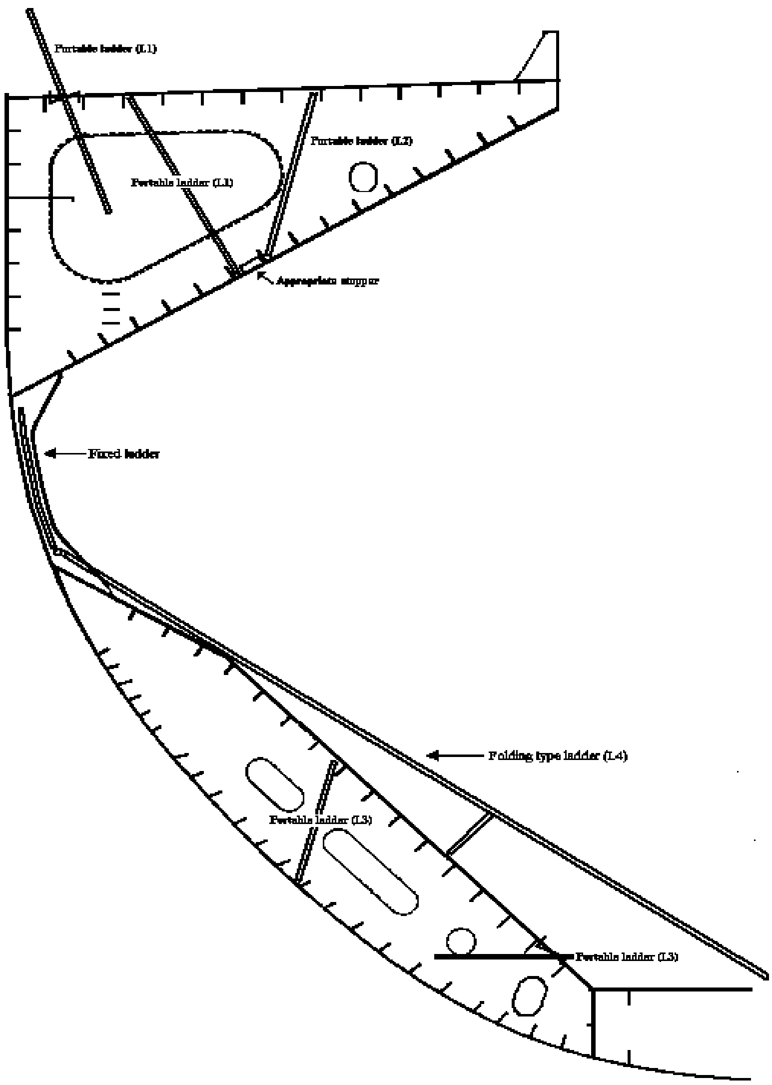


Appendix

Top Side Tank, Bilge Hopper Tank and Cargo Hold (Hold Frames) (*example*)

Notes:

1. Before use, the top of the ladder located in the top wing tank should be secured to ensure sufficient support of the ladder towards the deck longitudinals.
2. Where ladders are used at relatively small angles (*e.g.*, less than 45 degrees) such as those prepared for the use on the hopper tank sloping plate (see the folding type ladder in the following figure), the steps of such ladders are assumed to be designed in such a way that a safe walkway is provided. For such ladders of more than 5 *m* in length, handrails should be provided.



Appendix

Inventory of Portable Means of Access

[*Prepared appropriately*]

ID	Type	Dimensions	Applicable spaces	Number/Storage	Note
L1	Portable ladder	5 *m*	All spaces	2 sets / No.1 Deck Store	See the attached maker's specification.
L2	Portable ladder	4 *m*	All spaces	1 set / No.1 Deck Store	SG mark by Consumer Product Safety Association, Japan See the attached maker's specification.
L3	Portable ladder	3 *m*	All spaces	1 set / No.1 Deck Store 1 set / Boatswain Store	SG mark by Consumer Product Safety Association, Japan See the attached maker's specification.
L4	Folding type ladder	18 *m*	Cargo holds	3 sets / No.2 Deck Store	See the attached maker's specification.

Part II Records for Means of Access

(*This part is approved for its form only at new building.*)

7 Records of Inspections and Maintenance

[*Prepared appropriately*]

Note: The record for the portion of the means of access inspected should include, as a minimum, the date of the inspection, the name and title of the inspector, a confirmation signature, the sections of the means of access inspected, verification of continued serviceable condition or details of any deterioration or substantial damage found.

8 Records of Change of Portable Means of Access

[*Prepared appropriately*]

Appendix C4 PERFORMANCE STANDARD FOR PROTECTIVE COATINGS FOR DEDICATED SEAWATER BALLAST TANKS IN ALL TYPES OF SHIPS AND DOUBLE-SIDE SKIN SPACES OF BULK CARRIERS (Resolution MSC.215(82) and IACS Unified Interpretations SC223)

1 PURPOSE

This Standard provides technical requirements for protective coatings in dedicated seawater ballast tanks of all type of ships of not less than 500 gross tonnage and double-side skin spaces arranged in bulk carriers of 150*m* in length and upward[1] for which the building contract is placed, the keels of which are laid or which are delivered on or after the dates referred to in *SOLAS* regulation II-1/3-2 as adopted by resolution *MSC*.216(82).

[1] This Standard applies only to dedicated seawater ballast tanks in all types of ships and double-side skin spaces in bulk carriers which are constructed of steel.

2 DEFINITIONS

For the purpose of this Standard, the following definitions apply:

2.1 *Ballast tanks* are those as defined in the Guidelines for the selection, application and maintenance of corrosion prevention systems of dedicated seawater ballast tanks (resolution *A*.798(19)) and the International Code on the enhanced programme of inspections during surveys of bulk carriers and oil tankers (resolution *A*.1049(27) (2011 *ESP* code)).

2.2 *Dew point* is the temperature at which air is saturated with moisture.

2.3 *DFT* is dry film thickness.

2.4 *Dust* is loose particle matter present on a surface prepared for painting, arising from blast-cleaning or other surface preparation processes, or resulting from the action of the environment.

2.5 *Edge grinding* is the treatment of edge before secondary surface preparation.

2.6 "*GOOD*" *condition* is the condition with minor spot rusting as defined in resolution *A*.1049(27) (2011 *ESP* code).

2.7 *Hard coating* is a coating that chemically converts during its curing process or a non-convertible air drying coating which may be used for maintenance purposes. It can be either inorganic or organic.

2.8 *NDFT* is the nominal dry film thickness. A 90/10 practice means that 90% of all thickness measurements shall be greater than, or equal to, NDFT and none of the remaining 10% measurements shall be below 0.9×NDFT.

2.9 *Primer coat* is the first coat of the coating system applied in the shipyard after shop primer application.

2.10 *Shop-primer* is the prefabrication primer coating applied to steel plates, often in automatic plants (and before the first coat of a coating system).

2.11 *Stripe coating* is painting of edges, welds, hard to reach areas, etc., to ensure good paint adhesion and proper paint thickness in critical areas.

2.12 *Target useful life* is the target value, in years, of the durability for which the coating system is designed.

2.13 *Technical Data Sheet* is paint manufacturers' Product Data Sheet which contains detailed technical instruction and information relevant to the coating and its application.

****

Interpretation

GOOD: Condition with spot rusting on less than 3% of the area under consideration without visible failure of the coating. Rusting at edges or welds, must be on less than 20 % of edges or weld lines in the area under consideration.

Coating Technical File: A term used for the collection of documents describing issues related to the coating system and its application from the point in time when the first document is provided and for the entire life of the ship including the inspection agreement and all elements of PSPC 3.4.

****

3 GENERAL PRINCIPLES

3.1 The ability of the coating system to reach its target useful life depends on the type of coating system, steel preparation, application and coating inspection and maintenance. All these aspects contribute to the good performance of the coating system.

3.2 Inspection of surface preparation and coating processes shall be agreed upon between the shipowner, the shipyard and the coating manufacturer and presented to the Administration[2] for review. The Administration may, if it so requires, participate in the agreement process. Clear evidence of these inspections shall be reported and be included in the Coating Technical File (CTF) (see **3.4**).

[2] In accordance with *SOLAS* regulation I/6, for the purposes of this Standard, the Administration may entrust a recognized organization acting on its behalf to determine compliance with the prevision of this Standard.

****

Interpretation

1. Inspection of surface preparation and coating processes agreement shall be signed by shipyard, shipowner and coating manufacturer and shall be presented by the shipyard to the Administration for review prior to commencement of any coating work on any stage of a new building and as a minimum shall comply with the PSPC.
2. To facilitate the review, the following from the CTF, shall be available:
   a) Coating specification including selection of areas (spaces) to be coated, selection of coating system, surface preparation and coating process.
   b) Statement of Compliance or Type Approval of the coating system.
3. The agreement shall be included in the CTF and shall at least cover:
   a) Inspection process, including scope of inspection, who carries out the inspection, the qualifications of the coating inspector(s) and appointment of a qualified coating inspector (responsible for verifying that the coating is applied in accordance with the PSPC). Where more than one coating inspector will be used then their areas of responsibility shall be identified. (For example, multiple construction sites).
   b) Language to be used for documentation.
4. Any deviations in the procedure relative to the PSPC noted during the review shall be raised with the shipyard, which is responsible for identifying and implementing the corrective actions.
5. A Passenger Ship Safety Certificate or Cargo Ship Safety Certificate or Cargo Ship Safety Construction Certificate, as appropriate, shall not be issued until all required corrective actions have been closed to the satisfaction of the Administration.

****

3.3 When considering the Standard provided in **section 4**, the following is to be taken into account:

.1 it is essential that specifications, procedures and the various different steps in the coating application process (including, but not limited to, surface preparation) are strictly applied by the shipbuilder in order to prevent premature decay and/or deterioration of the coating system;

.2 the coating performance can be improved by adopting measures at the ship design stage such as reducing scallops, using rolled profiles, avoiding complex geometric configurations and ensuring that the structural configuration permits easy access for tools and to facilitate cleaning, drainage and drying of the space to be coated; and

.3 the coating performance standard provided in this document is based on experience from manufacturers, shipyards and ship operators; it is not intended to exclude suitable alternative coating systems, providing a performance at least equivalent to that specified in this Standard is demonstrated. Acceptance criteria for alternative systems are provided in **section 8**.

3.4 Coating Technical File

3.4.1 Specification of the coating system applied to the dedicated seawater ballast tanks and double-side skin spaces, record of the shipyard's and shipowner's coating work, detailed criteria for coating selection, job specifications, inspection, maintenance and repair[3] shall be documented in the Coating Technical File (CTF), and the Coating Technical File shall be reviewed by the Administration.

[3] Refer to the "*Guidelines for maintenance and repair of protective coatings*" (*MSC*.1/*Circ*.1330).

3.4.2 New construction stage

The Coating Technical File shall contain at least the following items relating to this Standard and shall be delivered by the shipyard at new ship construction stage:

.1 copy of Statement of Compliance or Type Approval Certificate;

.2 copy of Technical Data Sheet, including:

.2.1 product name and identification mark and/or number;

.2.2 materials, components and composition of the coating system, colours;

.2.3 minimum and maximum dry film thickness;

.2.4 application methods, tools and/or machines;

.2.5 condition of surface to be coated (de-rusting grade, cleanness, profile, etc.); and

.2.6 environmental limitations (temperature and humidity);

.3 shipyard work records of coating application, including:

.3.1 applied actual space and area (*in square metres*) of each compartment;

.3.2 applied coating system;

.3.3 time of coating, thickness, number of layers, etc.;

.3.4 ambient condition during coating; and

.3.5 method of surface preparation;

.4 procedures for inspection and repair of coating system during ship construction;

.5 coating log issued by the coating inspector, stating that the coating was applied in accordance with the specifications to the satisfaction of the coating supplier representative and specifying deviations from the specifications (example of daily log and non-conformity report (see annex 2));

.6 shipyard's verified inspection report, including:

.6.1 completion date of inspection;

.6.2 result of inspection;

.6.3 remarks (if given); and

.6.4 inspector signature; and

.7 procedures for in-service maintenance and repair of coating system[3A].

[3A] Refer to the "*Guidelines for maintenance and repair of protective coatings*" (*MSC*.1/*Circ*.1330).

3.4.3 In-service maintenance, repair and partial re-coating

In-service maintenance, repair and partial re-coating activities shall be recorded in the Coating Technical File in accordance with the relevant section of the Guidelines for coating maintenance and repair[4].

[4] Refer to the "*Guidelines for maintenance and repair of protective coatings*" (*MSC*.1/*Circ*.1330).

3.4.4 Re-coating

If full re-coating is carried out, the items specified in **3.4.2** shall be recorded in the Coating Technical File.

3.4.5 The Coating Technical File shall be kept on board and maintained throughout the life of the ship.

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Interpretation

Procedure for Coating Technical File Review

1 The shipyard is responsible for compiling the Coating Technical File (CTF) either in paper or electronic format, or a combination of the two.

2 The CTF is to contain all the information required by the PSPC 3.4 and the inspection of surface preparation and the coating processes agreement (see PSPC 3.2).

3 The CTF shall be reviewed for content in accordance with the PSPC 3.4.2.

4 Any deviations found under 3 shall be raised with the shipyard, which is responsible for identifying and implementing the corrective actions.

5 A Passenger Ship Safety Certificate or Cargo Ship Safety Certificate or Cargo Ship Safety Construction Certificate, as appropriate, shall not be issued until all required corrective actions have been closed to the satisfaction of the

Administration.

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3.5 Health and safety

The shipyard is responsible for implementation of national regulations to ensure the health and safety of individuals and to minimize the risk of fire and explosion.

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Interpretation

In order to document compliance with PSPC 3.5, relevant documentation from the coating manufacturer concerning health and safety aspects such as Material Safety Data Sheet is recommended to be included in the CTF for information.

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4 COATING STANDARD

4.1 Performance standard

This Standard is based on specifications and requirements which intend to provide a target useful coating life of 15 years, which is considered to be the time period, from initial application, over which the coating system is intended to remain in "GOOD" condition. The actual useful life will vary, depending on numerous variables including actual conditions encountered in service.

4.2 Standard application

Protective coatings for dedicated seawater ballast tanks of all ship types and double-side skin spaces arranged in bulk carriers of 150 *m* in length and upward shall at least comply with the requirements in this Standard.

4.3 Special application

4.3.1 This Standard covers protective coating requirements for the ship's steel structure. It is noted that other independent items are fitted within the tanks to which coatings are applied to provide protection against corrosion.

4.3.2 It is recommended that this Standard is applied, to the extent possible, to those portions of permanent means of access provided for inspection not integral to the ship structure, such as rails, independent platforms, ladders, etc. Other equivalent methods of providing corrosion protection for the non-integral items may also be used, provided they do not impair the performance of the coatings of the surrounding structure. Access arrangements that are integral to the ship structure, such as increased stiffener depths for walkways, stringers, etc., are to fully comply with this Standard.

4.3.3 It is also recommended that supports for piping, measuring devices, etc., be coated in accordance with the non-integral items indicated in **4.3.2**.

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Interpretation

Reference is made to the non-mandatory *MSC*/Circ.1279 "Guidelines for corrosion protection of permanent means of access arrangements", adopted by *MSC* 84 in May 2008.

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4.4 Basic coating requirements

4.4.1 The requirements for protective coating systems to be applied at ship construction for dedicated seawater ballast tanks of all ship types and double-side skin spaces arranged in bulk carriers of 150*m* in length and upward meeting the performance standard specified in **4.1** are listed in **table 1**.

4.4.2 Coating manufacturers shall provide a specification of the protective coating system to satisfy the requirements of **table 1**.

4.4.3 The Administration shall verify the Technical Data Sheet and Statement of Compliance or Type Approval Certificate for the protective coating system.

4.4.4 The shipyard shall apply the protective coating in accordance with the verified Technical Data Sheet and its own verified application procedures.

Table 1 Basic Coating System Requirements for Dedicated Seawater Ballast Tanks of All Type of Ships and Double-side Skin Spaces of Bulk Carriers of 150 m and Upwards

	Characteristic/ Reference Standards	Requirement
1 Design of coating system		
.1	Selection of the coating system	The selection of the coating system should be considered by the parties involved with respect to the service conditions and planned maintenance. The following aspects, among other things should be considered: .1 location of space relative to heated surfaces; .2 frequency of ballasting and deballasting operations; .3 required surface conditions; .4 required surface cleanliness and dryness; and .5 supplementary cathodic protections, if any (where coating is supplemented by cathodic protection, the coating shall be compatible with the cathodic protection system). Coating manufacturers shall have products with documented satisfactory performance records and technical data sheets. The manufacturers shall also be capable of rendering adequate technical assistance. Performance records, technical data sheet and technical assistance (if given) shall be recorded in the Coating Technical File. Coatings for application underneath sun-heated decks or on bulkheads forming boundaries of heated spaces shall be able to withstand repeated heating and/or cooling without becoming brittle.
.2	Coating type	Epoxy based systems. Other coating systems with performance according to the test procedure in **annex 1**. A multi-coat system with each coat of contrasting colour is recommended. The top coat shall be of a light colour in order to facilitate in-service inspection.
.3	Coating pre-qualification test	Epoxy based systems tested prior to the date of entry into force of this Standard in a laboratory by a method corresponding to the test procedure in **annex 1** or equivalent, which as a minimum meets the requirements for rusting and blistering; or which have documented field exposure for 5 years with a final coating condition of not less than "GOOD" may be accepted. For all other systems, testing according to the procedure in **annex 1**, or equivalent, is required.
.4	Job specification	There shall be a minimum of two stripe coats and two spray coats, except that the second stripe coat, by way of welded seams only, may be reduced in scope where it is proven that the NDFT can be met by the coats applied in order to avoid unnecessary over thickness. Any reduction in scope of the second stripe coat shall be fully detailed in the CTF. Stripe coats shall be applied by brush or roller. Roller to be used for scallops, ratholes, etc., only. Each main coating layer shall be appropriately cured before application of the next coat, in accordance with coating manufacturer's recommendations. Surface contaminants such as rust, grease, dust, salt, oil, etc. shall be removed prior to painting with proper method according to

		the paint manufacturer's recommendation. Abrasive inclusions embedded in the coating shall be removed. Job specifications shall include the dry-to-recoat times and walk-on time given by the manufacturer.
.5	NDFT (nominal total dry film thickness)[5]	NDFT 320μm with 90/10 rule for epoxy based coatings; other systems to coating manufacturer's specifications. Maximum total dry film thickness according to manufacturer's detailed specifications. Care shall be taken to avoid increasing the thickness in an exaggerated way. Wet film thickness shall be regularly checked during application. Thinner shall be limited to those types and quantities recommended by the manufacturer.
2 PSP (Primary Surface Preparation)		
.1	Blasting and Profile.[6, 7]	Sa2½; with profiles between 30-75μm Blasting shall not be carried out when: .1 the relative humidity is above 85%; or .2 the surface temperature of steel is less than 3°C above the dew point. Checking of the steel surface cleanliness and roughness profile shall be carried out at the end of the surface preparation and before the application of the primer, in accordance with the manufacturer's recommendations.
.2	Water soluble salt limit equivalent to NaCl [8]	≤ 50 mg/m^2 of sodium chloride.
.3	Shop primer	Zinc containing inhibitor free zinc silicate based or equivalent. Compatibility with main coating system shall be confirmed by the coating manufacturer.
3 Secondary surface preparation		
.1	Steel condition[9]	The steel surface shall be prepared so that the coating selected can achieve an even distribution at the required NDFT and have an adequate adhesion by removing sharp edges, grinding weld beads and removing weld spatter and any other surface contaminant. Edges shall be treated to a rounded radius of minimum 2mm, or subjected to three pass grinding or at least equivalent process before painting.
.2	Surface treatment[6]	Sa2½ on damaged shop primer and welds. Sa2 removing at least 70% of intact shop primer, which has not passed a prequalification certified by test procedures in **1.3**. If the complete coating system comprising epoxy-based main coating and shop primer has passed a pre-qualification certified by test procedures in **1.3**, intact shop primer may be retained provided the same epoxy coating system is used. The retained shop primer shall be cleaned by sweep blasting, high pressure water washing or equivalent method. If a zinc silicate shop primer has passed the pre-qualification test of **1.3** as part of an epoxy

		coating system, it may be used in combination with other epoxy coatings certified under **1.3**, provided that the compatibility has been confirmed by the manufacturer by the test in accordance with **1.7** of **appendix 1** to **annex 1** without wave movement.
.3	Surface treatment after erection[6]	Butts St3 or better or Sa2½ where practicable. Small damages up to 2% of total area: St3. Contiguous damages over 25m^2 or over 2% of the total area of the tank, Sa2½ shall be applied. Coating in overlap to be feathered.
.4	Profile requirements[7]	In case of full or partial blasting 30-75μm, otherwise as recommended by the coating manufacturer.
.5	Dust[10]	Dust quantity rating "1" for dust size class "3", "4" or "5". Lower dust size classes to be removed if visible on the surface to be coated without magnification.
.6	Water soluble salts limit equivalent to NaCl after blasting/ grinding[8]	≤ 50 mg/m^2 of sodium chloride.
.7	Oil contamination	No oil contamination.
4 Miscellaneous		
.1	Ventilation	Adequate ventilation is necessary for the proper drying and curing of coating. Ventilation should be maintained throughout the application process and for a period after application is completed, as recommended by the coating manufacturer.
.2	Environmental conditions	Coating shall be applied under controlled humidity and surface conditions, in accordance with the manufacturer's specifications. In addition, coating shall not be applied when: .1 the relative humidity is above 85%; or .2 the surface temperature is less than 3°C above the dew point.
.3	Testing of coating[5]	Destructive testing shall be avoided. Dry film thickness shall be measured after each coat for quality control purpose and the total dry film thickness shall be confirmed after completion of final coat, using appropriate thickness gauges (see **annex 3**).
.4	Repair	Any defective areas, e.g. pin-holes, bubbles, voids, etc. should be marked up and appropriate repairs effected. All such repairs shall be re-checked and documented.

5 Type of gauge and calibration in accordance with SSPC-PA2: 2004. *Paint Application Specification No.2.*

6 Reference standard: *ISO* 8501-1: *1988/Suppl: 1994. Preparation of steel substrate before application of paints and related products – Visual assessment of surface cleanliness.*

7 Reference standard: *ISO* 8503-1/2: *1988. Preparation of steel substrate before application of paints and related products – Surface roughness characteristics of blast-cleaned steel substrates.*

8 Conductivity measured in accordance with the following standards:

.1 *ISO* 8502-9: *1998. Preparation of steel substrate before application of paints and related products – Test for the assessment of surface cleanliness.* ; or

.2 *NACE SP*0508-2010 *Item no.*21134. *Standard practice methods of validating equivalence to ISO* 8502-9 *on measurement of the levels of soluble salts.*

9 Reference standard: *ISO* 8501-3: *2001 (grade P2). Preparation of steel substrate before application of paints and related products – Visual assessment of surface cleanliness.*

10 Reference standard: *ISO* 8502-3:*1993. Preparation of steel substrate before application of paints and related products – Test for the assessment of surface cleanliness.*

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Interpretation regarding Table 1

1 Design of coating system

1.3 Coating pre-qualification test

Procedure for Coating System Approval

Type Approval Certificate showing compliance with the PSPC 5 shall be issued if the results of either method A+D, or B+D, or C+D are found satisfactory by the Administration.

The Type Approval Certificate shall indicate the Product and the Shop Primer tested. The certificate shall also indicate other type approved shop primers with which the product may be used which have under gone the cross over test in a laboratory meeting the requirements in Method A, 1.1 of this UI.

The documents required to be submitted are identified in the following sections, in addition for all type approvals the following documentation is required:

Technical Data Sheet showing all the information required by PSPC 3.4.2.2.

Winter type epoxy is required separate prequalification test including shop primer compatibility test according to PSPC Annex 1. Winter and summer type coating are considered different unless Infrared (IR) identification and Specific Gravity (SG) demonstrates that they are the same.

Method A: Laboratory Test

1.1 Coating pre-qualification test shall be carried out by the test laboratory which is recognized by the Administration and the test laboratory shall meet the requirements set out in IACS UR Z17.

1.2 Results from satisfactory pre-qualification tests (PSPC Table 1: 1.3) of the coating system shall be documented and submitted to the Administration.

1.3.1 Type Approval tests shall be carried out for the epoxy based system with the stated shop primer in accordance with the PSPC Annex 1. If the tests are satisfactory, a Type Approval Certificate will be issued to include both the epoxy and the shop primer. The Type Approval Certificate will allow the use of the epoxy either with the named shop primer or on bare prepared steel.

1.3.2 An epoxy based system may be used with shop primers other than the one with which it was originally tested provided that, the other shop primers are approved as part of a system, PSPC Table 1: 2.3 and Table 1: 3.2, and have been tested according to PSPC Annex 1, Appendix 1, 1.7, which is known as the “Crossover Test”. If the test or tests are satisfactory, a Type Approval Certificate will be issued. In this instance the Type Approval Certificate will include the details of the epoxy and a list of all shop primers with which it has been tested that have passed these requirements. The Type Approval Certificate will allow the use of the epoxy with all the named shop primers or on bare prepared steel.

1.3.3 Alternatively the epoxy can be tested without shop primer on bare prepared steel to the requirements of the PSPC Annex 1. If the test or tests are satisfactory, a Type Approval Certificate will be issued. The Type Approval Certificate will just record the epoxy. The certificate will allow the use of the epoxy on bare prepared steel only. If in addition, crossover tests are satisfactorily carried out with shop primers, which are approved as part of a system, the Type Approval Certificate will include the details of shop primers which have satisfactorily passed the crossover test. In this instance the Type Approval Certificate will allow the use of the epoxy based system with all the named shop primers or on bare prepared steel.

1.3.4 The Type Approval Certificate is invalid if the formulation of either the epoxy or the shop primer is changed. It is the responsibility of the coating manufacturer to inform the Administration immediately of any changes to the formulation.

1.3.5 For the coating pre-qualification test, the measured average dry film thickness (DFT) on each prepared test panels shall not exceed a nominal DFT (NDFT) of 320 microns plus 20% unless a paint manufacturer specifies a NDFT greater than 320 microns. In the latter case, the average DFT shall not exceed the specified NDFT plus 20% and the coating system shall be certified to the specified NDFT if the system passes the tests according to Annex 1 of MSC 215(82). The measured DFT shall meet the “90/10” rule and the maximum DFT shall be below the maximum DFT value specified by the manufacturer.

Method B: 5 years field exposure

1.4 Coating manufacturer's records, which shall at least include the information indicated in 1.4.1, shall be examined to confirm coating system has 5 years field exposure, and the current product is the same as that being assessed.

1.4.1 Manufacturer's Records

- Original application records
- Original coating specification
- Original technical data sheet
- Current formulation's unique identification (Code or number)
- If the mixing ratio of base and curing agent has changed, a statement from the coating manufacturer confirming that the composition mixed product is the same as the original composition. This shall be accompanied by an explanation of the modifications made.
- Current technical data sheet for the current production site
- SG and IR identification of original product
- SG and IR identification of the current product
- If original SG and IR cannot be provided then a statement from the coating manufacturer confirming the readings for the current product are the same as those of the original.

1.5 Either class survey records from an Administration or a joint (coating manufacturer and Administration) survey of all ballast tanks of a selected vessel is to be carried out for the purpose of verification of compliance with the requirements of 1.3 and 1.7. The reporting of the coating condition in both cases shall be in accordance with the IACS Recommendation 87, section 2 (IACS Recommendation 87 is not mandatory).

1.6 The selected vessel is to have ballast tanks in regular use, of which:

- At least one tank is approximately 2,000m^3 or more in capacity
- At least one tank shall be adjacent to a heated tank and
- At least one tank contains an underdeck exposed to the sun.

1.7 In the case that the selected vessel does not meet the requirements in 1.6 then the limitations shall be clearly stated on the type approval certificate. For example, the coating cannot be used in tanks adjacent to heated tanks or underdeck or tanks with volume greater than the size surveyed.

1.8 In all cases of approval by Method B, the shop primer shall be removed prior to application of the approved epoxy based system coating, unless it can be confirmed that the shop primer applied during construction, is identical in formulation to that applied in the selected vessel used as a basis of the approval.

1.9 All ballast tanks shall be in "GOOD" condition excluding mechanical damages, without touch up or repair in the prior 5 years.

1.9.1 "Good" is defined as: Condition with spot rusting on less than 3% of the area under consideration without visible failure of the coating. Rusting at edges or welds, must be on less than 20% of edges or welds in the area under consideration.

1.9.2 Examples of how to report coating conditions with respect to areas under consideration should be as those given in IACS Recommendation 87.

1.10 If the applied NDFT is greater than required by the PSPC, the applied NDFT will be the minimum to be applied during construction. This will be reported prominently on the Type Approval Certificate.

1.11 If the results of the inspection are satisfactory, a Type Approval Certificate shall be issued to include both the epoxy based system and the shop primer. The Type Approval Certificate shall allow the use of the epoxy based system either with the named shop primer or on bare prepared steel. The Type Approval Certificate shall reference the inspection report which will also form part of the Coating Technical File.

1.12 The Type Approval Certificate is invalid if the formulation of either the epoxy based system or the shop primer is changed. It is the responsibility of the coating manufacturer to inform the Administration immediately of any changes to the formulation.

Method C: Existing Marintek B1 Approvals

1.13 Epoxy based system Coatings Systems with existing satisfactory Marintek test reports minimum level B1 including relevant IR identification and SG, issued before 8 December 2006 can be accepted. If original SG and IR documentation cannot be provided, then a statement shall be provided by the coating manufacturer confirming that the readings for the current product are the same as those of the original.

1.14 The Marintek test report with IR and SG information shall be reviewed and if satisfactory, a Type Approval certificate shall be issued. The certificate shall record the report reference and the shop primer used. The Type Approval Certificate shall allow the use of the epoxy based system either with the named shop primer, unless there is evidence to indicate that it is unsuitable, or on bare prepared steel.

1.15 The epoxy based system approved by this method may be used with other shop primers if satisfactory crossover tests are carried out with shop primers which are approved as part of a system, see Method A, 1.3.2. In this instance, the Type Approval Certificate will include the details of the epoxy based system and a list of all shop primers which have passed these requirements. The Type Approval Certificate will allow the use of the epoxy based system with all the named shop primers or on bare prepared steel.

1.16 Such coatings shall be applied in accordance with PSPC Table 1 rather than the application conditions used during the approval test which may differ from the PSPC, unless these are more stringent than PSPC Annex 1, for example if the NDFT is higher or high pressure water washing and or sweep blasting of the shop primer is used. In such cases these limiting conditions shall be added to the type approval certificate and shall be followed during coating application in the shipyard.

1.17 The Type Approval Certificate is invalid if the formulation of either the epoxy based system or the shop primer is changed. It is the responsibility of the coating manufacturer to inform the Administration immediately of any changes to the formulation.

Method D: Coating Manufacturer

1.18 The coating/shop primer manufacturer shall meet the requirements set out in IACS UR Z17 paragraphs 4, 5, 6 and 7, (except for 4.6) and paragraphs 1.18.1 to 1.18.6 below, which shall be verified by the Administration.

1.18.1 Coating Manufacturers

(a) Extent of Engagement – Production of coating systems in accordance with PSPC and this UI.

(b) These requirements apply to both the main coating manufacturer and the shop primer manufacturer where both coatings form part of the total system.

(c) The coating manufacturer should provide to the Administration the following information;

- A detailed list of the production facilities.
- Names and location of raw material suppliers will be clearly stated.
- A detailed list of the test standards and equipment to be used, (Scope of approval).
- Details of quality control procedures employed.
- Details of any sub-contracting agreements.
- List of quality manuals, test procedures and instructions, records, etc.
- Copy of any relevant certificates with their issue number and/or date e.g. Quality Management System certification.

(d) Inspection and audit of the manufacturer's facilities will be based on the requirements of the PSPC.

(e) With the exception of early 'scale up' from laboratory to full production, adjustment outside the limitations listed in the QC instruction referred to below is not acceptable, unless justified by trials during the coating system's development programme, or subsequent testing. Any such adjustments must be agreed by the formulating technical centre.

(f) If formulation adjustment is envisaged during the production process the maximum allowable limits will be approved by the formulating technical centre and clearly stated in the QC working procedures.

(g) The manufacturer's quality control system will ensure that all current production is the same formulation as that supplied for the Type Approval Certificate. Formulation change is not permissible without testing in accordance with the test procedures in the PSPC and the issue of a Type Approval Certificate by the Administration.

(h) Batch records including all QC test results such as viscosity, specific gravity and airless spray characteristics will be accurately recorded. Details of any additions will also be included.

(i) Whenever possible, raw material supply and lot details for each coating batch will be traceable. Exceptions may be where bulk supply such as solvents and pre-dissolved solid epoxies are stored in tanks, in which case it may only be possible to record the supplier's blend.

(j) Dates, batch numbers and quantities supplied to each coating contract will be clearly recorded.

1.18.2 All raw material supply must be accompanied the supplier's 'Certificate of Conformance'. The certificate will include all requirements listed in the coating manufacturer's QC system.

1.18.3 In the absence of a raw material supplier's certificate of conformance, the coating manufacturer must verify conformance to all requirements listed in the coating manufacturer's QC system.

1.18.4 Drums must be clearly marked with the details as described on the 'Type Approval Certificate'.

1.18.5 Product Technical Data Sheets must comply with all the PSPC requirements. The QC system will ensure that all Product Technical Data Sheets are current.

1.18.6 QC procedures of the originating technical centre will verify that all production units comply with the above stipulations and that all raw material supply is approved by the technical centre.

1.19 In the case that a coating manufacturer wishes to have products which are manufactured in different locations under the same name, then IR identification and SG shall be used to demonstrate that they are the same coating, or individual approval tests will be required for the paint manufactured in each location.

1.20 The Type Approval Certificate is invalid if the formulation of either the epoxy based system or the shop primer is changed. It is the responsibility of the coating manufacturer to inform class immediately of any changes to the formulation. Failure to inform class of an alteration to the formulation will lead to cancellation of the certificates for that manufacturer's products.

Interpretation regarding 1.4 Job specification and 1.5 NDFT (nominal total dry film thickness)

Wet film thickness shall be regularly checked during application for quality control by the Builder. PSPC does not state who should check WFT, it is accepted for this to be the Builder. Measurement of DFT shall be done as part of the inspection required in PSPC 6.

Stripe coats should be applied as a coherent film showing good film formation and no visible defects. The application method employed should insure that all areas that require stripe coating are properly coated by brush or roller. A roller may be used for scallops, ratholes etc., but not for edges and welds.

2 PSP (Primary Surface Preparation)

Interpretation regarding 2.2 Water soluble salt limit equivalent to NaCl

The conductivity of soluble salts is measured in accordance with ISO 8502-6 and ISO 8502-9 or equivalent method as validated according to NACE SP0508-2010, and compared with the conductivity of $50 mg/m^2$ NaCl. If the measured conductivity is less than or equal to, then it is acceptable. Minimum readings to be taken are one (1) per plate in the case of manually applied shop primer. In cases where an automatic process for application of shop primer is used, there should be means to demonstrate compliance with PSPC through a Quality Control System, which should include a monthly test.

Interpretation regarding 2.3 Shop primer

Shop primers not containing zinc or not silicate based are considered to be "alternative systems" and therefore equivalency is to be established in accordance with Section 8 of the PSPC with test acceptance criteria for "alternative systems" given in Section 3.1 (right columns) of Appendixes 1 and 2 to Annex 1.

Interpretation regarding Procedure for review of Quality Control of Automated Shop Primer plants

1 It is recognised that the inspection requirements of PSPC 6.2 may be difficult to apply to an automated shop primer plant and a Quality Control approach would be a more practical way of enabling compliance with the requirements of PSPC.

2 As required in PSPC it is the responsibility of the coating inspector to confirm that the quality control procedures are ensuring compliance with PSPC.

3 When reviewing the Quality Control for automated shop primer plants the following procedures should be included.

3.1 Procedures for management of the blasting grit including measurement of salt and contamination.

3.2 Procedures recording the following; steel surface temperature, relative humidity, dewpoint.

3.3 Procedures for controlling or monitoring surface cleanliness, surface profile, oil, grease, dust and other contamination.

3.4 Procedures for recording/measuring soluble salts.

3.5 Procedures for verifying thickness and curing of the shop primer conforms to the values specified in the Technical Specification.

3 SSP (Secondary Surface Preparation)

Interpretation regarding 3.2 Surface treatment, 3.3 Surface treatment after erection, and 3.4 Profile requirement

Usually, the fillet welding on tank boundary watertight bulkhead is left without coating on block stage (because not yet be leakage tested), in which case it can be categorized as erection joint ("butt") to be power tooled to St 3.

Interpretation regarding 3.6 Water soluble salts limit equivalent to NaCl after blasting/grinding

The conductivity of soluble salts is measured in accordance with ISO 8502-6 and ISO 8502-9 or equivalent method as validated according to NACE SP0508-2010, and compared with the conductivity of 50mg/m^2 NaCl. If the measured conductivity is less then or equal to, then it is acceptable.

All soluble salts have a detrimental effect on coatings to a greater or lesser degree. ISO 8502-9:1998 does not provide the actual concentration of NaCl. The % NaCl in the total soluble salts will vary from site to site. Minimum readings to be taken are one (1) reading per block/section/unit prior to applying.

4 Miscellaneous

4.3 Testing of coating

All DFT measurements shall be measured. Only the final DFT measurements need to be measured and reported for compliance with the PSPC by the qualified coating inspector. The Coating Technical File may contain a summary of the DFT measurements which typically will consist of minimum and maximum DFT measurements, number of measurements taken and percentage above and below required DFT. The final DFT compliance with the 90/10 practice shall be calculated and confirmed, see PSPC 2.8.

Interpretation regarding footnotes

Only the footnoted standards referred to in PSPC Table 1 are to be applied, i.e. they are mandatory.

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5 COATING SYSTEM APPROVAL

Results from prequalification tests (**table 1**, **paragraph 1.3**) of the coating system shall be documented and a Statement of Compliance or Type Approval Certificate shall be issued if found satisfactory by a third party, independent of the coating manufacturer.

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Interpretation

See Interpretation of PSPC Table 1: 1 Design of coating system, 1.3 Coating prequalification test.

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6 COATING INSPECTION REQUIREMENTS

6.1 General

6.1.1 To ensure compliance with this Standard, the following shall be carried out by qualified coating inspectors certified to NACE Coating Inspector Level 2, FROSIO Inspector Level III or equivalent as verified by the Administration.

6.1.2 Coating inspectors shall inspect surface preparation and coating application during the coating process by carrying out, as a minimum, those inspection items identified in section **6.2** to ensure compliance with this Standard. Emphasis shall be placed on initiation of each stage of surface preparation and coatings application as improper work is extremely difficult to correct later in the coating progress. Representative structural members shall be non-destructively examined for coating thickness. The inspector shall verify that appropriate collective measures have been carried out.

6.1.3 Results from the inspection shall be recorded by the inspector and shall be included in the CTF (refer to **annex 2** (Example of daily log and non-conformity report)).

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Interpretation

Procedure for Assessment of Coating Inspectors' Qualifications

1 Coating inspectors required to carry out inspections in accordance with the PSPC 6 shall be qualified to NACE Coating Inspector Level 2, FROSIO Inspector Level III, or an equivalent qualification. Equivalent qualifications are described in 3 below.

2 However, only coating inspectors with at least 2 years relevant coating inspector experience and qualified to NACE Coating Inspector Level 2 or FROSIO Inspector Level III, or with an equivalent qualification, can write and/or authorise procedures, or decide upon corrective actions to overcome non-compliances.

3 Equivalent Qualification

3.1 Equivalent qualification is the successful completion, as determined by course tutor, of an approved course.

3.1.1 The course tutors shall be qualified with at least 2 years relevant experience and qualified to NACE Coating Inspector Level 2 or FROSIO Inspector Level III, or with an equivalent qualification.

3.1.2 Approved Course: A course that has a syllabus based on the issues associated with the PSPC including the following:

- Health Environment and Safety
- Corrosion
- Materials and design
- International standards referenced in PSPC
- Curing mechanisms
- Role of inspector
- Test instruments
- Inspection Procedures
- Coating specification
- Application Procedures
- Coating Failures
- Pre-job conference
- MSDS and product data sheet review
- Coating technical file
- Surface preparation
- Dehumidification
- Waterjetting
- Coating types and inspection criteria
- Specialized Application Equipment
- Use of inspection procedures for destructive testing and non destructive testing instruments.
- Inspection instruments and test methods
- Coating inspection techniques
- Cathodic protection
- Practical exercises, case studies.

Examples of approved courses may be internal courses run by the coating manufacturers or shipyards etc.

3.1.3 Such a course shall have an acceptable measurement of performance, such as an examination with both theoretical and practical elements. The course and examination shall be approved by the Administration.

3.2 Equivalent qualification arising from practical experience: An individual may be qualified without attending a course where it can be shown that the individual:

- has a minimum of 5-years practical work experience as a coating inspector of ballast tanks during new construction within the last 10 years, and
- has successfully completed the examination given in 3.1.3.

4 Assistant to the coating inspectors

4.1 If the coating inspectors requires assistance from other persons to perform the part of the inspections, those persons shall perform the inspections under the coating inspector's supervision and shall be trained to the coating inspector's satisfaction.

4.2 Such training should be recorded and endorsed either by the inspector, the yard's training organization or inspection equipment manufacturer to confirm competence in using the measuring equipment and confirm knowledge of the measurements required by the PSPC.

4.3 Training records shall be available for verification.

****

6.2 Inspection items

Construction stage		Inspection items
Primary surface preparation	1	The surface temperature of steel, the relative humidity and the dew point shall be measured and recorded before the blasting process starts and at times of sudden changes in weather.
	2	The surface of steel plates shall be tested for soluble salt and checked for oil, grease and other contamination.
	3	The cleanliness of the steel surface shall be monitored in the shop primer application process.
	4	The shop primer material shall be confirmed to meet the requirements of **2.3** of **table 1**.
Thickness		If compatibility with the main coating system has been declared, then the thickness and curing of the zinc silicate shop primer to be confirmed to conform to the specified values.
Block assembly	1	After completing construction of the block and before secondary surface preparation starts, a visual inspection for steel surface treatment including edge treatment shall be carried out. Any oil, grease or other visible contamination to be removed.
	2	After blasting/grinding/cleaning and prior to coating, a visual inspection of the prepared surface shall be carried out. On completion of blasting and cleaning and prior to the application of the first coat of the system, the steel surface shall be tested for levels of remaining soluble salts in at least one location per block.
	3	The surface temperature, the relative humidity and the dew point shall be monitored and recorded during the coating application and curing.
	4	Inspection to be performed of the steps in the coating application process mentioned in **table 1**.
	5	DFT measurements shall be taken to prove that the coating has been applied to the thickness as specified and outlined in **annex 3**.
Erection	1	Visual inspection for steel surface condition, surface preparation and verification of conformance to other requirements in **table 1**, and the agreed specification shall be performed.
	2	The surface temperature, the relative humidity and the dew point shall be measured and recorded before coating starts and regularly during the coating process.
	3	Inspection shall be performed of the steps in the coating application process mentioned in **table 1**.

7 VERIFICATION REQUIREMENTS

The following shall be carried out by the Administration prior to reviewing the Coating Technical File for the ship subject to this Standard:

.1 check that the Technical Data Sheet and Statement of Compliance or Type Approval Certificate comply with this Standard;

.2 check that the coating identification on representative containers is consistent with the coating identified in the Technical Data Sheet and Statement of Compliance or Type Approval Certificate;

.3 check that the inspector is qualified in accordance with the qualification standards in paragraph **6.1.1**;

.4 check that the inspector's reports of surface preparation and the coating's application indicate compliance with the manufacturer's Technical Data Sheet and Statement of Compliance or Type Approval Certificate; and

.5 monitor implementation of the coating inspection requirements.

****

Interpretation

Procedure for Verification of Application of the PSPC

1 The verification requirements of PSPC 7 shall be carried out by the Administration.

1.1 Monitoring implementation of the coating inspection requirements, as called for in PSPC 7.5 means checking, on a sampling basis, that the inspectors are using the correct equipment, techniques and reporting methods as described in the inspection procedures reviewed by the Administration.

2 Any deviations found under 1.1 shall be raised initially with the coating inspector, who is responsible for identifying and implementing the corrective actions.

3 In the event that corrective actions are not acceptable to the Administration or in the event that corrective actions are not closed out then the shipyard shall be informed.

4 A Passenger Ship Safety Certificate or Cargo Ship Safety Certificate or Cargo Ship Safety Construction Certificate, as appropriate, shall not be issued until all required corrective actions have been closed out to the satisfaction of the Administration.

****

8 ALTERNATIVE SYSTEMS

8.1 All systems that are not an epoxy based system applied according to **table 1** of this Standard are defined as an alternative system.

8.2 This Standard is based on recognized and commonly used coating systems. It is not meant to exclude other, alternative, systems with proven equivalent performance, for example non epoxy based systems.

8.3 Acceptance of alternative systems will be subject to documented evidence that they ensure a corrosion prevention performance at least equivalent to that indicated in this Standard.

8.4 As a minimum, the documented evidence shall consist of satisfactory performance corresponding to that of a coating system which conforms to the coating standard described in **section 4**, a target useful life of 15 years in either actual field exposure for 5 years with final coating condition not less than “GOOD” or laboratory testing. Laboratory test shall be conducted in accordance with the test procedure given in **annex 1** of this Standard.

ANNEX 1
TEST PROCEDURES FOR COATING QUALIFICATION FOR DEDICATED SEAWATER BALLAST TANK OF ALL TYPES OF SHIPS AND DOUBLE-SIDE SKIN SPACES OF BULK CARRIERS

1 Scope

These Procedures provide details of the test procedure referred to in **5** and **8.3** of this Standard.

2 Definitions

Coating specification means the specification of coating systems which includes the type of coating system, steel preparation, surface preparation, surface cleanliness, environmental conditions, application procedure, acceptance criteria and inspection.

3 Testing

Coating specification shall be verified by the following tests. The test procedures shall comply with **appendix 1** (Test on simulated ballast tank conditions) and **appendix 2** (Condensation chamber tests) to this **annex** as follows:

.1 for protective coatings for dedicated seawater ballast tanks, **appendix 1** and **appendix 2** shall apply.

.2 for protective coatings for double-side spaces of bulk carriers of 150*m* in length and upwards other than dedicated seawater ballast tanks, **appendix 2** shall apply.

****

Interpretation

Only the footnoted standards referred to in Annex 1 are to be applied, i.e. they are mandatory.

****

APPENDIX 1 TEST ON SIMULATED BALLAST TANK CONDITIONS

1 Test condition

Test on simulated ballast tank conditions shall satisfy each of the following conditions:

.1 The test shall be carried out for 180 days.

.2 There are to be 5 test panels.

.3 The size of each test panel is 200 *mm* x 400 *mm* x 3 *mm*. Two of the panels (Panel 3 and 4 below) have a U-bar welded on. The U-bar is welded to the panel in a 120 *mm* distance from one of the short sides and 80 *mm* from each of the long sides.

The panels are to be treated according to this Standard, **table 1.1**, **1.2** and **1.3**, and coating system applied according to **table 1**, **paragraphs 1.4** and **1.5**. Shop primer to be weathered for at least 2 months and cleaned by low pressure washing or other mild method. Blast sweep or high pressure washing, or other primer removal methods not to be used. Weathering method and extent shall take into consideration that the primer is to be the foundation for a 15 year target useful life system. To facilitate innovation, alternative preparation, coating systems and dry film thicknesses may be used when clearly defined.

.4 The reverse side of the test piece shall be painted appropriately, in order not to affect the test results.

.5 As simulating the condition of actual ballast tank, the test cycle runs for two weeks with natural or artificial seawater and one week empty. The temperature of the seawater is to be kept at about 35°C.

.6 Test Panel 1: This panel is to be heated for 12 h at 50°C and cooled for 12 h at 20°C in order to simulate upper deck condition. The test panel is cyclically splashed with natural or artificial seawater in order to simulate a ship's pitching and rolling motion. The interval of splashing is 3 s or faster. The panel has a scribe line down to bare steel across width.

.7 Test Panel 2: This panel 2 has a fixed sacrificial zinc anode in order to evaluate the effect of cathodic protection. A circular 8 *mm* artificial holiday down to bare steel is introduced on the test panel 100 *mm* from the anode in order to evaluate the effect of the cathodic protection. The test panel is cyclically immersed with natural or artificial seawater.

.8 Test Panel 3: This panel is to be cooled on the reverse side, in order to give a temperature gradient to simulate a cooled bulkhead in a ballast wing tank, and splashed with natural or artificial seawater in order to simulate a ship's pitching and rolling motion. The gradient of temperature is approximately 20°C, and the interval of splashing is 3 s or faster. The panel has a scribe line down to bare steel across width.

.9 Test Panel 4: This panel is to be cyclically splashed with natural or artificial seawater in order to simulate a ship's pitching and rolling motion. The interval of splashing is 3 s or faster. The panel has a scribe line down to bare steel across width.

.10 Test Panel 5: This panel is to be exposed to dry heat for 180 days at 70°C to simulate boundary plating between heated bunker tank and ballast tank in double bottom.

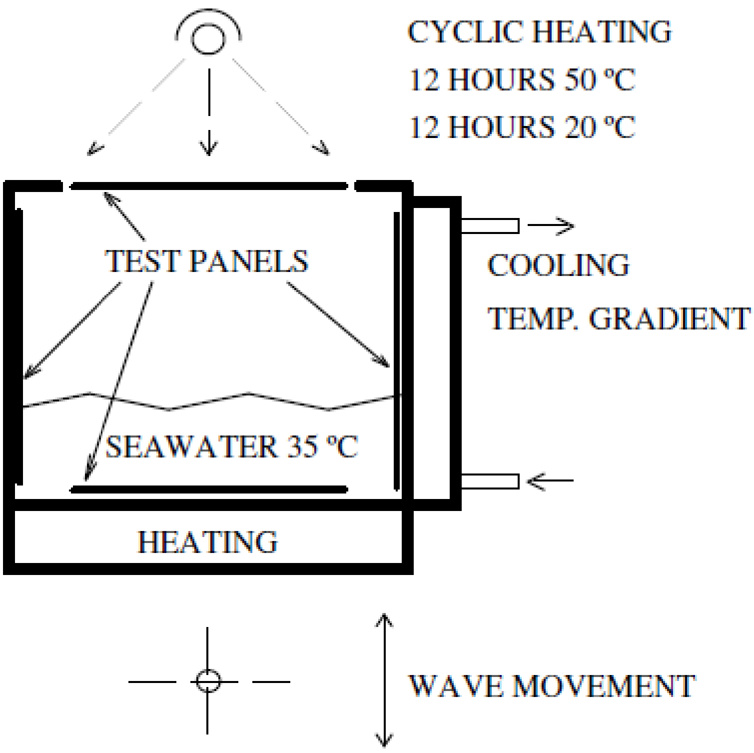

Fig. 1 Wave tank for testing of ballast tank coatings

2 Test results

2.1 Prior to the testing, the following measured data of the coating system shall be reported:

.1 infrared (*IR*) identification of the base and hardener components of the coating;

.2 specific gravity[11] of the base and hardener components of the paint; and

.3 number of pinholes, low voltage detector at 90 V.

2.2 After the testing, the following measured data shall be reported:

.1 blisters and rust[12];

.2 dry film thickness (DFT) (use of a template)[13];

.3 adhesion value[14];

.4 flexibility[15] modified according to panel thickness (3 *mm* steel, 300 *μm* coating, 150 *mm* cylindrical mandrel gives 2% elongation) for information only;

.5 cathodic protection weight loss/current demand/disbondment from artificial holiday; and

.6 undercutting from scribe. The undercutting along both sides of the scribe is measured and the maximum undercutting determined on each panel. The average of the three maximum records is used for the acceptance.

[11] Reference standard: *ISO* 2811-1/4:1997. *Paints and varnishes. Determination of density.*

[12] Reference standards: *ISO* 4628/2:*2003. Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of defects, and of intensity of uniform changes in appearance – Part 2. ISO* 4628/3: *2003. Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of common types of defect – Part 3: Designation of degree of rusting.*

[13] Nine equally distributed measuring points are used on panel's size 150*mm* x 150 *mm* or 15 equally distributed measuring points on panel's size 200*mm* x 400*mm*.

[14] Reference standard: *ISO* 4624:*2002. Pull-off test for adhesion.*

[15] Reference standards: *ASTM* D4145:*1983. Standard Test Method for Coating Flexibility of Prepainted Sheet.*

3 Acceptance criteria

3.1 The test results based on **section 2** shall satisfy the following criteria:

Item	Acceptance criteria for epoxy-based systems applied according to table 1 of this Standard	Acceptance criteria for alternative systems
Blisters on panel	No blisters	No blisters
Rust on panel	Ri 0 (0%)	Ri 0 (0%)
Number of pinholes	0	0
Adhesive failure	> 3.5 *MPa* Adhesive failure between substrate and coating or between coats for 60% or more of the areas.	> 5 *MPa* Adhesive failure between substrate and coating or between coats for 60% or more of the areas.
Cohesive failure	> 3 *MPa* Cohesive failure in coating for 40% or more of the area.	> 5 *MPa* Cohesive failure in coating for 40% or more of the area.
Cathodic protection current demand calculated from weight loss	< 5 mA/m^2	< 5 mA/m^2
Cathodic protection; disbondment from artificial holiday	< 8 *mm*	< 5 *mm*
Undercutting from scribe	< 8 *mm*	< 5 *mm*
U-bar	Any defects, cracking or detachment at the angle or weld will lead to system being failed.	Any defects, cracking or detachment at the angle or weld will lead to system being failed.

3.2 Epoxy-based systems tested prior to the date of entry into force of this Standard shall satisfy only the criteria for blistering and rust in the table above.

3.3 Epoxy-based systems tested when applied according to **table 1** of this Standard shall satisfy the criteria for epoxy-based systems as indicated in the table above.

3.4 Alternative systems not necessarily epoxy-based and/or not necessarily applied according to **table 1** of this Standard shall satisfy the criteria for alternative systems as indicated in the table above.

4 Test report

The test report shall include the following information:

.1 name of the manufacturer;

.2 date of tests;

.3 product name/identification of both paint and primer;

.4 batch number;

.5 data of surface preparation on steel panels, including the following:

.5.1 surface treatment;

.5.2 water soluble salts limit;

.5.3 dust; and

.5.4 abrasive inclusions;

.6 application data of coating system, including the following:

.6.1 shop primed;

.6.2 number of coats;

.6.3 recoat interval[16];

.6.4 dry film thickness (DFT) prior to testing[14];

.6.5 thinner[16];

.6.6 humidity[16];

.6.7 air temperature[16]; and

.6.8 steel temperature;

.7 test results according to **section 2**; and

.8 judgment according to **section 3**.

[16] Both of actual specimen data and manufacturer's requirement/recommendation.

APPENDIX 2 CONDENSATION CHAMBER TEST

1 Test condition

Condensation chamber test shall be conducted in accordance with applicable standards[17].

.1 The exposure time is 180 days.

.2 There are to be 2 test panels.

.3 The size of each test panel is 150 *mm* x 150 *mm* x 3 *mm*. The panels are to be treated according to the Performance Standard, **table 1**, **paragraphs 1**, **2** and **3** and coating system applied according to **table 1**, **paragraphs 1.4** and **1.5**. Shop primer to be weathered for at least 2 months and cleaned by low pressure washing or other mild method. Blast sweep or high pressure washing, or other primer removal methods not to be used. Weathering method and extent shall take into consideration that the primer is to be the foundation for a 15 year target life system. To facilitate innovation, alternative preparation, coating systems and dry film thicknesses may be used when clearly defined.

.4 The reverse side of the test piece shall be painted appropriately, in order not to affect the test results.

[17] Reference standard: *ISO* 6270-1:*1998 Paints and varnishes – Determination of resistance to humidity – Part 1: Continuous condensation.*

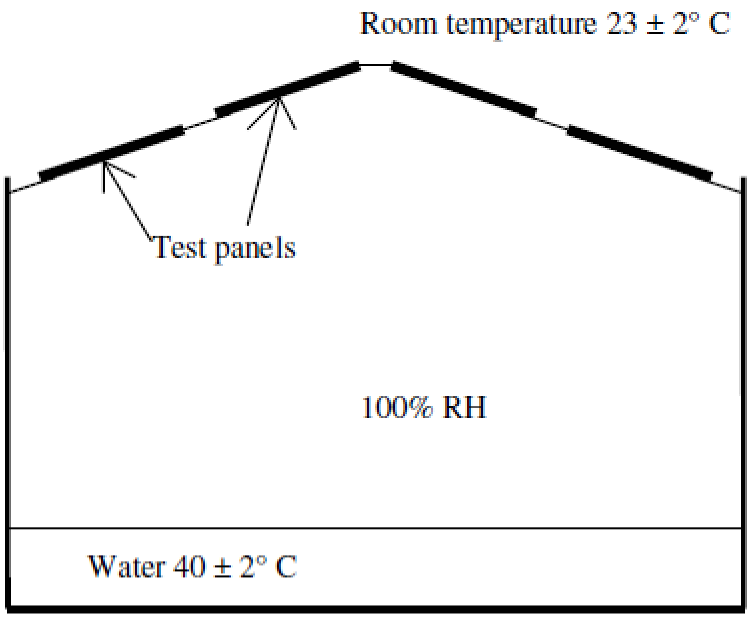

Fig. 2 Condensation chamber

2 Test results

According to **section 2** (except for **2.2.5** and **2.2.6**) of **appendix 1**.

3 Acceptance criteria

3.1 The test results based on **section 2** shall satisfy the following criteria:

Item	Acceptance criteria for epoxy-based systems applied according to **table 1** of this Standard	Acceptance criteria for alternative systems
Blisters on panel	No blisters	No blisters
Rust on panel	Ri 0 (0%)	Ri 0 (0%)
Number of pinholes	0	0
Adhesive failure	> 3.5 *MPa* Adhesive failure between substrate and coating or between coats for 60% or more of the areas.	> 5 *MPa* Adhesive failure between substrate and coating or between coats for 60% or more of the areas.
Cohesive failure	> 3 *MPa* Cohesive failure in coating for 40% or more of the area.	> 5 *MPa* Cohesive failure in coating for 40% or more of the area.

3.2 Epoxy-based systems tested prior to the date of entry into force of this Standard shall satisfy only the criteria for blistering and rust in the table above.

3.3 Epoxy based systems tested when applied according to **table 1** of this Standard shall satisfy the criteria for epoxy-based systems as indicated in the table above.

3.4 Alternative systems not necessarily epoxy-based and/or not necessarily applied according to **table 1** of this Standard shall satisfy the criteria for alternative systems as indicated in the table above.

4 Test report

According to **section 4** of **appendix 1**.

ANNEX 2 EXAMPLE OF DAILY LOG AND NON-CONFORMITY REPORT

DAILY LOG **Sheet No:**

Ship:	**Tank/Hold No:**	**Database:**
Part of structure:		
SURFACE PREPARATION		
Method: **Abrasive:** **Surface temperature:** **Relative humidity (max):** **Standard achieved:** **Rounding of edges:**	**Area (m^2):** **Grain size:** **Air temperature:** **Dew point:**	
Comments:		
Job No.:	**Date:**	**Signature:**
COATING APPLICATION: **Method:**		

Coat No.	**System**	**Batch No.**	**Date**	**Air temp.**	**Surf temp.**	**RH%**	**Dew point**	**DFT* Meas.***	**Specified**

* **Measured minimum and maximum DFT. DFT readings to be attached to daily log**

Comments:		
Job No:	**Date:**	**Signature:**

Non-conformity report **Sheet No:**

Ship:	**Tank/Hold No:**	**Database:**
Part of structure:		
DESCRIPTION OF THE INSPECTION FINDINGS TO BE CORRECTED		
Description of findings:		
Reference document (daily log):		
Action taken:		
Job No.:	**Date:**	**Signature:**

ANNEX 3 DRY FILM THICKNESS MEASUREMENTS

1 The following verification check points of DFT are to be taken:

.1 one gauge reading per $5m^2$ of flat surface areas;

.2 one gauge reading at 2 to $3m$ intervals and as close as possible to tank boundaries, but not further than $15mm$ from edges of tank boundaries;

.3 longitudinal and transverse stiffener members:

One set of gauge readings as shown below, taken at 2 to $3m$ run and not less than two sets between primary support members;

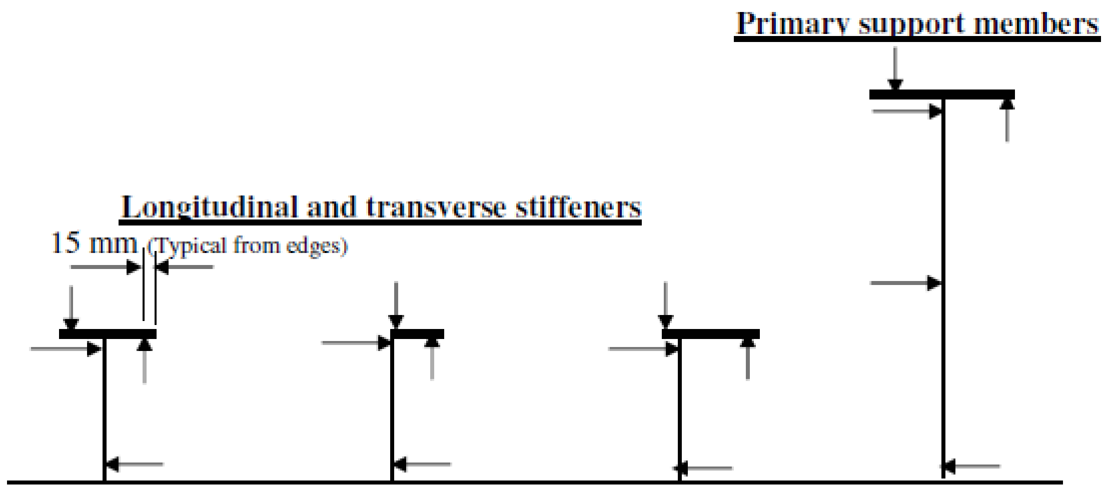

Fig. 3

NOTE: Arrows of diagram indicate critical areas and should be understood to mean indication for both sides.

.4 3 gauge readings for each set of primary support members and 2 gauge readings for each set of other members as indicated by the arrows in the diagram;

.5 for primary support members (girders and transverses) one set of gauge readings for 2 to 3 m run as shown in **Fig. 3** above but not less than three sets;

.6 around openings one gauge reading from each side of the opening;

.7 five gauge readings per square metre (m^2) but not less than three gauge readings taken at complex areas (i.e. large brackets of primary support members); and

.8 additional spot checks to be taken to verify coating thickness for any area considered necessary by the coating inspector.

Appendix C5 GUIDELINES FOR OWNERS/OPERATORS ON PREPARING EMERGENCY TOWING PROCEDURES (MSC.1/Circ.1255 ANNEX)

1 PURPOSE

The purpose of these Guidelines is to assist owners/operators in preparing ship-specific emergency towing procedures for ships subject to SOLAS regulation II-1/3-4. The procedures should be considered as part of the emergency preparedness required by paragraph 8 of part A of the International Safety Management (ISM) Code.

2 OBSERVATIONS

2.1 Owners, operators and crews should take into consideration that the nature of an emergency does not allow time for deliberation. Accordingly, the procedures should be practiced beforehand.

2.2 The towing procedures should be maintained on board the ship for ready use by the ship's crew in preparing their ship for towage in an emergency.

2.3 The crew should have good knowledge of equipment stowage location and accessibility. Any identified improvements to stowage arrangements should be implemented.

2.4 Crew dealing with an emergency situation should be aware of power availability required for winches and tools, as well as for deck lighting (for bad/low visibility and night time situations).

2.5 It is recognized that not all ships will have the same degree of shipboard equipment, so that there may be limits to possible towing procedures. Nevertheless, the intention is to predetermine what can be accomplished, and provide this information to the ship's crew in a ready-to-use format (booklet, plans, poster, etc.).

3 SHIP EVALUATION

3.1 The owner/operator should ensure that the ship is inspected and its capability to be towed under emergency situations is evaluated. Both equipment on board and available procedures should be reviewed. Items that need to be inspected are described in the following paragraphs.

3.2 The ability of the ship to be towed from bow and stern should be evaluated, and the following items should be reviewed:

- .1 line handling procedures (passing and receiving messenger lines, towlines, bridles); and
- .2 layout, structural adequacy and safe working loads of connection points (fairleads chocks, winches, bitts, bollards), etc.

3.3 The on-board tools and equipment available for assembling the towing gear and their locations should be identified. These should include but not be limited to:

- .1 chains;
- .2 cables;
- .3 shackles;
- .4 stoppers;
- .5 tools; and
- .6 line throwing apparatus.

3.4 The availability and characteristics of radio equipment on board should be identified, in order to enable communication between deck crew, bridge and the towing/salvage ship.

3.5 Unless the safe working loads of connection points are known, these loads should be determined by an engineering analysis reflecting the on-board conditions of the ship. The Guidance on shipboard towing and mooring equipment (MSC/Circ.1175) may be used for guidance.

3.6 The evaluation should be performed by persons knowledgeable in towing equipment and operations.

4 EMERGENCY TOWING BOOKLET

4.1 The Emergency Towing Booklet (ETB) should be ship specific and be presented in a clear, concise and ready-to-use format (booklet, plan, poster, etc.).

4.2 Ship-specific data should include but not be limited to:

.1 ship's name;

.2 call sign;

.3 IMO number;

.4 anchor details (shackle, connection details, weight, type, etc.);

.5 cable and chain details (lengths, connection details, proof load, etc.);

.6 height of mooring deck(s) above base;

.7 draft range; and

.8 displacement range.

4.3 All procedures developed in accordance with section 5 should be presented in a clear and easy to understand format, which will aid their smooth and swift application in an emergency situation.

4.4 Comprehensive diagrams and sketches should be available and include the following:

.1 assembly and rigging diagrams;

.2 towing equipment and strong point locations; and

.3 equipment and strong point capacities and safe working loads (SWLs).

4.5 A copy should be kept at hand by the owners/operators in order to facilitate the passing on of information to the towage company as early as possible in the emergency. A copy should also be kept in a common electronic file format, which will allow faster distribution to the concerned parties.

4.6 A minimum of three copies should be kept on board and located in:

.1 the bridge;

.2 a forecastle space; and

.3 the ship's office or cargo control room.

5 DEVELOPING PROCEDURES

5.1 Ship-specific procedures should be identified during the ship's evaluation and entered accordingly in the ETB. The procedures should include, as a minimum, the following:

.1 a quick-reference decision matrix that summarizes options under various emergency scenarios, such as weather conditions (mild, severe), availability of shipboard power (propulsion, on-deck power), imminent danger of grounding, etc.;

.2 organization of deck crew (personnel distribution, equipment distribution, including radios, safety equipment, etc.);

.3 organization of tasks (what needs to be done, how it should be done, what is needed for each task, etc.);

.4 diagrams for assembling and rigging bridles, tow lines, etc., showing possible emergency towing arrangements for both fore and aft. Rigged lines should be lead such that they avoid sharp corners, edges and other points of stress concentration;

.5 power shortages and dead ship situations, which must be taken into account, especially for the heaving across of heavy towing lines;

.6 a communications plan for contacting the salvage/towing ship . This plan should list all information that the ship's master needs to communicate to the salvage/towing ship. This list should include but not be limited to:

  .1 damage or seaworthiness;

  .2 status of ship steering;

  .3 propulsion;

  .4 on deck power systems;

  .5 on-board towing equipment;

  .6 existing emergency rapid disconnection system;

  .7 forward and aft towing point locations;

.8 equipment, connection points, strong points and safe working loads (SWL);

.9 towing equipment dimensions and capacities; and

.10 ship particulars;

.7 evaluation of existing equipment, tools and arrangements on board the ship for possible use in rigging a towing bridle and securing a towline;

.8 identification of any minor tools or equipment providing significant improvements to the "towability" of the ship;

.9 inventory and location of equipment on board that can be used during an emergency towing situation;

.10 other preparations (locking rudder and propeller shaft, ballast and trim, etc.); and

.11 other relevant information (limiting sea states, towing speeds, etc.).

Appendix C6 PERFORMANCE STANDARD FOR PROTECTIVE COATINGS FOR CARGO OIL TANKS (Resolution MSC.288(87) and IACS Unified Interpretations SC259)

1 PURPOSE

This Standard provides technical requirements for the minimum standard for protective coatings to be applied in cargo oil tanks during the construction of new crude oil tankers.

2 DEFINITIONS

For the purpose of this Standard, the following definitions apply:

2.1 *Crude oil tanker* is as defined in Annex I of *MARPOL* 73/78.

2.2 *Dew point* is the temperature at which air is saturated with moisture.

2.3 *DFT* is dry film thickness.

2.4 *Dust* is loose particulate matter present on a surface prepared for painting, arising from blast-cleaning or other surface preparation processes, or resulting from the action of the environment.

2.5 *Edge grinding* is the treatment of the edge before secondary surface preparation.

2.6 *"GOOD" condition* is the condition with minor spot rusting as defined in resolution *A*.1049(27) (2011 *ESP* Code) for assessing the ballast tank coatings for tankers.

2.7 *Hard coating* is a coating that chemically converts during its curing process or a non-convertible air drying coating which may be used for maintenance purposes. This can be either inorganic or organic.

2.8 *NDFT* is the nominal dry film thickness. 90/10 practice means that 90% of all thickness measurements shall be greater than or equal to NDFT and none of the remaining 10% measurements shall be below 0.9× NDFT.

2.9 *Primer coat* is the first coat of the coating system applied in the shipyard after shop primer application.

2.10 *Shop-primer* is the prefabrication primer coating applied to steel plates, often in automatic plants (and before the first coat of a coating system).

2.11 *Stripe coating* is painting of edges, welds, hard to reach areas, etc., to ensure good paint adhesion and proper paint thickness in critical areas.

2.12 *Target useful life* is the target value, in years, of the durability for which the coating system is designed.

2.13 *Technical Data Sheet* is the paint manufacturer's Product Data Sheet which contains detailed technical instruction and information relevant to the coating and its application.

****

Interpretation

GOOD: Condition with spot rusting on less than 3% of the area under consideration without visible failure of the coating, or no-perforated blistering. Breakdown at edges or welds should be less than 20% of edges or weld lines in the area under consideration.

Coating Technical File: A term used for the collection of documents describing issues related to the coating system and its application from the point in time when the first document is provided and for the entire life of the ship including the inspection agreement and all elements of PSPC-COT **3.4**.

****

3 GENERAL PRINCIPLES

3.1 The ability of the coating system to reach its target useful life depends on the type of coating system, steel preparation, operating environment, application and coating inspection and maintenance. All these aspects contribute to the good performance of the coating system.

3.2 Inspection of surface preparation and coating processes shall be agreed upon between the shipowner, the shipyard and the coating manufacturer and presented to the Administration for review. Clear evidence of these inspections shall be reported and included in the Coating Technical File (CTF) (see **3.4**).

****

Interpretation

1. Inspection of surface preparation and coating processes agreement shall be signed by shipyard, shipowner and coating manufacturer and shall be presented by the shipyard to the Administration for review prior to commencement of any coating work on any stage of a new building and as a minimum shall comply with the PSPC-COT.
2. To facilitate the review, the following from the CTF, shall be available:
   a) Coating specification including selection of areas (spaces) to be coated, selection of coating system, surface preparation and coating process.
   b) Statement of Compliance or Type Approval of the coating system.
3. The agreement shall be included in the CTF and shall at least cover:
   a) Inspection process, including scope of inspection, who carries out the inspection, the qualifications of the coating inspector(s) and appointment of one qualified coating inspector (responsible for verifying that the coating is applied in accordance with the PSPC-COT). Where more than one coating inspector will be used then their areas of responsibility shall be identified. (For example, multiple construction sites).
   b) Language to be used for documentation.
4. Any deviations in the procedure relative to the PSPC-COT noted during the review shall be raised with the shipyard, which is responsible for identifying and implementing the corrective actions.
5. Cargo Ship Safety Certificate or Cargo Ship Safety Construction Certificate, as appropriate, shall not be issued until all required corrective actions have been closed to the satisfaction of the Administration.

****

3.3 When considering the Standard provided in **section 4**, the following is to be taken into account:

.1 it is essential that specifications, procedures and the various different steps in the coating application process (including, but not limited to, surface preparation) are strictly applied by the shipbuilder in order to prevent premature decay and/or deterioration of the coating system;

.2 the coating performance can be improved by adopting measures at the ship design stage such as reducing scallops, using rolled profiles, avoiding complex geometric configurations and ensuring that the structural configuration permits easy access for tools and to facilitate cleaning, drainage and drying of the space to be coated; and

.3 the coating performance standard provided in this document is based on experience from manufacturers, shipyards and ship operators; it is not intended to exclude suitable alternative coating systems, providing a performance at least equivalent to that specified in this Standard is demonstrated. Acceptance criteria for alternative systems are provided in **section 8**.

3.4 Coating Technical File (CTF)

3.4.1 Specification of the cargo oil tank coating system applied, record of the shipyard's and shipowner's coating work, detailed criteria for coating selection, job specifications, inspection, maintenance and repair shall be included in the Coating Technical File required by resolution *MSC*.215(82).

3.4.2 New construction stage

The Coating Technical File shall contain at least the following items relating to this Standard and shall be delivered by the shipyard at new ship construction stage:

.1 copy of Statement of Compliance or Type Approval Certificate;

.2 copy of Technical Data Sheet, including:

.2.1 product name and identification mark and/or number;

.2.2 materials, components and composition of the coating system;

.2.3 minimum and maximum dry film thickness;

.2.4 application methods, tools and/or machines;

.2.5 condition of surface to be coated (de-rusting grade, cleanness, profile, etc.); and

.2.6 environmental limitations (temperature and humidity);

.3 shipyard work records of coating application, including:

.3.1 applied actual areas (*in square metres*) of coating in each cargo oil tank;

.3.2 applied coating system;
.3.3 time of coating, thickness, number of layers, etc.;
.3.4 ambient conditions during coating; and
.3.5 details of surface preparation;

.4 procedures for inspection and repair of coating system during ship construction;

.5 coating log issued by the coating inspector – stating that the coating was applied in accordance with the specifications to the satisfaction of the coating supplier representative and specifying deviations from the specifications (see **annex 2**);

.6 shipyard's verified inspection report, including:
.6.1 completion date of inspection;
.6.2 result of inspection;
.6.3 remarks (if given); and
.6.4 inspector signature; and

.7 procedures for in-service maintenance and repair of coating systems*.

* Refer to the "*Guidelines on procedures for in-service maintenance and repair of Coating systems for cargo oil tanks of crude oil tankers*" (*MSC*.1/*Circ*.1399).

3.4.3 In-service maintenance and repair

In-service maintenance and repair activities shall be recorded in the Coating Technical File in accordance with the relevant section of the Guidelines for coating maintenance and repair.

3.4.4 The Coating Technical File shall be kept on board and maintained throughout the life of the ship.

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Interpretation

Procedure for Coating Technical File Review

1 The shipyard is responsible for compiling the Coating Technical File (CTF) either in paper or electronic format, or a combination of the two.

2 The CTF is to contain all the information required by the PSPC-COT **3.4** and the inspection of surface preparation and the coating processes agreement (see PSPC-COT **3.2**).

3 The CTF shall be reviewed for content in accordance with the PSPC-COT **3.4.2**.

4 Any deviations found under **3** shall be raised with the shipyard, which is responsible for identifying and implementing the corrective actions.

5 Cargo Ship Safety Certificate or Cargo Ship Safety Construction Certificate, as appropriate, shall not be issued until all required corrective actions have been closed to the satisfaction of the Administration.

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3.5 Health and safety

The shipyard is responsible for implementation of national regulations to ensure the health and safety of individuals and to minimize the risk of fire and explosion.

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Interpretation

In order to document compliance with PSPC-COT **3.5**, relevant documentation from the coating manufacturer concerning health and safety aspects such as Material Safety Data Sheet is recommended to be included in the CTF for information.

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4 COATING STANDARD

4.1 Performance standard

This Standard is based on specifications and requirements to provide a target useful coating life of 15 years, which is considered to be the time period, from initial application, over which the coating system is intended to remain in "GOOD" condition. The actual useful life will vary, depending on numerous variables including actual conditions encountered in service.

4.2 Standard application

Protective coatings for cargo oil tanks applied during the construction of new crude oil tankers shall at least comply with the requirements in this Standard.

4.3 Coating system

An epoxy-based system meeting test and physical properties (**table 1.1.3**) shall be documented, and a Type Approval Certificate or Statement of Compliance shall be provided.

4.4 Area of application

The following areas are the minimum areas that shall be protected according to this Standard:

.1 Deckhead with complete internal structure, including brackets connecting to longitudinal and transverse bulkheads. In tanks with ring frame girder construction the underdeck transverse framing to be coated down to level of the first tripping bracket below the upper faceplate.

.2 Longitudinal and transverse bulkheads to be coated to the uppermost means of access level. The uppermost means of access and its supporting brackets to be fully coated.

.3 On cargo tank bulkheads without an uppermost means of access the coating to extend to 10% of the tanks height at centreline but need not extend more than 3 *m* down from the deck.

.4 Flat inner bottom and all structure to height of 0.3 *m* above inner bottom to be coated.

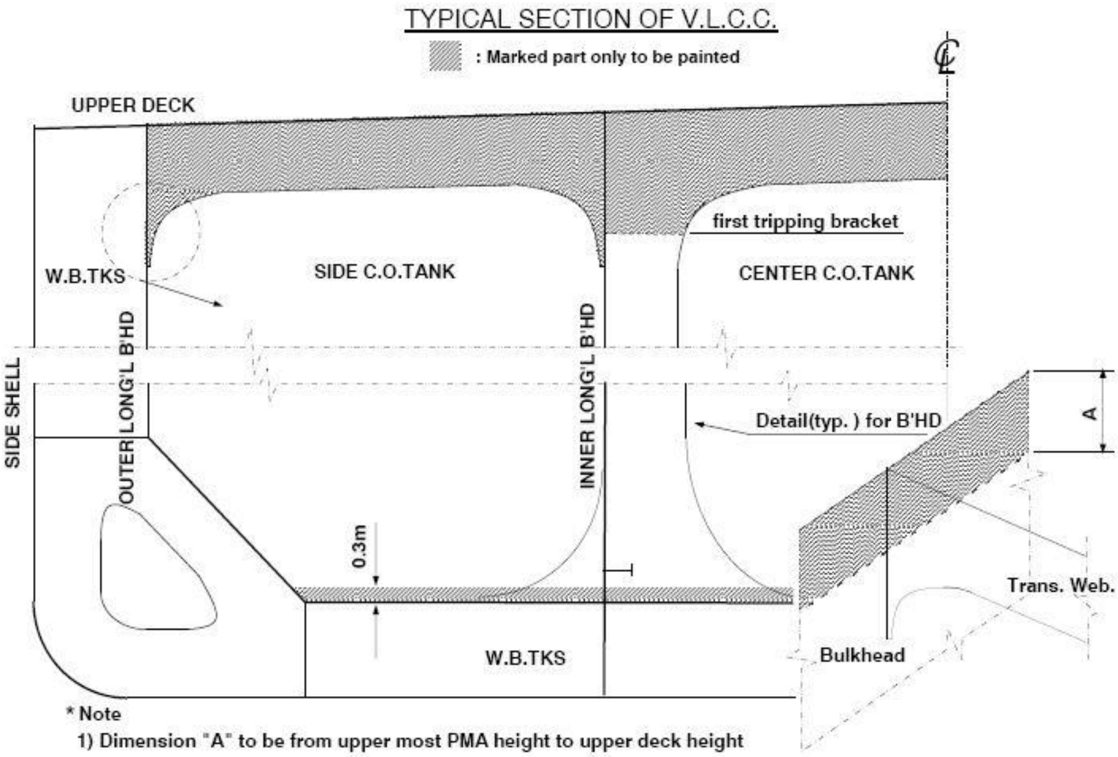

Fig. 1

4.5 Special application

4.5.1 This Standard covers protective coating requirements for steel structure within cargo oil tanks. It is noted that there are other independent items that are fitted within the cargo oil tanks and to which coatings are applied to provide protection against corrosion.

4.5.2 It is recommended that this Standard is applied, to the extent practicable, to those portions of means of access provided for inspection within the areas specified in subsection **4.4** that are not integral to the ship structure, such as rails, independent platforms, ladders, etc. Other equivalent methods of providing corrosion protection for non-integral items may also be used, provided they do not impair the performance of the coatings of the surrounding structure. Access arrangements that are integral to the ship structure, such as stiffener depths for walkways, stringers, etc., are to fully comply with this Standard when located within the coated areas.

4.5.3 It is also recommended that supports for piping, measuring devices, etc., be coated as a minimum in accordance with the non-integral items indicated in paragraph **4.5.2**.

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Interpretation

Reference is made to the non-mandatory *MSC/Circ.*1279 "Guidelines for corrosion protection of permanent means of access arrangements", adopted by *MSC* 84 in May 2008.

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4.6 Basic coating requirements

4.6.1 The requirements for protective coating systems to be applied at ship construction for the cargo oil tanks of crude oil tankers meeting the performance standard specified in paragraph **4.1** are listed in **table 1**.

4.6.2 Coating manufacturers shall provide a specification of the protective coating system to satisfy the requirements of **table 1** and the operating environment.

4.6.3 The Administration shall verify the Technical Data Sheet and Statement of Compliance or Type Approval Certificate for the protective coating system.

4.6.4 The shipyard shall apply the protective coating in accordance with the verified Technical Data Sheet and its own verified application procedures.

4.7 The referenced standards listed in this Standard are acceptable to the Organization. Test equipment, test methods, preparation methods and/or test results shall conform to performance standards not inferior to those acceptable to the Organization.

Table 1 Basic Coating System Requirements for Cargo Oil Tanks of Crude Oil Tankers

	Characteristic	Requirement
1 Design of coating system		
.1	Selection of the coating system	The selection of the coating system shall be considered by the parties involved with respect to the service conditions and planned maintenance. The following aspects, among other things shall be considered: .1 location of space relative to heated surfaces; .2 frequency of cargo operations; .3 required surface conditions; .4 required surface cleanliness and dryness; .5 supplementary cathodic protections, if any (where coating is supplemented by cathodic protection, the coating shall be compatible with the cathodic protection system); .6 permeability of the coating and resistance to inert gas and acids; and .7 appropriate mechanical properties (flexibility, impact resistance). The coating manufacturer shall supply products with documented satisfactory performance records and technical data sheets. The manufacturer shall also be capable of rendering adequate technical assistance. Performance records, technical data sheet and any manufacturer's technical assistance provided shall be recorded in the Coating Technical File. Coatings for application underneath sun-heated decks or on bulkheads forming boundaries of heated spaces shall be able to withstand repeated heating and/or cooling without becoming brittle.
.2	Coating type	Epoxy based systems. Other coating systems with performance according to the test procedure in **annex 1**. A multi-coat system with each coat of contrasting colour is recommended. The top coat shall be of a light colour to facilitate in-service inspection. Consideration should be given to the use of enhanced coatings in way of suction bellmouths and heating coil downcomers. Consideration should be given to the use of supplementary cathodic protection where there may be galvanic issues.
.3	Coating test	Epoxy based systems tested prior to the date of entry into force of this Standard in a laboratory by a method corresponding to the test procedure in **annex 1** or equivalent, which as a minimum meets the requirements for rusting and blistering; or which have documented field exposure for 5 years with a final coating condition of not less than "GOOD" may be accepted. For epoxy-based systems approved on or after entry into force of this Standard, testing according to the procedure in **annex 1**, or equivalent, is required.

.4	Job specification	There shall be a minimum of two stripe coats and two spray coats, except that the second stripe coat, by way of welded seams only, may be reduced in scope where it is proven that the NDFT can be met by the coats applied in order to avoid unnecessary over thickness. Any reduction in scope of the second stripe coat shall be fully detailed in the CTF. Stripe coats shall be applied by brush or roller. Roller shall be used for scallops, ratholes, etc. , only. Each main coating layer shall be appropriately cured before application of the next coat, in accordance with the coating manufacturer's recommendations. Job specifications shall include the dry-to-recoat times and walk-on time given by the manufacturer. Surface contaminants such as rust, grease, dust, salt, oil, etc., shall be removed prior to painting. The method to be according to the paint manufacturer's recommendations. Abrasive inclusions embedded in the coating shall be removed.
.5	NDFT (nominal total dry film thickness)[1]	NDFT 320μm with 90/10 rule for epoxy based systems; other systems to coating manufacturer's specifications. Maximum total dry film thickness according to manufacturer's detailed specifications. Care shall be taken to avoid increasing the DFT in an exaggerated way. Wet film thickness shall be regularly checked during application. Thinner shall be limited to those types and quantities recommended by the manufacturer.
2 PSP (Primary Surface Preparation)		
.1	Blasting and Profile.[2, 3]	Sa2½; with profiles between 30-75μm Blasting shall not be carried out when: .1 the relative humidity is above 85%; or .2 the surface temperature of steel is less than 3°C above the dew point. Checking of the steel surface cleanliness and roughness profile shall be carried out at the end of the surface preparation and before the application of the primer, and in accordance with the coating manufacturer's recommendations.
.2	Water soluble salt limit equivalent to NaCl[4]	≤ 50 mg/m^2 of sodium chloride.
.3	Shop primer	Zinc containing inhibitor free zinc silicate based or equivalent. Compatibility with main coating system shall be confirmed by the coating manufacturer.
3 Secondary surface preparation		
.1	Steel condition[5]	The steel surface to be coated shall be prepared so that the coating selected can achieve an even distribution at the required NDFT and have an adequate adhesion by removing sharp edges, grinding weld beads and removing weld spatter and any other surface contaminant to grade P2. Edges to be treated to a rounded radius of minimum 2 mm, or subjected to three pass grinding

		or at least equivalent process before painting.
.2	Surface treatment[2]	Sa2½ on damaged shop primer and welds. All surfaces to be coated shall be blasted to Sa 2, removing at least 70% of intact shop primer, which has not passed a pre-qualification certified by test procedures in **1.3**. If the complete coating system comprising epoxy-based main coating and shop primer has passed a pre-qualification certified by test procedures in **1.3** intact shop primer may be retained provided the same epoxy-based system is used. Retained shop primer shall be cleaned by sweep blasting, high pressure water washing or equivalent method. If a zinc silicate shop primer has passed the pre-qualification test of **1.3** as part of an epoxy coating system, it may be used in combination with other epoxy coatings certified under **1.3**, provided that the compatibility has been confirmed by the manufacturer by the test with reference to the immersion test of **annex 1** or in accordance with the Performance standard for protective coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers (resolution *MSC*.215(82)).
.3	Surface treatment after erection	Erection joints St 3 or better or Sa 2½ where practicable. For inner bottom: - Damages up to 20% of the area to be coated to be treated to minimum St 3. - Contiguous damages over 25m^2 or over 20% of the area to be coated, Sa 2½ shall be applied. For underdeck: - Damages up to 3% of area to be coated to be treated to minimum St 3. - Contiguous damages over 25m^2 or over 3% of the area to be coated, Sa 2½ shall be applied. Coating in overlap to be feathered.
.4	Profile requirements[3]	In case of full or partial blasting 30-75μm, otherwise as recommended by the coating manufacturer.
.5	Dust[6]	Dust quantity rating “1” for dust size class “3”, “4” or “5”. Lower dust size classes to be removed if visible on the surface to be coated without magnification.
.6	Water soluble salts limit equivalent to NaCl after blasting/ grinding[4]	≤ 50 mg/m^2 of sodium chloride.
.7	Contamination	No oil contamination. Paint manufacturer's recommendations should be followed regarding any other contamination between coats.
4 Miscellaneous		
.1	Ventilation	Adequate ventilation is necessary for the proper drying and curing of coating. Ventilation should be maintained throughout the application process and for a period after application is completed, as recommended by the coating manufacturer.
.2	Environmental conditions	Coating shall be applied under controlled humidity and surface conditions, in accordance with the manufacturer’s specifications. In addition, coating shall not be applied when:

		.1 the relative humidity is above 85%; or .2 the surface temperature is less than 3°C above the dew point; or .3 any other requirements of the paint manufacturer are not being met.
.3	Testing of coating[1]	Destructive testing should be avoided. Sample dry film thickness shall be measured after each coat for quality control purpose and the total dry film thickness shall be confirmed after completion of the final coat, using appropriate thickness gauges.
.4	Repair	Any defective areas, e.g. pin-holes, bubbles, voids, etc. should be marked up and appropriate repairs effected. All such repairs shall be re-checked and documented.

[1] Type of gauge and calibration in accordance with SSPC-PA2: 2004. *Paint Application Specification No.2.*

[2] Refer to standard: *ISO* 8501-1: *1988/Suppl: 1994. Preparation of steel substrate before application of paints and related products – Visual assessment of surface cleanliness.*

[3] Refer to standard: *ISO* 8503-1/2: *1988. Preparation of steel substrate before application of paints and related products – Surface roughness characteristics of blast-cleaned steel substrates.*

[4] Conductivity measured in accordance with the following standards:

.1 *ISO* 8502-9: *1998. Preparation of steel substrate before application of paints and related products – Test for the assessment of surface cleanliness*; or

.2 *NACE SP*0508-2010 *Item no.*21134. *Standard practice methods of validating equivalence to ISO* 8502-9 *on measurement of the levels of soluble salts.*

[5] Refer to standard: *ISO* 8501-3: *2001. Preparation of steel substrate before application of paints and related products – Visual assessment of surface cleanliness.*

[6] Refer to standard: *ISO* 8502-3:*1993. Preparation of steel substrate before application of paints and related products – Test for the assessment of surface cleanliness.*

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Interpretation regarding Table 1

1 Design of coating system

1.3 Coating pre-qualification test

Procedure for Coating System Approval

Type Approval Certificate showing compliance with the PSPC-COT 5 shall be issued if the results of either method A+C or B+C are found satisfactory by the Administration.

The Type Approval Certificate shall indicate the Product and the Shop Primer tested. The certificate shall also indicate other type approved shop primers with which the product may be used which have under gone the cross over test in a laboratory meeting the requirements in Method A, **1.1** of this UI.

The documents required to be submitted are identified in the following sections, in addition for all type approvals the following documentation is required:

Technical Data Sheet showing all the information required by PSPC-COT **3.4.2.2**.

Winter type epoxy is required separate prequalification test including shop primer compatibility test according to PSPC-COT **Annex 1**. Winter and summer type coating are considered different unless Infrared (IR) identification and Specific Gravity (SG) demonstrates that they are the same.

Method A: Laboratory Test

1.1 Coating pre-qualification test shall be carried out by the test laboratory which is recognized by the Administration.

1.2 Results from satisfactory pre-qualification tests (PSPC-COT **Table 1**: **1.3**) of the coating system shall be documented and submitted to the Administration.

1.3.1 Type Approval tests shall be carried out for the epoxy based system with the stated shop primer in accordance with the PSPC-COT **Annex 1**. If the tests are satisfactory, a Type Approval Certificate will be issued to include both the epoxy and the shop primer. The Type Approval Certificate will allow the use of the epoxy either with the named shop primer or on bare prepared steel.

1.3.2 An epoxy based system may be used with shop primers other than the one with which it was originally tested provided that, the other shop primers are approved as part of a system, PSPC-COT **Table 1**: **2.3** and **Table 1**: **3.2**, and have been tested according to the immersion test of PSPC-COT **Annex 1** or in accordance with Res.MSC.215(82), which is known as the "Crossover Test". If the test or tests are satisfactory, a Type Approval Certificate will be issued. In this instance the Type Approval Certificate will include the details of the epoxy and a list of all shop primers with which it has been tested that have passed these requirements. The Type Approval Certificate will allow the use of the epoxy with all the named shop primers or on bare prepared steel.

1.3.3 Alternatively the epoxy can be tested without shop primer on bare prepared steel to the requirements of the PSPC-COT **Annex 1**. If the test or tests are satisfactory, a Type Approval Certificate will be issued. The Type Approval Certificate will just record the epoxy. The certificate will allow the use of the epoxy on bare prepared steel only. If in addition, crossover tests are satisfactorily carried out with shop primers, which are approved as part of a system, the Type Approval Certificate will include the details of shop primers which have satisfactorily passed the crossover test. In this instance the Type Approval Certificate will allow the use of the epoxy based system with all the named shop primers or on bare prepared steel.

1.3.4 The Type Approval Certificate is invalid if the formulation of either the epoxy or the shop primer is changed. It is the responsibility of the coating manufacturer to inform the Administration immediately of any changes to the formulation.

1.3.5 For the coating pre-qualification test, the measured average dry film thickness (DFT) on each prepared test panels shall not exceed a nominal DFT (NDFT) of 320 microns plus 20% unless a paint manufacturer specifies a NDFT greater than 320 microns. In the latter case, the average DFT shall not exceed the specified NDFT plus 20% and the coating system shall be certified to the specified NDFT if the system passes the tests according to **Annex 1** of PSPC-COT. The measured DFT shall meet the "90/10" rule and the maximum DFT shall be below the maximum DFT value specified by the manufacturer.

Method B: 5 years field exposure

1.4 Coating manufacturer's records, which shall at least include the information indicated in **1.4.1**, shall be examined to confirm coating system has 5 years field exposure, and the current product is the same as that being assessed.

1.4.1 Manufacturer's Records

- Original application records
- Original coating specification
- Original technical data sheet
- Current formulation's unique identification (Code or number)
- If the mixing ratio of base and curing agent has changed, a statement from the coating manufacturer confirming that the composition mixed product is the same as the original composition. This shall be accompanied by an explanation of the modifications made.
- Current technical data sheet for the current production site
- SG and IR identification of original product
- SG and IR identification of the current product
- If original SG and IR cannot be provided then a statement from the coating manufacturer confirming the readings for the current product are the same as those of the original.

1.5 Either class survey records from an Administration or a joint (coating manufacturer and Administration) survey of cargo tanks of a selected vessel is to be carried out for the purpose of verification of compliance with the requirements of **1.4** and **1.9**. The reporting of the coating condition in both cases shall be in accordance with the principles given in **section 4** of *MSC*.1/*Circ*.1399.

1.6 The selected vessel is to have cargo tanks in regular use, of which:

- At least one tank is exposed to minimum temperature of 60 degree C plus or minus 3 degree
- For field exposure the ship should be trading in varied trade routes and carrying substantial varieties of crude oils including highest temperature and lowest pH limits to ensure a realistic sample: for example, three ships on three different trade areas with different varieties of crude cargoes.

1.7 In the case that the selected vessel does not meet the requirements in **1.6** then the limitations on lowest pH and Highest temperature of crude oils carried shall be clearly stated on the type approval certificate.

1.8 In all cases of approval by Method B, the shop primer shall be removed prior to application of the approved epoxy based system coating, unless it can be confirmed that the shop primer applied during construction, is identical in formulation to that applied in the selected vessel used as a basis of the approval.

1.9 All cargo oil tanks shall be in "GOOD" condition excluding mechanical damages, without touch up or repair in the prior 5 years.

1.9.1 "Good" is defined as: Condition with spot rusting on less than 3% of the area under consideration without visible failure of the coating, or no perforated blistering. Breakdown at edges or welds should be less than 20% of edges or welds in the area under consideration.

1.9.2 Examples of how to report coating conditions with respect to areas under consideration should be as those given in the principles given in **section 4** of *MSC*.1/*Circ*.1399.

1.10 If the applied NDFT is greater than required by the PSPC, the applied NDFT will be the minimum to be applied during construction. This will be reported prominently on the Type Approval Certificate.

1.11 If the results of the inspection are satisfactory, a Type Approval Certificate shall be issued to include both the epoxy based system and the shop primer. The Type Approval Certificate shall allow the use of the epoxy based system either with the named shop primer or on bare prepared steel. The Type Approval Certificate shall reference the inspection report which will also form part of the Coating Technical File.

1.12 The Type Approval Certificate is invalid if the formulation of either the epoxy based system or the shop primer is changed. It is the responsibility of the coating manufacturer to inform the Administration immediately of any changes to the formulation.

Method C: Coating Manufacturer

1.13 The coating/shop primer manufacturer shall meet the requirements set out in **IACS UR Z17** paragraphs **4**, **5**, **6** and **7**, (except for **4.6**) and paragraphs **1.13.1** to **1.13.6** below, which shall be verified by the Administration.

1.13.1 Coating Manufacturers

(a) Extent of Engagement – Production of coating systems in accordance with PSPC-COT and this UI.

(b) These requirements apply to both the main coating manufacturer and the shop primer manufacturer where both coatings form part of the total system.

(c) The coating manufacturer should provide to the Administration the following information;

- A detailed list of the production facilities.
- Names and location of raw material suppliers will be clearly stated.
- A detailed list of the test standards and equipment to be used, (Scope of approval).
- Details of quality control procedures employed.
- Details of any sub-contracting agreements.
- List of quality manuals, test procedures and instructions, records, etc.
- Copy of any relevant certificates with their issue number and/or date e.g. Quality Management System certification.

(d) Inspection and audit of the manufacturer's facilities will be based on the requirements of the PSPC-COT.

(e) With the exception of early 'scale up' from laboratory to full production, adjustment outside the limitations listed in the QC instruction referred to below is not acceptable, unless justified by trials during the coating system's development programme, or subsequent testing. Any such adjustments must be agreed by the formulating technical centre.

(f) If formulation adjustment is envisaged during the production process the maximum allowable limits will be approved by the formulating technical centre and clearly stated in the QC working procedures.

(g) The manufacturer's quality control system will ensure that all current production is the same formulation as that supplied for the Type Approval Certificate. Formulation change is not permissible without testing in accordance with the test procedures in the PSPC-COT and the issue of a Type Approval Certificate by the Administration.

(h) Batch records including all QC test results such as viscosity, specific gravity and airless spray characteristics will be accurately recorded. Details of any additions will also be included.

(i) Whenever possible, raw material supply and lot details for each coating batch will be traceable. Exceptions may be where bulk supply such as solvents and pre-dissolved solid epoxies are stored in tanks, in which case it may only be possible to record the supplier's blend.

(j) Dates, batch numbers and quantities supplied to each coating contract will be clearly recorded.

1.13.2 All raw material supply must be accompanied the supplier's 'Certificate of Conformance'. The certificate will include all requirements listed in the coating manufacturer's QC system.

1.13.3 In the absence of a raw material supplier's certificate of conformance, the coating manufacturer must verify conformance to all requirements listed in the coating manufacturer's QC system.

1.13.4 Drums must be clearly marked with the details as described on the 'Type Approval Certificate'.

1.13.5 Product Technical Data Sheets must comply with all the PSPC-COT requirements. The QC system will ensure that all Product Technical Data Sheets are current.

1.13.6 QC procedures of the originating technical centre will verify that all production units comply with the above stipulations and that all raw material supply is approved by the technical centre.

1.14 In the case that a coating manufacturer wishes to have products which are manufactured in different locations under the same name, then IR identification and SG shall be used to demonstrate that they are the same coating, or individual approval tests will be required for the paint manufactured in each location.

1.15 The Type Approval Certificate is invalid if the formulation of either the epoxy based system or the shop primer is changed. It is the responsibility of the coating manufacturer to inform class immediately of any changes to the formulation. Failure to inform class of an alteration to the formulation will lead to cancellation of the certificates for that manufacturer's products.

Interpretation regarding 1.4 Job specification and 1.5 NDFT (nominal total dry film thickness)

Wet film thickness shall be regularly checked during application for quality control by the Builder. PSPC-COT does not state who should check WFT, it is accepted for this to be the Builder. Measurement of DFT shall be done as part of the inspection required in PSPC-COT **6**.

Stripe coats should be applied as a coherent film showing good film formation and no visible defects. The application method employed should insure that all areas that require stripe coating are properly coated by brush or roller. A roller may be used for scallops, ratholes etc., but not for edges and welds.

2 PSP (Primary Surface Preparation)

Interpretation regarding 2.2 Water soluble salt limit equivalent to NaCl

The conductivity of soluble salts is measured in accordance with *ISO* 8502-6 and *ISO* 8502-9 or equivalent method as validated according to NACE SP0508-2010, and compared with the conductivity of $50 mg/m^2$ NaCl. If the measured conductivity is less than or equal to, then it is acceptable. Minimum readings to be taken are one (1) per plate in the case of manually applied shop primer. In cases where an automatic process for application of shop primer is used, there should be means to demonstrate compliance with PSPC-COT through a Quality Control System, which should include a monthly test.

Interpretation regarding 2.3 Shop primer

Shop primers not containing zinc or not silicate based are considered to be "alternative systems" and therefore equivalency is to be established in accordance with **Section 8** of the PSPC-COT with test acceptance criteria for "alternative systems" given in Section 3.1 (right columns) of **Appendixes 1** and **2** to Annex 1 of PSPC-COT.

Interpretation regarding Procedure for review of Quality Control of Automated Shop Primer plants

1 It is recognised that the inspection requirements of PSPC-COT **6.2** may be difficult to apply to an automated shop primer plant and a Quality Control approach would be a more practical way of enabling compliance with the requirements of PSPC-COT.

2 As required in PSPC it is the responsibility of the coating inspector to confirm that the quality control procedures are ensuring compliance with PSPC-COT.

3 When reviewing the Quality Control for automated shop primer plants the following procedures should be included.

3.1 Procedures for management of the blasting grit including measurement of salt and contamination.

3.2 Procedures recording the following; steel surface temperature, relative humidity, dewpoint.

3.3 Procedures for controlling or monitoring surface cleanliness, surface profile, oil, grease, dust and other contamination.

3.4 Procedures for recording/measuring soluble salts.

3.5 Procedures for verifying thickness and curing of the shop primer conforms to the values specified in the Technical Specification.

3 SSP (Secondary Surface Preparation)

Interpretation regarding 3.2 Surface treatment, 3.3 Surface treatment after erection, and 3.4 Profile requirement

Usually, the fillet welding on tank boundary watertight bulkhead is left without coating on block stage (because not yet be leakage tested), in which case it can be categorized as erection joint ("butt") to be power tooled to St 3.

Interpretation regarding 3.6 Water soluble salts limit equivalent to NaCl after blasting/grinding

The conductivity of soluble salts is measured in accordance with *ISO* 8502-6 and *ISO* 8502-9 or equivalent method as validated according to NACE SP0508-2010, and compared with the conductivity of $50 mg/m^2$ NaCl. If the measured conductivity is less than or equal to, then it is acceptable.

All soluble salts have a detrimental effect on coatings to a greater or lesser degree. *ISO* 8502-9:1998 does not provide the actual concentration of NaCl. The % NaCl in the total soluble salts will vary from site to site. Minimum readings to be taken are one (1) reading per block/section/unit prior to applying.

4 Miscellaneous

4.3 Testing of coating

All DFT measurements shall be measured. Only the final DFT measurements need to be measured and reported for compliance with the PSPC-COT by the qualified coating inspector. The Coating Technical File may contain a summary of the DFT measurements which typically will consist of minimum and maximum DFT measurements, number of measurements taken and percentage above and below required DFT. The final DFT compliance with the 90/10 practice shall be calculated and confirmed, see PSPC-COT **2.8**.

Interpretation regarding footnotes

Only the footnoted standards referred to in PSPC-COT **Table 1** are to be applied, i.e. they are mandatory.

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5 COATING SYSTEM APPROVAL

Results from prequalification tests (**table 1**, **paragraph 1.3**) of the coating system shall be documented, and a Statement of Compliance or Type Approval Certificate shall be issued if found satisfactory by a third party, independent of the coating manufacturer.

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Interpretation

See Interpretation of PSPC-COT **Table 1: 1** Design of coating system, **1.3** Coating prequalification test.

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6 COATING INSPECTION REQUIREMENTS

6.1 General

6.1.1 To ensure compliance with this Standard, the following shall be carried out by qualified coating inspectors certified to NACE Coating Inspector Level 2, FROSIO Inspector Level III or equivalent as verified by the Administration.

6.1.2 Coating inspectors shall inspect surface preparation and coating application during the coating process by carrying out, as a minimum, those inspection items identified in subsection **6.2** to ensure compliance with this Standard. Emphasis shall be placed on initiation of each stage of surface preparation and coatings application as improper work is extremely difficult to correct later in the coating progress. Representative structural members shall be non-destructively examined for coating thickness. The inspector shall verify that appropriate collective measures have been carried out.

6.1.3 Results from the inspection shall be recorded by the inspector and shall be included in the CTF (see **annex 2**).

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Interpretation

Procedure for Assessment of Coating Inspectors' Qualifications

1 Coating inspectors required to carry out inspections in accordance with the PSPC-COT **6** shall be qualified to NACE Coating Inspector Level 2, FROSIO Inspector Level III, or an equivalent qualification. Equivalent qualifications are described in **3** below.

2 However, only coating inspectors with at least 2 years relevant coating inspector experience and qualified to NACE Coating Inspector Level 2 or FROSIO Inspector Level III, or with an equivalent qualification, can write and/or authorise procedures, or decide upon corrective actions to overcome non-compliances.

3 Equivalent Qualification

3.1 Equivalent qualification is the successful completion, as determined by course tutor, of an approved course.

3.1.1 The course tutors shall be qualified with at least 2 years relevant experience and qualified to NACE Coating Inspector Level 2 or FROSIO Inspector Level III, or with an equivalent qualification.

3.1.2 Approved Course: A course that has a syllabus based on the issues associated with the PSPC including the following:

- Health Environment and Safety
- Corrosion
- Materials and design
- International standards referenced in PSPC
- Curing mechanisms
- Role of inspector
- Test instruments
- Inspection Procedures
- Coating specification
- Application Procedures
- Coating Failures
- Pre-job conference
- MSDS and product data sheet review
- Coating technical file
- Surface preparation
- Dehumidification
- Waterjetting
- Coating types and inspection criteria
- Specialized Application Equipment
- Use of inspection procedures for destructive testing and non destructive testing instruments.
- Inspection instruments and test methods
- Coating inspection techniques
- Cathodic protection
- Practical exercises, case studies.

Examples of approved courses may be internal courses run by the coating manufacturers or shipyards etc.

3.1.3 Such a course shall have an acceptable measurement of performance, such as an examination with both theoretical and practical elements. The course and examination shall be approved by the Administration.

3.2 Equivalent qualification arising from practical experience: An individual may be qualified without attending a course where it can be shown that the individual:

- has a minimum of 5-years practical work experience as a coating inspector of ballast tanks and/or cargo tanks during new construction within the last 10 years, and
- has successfully completed the examination given in **3.1.3**.

4 Assistants to coating inspectors

4.1 If the coating inspectors requires assistance from other persons to perform the part of the inspections, those persons shall perform the inspections under the coating inspector's supervision and shall be trained to the coating inspector's satisfaction.

4.2 Such training should be recorded and endorsed either by the inspector, the yard's training organization or inspection equipment manufacturer to confirm competence in using the measuring equipment and confirm knowledge of the measurements required by the PSPC-COT.

4.3 Training records shall be available for verification.

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6.2 Inspection items

Construction stage		Inspection items
Primary surface preparation	1	The surface temperature of steel, the relative humidity and the dew point shall be measured and recorded before the blasting process starts and at times of sudden changes in weather.
	2	The surface of steel plates shall be tested for soluble salt checked for oil, grease and other contamination.
	3	The cleanliness of the steel surface shall be monitored in the shop primer application process.
	4	The shop primer material shall be confirmed to meet the requirements of **2.3** of **table 1**.
Thickness		If compatibility with the main coating system has been declared, then the thickness and curing of the zinc silicate shop primer to be confirmed to conform to the specified values.
Block assembly	1	After completing construction of the block and before secondary surface preparation starts, a visual inspection for steel surface treatment including edge treatment shall be carried out. Any oil, grease or other visible contamination to be removed.
	2	After blasting/grinding/cleaning and prior to coating, a visual inspection of the prepared surface shall be carried out. On completion of blasting and cleaning and prior to the application of the first coat of the system, the steel surface shall be tested for levels of remaining soluble salts in at least one location per block.
	3	The surface temperature, the relative humidity and the dew point shall be monitored and recorded during the coating application and curing.
	4	Inspection to be performed of the steps in the coating application process mentioned in **table 1**.
	5	DFT measurements shall be taken to prove that the coating has been applied to the thickness as specified.
Erection	1	Visual inspection for steel surface condition, surface preparation and verification of conformance to other requirements in **table 1**, and the agreed specification to be performed.
	2	The surface temperature, the relative humidity and the dew point shall be measured and recorded before coating starts and regularly during the coating process.
	3	Inspection to be performed of the steps in the coating application process mentioned in **table 1**.

7 COATING VERIFICATION REQUIREMENTS

The following shall be carried out by the Administration prior to reviewing the Coating Technical File for the ship subject to this Standard:

.1 check that the Technical Data Sheet and Statement of Compliance or Type Approval Certificate comply with the Standard;

.2 check that the coating identification on representative containers is consistent with the coating identified in the Technical Data Sheet and Statement of Compliance or Type Approval Certificate;

.3 check that the inspector is qualified in accordance with the qualification standards in paragraph **6.1.1**;

.4 check that the inspector's reports of surface preparation and the coating's application indicate compliance with the manufacturer's Technical Data Sheet and Statement of Compliance or Type Approval Certificate; and

.5 monitor implementation of the coating inspection requirements.

****

Interpretation

Procedure for Verification of Application of the PSPC-COT

1 The verification requirements of PSPC-COT **7** shall be carried out by the Administration.

1.1 Monitoring implementation of the coating inspection requirements, as called for in PSPC-COT **7.5** means checking, on a sampling basis, that the inspectors are using the correct equipment, techniques and reporting methods as described in the inspection procedures reviewed by the Administration.

2 Any deviations found under **1.1** shall be raised initially with the coating inspector, who is responsible for identifying and implementing the corrective actions.

3 In the event that corrective actions are not acceptable to the Administration or in the event that corrective actions are not closed out then the shipyard shall be informed.

4 Cargo Ship Safety Certificate or Cargo Ship Safety Construction Certificate, as appropriate, shall not be issued until all required corrective actions have been closed out to the satisfaction of the Administration.

****

8 ALTERNATIVE COATING SYSTEMS

8.1 All systems that are not an epoxy based system applied according to **table 1** of this Standard are defined as an alternative system.

8.2 This Standard is based on recognized and commonly used coating systems. It is not meant to exclude other, alternative, systems with proven equivalent performance, for example non epoxy based systems.

8.3 Acceptance of alternative systems shall be subject to documented evidence that they ensure a corrosion prevention performance at least equivalent to that indicated in this Standard, by either:

.1 testing according to this standard; or

.2 five years' field exposure with documentary evidence of continuous trading with crude oil cargoes.* The coating condition is not less than "GOOD" after five years.

* For field exposure the ship should be trading in varied trade routes and carrying substantial varieties of crude oils to ensure a realistic sample: for example, three ships on three different trade areas with different varieties of crude cargoes.

ANNEX 1
TEST PROCEDURES FOR COATING QUALIFICATION FOR CARGO OIL TANKS OF CRUDE OIL TANKERS

1 Scope

This annex provides details of the test procedures for cargo tank coatings for crude oil carriers as referred to in paragraphs **4.6** and **8.3** of this Standard. Both the tank-top and deck-head should be applied with coating systems that have passed the full test protocol as described in this document.

2 Definitions

Coating specification means the specification of coating systems which include the type of coating system, steel preparation, surface preparation, surface cleanliness, environmental conditions, application procedure, inspection and acceptance criteria.

3 Background

It is acknowledged that a crude oil cargo tank on board a ship is exposed to two very different environmental conditions.

3.1 When the cargo tank is loaded there are three distinct vertical zones:

.1 Lowest part, and horizontal parts on stringer decks, etc., exposed to water that can be acidic and sludge that can contain anaerobic bacteria.

.2 Mid part where the oil cargo is in contact with all immersed steel.

.3 Vapour space where the air is saturated with various vapours from the loaded cargo tank such as H_2S, CO_2, SO_2, water vapour and other gases and compounds from the inert gas system.

3.2 When the tank is in a ballast condition:

.1 Lowest part and horizontal parts on stringer decks, etc., exposed to cargo residues and water that can be acidic and sludge that can contain anaerobic bacteria.

.2 Tank space where the air contains various vapours from the crude oil residues such as H_2S, CO_2, SO_2, water vapour and other gases and compounds from the inert gas system.

4 Testing

The tests herein are designed to simulate, as far as practicable, the two main environmental conditions to which the crude oil cargo tank coating will be exposed. The coating shall be validated by the following tests: the test procedures shall comply with **Appendix 1** (Gas-tight chamber simulating the vapour phase of the loaded tank) and **Appendix 2** (Immersion test simulating the loaded condition of the crude oil tank[1])

[1] Related test method is derived from, but not identical to, standard *ISO* 2812-1:*2007 - Paints and varnishes - Determination of resistance to liquids - Part 1: Immersion in liquids other than water*.

5 Test gas composition

The test gas is based on the composition of the vapour phase in crude oil tanks, except that the hydrocarbon components are not included as these have no detrimental effect on epoxy coatings such as those used in cargo oil tanks.

TEST GAS COMPOSITION

N_2	83 ± 2 %vol.
CO_2	13 ± 2 %vol.
O_2	4 ± 1 %vol.
SO_2	300 ± 20 *ppm*
H_2S	200 ± 20 *ppm*

6 Test liquid

Crude oil is a complex chemical material which is not stable over time when stocked. Crude oils can also vary in composition over time. In addition the use of crude oil has proven to create practical and HSE barriers for the involved testing institutes. To overcome this, a model immersion liquid is used to simulate crude oil. The formulation of this crude oil model system is given below:

.1 start with distillate Marine Fuel, DMA Grade[2] density at 15ºC: maximum 890 kg/m^3, viscosity of maximum 6 mm^2/s at 40ºC;

.2 add naphthenic acid up to an acid number[3] of 2.5 ± 0.1 *mg KOH/g*;

.3 add benzene/ toluene (1:1 ratio) up to a total of 8.0 ± 0.2% *w/w* of the DMA;

.4 add artificial seawater[4] up to a total of 5.0 ± 0.2% *w/w* to the mixture;

.5 add H_2S dissolved in a liquid carrier (in order to get 5 ± 1 *ppm w/w* H_2S in the total test liquid);

.6 thoroughly mix the above constituents immediately prior to use; and

.7 once the mixture is completed, it should be tested to confirm the mixture is compliant with the test mixture concentrations.

Note: To prevent the risk of H_2S release into the test facility, it is recommended to use a stock solution for steps 1 to 4, then fill the test containers and complete the test solution with steps 5 and 6.

[2] Refer to *ISO* 8217:*2005. Petroleum products - Fuels (class F) - Specifications of marine fuels*.

[3] Refer to *ISO* 6618:*1997. Petroleum products and lubricants - Determination of acid or base number - Colour-indicator titration method*.

[4] Refer to *ASTM D*1141 - 98(*2008*) - *Standard Practice for the Preparation of Substitute Ocean Water*.

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Interpretation

Only the footnoted standards referred to in **Annex 1** are to be applied, i.e. they are mandatory.

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APPENDIX 1 GAS-TIGHT CABINET TEST

1 Test condition

The vapour test shall be carried out in a gas-tight cabinet. The dimensions and design of the air tight gas cabinet are not critical, provided the requirements of subparagraphs **.6** to **.10** below are met. The test gas is designed to simulate the actual crude oil cargo tank environment in ballast condition as well as the vapour conditions of the loaded tank.

.1 The exposure time is 90 days.

.2 Testing shall be carried out using duplicate panels; a third panel shall be prepared and stored at ambient conditions to act as a reference panel during final evaluation of the test panels.

.3 The size of each test panel is 150 *mm* × 100 *mm* × 3 *mm*.

.4 The panels shall be treated according to the Performance standard, **Table 1**, **1.2** and the coating system applied according to **Table 1**, **1.4** and **1.5**.

.5 The zinc silicate shop primer, when used, shall be weathered for at least 2 months and cleaned by low pressure fresh water washing. The exact method of shop primer preparation before being over coated shall be reported, and the judgement issued for that specific system. The reverse side and edges of the test piece shall be coated appropriately, in order not to influence the test results.

.6 Inside the gas-tight cabinet a trough shall be present. This trough shall be filled with 2 ± 0.2 *l* of water. The water in the trough shall be drained and renewed prior to each time the test gas is refreshed.

.7 The vapour spaces inside the gas-tight cabinet are to be filled with a mixture of test gas as per item **5** of the Standard. The cabinet atmosphere shall be maintained over the period of the test. When the gas is outside the scope of the test method, it shall be refreshed. The monitoring frequency and method, and the date and time for refreshing the test gas, shall be in the test report.

.8 The atmosphere in the test cabinet shall at all times be 95 ± 5% relative humidity.

.9 Temperature of the test atmosphere shall be 60 ± 3 °C.

.10 A stand for the test panels shall be made of a suitable inert material to hold the panels vertically spaced at least 20 *mm* between panels. The stand shall be positioned in the cabinet to ensure the lower edge of the panels is at least 200 *mm* above the height of the water and at least 100 *mm* from the walls of the cabinet. If two shelves are in the cabinet, care shall be taken to ensure solution does not drip on to the lower panels.

2 Test results

2.1 Prior to testing, the following measured data of each coating composing the coating system, including the zinc silicate shop primer when used under the coating system, shall be reported:

.1 infrared (*IR*) identification of the base and hardener components of the coating;

.2 specific gravity[1] of the base and hardener components of the paint; and

.3 mean dry film thickness (*DFT*) (by using a template). [2]

2.2 After completion of the test duration, the panels shall be removed from the cabinet and rinsed with warm tap water. The panels shall be dried by blotting with absorbent paper and, then, evaluated for rust and blistering within 24 *h* of the end of the test.

2.3 After testing, the measured data of blisters and rust are to be reported. [3, 4, 5]

[1] Refer to *ISO* 2811-1/4:*1997. Paints and varnishes. Determination of density*.

[2] Six equally distributed measuring points are used on panels size 150 *mm* × 100 *mm*.

[3] *ISO* 4628-1:*2003. Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of defects, and of intensity of uniform changes in appearance – Part 1: General introduction and designation system*.

[4] *ISO* 4628-2:*2003. Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of defects, and of intensity of uniform changes in appearance – Part 2: Assessment of degree of blistering*.

[5] *ISO* 4628-3:*2003. Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of defects, and of intensity of uniform changes in appearance – Part 3: Assessment of degree of rusting*.

3 Acceptance criteria

3.1 The test results based on **section 2** shall satisfy the following criteria, the poorest performing of the duplicate test panels shall be used in the report:

Item	Acceptance criteria for epoxy-based systems	Acceptance criteria for alternative systems
Blisters on panel	No blisters	No blisters
Rust on panel	Ri 0 (0%)	Ri 0 (0%)

3.2 When evaluating test panels, blistering or rusting within 5*mm* of the panel edge shall be ignored.

4 Test report

The test report shall include the following information:

.1 coating manufacturers' name and manufacturing site;[6]

.2 dates of test;

.3 product name/identification of each coat and, where applicable, zinc silicate shop primer;

.4 batch numbers of each component of each product;

.5 details of surface preparation of steel panels, before shop primer application, and treatment of the shop primer before over coating where relevant and at a minimum including the following:

.5.1 surface treatment, or treatment of weathered shop primer, and any other important information on treatment influencing the performance; and

.5.2 water soluble salt level measured on the steel prior to application of the shop primer;[7, 8]

.6 details of coating system, including the following:

.6.1 zinc silicate shop primer if relevant, its secondary surface pre-treatment and condition under which applied, weathering period;

.6.2 number of coats, including the shop primer, and thickness of each;

.6.3 mean dry film thickness (*DFT*) prior to testing;[9]

.6.4 thinner if used;[9]

.6.5 humidity;[9]

.6.6 air temperature;[9] and

.6.7 steel temperature;[9]

.7 details of schedule for refreshing the test gas;

.8 test results according to **section 2**; and

.9 results according to **section 3**.

[6] It should be noted that the test is valid irrespective of production site, meaning that no individual testing of product from different production sites is required.

[7] *ISO* 8502-6:*2006. Preparation of steel substrates before application of paints and related products – Tests for the assessment of surface cleanliness – Part 6: Extraction of soluble contaminants for analysis – The Bresle method.*

[8] *ISO* 8502-9:*1998. Preparation of steel substrates before application of paints and related products – Tests for the assessment of surface cleanliness – Part 9: Field method for the conductometric determination of water-soluble salts.*

[9] Both of actual specimen data and manufacturer's requirement/recommendation.

APPENDIX 2 IMMERSION TEST

1 Test condition

The immersion test[1] is developed to simulate the conditions in a crude oil tank in loaded condition.

.1 The exposure time is 180 days.

.2 The test liquid should be made as per **item 6** in the Standard.

.3 The test liquid should be added to a container with an inside flat bottom until a column of the test liquid of height of 400*mm* is reached, resulting in an aqueous phase of 20*mm*. Any other alternative test set-up, using an identical test liquid, which will also result in the immersion of the test panel in 20*mm* of the aqueous phase, is also accepted. This can be achieved by using, for instance, inert marbles.

.4 The temperature of the test liquid should be 60 ± 2°C and should be uniform and maintained constant with recognized methods such as water or oil bath or air circulation oven capable of keeping the immersion liquid within the required temperature range.

.5 Test panels shall be positioned vertically and fully immersed during the test.

.6 Testing shall be carried out using duplicate panels.

.7 Inert spacers which do not cover the test area shall be used to separate test panels.

.8 The size of each test panel is 150*mm* × 100*mm* × 3*mm*.

.9 The panels shall be treated according to the Performance Standard **Table 1**, **1.2** and the coating system applied according to **Table 1**, **1.4** and **1.5**.

.10 The zinc silicate shop primer, when used, shall be weathered for at least 2 months and cleaned by low pressure fresh water washing. The exact method of shop primer preparation before being over coated shall be reported, and the judgement issued for that specific system. The reverse side, and edges, of the test piece shall be coated appropriately, in order not to influence the test results.

.11 After the full immersion test period is completed the panels shall be removed from the test liquid and wiped with dry clean cloth before evaluation of the panels.

.12 Evaluation of the test panels shall be done within 24 *h* after completion of the test.

[1] Related test method is derived from, but not identical to, standard *ISO* 2812-1:*2007 - Paints and varnishes - Determination of resistance to liquids - Part 1: Immersion in liquids other than water*.

2 Test results

2.1 Prior to testing, the following measured data of each coating composing the coating system, including the zinc silicate shop primer when used under the coating system, shall be reported:

.1 infrared (*IR*) identification of the base and hardener components of the coating;

.2 specific gravity of the base and hardener components of the paint;[2] and

.3 mean dry film thickness (*DFT*) (by using a template).[3]

2.2 After testing, the following measured data shall be reported: blisters and rust.[4, 5, 6]

[2] Refer to *ISO* 2811-1/4:*1997. Paints and varnishes. Determination of density*.

[3] Six equally distributed measuring points are used on panels size 150*mm* × 100*mm*.

[4] *ISO* 4628-1:*2003. Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of defects, and of intensity of uniform changes in appearance – Part 1: General introduction and designation system*.

[5] *ISO* 4628-2:*2003. Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of defects, and of intensity of uniform changes in appearance – Part 2: Assessment of degree of blistering*.

[6] *ISO* 4628-3:*2003. Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of defects, and of intensity of uniform changes in appearance – Part 3: Assessment of degree of rusting*.

3 Acceptance criteria

3.1 The test results based on **section 2** shall satisfy the following criteria, the poorest performing of the duplicate test panels shall be used in the report:

Item	Acceptance criteria for epoxy-based systems	Acceptance criteria for alternative systems
Blisters on panel	No blisters	No blisters
Rust on panel	Ri 0 (0%)	Ri 0 (0%)

3.2 When evaluating test panels, blistering or rusting within 5*mm* of the panel edge should be ignored.

4 Test report

The test report shall include the following information:

.1 coating manufacturers' name and manufacturing site;[7]

.2 dates of test;

.3 product name/identification of each coat and, where applicable, zinc silicate shop primer;

.4 batch numbers of each component of each product;

.5 details of surface preparation of steel panels, before shop primer application, and treatment of the shop primer before over coating where relevant and at a minimum including the following:

.5.1 surface treatment, or treatment of weathered shop primer, and any other important information on treatment influencing the performance; and

.5.2 water soluble salt level measured on the steel prior to application of the shop primer;[8, 9]

.6 details of coating system, including the following:

.6.1 zinc silicate shop primer if relevant, its secondary surface pre-treatment and condition under which applied, weathering period;

.6.2 number of coats, including the shop primer, and thickness of each;

.6.3 mean dry film thickness (*DFT*) prior to testing;[10]

.6.4 thinner if used;[10]

.6.5 humidity;[10]

.6.6 air temperature;[10] and

.6.7 steel temperature;[10]

.7 details of schedule for refreshing the test gas;

.8 test results according to **section 2**; and

.9 results according to **section 3**.

[7] It should be noted that the test is valid irrespective of production site, meaning that no individual testing of product from different production sites is required.

[8] *ISO* 8502-6:*2006. Preparation of steel substrates before application of paints and related products – Tests for the assessment of surface cleanliness – Part 6: Extraction of soluble contaminants for analysis – The Bresle method.*

[9] *ISO* 8502-9:*1998. Preparation of steel substrates before application of paints and related products – Tests for the assessment of surface cleanliness – Part 9: Field method for the conductometric determination of water-soluble salts.*

[10] Both of actual specimen data and manufacturer's requirement/recommendation.

APPENDIX 3 PRECAUTIONS REGARDING THE USE OF DANGEROUS MATERIALS

1 The test methods involve the use of materials that may be hazardous to health as follows:

.1 Sulphur Dioxide: Corrosive when wet, toxic if inhaled, causes burns, and is an irritant to the eyes and respiratory system.

.2 Hydrogen Sulphide: Highly flammable (Flash point of -82°C), can form an explosive mixture with air, corrosive when wet, causes burns, has to be kept away from sources of ignition, irritant and asphyxiant, LTEL 5*ppm*, STEL 10*ppm*, higher concentrations can be fatal and have no odour. Repeated exposure to low concentrations can result in the sense of smell for the gas being diminished.

.3 Benzene: Highly flammable (Flash point of -11°C), can form an explosive mixture with air, toxic, carcinogenic, acute health risk.

.4 Toluene: Highly flammable (Flash point of 4°C), can form an explosive mixture with air, irritant, acute health risk, reprotoxin.

2 Special test apparatus and precautions may be required depending on the regulations in force in the country where the tests are carried out.

3 Although some countries have no specific requirements preventing either of the tests being carried out, it shall anyhow be required that:

.1 a risk assessment of the working conditions is carried out;

.2 during the test period, the system shall be enclosed; and

.3 the environment shall be controlled, particularly at the start and end of the tests, suitable air exhaust shall be available and personal protective equipment shall be worn.

ANNEX 2 EXAMPLE OF DAILY LOG AND NON-CONFORMITY REPORT

DAILY LOG **Sheet No:**

Ship:	**Tank/Hold No:**	**Database:**
Part of structure:		
SURFACE PREPARATION		
Method:		**Area (m^2):**
Abrasive:		**Grain size:**
Surface temperature:		**Air temperature:**
Relative humidity (max):		**Dew point:**
Standard achieved:		
Rounding of edges:		
Comments:		
Job No.:	**Date:**	**Signature:**
COATING APPLICATION:		
Method:		

Coat No.	**System**	**Batch No.**	**Date**	**Air temp.**	**Surf temp.**	**RH%**	**Dew point**	**DFT* Meas.**	**Specified**

* **Measured minimum and maximum DFT. DFT readings to be attached to daily log.**

Comments:		
Job No:	**Date:**	**Signature:**

NON-CONFORMITY REPORT **Sheet No:**

Ship:	**Tank/Hold No:**	**Database:**
Part of structure:		
DESCRIPTION OF THE INSPECTION FINDINGS TO BE CORRECTED		
Description of findings:		
Reference document (daily log):		
Action taken:		
Job No.:	**Date:**	**Signature:**