Section
1 **General**
2 **Materials and protection**
3 **Longitudinal strength**
4 **Deck structure**
5 **Shell envelope plating**
6 **Shell envelope framing**
7 **Topside tank structure**
8 **Double bottom structure**
9 **Hopper side tank structure**
10 **Bulkheads**
11 **Direct calculation**
12 **Steel hatch covers**
13 **Hatch coamings**
14 **Forecastles**

■ *Section 1* General

1.1 General

1.1.1 This Chapter applies to sea-going self propelled ships, constructed generally with single deck, double bottom, hopper side tanks and topside tanks and with single or double side skin construction in the cargo length area, and intended primarily for the carriage of bulk dry cargoes.

1.1.2 A 'bulk carrier of single side skin construction' is defined as a bulk carrier where one or more cargo holds are bound by the side shell only, or by two watertight boundaries, one of which is the side shell, which are less than 1000 mm apart.

1.1.3 The term 'bulk carrier of double side skin construction' is defined as a bulk carrier where all cargo holds are bound by two watertight boundaries, one of which is the side shell, which are greater than or equal to 1000 mm apart at any location within the hold length.

1.1.4 The ShipRight Procedures for the hull construction of ships are detailed in *Pt 3, Ch 16 ShipRight Procedures for the Design, Construction and Lifetime Care of Ships* and the classification notations and descriptive notes associated with these procedures are given in *Pt 1, Ch 2, 3 Surveys - General*.

1.1.5 The attention of Owners, Masters and Cargo Shippers is drawn to the IMO Code of Safe Practice for Solid Bulk Cargoes when shipping these cargoes. Attention is also drawn to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered, and any special requirements of the Port Authorities at the ports of loading and discharge.

1.1.6 The Regulations for classification and the assignment of class notations are given in *Pt 1, Ch 2 Classification Regulations* to which reference should be made.

1.2 Application

1.2.1 Single skin and double skin bulk carriers with length, L , greater than or equal to 90 m with structural configuration as shown in *Figure 7.1.1 CSR-BC Applicability* are defined as '*CSR Bulk Carriers*' and are to comply with *Pt 4, Ch 7, 1.4 Class notation for CSR bulk carriers*.

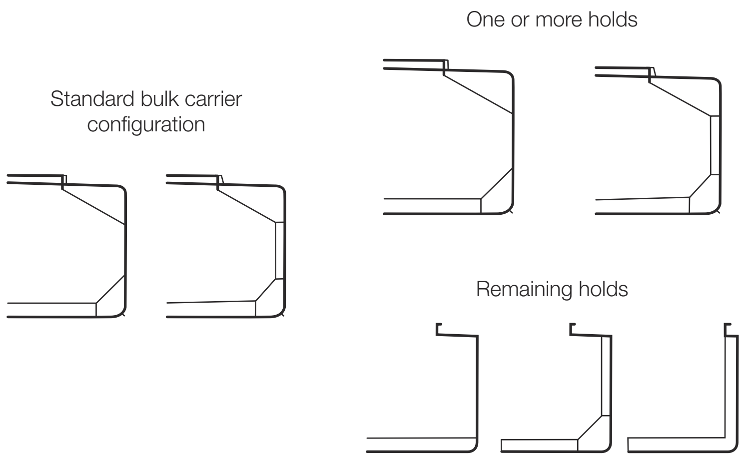


Figure 7.1.1 CSR-BC Applicability

1.2.2 Single skin and double skin bulk carriers other than those described in *Pt 4, Ch 7, 1.2 Application 1.2.1* are defined as '*Non- CSR Bulk Carriers*' and are to comply with *Pt 4, Ch 7, 1.5 Class notation for non-CSR bulk carriers*.

1.3 General class notations

1.3.1 Class notations applicable to CSR bulk carriers are defined as follows:

- **CSR**

Identifies the bulk carrier as being compliant with the *IACS Common Structural Rules for Bulk Carriers and Oil Tankers (CSR);*.

- **ESP**

Identifies the bulk carrier as being subject to an Enhanced Survey Programme as detailed in *Pt 1, Ch 3, 3 Intermediate Surveys - Hull and machinery requirements* and *Pt 1, Ch 3, 6 Special Survey - Bulk carriers - Hull requirements*, *see also Pt 1, Ch 2, 2.3 Class notations (hull) 2.3.12*.

1.3.2 Class notations applicable to non-CSR bulk carriers are defined as follows:

- **Strengthened for heavy cargoes**

For bulk carriers with scantlings complying with *Pt 4, Ch 7, 8.2 Carriage of heavy cargoes*;

- **ESP**

Identifies the bulk carrier as being subject to an Enhanced Survey Programme as detailed in *Pt 1, Ch 3, 3 Intermediate Surveys - Hull and machinery requirements* and *Pt 1, Ch 3, 6 Special Survey - Bulk carriers - Hull requirements*, *see also Pt 1, Ch 2, 2.3 Class notations (hull) 2.3.12*;

- **ESN**

Identifies the bulk carrier as having been assessed for enhanced survivability with respect to flooding. Scantlings and arrangements are to comply with *Pt 4, Ch 7, 3.1 General 3.1.2*, *Pt 4, Ch 7, 8.8 Allowable hold loading in the flooded condition* and *Pt 4, Ch 7, 10.4 Vertically corrugated transverse watertight bulkheads – Application and definitions*.

1.4 Class notation for CSR bulk carriers

1.4.1 In general, CSR bulk carriers less than 150 m in length are to comply with the requirements of *Pt 4, Ch 7, 1.6 Information required for CSR bulk carriers*, *Pt 3, Ch 2 Materials* and the *IACS Common Structural Rules* (CSR) and will be eligible for one of the following mandatory class notations:

(a) **100A1 bulk carrier, CSR, any holds may be empty, ESP**. This class notation is normally assigned to a ship designed to carry dry bulk cargoes of cargo density 1,0 tonne/m^3 and above, with an approved arrangement of loaded holds such that any hold may be empty at the full loaded draught.
(b) **100A1 bulk carrier, CSR, hold, nos. 1, 2 ... may be empty, ESP**. This class notation is normally assigned to a ship designed to carry dry bulk cargoes of cargo density 1,0 tonne/m^3 and above with specified holds empty at maximum draught.
(c) **100A1 bulk carrier, CSR, ESP**. This class notation will be assigned to a ship designed to carry dry bulk cargoes of cargo density less than 1,0 tonne/m^3.

1.4.2 In general, CSR bulk carriers equal to or greater than 150 m in length are to comply with the requirements of *Pt 4, Ch 7, 1.6 Information required for CSR bulk carriers*, *Pt 3, Ch 2 Materials* and the *IACS Common Structural Rules* (CSR) and will be eligible for one of the following mandatory class notations:

(a) **100A1 bulk carrier, CSR, BC-A, hold, nos. 1, 2 … may be empty, GRAB [X] ESP**. This class will be assigned for bulk carriers designed to carry dry bulk cargoes of cargo density 1,0 tonne/m^3 and above with specified holds empty at maximum draught.
(b) **100A1 bulk carrier, CSR, BC-B, GRAB [X], ESP**. This class will be assigned for bulk carriers designed to carry dry bulk cargoes of cargo density 1,0 tonne/m^3 and above with all cargo holds loaded.
(c) **100A1 bulk carrier, CSR, BC-C, ESP**. This class will be assigned for bulk carriers designed to carry dry bulk cargoes of cargo density less than 1,0 tonne/m^3 with all cargo holds loaded.

1.4.3 The following additional notations and annotations are to be provided giving further detailed description of limitations to be observed during operation as a consequence of the design loading condition applied during the design.

- **Notations:**

(a) (**maximum cargo density (in tonnes/m^3**)) For notations **BC-A** and **BC-B** if the maximum cargo density is less than 3,0 tonnes/m^3,

(**no MP**) For all notations when the vessel has not been designed for loading and unloading in multiple ports in accordance with the conditions specified in *IACS Common Structural Rules* (CSR), Pt 1, Ch 4, Sec 8,4.2.2:

GRAB [X] where the net thickness of inner bottom, lower strake of hopper tank sloping plate and transverse lower stool plating comply with *IACS Common Structural Rules* (CSR), Pt 2, Ch 1, 6 for **BC-A** and **BC-B**, *see IACS Common Structural Rules (CSR)*, Pt 1, Ch 1, *Sec* 1,3.2.1;

- **Annotations:**

(allowed combination of specified empty holds). For notation **BC-A**.

1.4.4 The ShipRight notation **CM** is mandatory for CSR bulk carriers greater than 150 m in length, *see Pt 4, Ch 7, 1.5 Class notation for non-CSR bulk carriers 1.5.7*.

1.4.5 Optional notations indicating compliance with specific requirements of *Pt 4, Ch 7, 3 Longitudinal strength* to *Pt 4, Ch 7, 14 Forecastles* on a voluntary basis may also be assigned.

1.5 Class notation for non-CSR bulk carriers

1.5.1 In general, non-CSR Bulk Carriers are to comply with the requirements of *Pt 4, Ch 7, 1.5 Class notation for non-CSR bulk carriers 1.5.2* to *Pt 4, Ch 7, 1.5 Class notation for non-CSR bulk carriers 1.5.10* and will be eligible for one of the following mandatory class notations:

(a) **100A1 bulk carrier, ESP**.
(b) **100A1 bulk carrier, strengthened for heavy cargoes, ESP**. This class notation will be assigned to a ship when the double bottom structure has been specially strengthened in accordance with the requirements of *Table 7.8.1 Strengthening for heavy cargo requirements*.
(c) **100A1 bulk carrier, strengthened for heavy cargoes, hold, nos. 1, 2 ... may be empty, ESP**. This class notation is normally assigned to a ship which has been specially strengthened for heavy cargoes, *see Pt 4, Ch 7, 1.5 Class notation for*

non-CSR bulk carriers 1.5.1.(b), so as to enable the ship to be fully loaded with an approved arrangement of empty holds, *see also Pt 4, Ch 7, 1.5 Class notation for non-CSR bulk carriers 1.5.10* and *Pt 4, Ch 7, 1.4 Class notation for CSR bulk carriers 1.4.3*.

(d) **100A1 bulk carrier, strengthened for heavy cargoes, any holds may be empty, ESP**. This class notation is normally assigned to a ship which has been specially strengthened for heavy and ore cargoes, with an approved arrangement of loaded holds such that any hold may be empty at the full loaded draught.

1.5.2 Plans and information are to be submitted in accordance with *Pt 4, Ch 7, 1.7 Information required for non-CSR bulk carriers*.

1.5.3 Requirements are also given for special strengthening for heavy cargoes, *see Pt 4, Ch 7, 8.2 Carriage of heavy cargoes*.

1.5.4 The scantlings and arrangements of the cargo region are to be as specified in this Chapter in *Pt 4, Ch 7, 2 Materials and protection* to *Pt 4, Ch 7, 14 Forecastles*. The requirements are intended to cover the midship region, but also apply, with suitable modification, to the taper regions forward and aft in way of cargo spaces.

1.5.5 The ShipRight notation **CM** is mandatory for non-CSR bulk carriers greater than 150 m in length, *see Pt 4, Ch 7, 1.5 Class notation for non-CSR bulk carriers 1.5.7*.

1.5.6 Where the length of the ship is greater than 190 m, or where the structural arrangements are considered such as to necessitate it, the scantlings of the primary supporting structure are to be assessed by direct calculation and the ShipRight notations **SDA**, **FDA** and **CM** are mandatory, *see Pt 4, Ch 7, 1.5 Class notation for non-CSR bulk carriers 1.5.7* and *Pt 4, Ch 7, 11 Direct calculation*.

1.5.7 The 'ShipRight Procedures' for the hull construction of ships are detailed in *Pt 3, Ch 16 ShipRight Procedures for the Design, Construction and Lifetime Care of Ships* and the classification notations and descriptive notes associated with these procedures are given in *Pt 1, Ch 2, 2 Character of classification and class notations*.

1.5.8 The 'Structural Design Assessment' (**SDA**), 'Fatigue Design Assessment' (**FDA**) and 'Construction Monitoring' (**CM**) procedures detailed in the *ShipRight Procedures Manual*, published by LR, are mandatory for non-CSR bulk carriers greater than 190 m in length and for other non-CSR bulk carriers of abnormal hull form, or of unusual structural configuration or complexity *see Pt 4, Ch 7, 1.1 General 1.1.5* and *Pt 4, Ch 7, 11 Direct calculation*.

1.5.9 Where the class notation referred to in *Pt 4, Ch 7, 1.5 Class notation for non-CSR bulk carriers 1.5.1.(d)* is assigned such that any hold may be empty at the full draught the following items are to be considered and the corresponding requirements complied with:

(a) Longitudinal strength calculations are to be carried out for all the operational fully loaded, non-homogeneous, part loaded, heavy cargo conditions, and these conditions included in the approved Loading Manual, *see Pt 4, Ch 7, 3 Longitudinal strength*. Envelopes of the still water bending moments and the shear forces covering these conditions are also to be submitted.
(b) The double bottom structure in each hold is to satisfy the requirements of *Pt 4, Ch 7, 8.4 Ships to be classed '100A1 bulk carrier, strengthened for heavy cargoes, any hold may be empty, ESP'*.
(c) The arrangement and scantlings of cross-deck structure between the upper deck cargo hatchways, *see Pt 4, Ch 7, 4.1 General 4.1.2*.
(d) Transverse bulkheads in holds, *see Pt 4, Ch 7, 10.1 General 10.1.4*.
(e) For main cargo hatchway openings the requirements of *Pt 4, Ch 7, 4.3 Main cargo hatchway openings 4.3.1* are to be complied with.

1.5.10 Where appropriate, other cargoes or particular loading arrangements will be included in the class notation. When the class notation referred to in *Pt 4, Ch 7, 1.5 Class notation for non-CSR bulk carriers 1.5.1.(c)* is to be assigned for other combinations of empty and loaded holds, for example where it is the intention to load fully any two adjoining holds with adjacent holds empty in sea-going or short voyage conditions, the longitudinal and local strength aspects will be specially considered, *see also Pt 4, Ch 7, 4.1 General 4.1.2*. In addition, permissible weights of cargo in each hold or pair of adjacent holds, plotted against ship's draught likely to be incurred, are to be included in the ship's approved Loading Manual.

1.5.11 The scantlings of structural items may be determined by direct calculation.

1.5.12 The additional requirements for bulk carriers for the alternate carriage of oil cargo and dry bulk cargo are given in *Pt 4, Ch 9, 11 Ships for alternate carriage of oil cargo and dry bulk cargo*. When complying with the requirements of this Chapter, such ships may be excluded from all requirements and notations pertaining to vessels with length, *L*, greater than or equal to 150 m. The requirements of *Pt 4, Ch 7, 1.5 Class notation for non-CSR bulk carriers 1.5.8* are however to be complied with.

1.6 Information required for CSR bulk carriers

1.6.1 Plans and supporting documents/calculations are to be submitted for approval in accordance with the requirements of the CSR.

1.6.2 In addition, where not already required by the CSR, plans and supporting documents/calculations are to be submitted for approval as required by *Pt 3, Ch 1, 5.2 Plans and supporting calculations*.

1.6.3 A Ship Construction File (SCF) is to be provided on board of the ship containing information to facilitate inspection/ survey, repair and maintenance. As a minimum it is to include documentation and plans in accordance with the requirements of the CSR.

1.6.4 For CSR bulk carriers subject to *SOLAS - International Convention for the Safety of Life at Sea Chapter II-1 - Construction - Structure, subdivision and stability, machinery and electrical installations Part A-1 - Structure of ships Regulation 3-10 – Goal-based ship construction standards for bulk carriers and oil tankers*, the SCF is to be provided instead in accordance with the requirements specified therein in SOLAS and for these goal-based standard ships an SCF contents list is to be prepared and submitted for approval.

1.6.5 These SCFs are also to include the documentation and plans as listed in *Pt 3, Ch 1, 5.3 Plans to be supplied to the ship*, where not already required by the CSR or *SOLAS - International Convention for the Safety of Life at Sea Chapter II-1 - Construction - Structure, subdivision and stability, machinery and electrical installations Part A-1 - Structure of ships Regulation 3-10 – Goal-based ship construction standards for bulk carriers and oil tankers*.

1.6.6 In all cases, as required by the CSR, *Pt 1, Ch 13 Ship in Operation - Renewal Criteria,* the mid-ship section plan to be supplied on board the ship is to include the minimum required hull girder sectional properties. Sectional properties are to be provided for transverse sections within the cargo length, i.e. each cargo hold, and are to include:

- sectional properties as defined in CSR, *Pt 1, Ch 5, 1 Strength Characteristics of Hull Girder Transverse Sections;*
- the defined section modulus at Deck and at Bottom calculated with the gross offered thickness;
- the sectional area of the defined Deck and Bottom Zones calculated with the gross offered thickness; and
- the sectional area of the defined Neutral Axis Zone calculated with the gross offered thickness minus 0,5 t_c.

1.7 Information required for non-CSR bulk carriers

1.7.1 In addition to the information and plans required by *Pt 3, Ch 1, 5 Information required*, the following are to be submitted:

- Cargo loadings on decks, hatchways and inner bottom if these are to be in excess of Rule, *see Pt 3, Ch 3, 5 Design loading*.
- The maximum pressure head in service on tanks, also details of any double bottom tanks interconnected with hopper and topside tanks.
- Details of the proposed depths of any partial fillings where water ballast or liquid cargo is intended to be carried in the holds.
- Details of loading arrangements where combinations of empty and loaded holds are envisaged, and where it is the intention to load fully any two adjoining holds with adjacent holds empty in sea-going or short voyage conditions.

1.7.2 Additional information required for bulk carriers of length, L, 150 m or above:

- The bulk cargo density to be used in the design homogeneous loading condition at scantling draught with all holds, including hatchways, being 100 per cent full.
- The maximum bulk cargo density the ship is designed to carry.
- The maximum bulk cargo weight to be carried in each hold.
- Tables or curves indicating the change of cargo hold volume as a function of height above moulded baseline.

1.8 Symbols and definitions

1.8.1 The following symbols and definitions are applicable to this chapter unless otherwise stated: L, B, D, T as defined in *Pt 3, Ch 1, 6 Definitions*

k_L, k = higher tensile steel factor, *see Pt 3, Ch 2, 1 Materials of construction*

l = overall length of stiffening member, in metres, *see Pt 3, Ch 3, 3 Structural idealisation*

l_e = effective length of stiffening member, in metres, *see Pt 3, Ch 3, 3 Structural idealisation*

s = spacing of secondary stiffeners, in mm

t = thickness of plating, in mm

C = stowage rate, in m^3/tonne, as defined in *Pt 3, Ch 3, 5 Design loading*

I = inertia of stiffening member, in cm^4, *see Pt 3, Ch 3, 3 Structural idealisation*

M_H = the actual cargo mass in a cargo hold corresponding to a homogenously loaded condition at maximum draught

M_{Full} = the cargo mass in a cargo hold corresponding to cargo with virtual density (homogenous mass/hold cubic capacity, minimum 1,0 tonne/m^3) filled to the top of the hatch coaming. M_{Full} is in no case to be less than M_H

M_{HD} = the maximum cargo mass allowed to be carried in a cargo hold according to design Loading conditions with specified holds empty at maximum draught

R = $\sin\theta$

S = spacing, or mean spacing, of primary members, in metres

Z = section modulus of stiffening member, in cm^3, *see Pt 3, Ch 3, 3 Structural idealisation*

ρ = relative density (specific gravity) of liquid carried in a tank, and is not to be taken less than 1,025

θ = roll angle, in degrees

$$\sin\theta = \left(0,45 + 0,1\frac{L}{B}\right)\left(0,54 - \frac{L}{1270}\right)$$

■ *Section 2* Materials and protection

2.1 Materials and grades of steel

2.1.1 Materials and grades of steel are to comply with the requirements of *Pt 3, Ch 2 Materials*.

2.2 Protection of steelwork

2.2.1 For the protection of steelwork, in addition to the requirements specified in *Pt 4, Ch 1, 2 Materials and protection* and *Pt 3, Ch 2, 3 Corrosion protection* the requirements of *Pt 4, Ch 7, 2.2 Protection of steelwork 2.2.2* are to be complied with.

2.2.2 All internal and external surfaces of hatch coamings and hatch covers, and all internal surfaces of the cargo holds, except where excluded below, are to have an efficient protective coating (epoxy coating or equivalent) applied in accordance with the manufacturer's recommendations. In the selection of coating, due consideration is to be given to the intended cargo conditions in service. Areas which may remain uncoated are:

(a) The inner bottom plating.
(b) The hopper tank sloping plating between the intersection with the inner bottom plating and a line approximately 300 mm below the toe of the side shell frame end brackets.

2.2.3 For the notation **`strengthened for regular discharge by heavy grabs'**, *see Pt 3, Ch 9, 7 Bottom strengthening for loading and unloading aground*.

Section 3
Longitudinal strength

3.1 General

3.1.1 Longitudinal strength calculations are to be made in accordance with the requirements given in *Pt 3, Ch 4 Longitudinal Strength* and *Pt 4, Ch 7, 1.5 Class notation for non-CSR bulk carriers 1.5.9* and *Pt 4, Ch 7, 1.5 Class notation for non-CSR bulk carriers 1.5.10* where appropriate.

3.1.2 Longitudinal strength calculations for the flooded conditions defined in *Pt 4, Ch 7, 3.2 Hull vertical bending stresses for flooded conditions* to *Pt 4, Ch 7, 3.4 Flooded conditions* are to be applied for bulk carriers which satsify all of the following criteria:

- Single skin construction, or double skin construction where any part of the 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.
- Length, *L*, of 150 m or above.
- Intended for the carriage of cargoes having bulk densities of 1,0 tonne/m^3 or above.

3.2 Hull vertical bending stresses for flooded conditions

3.2.1 The maximum hull vertical bending stresses in the flooded condition at deck, σ_{Df}, and keel, σ_{Bf}, for use in *Pt 3, Ch 4 Longitudinal Strength* are given by the following, using the appropriate combination of bending moments to give sagging and hogging stresses:

$$\sigma_{Df} = \frac{\left|M_{sf} + 0,8M_{w}\right| \times 10^{-3}}{Z_D} \text{ N/mm}^2$$

$$\sigma_{Bf} = \frac{\left|M_{sf} + 0,8M_{w}\right| \times 10^{-3}}{Z_B} \text{ N/mm}^2$$

where

M_{sf} = maximum still water bending moment in the flooded condition, in kN m, at the section under consideration, *see Pt 4, Ch 7, 3.4 Flooded conditions*

M_w = design hull vertical wave bending moment, in kN m, as defined in *Pt 3, Ch 4, 5 Hull bending strength* at the section under consideration

Z_D,Z_B = actual hull section moduli, in m^3, at strength deck and keel respectively, at the section under consideration.

3.2.2 The maximum values of σ_{Df} and σ_{Bf} are to be used in *Pt 3, Ch 4 Longitudinal Strength*.

3.3 Shear stresses for flooded conditions

3.3.1 The shear stress, τ_{Af}, in the flooded condition to be used in *Pt 3, Ch 4, 6 Hull shear strength*, is to be taken as:

$$\tau_{Af} = 100Az\frac{\left|Q_{sf}\right| + \left|0,8Q_{w}\right|}{I\,\delta_i} \text{ N/mm}^2$$

where

Az = the first moment, in cm^3, about the neutral axis, of the area of the effective longitudinal members between the vertical level under consideration and the vertical extremity of the effective longitudinal members, taken at the section under consideration

Q_{sf} = maximum hull still water shear force, in kN, in the flooded condition at the section under consideration

Q_w = design hull wave shear force, in kN, as defined in *Pt 3, Ch 4, 6.3 Design wave shear force* at the section under consideration

where

I = moment of inertia of the hull about the horizontal neutral axis, in cm^4, at the longitudinal section under consideration

δ_i = defined in *Pt 3, Ch 4, 6.5 Permissible still water shear force*.

3.4 Flooded conditions

3.4.1 For the relevant loading conditions specified in *Pt 3, Ch 4, 5.3 Design still water bending moments* and *Pt 3, Ch 4, 5.4 Minimum hull section modulus*, each cargo hold is to be considered individually flooded up to the equilibrium waterline. The shear forces and still water bending moments are to be calculated for the most severe flooded conditions which will significantly load the ship's structure. Harbour conditions, docking conditions afloat, loading and unloading transitory conditions in port and loading conditions encountered during ballast water exchange need not be considered.

3.4.2 For self-unloading bulk carriers where the boundary of the conveyor space between the bottom of the cargo hold and the top of the conveyor space is not watertight during seagoing operations, the longitudinal strength in flooded conditions is to be considered using the extent to which flooding can occur, i.e. both the conveyor space and the cargo hold are to be assumed to be flooded. *See Pt 4, Ch 7, 3.4 Flooded conditions 3.4.1*.

3.4.3 In calculating the weight of ingressed water into the cargo hold under consideration, the permeabilities and bulk densities given in *Table 7.3.1 Permeability and bulk density factors* are to be used.

Table 7.3.1 Permeability and bulk density factors

Hold condition	Permeability (*see* Note 1)	Bulk density (tonne/m^3)
Empty cargo space	0,95	-
Volume left in loaded cargo spaces above any cargo	0,95	-
Iron ore cargo	0,3 (*see* Note 2)	3,0
Cement	0,3 (*see* Note 2)	1,3
Note 1. Bulk cargo permeability is defined as the ratio of the voids within the cargo mass to the volume occupied by the cargo. Note 2. More specific information relating to the bulk cargo may be used where available, but permeabilities are not to be less than those given above. Note 3. For packed cargo, the actual density of the cargo is to be used with a permeability of zero.		

3.4.4 In calculating the strength of the ship's structure in the flooded condition it is to be assumed that the ship's structure will remain fully effective in resisting the applied loads.

■ *Section 4* Deck structure

4.1 General

4.1.1 Longitudinal framing is, in general, to be adopted outside line of openings. The arrangement of structure between hatches is to be such as to ensure continuity of the main deck structure to resist athwartship forces, and transverse stiffening is to be arranged. For and aft knuckles in cross deck strip plating between hatches should be arranged close to longitudinal girders or supported by brackets.

4.1.2 In the case of large bulk carriers with narrow deck strips between hatchways, or where it is the intention to load any two adjoining holds with adjacent holds fully empty for a sea-going condition or for bulk carriers to be classed `any hold may be empty', the cross deck scantlings will be specially considered.

4.1.3 The requirements of *Pt 4, Ch 1, 4 Deck structure* are to be applied, together with the requirements of this Section.

4.1.4 The *Shipright FDA Procedure, Structural Detail Design Guide* (SDDG), indicates recommended structural design configurations in critical areas, for the deck structure outside the line of openings and between hatches.

4.2 Deck plating

4.2.1 Where the difference between the thickness of plating inside and outside the line of main hatches exceeds 12 mm, a transitional plate of thickness equivalent to the mean of the adjacent plate thicknesses is to be fitted. The plate thickness outside the line of hatches is to be continued inboard between hatches beyond the end of the hatch corner curvature, to ensure that the chamfered plating is clear of the corner tangent point.

4.3 Main cargo hatchway openings

4.3.1 The following requirements apply to bulk carriers with vertically corrugated transverse bulkheads in cargo holds having one or more of the following characteristics:

(a) $B \geq 40$ m

(b) $\frac{b}{w} \geq 2,2$

b = breadth of deck opening

w = width of cross deck strip

B = moulded breadth of ship

(c) A structural arrangement where the hatch side coaming and deck opening are arranged inboard of the topside tank.

(d) All bulk carriers to be classed 100A1 bulk carrier, strengthened for heavy cargoes, any hold may be empty, ESP.

4.3.2 The corners of main cargo hatchways in the strength deck are to be rounded with a radius not less than $\frac{1}{20}$ of the breadth of the opening, with a maximum radius of 1000 mm.

4.3.3 Insert plates are to be fitted at the corners having a thickness not less than 25 per cent greater than the adjacent deck thickness outside the line of openings, with a minimum increase of 5 mm, *see also Pt 4, Ch 7, 4.3 Main cargo hatchway openings 4.3.4*.

The corner inserts are to be extended transversely into the cross deck plating for a minimum distance equal to 0,075*b*, where *b*, is the breadth of deck opening.

4.3.4 For the extreme corners of the end hatchways of the cargo region furthest from amidships the thickness of the corner insert plates is to be not less than 60 per cent greater than the adjacent deck thickness outside the line of openings.

4.4 Deck supporting structure

4.4.1 For the scantlings of deck longitudinals and transverses in way of topside tanks, *see Pt 4, Ch 7, 7.4 Shell and deck structure* and *Pt 4, Ch 7, 7.5 Primary supporting structure*, respectively.

■ *Section 5*
Shell envelope plating

5.1 General

5.1.1 Longitudinal framing is, in general, to be adopted at the bottom, but special consideration will be given to proposals for transverse framing in this region. The side shell may be longitudinally or transversely framed.

5.1.2 The requirements of *Pt 4, Ch 1, 5 Shell envelope plating* are to be applied together with the requirements of this Section.

5.2 Bottom shell

5.2.1 The thickness of the bottom shell plating below loaded holds may be required to be increased for local strength considerations.

5.3 Side shell

5.3.1 The thickness of the side shell plating may be required to be increased for shear forces to satisfy the requirements of *Pt 4, Ch 7, 3.2 Hull vertical bending stresses for flooded conditions 3.2.1*.

5.3.2 The thickness of the side shell plating located between the hopper and topside tanks of single skin bulk carriers is to be not less than:

$$t = \sqrt{L} \text{ mm}$$

■ *Section 6* Shell envelope framing

6.1 Longitudinal stiffening

6.1.1 Side frames of all single skin bulk carriers with a hopper are to comply with *Pt 4, Ch 7, 6.2 Transverse stiffening* and *Pt 4, Ch 7, 6.3 Primary supporting structure*.

6.1.2 Side frames and end brackets of all double skin bulk carriers are to comply with *Pt 4, Ch 1, 6 Shell envelope framing*.

6.1.3 Side frames and end brackets of other structural configurations will be specially considered.

6.1.4 The end connections for the longitudinal stiffening are to satisfy the requirements of *Pt 3, Ch 10, 3 Secondary member end connections*, *see also Pt 4, Ch 7, 7.6 Structural details 7.6.1* and *Pt 4, Ch 7, 9.7 Structural details 9.7.1*.

6.1.5 The arrangements at the intersections of continuous secondary and primary members are to satisfy the requirements of *Pt 3, Ch 10, 5.2 Arrangements at intersections of continuous secondary and primary members* and *Pt 4, Ch 1, 6.2 Longitudinal stiffening*.

6.2 Transverse stiffening

6.2.1 The modulus and inertia of main and topside tank frames in the midship region are to comply with the requirements given in *Table 7.6.1 Shell framing*. Arrangements of main frames in holds in association with web frames are not recommended in view of the vulnerability to cargo handling damage. Where such web frames are proposed the arrangements and scantlings will be specially considered.

6.2.2 Main frames in the cargo and ballast holds are to have a web thickness not less than:

(a) In general:

$$t_{min} = 7 + 0{,}03L \text{ mm,}$$

or 13 mm whichever is the lesser

(b) In the foremost hold:

$$t_{min} = 1{,}15\,(7 + 0{,}03L) \text{ mm,}$$

or 15 mm whichever is the lesser

where L is the Rule length, in metres.

6.2.3 The web depth to thickness ratio of the frames is not to be greater than:

$60\sqrt{k}$, for symmetric sections

$50\sqrt{k}$, for asymmetric sections

The breadth to thickness ratio of the flange outstand is not to be greater than:

$10\sqrt{k}$

6.2.4 The upper and lower end brackets of the main frames in the cargo and ballast holds are to satisfy the requirements of *Pt 4, Ch 7, 6.2 Transverse stiffening 6.2.5* to *Pt 4, Ch 7, 6.2 Transverse stiffening 6.2.14* inclusive, based on the mild steel section modulus Z in cm^3, derived from *Table 7.6.1 Shell framing*, or the equivalent mild steel section modulus for higher tensile steel frames.

6.2.5 The lengths of the arms of the brackets, measured as shown in *Figure 7.6.1 Diagrammatic arrangement of end brackets*, are not to be less than:

(a) Frame connection to hopper tank.

Athwartship arm:

Dry cargo hold $l_a = 32,43\sqrt{Z}$ mm

Ballast hold $l_a = 32,43(\sqrt{Z} - 7,5)$ mm

Vertical arm:

Dry cargo hold $l_v = 27,6\sqrt{Z}$ mm

Ballast hold $l_v = 27,6(\sqrt{Z} - 9,0)$ mm

(b) Frame connection to topside tank

Athwartship arm:

Dry cargo hold $l_a = 30,0\sqrt{Z}$ mm

Ballast hold $l_a = 30,0(\sqrt{Z} - 9,0)$ mm

Vertical arm:

Dry cargo hold $l_v = 26,85\sqrt{Z}$ mm

Ballast hold $l_v = 26,85(\sqrt{Z} - 11,0)$ mm

In no case are the bracket arm lengths to be taken less than 0,125H, where H is as defined in *Table 7.6.1 Shell framing*.

Table 7.6.1 Shell framing

Location	Modulus, in cm^3	Inertia, in cm^4
(1) Main frames in dry cargo holds	$Z = 3{,}50 s k h_{T1} H^2 \times 10^{-3}$	$I = \frac{3{,}2}{k} HZ$
(2) Main frames in cargo holds used for water ballast	The greater of the following: (a) Z = 1,15 x modulus given in (1) (b) $Z = 6{,}7 s k h_4 H^2 \times 10^{-3}$	$I = \frac{3{,}2}{k} HZ$
(3) Transverse frames in topside wing tanks	The greater of the following: (a) 1,15 x Z as given in location (1) of *Table 1.6.3 Shell framing (transverse)* (b) As required by *Pt 4, Ch 7, 7.3 Bulkhead stiffeners 7.3.1* for the sloped bulkhead stiffeners	$I = \frac{3{,}2}{k} HZ$

Symbols

D, T, s, k = as defined in *Pt 4, Ch 7, 1.7 Information required for non-CSR bulk carriers 1.7.1*

h_{T1} = head, in metres, at middle of H

= $C_W \left(1 - \frac{h_6}{D-T}\right) F_\lambda$ in metres, for frames where the mid-length of frame is above the summer load waterline,

= $\left(1 - \frac{h_6}{D-T}\right)$ is not to be taken less than 0,7

= $\left(h_6 + C_w \left(1 - \frac{h_6}{2T}\right)\right) F_\lambda$, in metres, where the mid-length of frame is below the summer load waterline

h_4 = head, in metres, measured from the middle of H to the deck at side, or half the distance from the middle of H to the top of the overflow, whichever is greater.

h_6 = vertical distance in metres, from the summer load waterline at draught T to the mid-length of H

C_w = a wave head, in metres

= $7{,}71 \times 10^{-2} L e^{-0{,}0044L}$

= where e = base of natural logarithms 2,7183

$F\lambda$ = 1,0 for $L \leq 200$ m

= $(1{,}0 + 0{,}0023 (L - 200))$ for $L > 200$ m

H = length overall of frame, in metres, but is to be taken not less than 2,5 m

6.2.6 The section modulus of the frame and bracket or integral bracket, and associated shell plating at the location marked Z_a in *Figure 7.6.1 Diagrammatic arrangement of end brackets* is to be not less than 2,0Z.

In addition, the minimum depth of the frame and bracket or integral bracket at the location indicated in *Figure 7.6.1 Diagrammatic arrangement of end brackets* is to be not less than 1,5d.

6.2.7 The upper and lower integral or separate brackets are to have a web thickness not less than the as built web thickness of the side frame. In addition, the lower bracket thickness is to be not less than:

$t = t_{min} + 2$ mm, where t_{min} is derived from *Pt 4, Ch 7, 6.2 Transverse stiffening 6.2.2*

The toes of the brackets are to be designed to avoid notch effects by making the upper and lower toes concave or otherwise tapering them off, *see also Pt 3, Ch 10, 5.1 Continuity and alignment 5.1.7*.

6.2.8 Except as indicated in *Pt 4, Ch 7, 6.2 Transverse stiffening 6.2.9*, frames are to be fabricated symmetrical sections with integral upper and lower brackets.

The side frame face plate is to be curved (not knuckled) at the connection with the end brackets. The radius of curvature, *r*, is to be not less than:

$$r = \frac{0,4 b_f^2}{t_f} \text{ mm}$$

where

b_f = breadth of the bracket face plate, in mm

t_f = thickness of the bracket face plate, in mm

The brackets are to be arranged with soft toes and the frame section face bar tapered symmetrically to the toes with a taper rate not exceeding 1 in 3. Where the free edge of the bracket is hollowed out, it is to be stiffened or increased in size to ensure that the section modulus of the bracket through the throat is not less than that of the required straight edged bracket.

6.2.9 In ships of length, *L*, less than 190 m, mild steel fabricated frames may be asymmetric and fitted with separate brackets. Brackets are to be arranged with soft toes. The free edges of the brackets are to be stiffened as follows:

(a) Where a flange is fitted, its breadth, b_f, is to be not less than:

$$b_f = 40\left(1 + \frac{Z}{1000}\right) \text{mm}$$

or 50 mm, whichever is the greater

The flange is to be tapered at the ends with a taper rate not exceeding 1 in 3.

(b) Where the edge is stiffened by a welded face flat, the cross-sectional area of the face flat is to be not less than:

(i) 0,009 $b_f t$ cm^2 for offset edge stiffening

(ii) 0,014 $b_f t$ cm^2 for symmetrically placed stiffening

where

t = web thickness of bracket, in mm

The face plate is to be tapered at the ends with a taper rate not exceeding 1 in 3.

6.2.10 For mild steel construction with separate brackets where the frames are lapped on to the bracket, the length of the overlap is to be adequate to provide for the required area of welding to achieve equivalent strength.

6.2.11 Double continuous welding is to be adopted for the connections of frames and brackets to side shell, hopper and topside tank plating and web to face plates. For this purpose, the following weld factors are to be adopted:

- 0,44 in Zone `a' and
- 0,40 in Zone `b', *see Figure 7.6.1 Diagrammatic arrangement of end brackets*.

Where the hull form is such that an effective fillet weld cannot be made, edge preparation of the web of the frame and bracket may be required, in order to ensure the required efficiency of the weld connection.

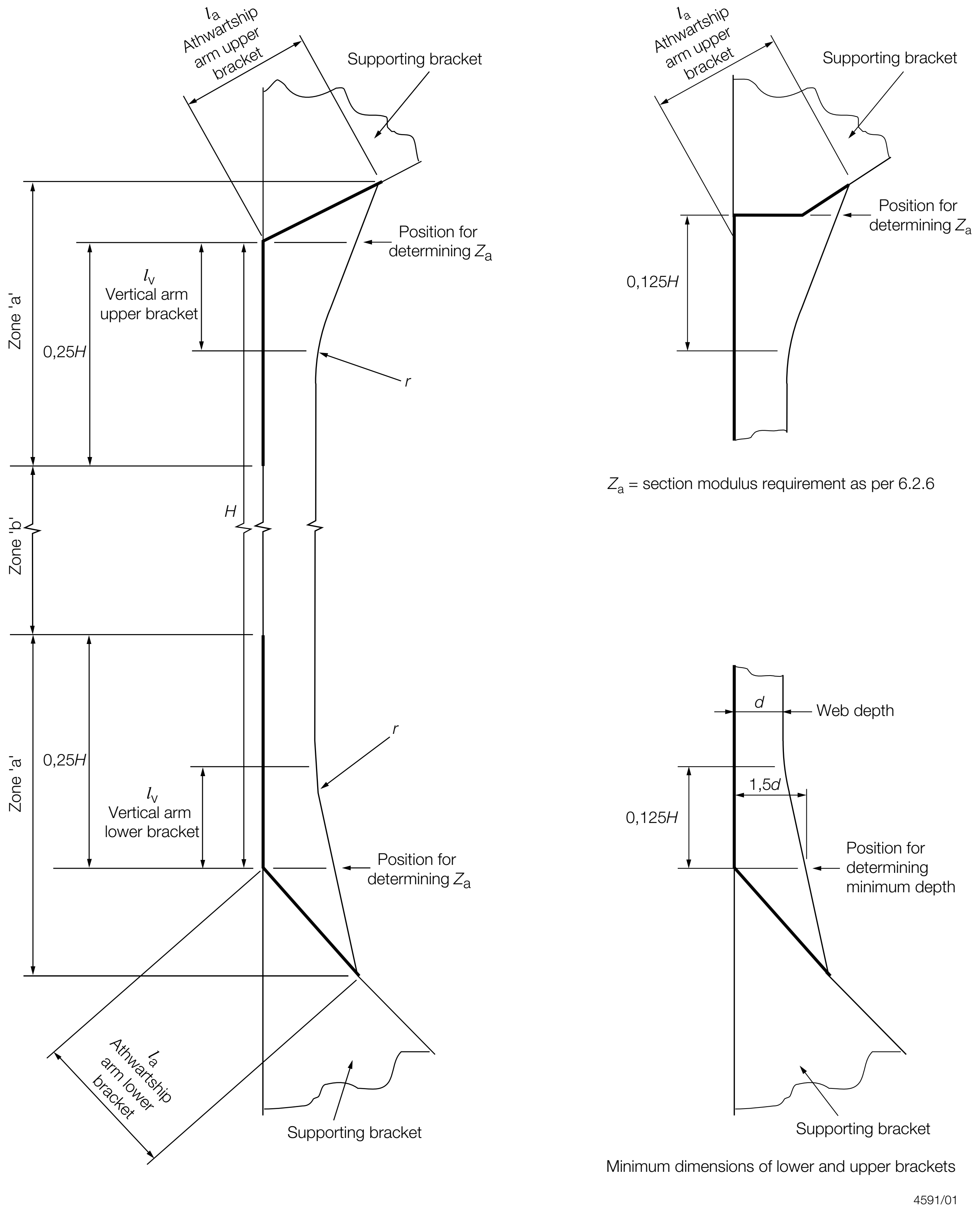


Figure 7.6.1 Diagrammatic arrangement of end brackets

6.2.12 Continuity of the frames is to be maintained by supporting brackets, *see Figure 7.6.2 Supporting brackets in topside and hopper tanks*, in the topside and hopper tanks. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint. For this purpose, in the hopper and topside tanks, the thickness of the supporting brackets (which must align with the hold main frame brackets) is to be not less than the following:

(a) Lower brackets (in hopper tank):

$t = t_{min} + 0{,}5$ mm, where t_{min} is derived from *Pt 4, Ch 7, 6.2 Transverse stiffening 6.2.2* or

$t = 9{,}0$ mm

whichever is the greater.

(b) Upper brackets (in topside tank):

$t = t_{min}$, where t_{min} is derived from *Pt 4, Ch 7, 6.2 Transverse stiffening 6.2.2* or

$t = 9{,}0$ mm

whichever is the greater.

The size and arrangement of stiffening of the supporting brackets will be specially considered. Where the toe of the hold frame bracket is situated on or in close proximity to the first longitudinal from the shell of the hopper or topside tank sloped bulkheads, the supporting brackets are to be extended to the next longitudinal. This extension is to be achieved by enlarging the supporting bracket or by fitting an intercostal flat bar stiffener the same depth as the longitudinal and connected to the webs of the longitudinals.

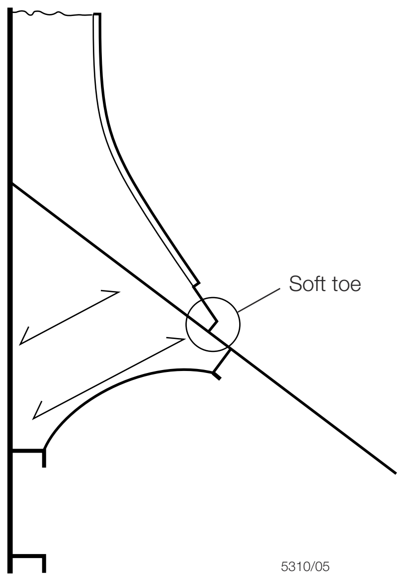


Figure 7.6.2 Supporting brackets in topside and hopper tanks

6.2.13 The requirements are to be maintained throughout the cargo hold region. However, in the forward and aft cargo holds where the shape becomes finer because of the ship form, increased requirements may be necessary and each case will be specially considered.

6.2.14 In way of the foremost hold, side frames of asymmetric section are to be effectively supported by intercostal brackets, *see Figure 7.6.3 Typical arrangement of intercostal brackets supporting asymmetric side shell frames in No. 1 hold*.

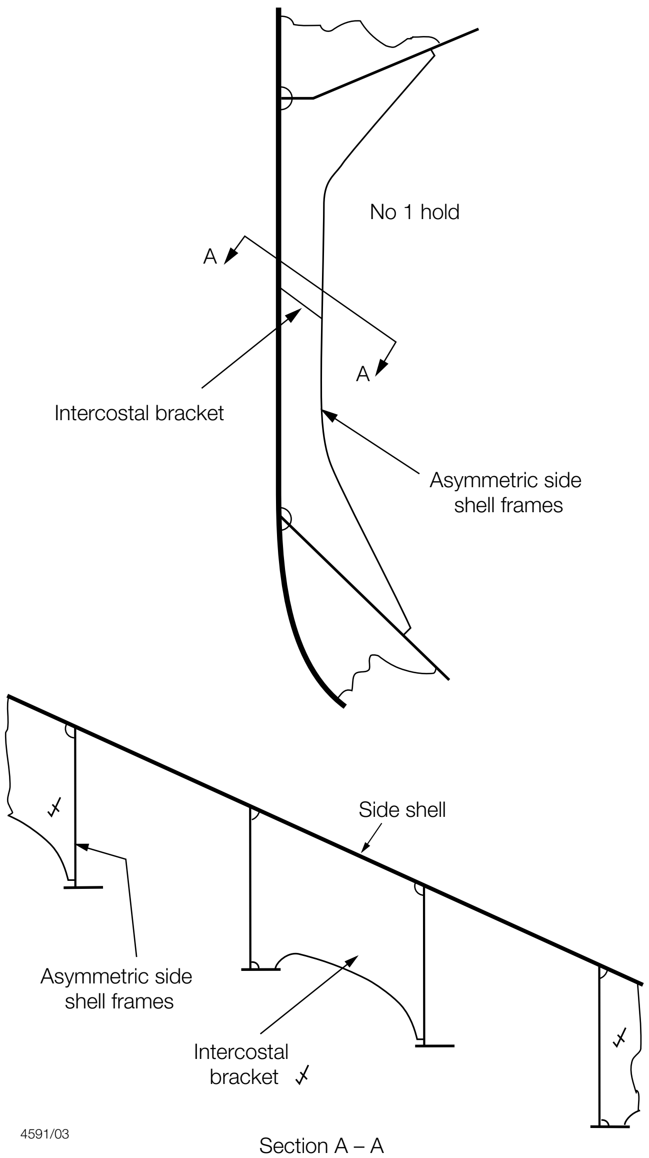


Figure 7.6.3 Typical arrangement of intercostal brackets supporting asymmetric side shell frames in No. 1 hold

6.2.15 The hold side shell frame adjacent to the collision bulkhead is to be suitably strengthened. As an alternative, at least two supporting structures are to be fitted which align with the forepeak stringers or flats, *see Figure 7.6.4 Hold frame supporting structures at fore end of No. 1 cargo hold*. The supporting structures are to have adequate cross-sectional shear resisting area at their connections to the hold frame.

6.2.16 Detail design guidelines for connection of side shell frames to hopper and topside tank plating are shown in the *Shipright FDA Procedure, Structural Detail Design Guide* (SDDG).

6.3 Primary supporting structure

6.3.1 For the requirements for primary supporting structure, *see Pt 4, Ch 7, 7.5 Primary supporting structure* and *Pt 4, Ch 7, 9.6 Primary supporting structure*.

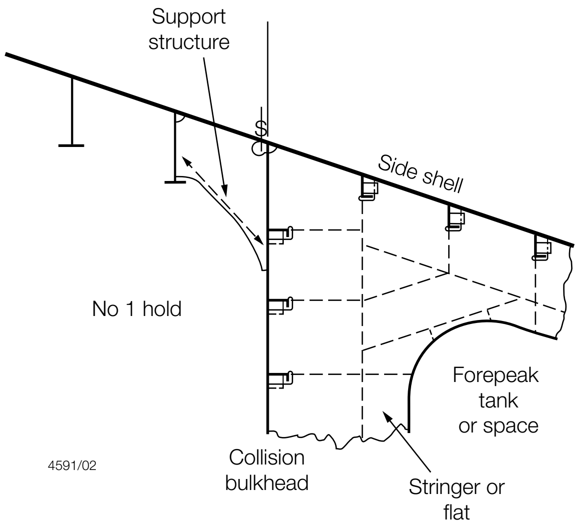


Figure 7.6.4 Hold frame supporting structures at fore end of No. 1 cargo hold

■ *Section 7*
Topside tank structure

7.1 General

7.1.1 Requirements are given in this Section for longitudinal or transverse framing in the topside tank, but, in general, the deck is to be longitudinally framed. The sloped bulkhead is to be of plane construction with the associated stiffening arranged inside or outside the tank.

7.1.2 The buckling requirements of *Pt 3, Ch 4, 7 Hull buckling strength* are also to be satisfied.

7.1.3 Recommended examples of structural design configurations around the transverse ring web of the topside tank can be seen in the *ShipRight FDA Procedure, Structural Detail Design Guide* (SDDG).

7.2 Bulkhead plating

7.2.1 The thickness of the sloped bulkhead, tank end bulkhead, and diaphragm, if fitted, is to be the greater of the following:

(a) For watertight bulkheads, the thickness, t, as derived from *Table 1.9.1 Watertight and deep tank bulkhead scantlings* in *Pt 4, Ch 1 General Cargo Ships* for a deep tank bulkhead using a head, h_4, in metres, determined as follows:

h_4 = $h_o \cos\theta + Rb_1$ or

= the greater of the distance from a point one-third of the height of the plate above its lower edge to the top of the tank, or half the distance to the top of the overflow

whichever is the greater, or

(b) $(b)\quad t = 7.5$ mm

In no case, however, is the thickness of the sloped bulkhead and diaphragm to be taken less than:

(i) $t = 0,012s$ mm, or

$$t = 0,012s\sqrt{\frac{F_D}{k_D}}\ \text{mm}$$

whichever is the greater

where

k_D = the higher tensile steel factor equal to k_L value for deck material

F_D = as defined in *Pt 3, Ch 4, 5.7 Local reduction factors*

R = as defined in *Pt 4, Ch 7, 1.8 Symbols and definitions 1.8.1*

h_o = the vertical distance, in metres, from a point one third of the height of the plate from the lower edge to the highest point of the tank excluding hatchway

b_1 = the larger horizontal distance, in metres, from the tank corner at top of tank either side to point of plate under consideration.

7.2.2 The thickness of the top strake of the sloped bulkhead, including the vertical plate attached to deck, may be required to be increased to form an effective girder below the deck. In general, this plate is to be not less in thickness than 60 per cent of the thickness of the deck plate outside the line of openings nor less than:

(a) $t = 0,018s$ mm, or

(b) $t = 0,018s\sqrt{\dfrac{F_D}{k_D}}$ mm

(a) whichever is the greater.

7.2.3 The thickness of the transverse wash bulkhead, where fitted, is to be not less than:

t = 0,012s mm or 7,5 mm

= whichever is the greater.

7.3 Bulkhead stiffeners

7.3.1 The section modulus of longitudinal or transverse stiffeners on the sloped bulkhead or watertight diaphragms, if fitted, is to be not less than:

$Z = 0,01skh_4 l_e^2$ cm^3

where

$h_4 = h_o \cos\theta + Rb_1$

= the greater of the distance, in metres, from the middle of the effective length to the top of the tank, or half the distance to the top of the overflow, or

= 1,5 m

= whichever is the greatest

R = as defined in *Pt 4, Ch 7, 1.7 Information required for non-CSR bulk carriers 1.7.1*

h_o = the vertical distance, in metres, from the mid-point of span of the stiffener to the highest point of the tank excluding hatchway

b_1 = the larger horizontal distance, in metres, from the tank corner at top of tank, either side to midpoint of span.

7.3.2 Where the bulkhead stiffening is fitted on the hold side of the sloped bulkhead, suitable arrangements are to be made to prevent tripping.

7.3.3 The scantlings of stiffeners on tank end bulkheads are to be not less than those given in *Table 1.9.1 Watertight and deep tank bulkhead scantlings* of *Pt 4, Ch 1 General Cargo Ships* for deep tanks, using h as defined in *Pt 4, Ch 7, 7.3 Bulkhead stiffeners 7.3.1*.

7.3.4 The section modulus of stiffeners of non-watertight fore and aft diaphragms, or transverse wash bulkheads is to be not less than 50 per cent of that required by *Pt 4, Ch 7, 7.3 Bulkhead stiffeners 7.3.3*. The stiffeners are to be bracketed at both ends.

7.3.5 Tank end bulkheads are generally to be in line with the main hold bulkheads.

7.4 Shell and deck structure

7.4.1 The scantlings of shell and deck longitudinals are to comply with *Pt 4, Ch 7, 7.3 Bulkhead stiffeners 7.3.1*. The scantlings must also satisfy the requirements of *Pt 4, Ch 1 General Cargo Ships*, *see also Pt 4, Ch 7, 7.6 Structural details 7.6.1*.

7.4.2 The scantlings of side shell frames are to comply with *Pt 4, Ch 7, 6.2 Transverse stiffening*.

7.5 Primary supporting structure

7.5.1 The section modulus and inertia of deck, shell and bulkhead transverses or stringers are to be not less than:

$$Z = 7,5\, k\, S\, h\, l_e^2 \text{ cm}^3$$

$$I = \frac{2,5}{k} l_e Z \text{ cm}^4$$

using *h* as defined in *Pt 4, Ch 7, 7.3 Bulkhead stiffeners 7.3.1*. The scantlings of shell and deck members must also satisfy the requirements of *Pt 4, Ch 1 General Cargo Ships* for dry cargo holds.

7.5.2 Primary transverse members are, in general, to be spaced not more than 3,8 m apart where the length, *L*, is 100 m or less, and (0,006*L* + 3,2) m apart for lengths greater than 100 m.

7.5.3 Transverses are to be arranged in line with the primary structure at ends of hatchways, or equivalent scarfing arranged. Where the sloped bulkhead or side shell is transversely framed, arrangements are to be made to ensure effective continuity at the ends of the deck transverse.

7.5.4 Where non-watertight transverse diaphragms are arranged instead of open transverses, the thickness of plating is to be in accordance with *Pt 4, Ch 7, 7.2 Bulkhead plating 7.2.3*. The diaphragms are to be efficiently stiffened.

7.6 Structural details

7.6.1 Bracket/diaphragm connections at the bottom of the topside tank are to be of sufficient size and thickness to provide effective rigidity, and care is to be taken to ensure alignment with brackets at the heads of the side frames in the holds, *see also Pt 4, Ch 7, 6.2 Transverse stiffening 6.2.12*. The shell and sloped bulkhead longitudinals supporting the diaphragms are to be derived using the span taken between transverses.

7.6.2 For ships where $L \geq 300$ m a fore and aft diaphragm extending vertically from the deck to the sloping plating of the topside tank is to be arranged at about the half-width of the tank.

7.6.3 Where longitudinal framing is fitted to the side shell, a bracket may be required in way of a rounded gunwale, approximately halfway between transverses and extending to the adjacent shell and deck longitudinal.

■ *Section 8* Double bottom structure

8.1 General

8.1.1 The double bottom is, in general, to be longitudinally framed, but special consideration will be given to proposals for a transverse framing system.

8.1.2 The requirements of *Pt 4, Ch 1, 8 Double bottom structure* are to be applied, together with the requirements of this Section, *see also Pt 4, Ch 7, 2.2 Protection of steelwork 2.2.3*.

8.1.3 Where the double bottom tanks are interconnected with double skin side tanks or combined hopper and top-side tanks, the double bottom scantlings are also to satisfy the requirements of *Table 7.8.1 Strengthening for heavy cargo requirements* (3)(c), (3)(d), (4)(c) and (4)(d) for ballast holds and (3)(c) and (4)(c) in way of dry cargo holds, *see also Pt 4, Ch 1, 6.2 Longitudinal stiffening*.

8.1.4 The requirements given in *Pt 4, Ch 7, 8.8 Allowable hold loading in the flooded condition* are to be applied to bulk carriers which satisfy the following criteria:

- Single skin construction, or double skin construction where any part of the 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.

- Length, L, of 150 m or above.
- Intended for the carriage of cargoes having bulk densities of 1,0 tonne/m^3 or above.

8.1.5 For all bulk carriers where bulk cargoes are discharged by grabs the maximum recommended unladen weight of the grab corresponding to the approved inner bottom plating thickness is to be calculated using the following formulae:

$$P = \left(\frac{s}{k}\right)^2 \frac{10^d}{1,775} \text{ tonnes}$$

where:

$$d = \frac{40,875(t - 1,5)\sqrt{k} + 344,5}{s} - 5,7633$$

P = unladen grab weight, in tonnes

s = spacing of inner bottom longitudinal, in mm

k = higher tensile steel factor as defined in *Pt 4, Ch 7, 1.8 Symbols and definitions 1.8.1*

t = thickness of inner bottom plating, in mm

The maximum recommended unladen weight of the grab rounded up to the next tonne above, is to be recorded in the Loading Manual (*see also Pt 3, Ch 4, 8.2 Loading Manual 8.2.4.(e)*), and does not preclude the use of heavier grabs. It is intended as an indication to the Builders, Owners and operators of the increased risk of local damage and the possibility of accelerated diminution of the plating thickness if grabs heavier than this are used regularly to discharge cargo.

8.1.6 Detail design guidelines for stiffeners connecting inner bottom and bottom longitudinals are shown in the *ShipRight FDA Procedure, Structural Detail Design Guide* (SDDG).

Table 7.8.1 Strengthening for heavy cargo requirements

Symbols	Item	Requirement
L, l_e, *D*, *T*, *s*, *S*, *k*, *Z* and *t* as defined in *Pt 4, Ch 7, 1.8 Symbols and definitions 1.8.1*	(1) Double bottom floors	The spacing of floors, generally, is not to exceed 2,5 m. Scantlings are to comply with the requirements of *Pt 4, Ch 1, 8.5 Floors*
C_1 = a factor varying from 1,0 at $\frac{D}{2}$ to $\frac{75}{225 - 150F_B}$ at base line of ship	(2) Double bottom side girders	The spacing of side girders, generally, is not to exceed 3,7 m. Scantlings are to comply with the requirements of *Pt 4, Ch 1, 8.3 Girders*
C = stowage rate, in m^3/tonne, and is defined as the volume of the hold excluding the volume contained within the depth of the cargo hatchway divided by the weight of cargo stowed in the hold. The value is not to be taken greater than 0,865 F_B as defined in *Pt 3, Ch 4, 5.7 Local reduction factors* *R* and θ as defined in *Pt 4, Ch 7, 1.8 Symbols and definitions 1.8.1* *H* = height from tank top, at position under consideration, to deck at side amidships, in metres Y_1 = distance from $\frac{D}{2}$ to tank top, in metres	(3) Inner bottom plating, *see* Note 3	The thickness of the inner bottom plating in the holds is to be not less than required by the greatest of the following: (a) $t = 0,00136(s + 660)\sqrt[4]{k^2 LT} + 5mm$, or (b) $t = 0,00455s\sqrt{\frac{Hk}{C}}$ mm, or (c) Where the double bottom tanks are interconnected with double skin side tanks or combined hopper and topside tanks the scantlings are also to satisfy the requirements for deep tanks in *Table 1.9.1 Watertight and deep tank bulkhead scantlings* in Chapter 1, with the load head h_4, = $h_0 \cos\theta + Rb_1$ m (d) In way of ballast holds the scantlings are also to satisfy the requirements for deep tanks in *Table 1.9.1 Watertight and deep tank bulkhead scantlings* in *Pt 4, Ch 1 General Cargo Ships*, with the load head h_4, in metres, measured to the deck at centre, but *see also Pt 3, Ch 9, 7 Bottom strengthening for loading and unloading aground* if protection against heavy grabs is desired.
h_0 = for plating and stiffeners the vertical distance, in metres, from the inner bottom to the highest point of the tank excluding hatchway b_1 = the larger horizontal distance, in metres, from the tank corner at top of tank either side to the point of plate or stiffener under consideration	(4) Inner bottom longitudinals *see* Notes 1 and 2	The section modulus of inner bottom longitudinals is to be not less than the greatest of the following: (a) *Z* = 85 per cent of the Rule value for bottom longitudinals as given in *Table 1.6.2 Shell framing (longitudinal) Pt 4, Ch 1 General Cargo Ships* , or (b) $Z = \frac{0,0083 s l_e^2 H C_1 k}{\left(1 - 0,233\frac{Y_1}{D}\right) C}$ cm^3 or (c) Where the double bottom tanks are interconnected with double skin side tanks or combined hopper and topside tanks $Z = 0,0073 s k h_4 l_e^2$ cm^3 where $h_4 = h_0 \cos\theta + Rb_1$ m. *Z* is not to be less than the requirements for deep tanks in *Table 1.9.1 Watertight and deep tank bulkhead scantlings* in *Pt 4, Ch 1 General Cargo Ships*, with the load head h_4, in metres, measured to the highest point of the topside tank, or side tank, or (d) In way of ballast holds the section modulus of the longitudinals is to be not less than required for deep tanks in *Table 1.9.1 Watertight and deep tank bulkhead scantlings* in *Pt 4, Ch 1 General Cargo Ships*, with the load head h_4, in metres, measured to the deck at centre
Note 1. If plate girders are fitted alternatively with built or rolled sections, the section modulus as given in (4)(b) may be reduced by 10 per cent.		

Note 2. Consideration will be given to the fitting of struts in way of double bottom tanks in ships with homogeneous loading. The arrangement and scantlings are, in general, to be confirmed by direct calculation.

Note 3. *See also Pt 4, Ch 7, 8.1 General 8.1.5* for the maximum recommended unladen weight of the grab corresponding to the approved inner bottom plating thickness.

8.2 Carriage of heavy cargoes

8.2.1 When the notation `strengthened for heavy cargoes' is to be assigned, the requirements of *Table 7.8.1 Strengthening for heavy cargo requirements* are to be complied with.

8.3 Carriage of heavy cargoes with specified or alternate holds empty

8.3.1 For ships strengthened for heavy cargoes and having a class notation permitting specified or alternate holds to be empty, the requirements of *Pt 4, Ch 7, 8.2 Carriage of heavy cargoes 8.2.1* are to be complied with. In addition the scantlings and arrangements of the primary structure are to be confirmed by additional calculations, *see Pt 4, Ch 7, 11.1 Application*.

8.4 Ships to be classed '100A1 bulk carrier, strengthened for heavy cargoes, any hold may be empty, ESP'

8.4.1 For ships to be classed **‘100A1 bulk carrier, strengthened for heavy cargoes, any hold may be empty, ESP’**, the requirements of *Pt 4, Ch 7, 8.2 Carriage of heavy cargoes 8.2.1* and *Pt 4, Ch 7, 8.3 Carriage of heavy cargoes with specified or alternate holds empty 8.3.1* are to be complied with. In addition the value for *C*, the stowage rate in m^3/tonne, as defined in *Table 7.8.1 Strengthening for heavy cargo requirements*, is not be taken greater than 0,60 for each hold.

8.5 Ballast ducts

8.5.1 Where ballast ducts are arranged in lieu of suction and/or filling pipes, the scantlings will be approved as suitable for a specified equivalent static head of water. This head must not be exceeded in service, and details of methods to ensure this are to be submitted. The continuity of the floors is to be maintained in way of the ducts.

8.6 Structural details in way of double bottom tank and hopper tank knuckle

8.6.1 In all dry holds where the double bottom tank and hopper tank knuckle is of radiused construction and the floor spacing is 2,5 m or greater brackets shown as in *Figure 7.8.1 Intermediate brackets at knuckle* are to be arranged mid-length between floors in way of the intersection. The brackets are to be attached to the adjacent inner bottom and hopper longitudinals. The thickness of the brackets is to be in accordance with *Pt 4, Ch 1, 8.5 Floors 8.5.3* but need not exceed 15 mm. This requirement does not apply where the double bottom tank and hopper tank knuckle is of welded construction.

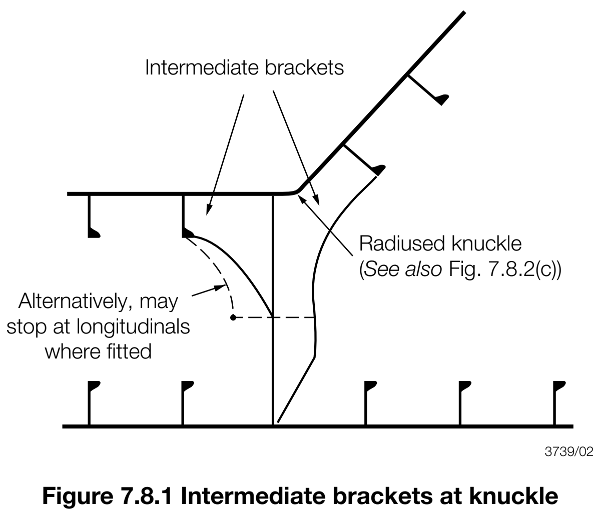


Figure 7.8.1 Intermediate brackets at knuckle

8.6.2 In way of floodable holds, two intermediate bracket arrangements, as shown in *Figure 7.8.1 Intermediate brackets at knuckle*, are to be provided in all cases where the hopper to double bottom knuckle is radiused and are, in general, to be located at each frame space. Where the double bottom tank and hopper tank knuckle is of welded construction, a single intermediate bracket arrangement, as shown in *Figure 7.8.1 Intermediate brackets at knuckle*, is to be provided only when the floor spacing is greater than 2,5 m.

8.6.3 The connections at the intersection are to be as follows:

(a) Where of welded construction the corner scallops in floors and transverses are to be omitted, or closed by welded collars where arranged for purposes of construction. In such cases to ensure satisfactory welding of the collars the radius of the scallops should not be less than 150 mm,*see Figure 7.8.2 Connection at intersection of double bottom and hopper*. Alternatively the scallop may be retained on the hopper tank side provided gusset plates are arranged in line with the inner bottom plating, *see Figure 7.8.2 Connection at intersection of double bottom and hopper*.

(b) Where of radiused construction the corner scallops are to be omitted, and full penetration welding is to be arranged locally for the connection to the inner bottom plating. The centre of the flange is not to be greater than 70 mm from the side girder, *see Figure 7.8.2 Connection at intersection of double bottom and hopper*.

8.6.4 Detail design guidelines for the connection of hopper tank sloping plating to inner bottom plating are shown in the *ShipRight FDA Procedure, Structural Detail Design Guide* (SDDG).

8.7 Combined double bottom/hopper tank and topside tank

8.7.1 Where a double bottom/hopper tank is interconnected with a topside tank the dimensions of the connecting trunks or pipes, and the air/overflow pipe(s) and the type of closing appliance are to comply with the requirements of *Pt 5, Ch 13, 12 Air, overflow and sounding pipes*.

8.8 Allowable hold loading in the flooded condition

8.8.1 The requirements of this sub-Section are to be applied as defined in *Pt 4, Ch 7, 8.1 General 8.1.4*.

8.8.2 The maximum load which may be carried in each cargo hold in combination with flood water is to be determined for the most severe homogeneous, non-homogeneous and packed cargo conditions contained in the Loading Manual. The maximum density of cargo intended to be carried in each condition is to be used.

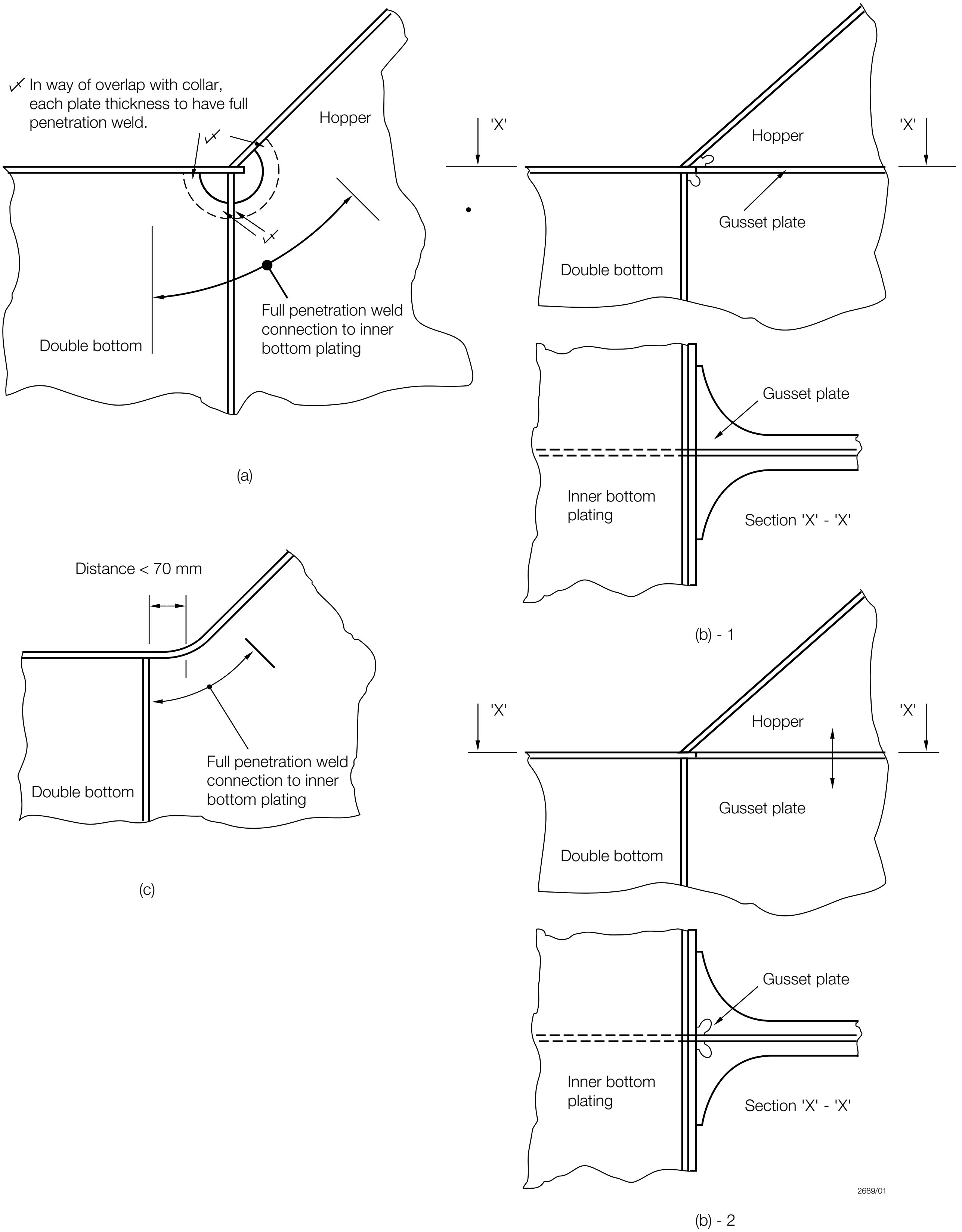


Figure 7.8.2 Connection at intersection of double bottom and hopper

8.8.3 The ship is to be assumed immersed to the draught, T_F, in metres, in way of the flooded cargo hold under consideration. The flooding head, h_f, *see Figure 7.8.3 Loading*, is to be taken as the distance, in metres, measured vertically with the ship in the upright position, from the inner bottom to position, d_f, in metres, from the baseline given by:

(a) In general:

(i) $d_f = D$ for the foremost hold

(ii) $d_f = 0{,}9D$ for other holds

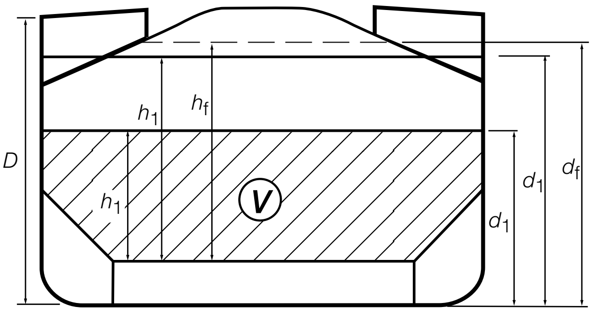
(b) For ships less than 50 000 tonnes deadweight with Type B freeboard:

(i) $d_f = 0{,}95D$ for the foremost hold

(ii) $d_f = 0{,}85D$ for other holds

where

D = distance, in metres, from the baseline to the freeboard deck at side amidships.



V = Volume of cargo

Figure 7.8.3 Loading

8.8.4 For this application, the double bottom is defined as the structure bounded by the transverse bulkhead lower stools (or bulkhead plating if no lower stools are fitted) and the hopper sides. The floors and girders immediately in way of these structures are excluded.

8.8.5 The determination of shear strength required for the permissible load assessment in *Pt 4, Ch 7, 8.8 Allowable hold loading in the flooded condition 8.8.9*, is to be performed using the net plate thickness, t_{net}, for the floors and girders:

$$t_{net} = t - t_c$$

where

t = as built thickness, in mm

t_c = thickness deduction for corrosion, in mm, generally to be taken as 2,5 mm.

8.8.6 Shear capacity of the double bottom is defined as the sum of the shear strengths for:

(a) all the floors adjacent to both hoppers, less one half the strength of the floors adjacent to each lower stool (or transverse bulkhead if no lower stool is fitted), *see Figure 7.8.4 Double bottom structure*, and

(b) all the girders adjacent to the lower stools (or transverse bulkheads if no lower stool is fitted).

Where a girder or floor terminates without direct attachment to the boundary stool or hopper side girder, its shear capacity is to include only that for the effectively connected end.

8.8.7 The shear strengths, S_{f1}, of floors adjacent to hoppers, and S_{f2}, of floors in way of openings in bays nearest to the hoppers, are as follows:

$$S_{f1} = 0{,}001\, A_f\, \tau_p / \eta_1 \text{ kN}$$

S_{f2} = $0,001\ A_{f,h}\ \tau_p/\eta_2$ kN

where

A_f = net sectional area, in mm^2, of floor panel adjacent to hopper

$A_{f,h}$ = net sectional area, in mm^2, of floor panel in way of opening in the bay closest to hopper

η_1 = 1,10

η_2 = 1,20 generally

= 1,10 where appropriate reinforcement is fitted in way of the opening

σ_0 = specified minimum yield stress, in N/mm^2

τ_p = permissible shear stress, to be taken equal to the lesser of:

$$\tau_0 = \frac{\sigma_0}{\sqrt{3}}\ \text{N/mm}^2 \text{ and}$$

$$\tau_c = \frac{162\ \sigma_0^{0,6}}{(s_1/t_{net})^{0,8}}\ \text{N/mm}^2$$

where

s_1 = spacing of stiffening members, in mm, for the panel under consideration

t_{net} = net thickness, in mm, of the panel under consideration.

For floors adjacent to the stools (or bulkhead plating if no lower stools are fitted), τ_p may be taken as $\frac{\sigma_0}{\sqrt{3}}$ N/mm^2.

8.8.8 The shear strengths S_{g1}, of girders adjacent to transverse bulkhead lower stools (or transverse bulkheads if no lower stools are fitted), and S_{g2}, of girders in way of the largest openings in bays nearest to the lower stools (or transverse bulkheads if no lower stools are fitted), are as follows:

S_{g1} = $0,001\ A_g\ \tau_p/\eta_1$ kN

S_{g2} = $0,001\ A_{g,h}\ \tau_p/\eta_2$ kN

where

A_g = net sectional area, in mm^2, of the girder adjacent to transverse bulkhead lower stool (or transverse bulkhead, if no lower stool is fitted)

$A_{g,h}$ = net sectional area, in mm^2, of the girder in way of the largest openings in the bays closest to the transverse bulkhead lower stool (or transverse bulkhead if no lower stool is fitted)

η_1 = 1,10

η_2 = 1,15 generally

= 1,10 where appropriate reinforcement is fitted in way of the opening.

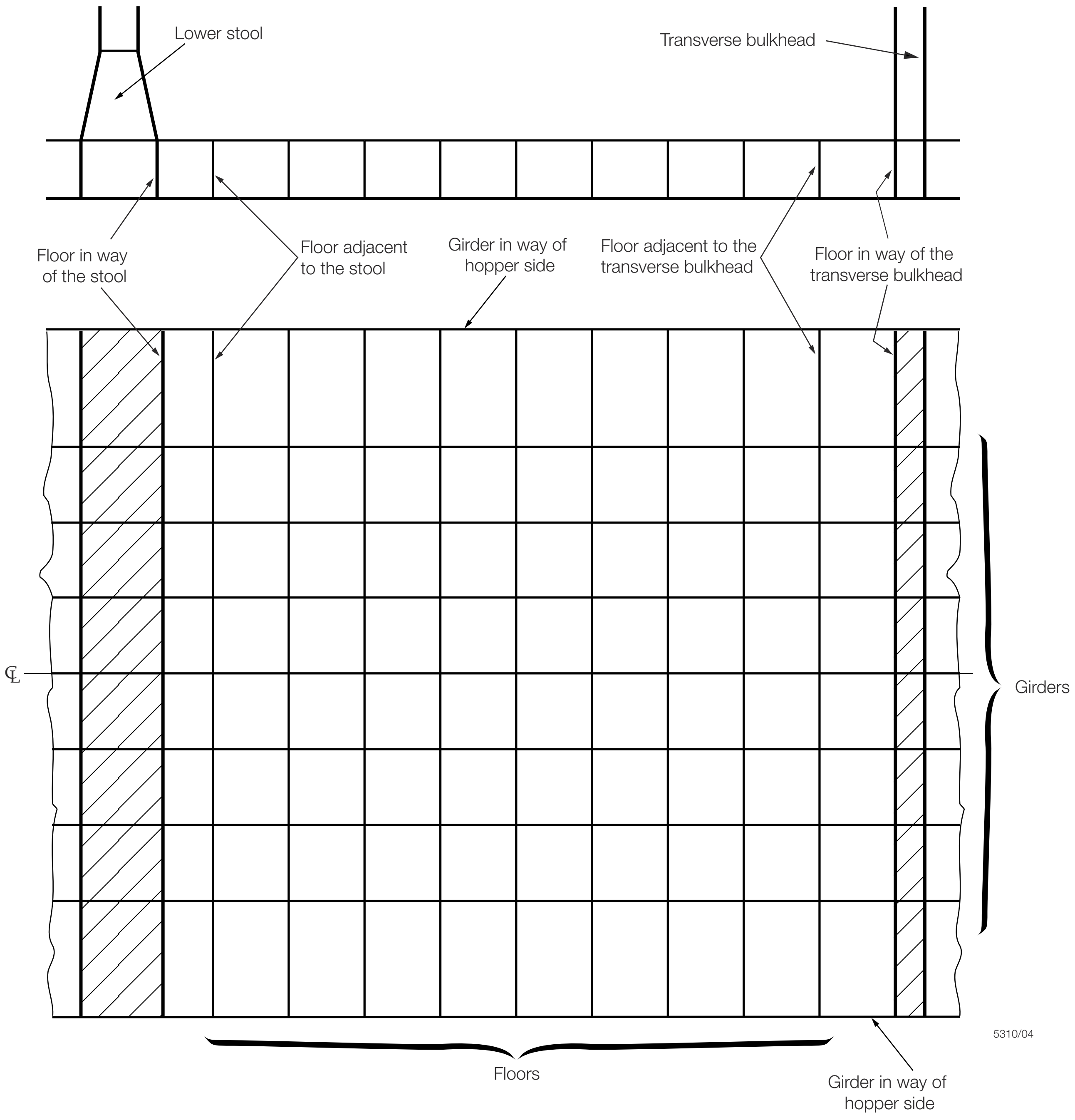


Figure 7.8.4 Double bottom structure

8.8.9 The permissible cargo hold loading, W_p, is given by:

$$W_p = g\,\rho_c\,V/F_c \text{ kN}$$

where

d_f, D = as defined in *Pt 4, Ch 7, 8.8 Allowable hold loading in the flooded condition 8.8.3*

g = gravitational constant, 9,81 m/sec^2

where

h_f = flooding head, in metres, as defined in *Pt 4, Ch 7, 8.8 Allowable hold loading in the flooded condition 8.8.3*

h_1 = $\dfrac{X}{\rho_c g}$ where Y is in kN/m^2

n = number of floors between transverse bulkhead lower stools or transverse bulkheads, if no lower stools are fitted

s = spacing, in metres, of double bottom longitudinals adjacent to hoppers

$A_{DB,e}$ = $\left[\sum_{i=1}^{n}\right] S_i\left(B_{DB}-s\right)$

$A_{DB,h}$ = $\left[\sum_{i=1}^{n}\right] S_i B_{DB,i}$

B_{DB} = breadth of double bottom, in metres, between hoppers *see Figure 7.8.5 Double bottom breadth*

$B_{DB,h}$ = distance, in metres, between openings *see Figure 7.8.5 Double bottom breadth*

$B_{DB,i}$ = (B_{DB}-s) for floors where shear strength is given by S_{f1}

= $B_{DB,h}$ for floors where shear strength is given by S_{f2}

C_e = shear capacity of the double bottom, in kN (tonne- f), as defined in *Pt 4, Ch 7, 8.8 Allowable hold loading in the flooded condition 8.8.6*, considering for each floor, the shear strength S_{f1}, *see Pt 4, Ch 7, 8.8 Allowable hold loading in the flooded condition 8.8.7*, and for each girder, the lesser of the shear strengths S_{g1} and S_{g2}, *see Pt 4, Ch 7, 8.8 Allowable hold loading in the flooded condition 8.8.8*

C_h = shear capacity of the double bottom, in kN (tonne- f), as defined in *Pt 4, Ch 7, 8.8 Allowable hold loading in the flooded condition 8.8.6*, considering for each floor, the lesser of the shear strengths S_{f1} and S_{f2}, *see Pt 4, Ch 7, 8.8 Allowable hold loading in the flooded condition 8.8.7*, and for each girder, the lesser of the shear strengths S_{g1} and S_{g2}, *see Pt 4, Ch 7, 8.8 Allowable hold loading in the flooded condition 8.8.8*

F_c = 1,1 in general

= 1,05 for steel mill products

S_i = spacing of *i*th floor, in metres

T_F = d_f - 0,1D

V = volume, in m^3, occupied by cargo at a level h_1

X = the lesser of X_1 and X_2 for bulk cargoes and

X = X_1 for steel mill products

where

X_1 = $\dfrac{Y+\rho g\left(T_F-h_f\right)}{1+\left(\dfrac{\rho}{\rho_c}\right)(\mu-1)}$ where Y is in kN/m^2

X_2 = $Y + \rho g\,(T_F - h_f\,\mu)$ where Y is in kN/m^2

Y = the lesser of Y_1 and Y_2 given by:

Y_1 = $\dfrac{C_h}{A_{DB,h}}$

where

$Y_2 = \dfrac{C_e}{A_{DB,e}}$

μ = permeability of cargo but need not exceed 0,3

= 0,0 for steel mill products

ρ = density of sea water, 1,025 tonne/m^3

ρ_c = cargo density, in tonne/m^3 (bulk density for bulk cargoes and actual cargo density for steel mill products).

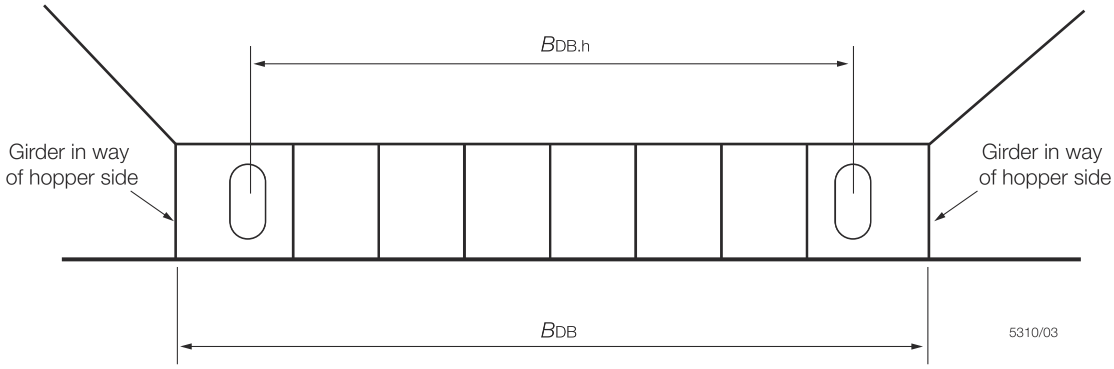


Figure 7.8.5 Double bottom breadth

■ *Section 9*
Hopper side tank structure

9.1 General

9.1.1 Provision is made in this Section for longitudinal framing of the hopper side tank, but proposals for transverse framing will be specially considered.

9.1.2 Where oil cargoes are carried the scantlings of the sloped bulkhead are to comply with the requirements of *Pt 4, Ch 7, 10.2 Bulkheads supported by stools*.

9.1.3 For ships to be classed **'100A1 bulk carrier, strengthened for heavy cargoes, any hold may be empty, ESP'**, the requirements of *Pt 4, Ch 7, 9.2 Sloped bulkhead plating*, *Pt 4, Ch 7, 9.3 Sloped bulkhead stiffeners* and *Pt 4, Ch 7, 9.6 Primary supporting structure* are to be complied with. In addition the value for *C*, the stowage rate in m^3/tonne, as defined in *Table 7.8.1 Strengthening for heavy cargo requirements*, is not be taken greater than 0,60 for each hold.

9.1.4 The buckling requirements of *Pt 3, Ch 4, 7 Hull buckling strength* are also to be satisfied.

9.1.5 The *ShipRight FDA Procedure, Structural Detail Design Guide* (SDDG), indicates recommended details of structural design configurations around the transverse ring web of the hopper tank.

9.2 Sloped bulkhead plating

9.2.1 The thickness of the sloped bulkhead plating is to be as required by *Pt 4, Ch 1, 8.4 Inner bottom plating and stiffening 8.4.1* but based on actual spacing of sloped bulkhead stiffeners.

9.2.2 Where the ship is regularly discharged by grabs and the optional notation for heavy grabs is not desired (*see Pt 3, Ch 9, 7 Bottom strengthening for loading and unloading aground*), the increase in thickness, as required by *Pt 4, Ch 1, 2.2 Protection of steelwork*, is to be tapered from the inner bottom knuckle to nil at the top corner of the tank.

9.2.3 Where a `strengthened for heavy cargo notation' is desired, in addition to *Pt 4, Ch 7, 9.2 Sloped bulkhead plating 9.2.2* the thickness of the sloped bulkhead plating is also to comply with the requirements of *Table 7.8.1 Strengthening for heavy cargo requirements* (3)(b) using the actual spacing of stiffeners and with *H*, in metres, measured vertically from a point one third of each plate width from its lower edge to the upper deck at side.

9.2.4 Where the hopper tanks are interconnected with the topside tanks, or in way of ballast holds, the plating is also to comply with the requirements of *Table 7.8.1 Strengthening for heavy cargo requirements* (3)(c) and (3)(d), whichever is appropriate.

9.3 Sloped bulkhead stiffeners

9.3.1 The scantlings of sloped bulkhead stiffeners are to be as required for inner bottom longitudinals, *see Pt 4, Ch 7, 8 Double bottom structure*. In ships strengthened for heavy cargoes, the scantlings of the stiffeners are to be derived from *Table 7.8.1 Strengthening for heavy cargo requirements* using a head for heavy cargo measured vertically from the mid-point of the effective length to the underside of the topside tank sloped bulkhead. Where the hopper tanks are interconnected with the topside tanks, or in way of ballast holds, the scantlings of the stiffeners are also to comply with the requirements of *Table 7.8.1 Strengthening for heavy cargo requirements* (4)(c) and (4)(d), whichever is appropriate. For higher tensile steel longitudinals the requirements of *Pt 4, Ch 1, 6.2 Longitudinal stiffening 6.2.3* are to be complied with where applicable, *see also Pt 4, Ch 7, 9.7 Structural details 9.7.1*.

9.4 Shell and bilge stiffeners

9.4.1 The scantlings of the shell and bilge longitudinals are to comply with the requirements of *Pt 4, Ch 1, 6 Shell envelope framing*.

9.5 Tank end bulkheads

9.5.1 The scantlings of tank end bulkheads are to comply with the requirements for deep tanks in *Table 1.9.1 Watertight and deep tank bulkhead scantlings*. Where the hopper tanks are interconnected with the topside tanks, the scantlings are to be derived, using the load head h_4, in metres, from *Table 7.8.1 Strengthening for heavy cargo requirements* (3)(c) and (4)(c), as appropriate.

9.6 Primary supporting structure

9.6.1 Transverses supporting longitudinal stiffening are to comply with the requirements of *Table 7.9.1 Hopper tank primary structure*, and are to be in line with the double bottom floors.

9.7 Structural details

9.7.1 Bracket/diaphragms at the top of the hopper tank are to be of sufficient size and thickness to provide effective rigidity, and care is to be taken to ensure alignment with brackets at the bottom of the side frames in the holds. The shell and sloped bulkhead longitudinals supporting the diaphragms are to be derived using the span taken between transverses, *see also Pt 4, Ch 7, 6.2 Transverse stiffening 6.2.11*.

Table 7.9.1 Hopper tank primary structure

Item		Modulus, in cm^3	Inertia, in cm^4
(1)	Bottom and side shell transverses	$Z = 11{,}71\rho k S h l_e^2$	$I = \frac{2,5}{k} l_e Z$
(2)	Sloped bulkhead transverses	The greater of: (a) $Z = 11{,}71\rho k S h_1 l_e^2$ (b) $Z = 6,6\frac{kSH_H l_e^2}{C} tan$	$I = \frac{2,5}{k} l_e Z$ $I = \frac{1,85}{k} l_e Z$

Symbols	
S, k, l_e, Z, I, ρ =	as defined in *Pt 4, Ch 7, 1.7 Information required for non-CSR bulk carriers 1.7.1*
h =	distance, in metres, from the mid-point of the effective length to the upper deck at side
h_1 =	the greater of the distance, in metres, from the midpoint of the effective length to the top of the tank or half the distance, in metres, to the top of the overflow, or in way of cargo oil or ballast holds: the distance from the tank top to the deck at centre, or where the hopper tank is interconnected with the topside tank: the load head h_4, as derived from *Table 7.8.1 Strengthening for heavy cargo requirements*(4)(c), whichever is the greatest
C =	stowage rate, in m^3/tonne, as defined in *Table 7.8.1 Strengthening for heavy cargo requirements*. For bulk carriers without the notation `strengthened for heavy cargoes', the value to be used is 1,39 $m^3$/tonne. For bulk carriers with the notation `strengthened for heavy cargoes', the actual stowage rate is to be used, but the value is not to be taken greater than 0,865 m^3/tonne.
H_H =	distance, in metres, measured vertically from the mid-point of the effective length to the underside of the topside tank sloped bulkhead

■ *Section 10*
Bulkheads

10.1 General

10.1.1 The requirements of *Pt 4, Ch 1, 9 Bulkheads* are to be applied, together with the requirements of this Section.

10.1.2 Where vertically corrugated transverse watertight bulkheads are fitted, the scantlings and arrangements are also to satisfy the requirements of *Pt 4, Ch 7, 10.4 Vertically corrugated transverse watertight bulkheads – Application and definitions*. Other transverse watertight bulkhead types will be specially considered.

10.1.3 In way of ballast holds, the scantlings are to satisfy the requirements of *Table 1.9.1 Watertight and deep tank bulkhead scantlings* in *Pt 4, Ch 1 General Cargo Ships* for deep tanks with the load head, h_4, in metres, taken to the deck at centre. This includes the scantlings of vertically corrugated and double plate transverse bulkheads supported by stools. In addition, the thickness of corrugations is to be not less than given by *Pt 4, Ch 7, 10.5 Vertically corrugated transverse watertight bulkheads – Scantling assessment 10.5.8* for watertight corrugated bulkheads. Alternatively, the scantlings may be based on direct calculations which are to be submitted.

10.1.4 All bulk carriers to be classed **‘100A1 bulk carrier, strengthened for heavy cargoes, any hold may be empty, ESP’** are to be arranged with top and bottom stools. The requirements of *Pt 4, Ch 7, 10.2 Bulkheads supported by stools* are to be complied with as appropriate.

10.1.5 For self-unloading bulk carriers, the conveyor space is to be maintained watertight at the transverse watertight bulkheads, i.e. watertight gates are to be fitted. The gates are to be of equivalent strength to the unpierced bulkhead, prototype tested, and hose tested in place in accordance with *Pt 3, Ch 1, 9 Procedures for testing tanks and tight boundaries*. Alternative equivalent arrangements will be specially considered.

10.2 Bulkheads supported by stools

10.2.1 The stools are to be reinforced with plate diaphragms or deep webs, and in bottom stools the diaphragms are to be aligned with double bottom side girders. Continuity is also to be maintained between the diaphragms and the bulkhead corrugations for 90° corrugations.

10.2.2 The sloping plate of bottom stools is to be aligned with double bottom floors. Particular attention is to be given to the through thickness properties of the inner bottom plating and continuity at the connection to the inner bottom, and to the through thickness properties of the bottom stool shelf plate, *see Ch 3, 8 Plates with specified through thickness properties* of the *Rules for* *the Manufacture, Testing and Certification of Materials* regarding requirements for plates with specified through thickness properties.

10.2.3 An efficient system of reinforcement is to be arranged in line with the hold transverse bulkheads or bulkhead stools at the intersection with the sloped plating of the hopper and topside tanks. The reinforcement fitted in the tanks is to consist of girders or intercostal bulb plate or equivalent stiffeners fitted between, and connected to, the sloped bulkhead longitudinals.

10.2.4 The shelf plates of the bulkhead stools are to be arranged to align with the longitudinals in the hopper and topside tanks. Where sloping shelf plates are fitted to stools, suitable scarfing is to be arranged in way of the connections of the stools to the adjoining structures.

10.2.5 The *ShipRight FDA Procedure, Structural Detail Design Guide* (SDDG), indicates recommended structural design configurations in the critical areas of the lower stool and of the upper boundaries.

10.3 Structural details in way of holds confined to dry cargoes

10.3.1 In dry cargo holds where transverse bulkheads are arranged without bottom stools, the stiffeners and brackets of plane bulkheads, and rectangular corrugations of corrugated bulkheads, are to be aligned with floors and inner bottom longitudinals. In the case of non-rectangular corrugations, the flanges are to be aligned with floors, but consideration will be given to the fitting of a substantial transverse girder in place of one of the floors.

10.3.2 Where transverse corrugated bulkheads are arranged without top stools, transverse beams are to be arranged under the deck in way.

10.4 Vertically corrugated transverse watertight bulkheads – Application and definitions

10.4.1 Where corrugated transverse watertight bulkheads are fitted, the scantlings are to be determined in accordance with the following requirements.

10.4.2 For ships of length, *L*, 190 m or above, the vertically corrugated transverse bulkheads are to be fitted with a bottom stool and, generally, with a top stool below the deck. The requirements of *Pt 4, Ch 7, 10.6 Vertically corrugated transverse bulkheads – Support structure at ends* are to be complied with as appropriate.

10.4.3 The loads to be considered as acting on the bulkheads are those given by the combination of cargo loads with those induced by the flooding of one hold adjacent to the bulkhead under consideration. The most severe combinations of cargo induced loads and flooding loads are to be used for the determination of the scantlings of each bulkhead, depending on the specified design loading conditions:

(a) homogeneous loading conditions;
(b) non-homogeneous loading conditions (excluding part loading conditions associated with multi-port loading and unloading); and
(c) packed cargo conditions (such as steel mill products).

The individual flooding of loaded and empty holds is to be considered, but the pressure used in the assessment is not to be less than that obtained for flood water alone. Holds containing packed cargo are to be treated as empty holds. For self-unloading bulk carriers where the boundary of the conveyor space between the bottom of the cargo hold and the top of the conveyor space is not watertight during seagoing operations, the loads acting on the bulkheads are to be considered using the extent to which flooding can occur, i.e. both the conveyor space and the cargo hold are to be assumed to be flooded.

10.4.4 The cargo surface is to be taken as horizontal and at a distance d_1, in metres, from the base line, *see Figure 7.10.1 Cargo hold dimensions*, where d_1 is calculated taking into account the cargo properties and the hold dimensions. Unless the ship is designed to carry only cargo of bulk density greater than or equal to 1,78 tonne/m^3 in non-homogeneous loading conditions, the maximum mass of cargo which may be carried in the hold is to be taken as filling that hold to the upper deck level at centreline. A permeability, μ, of 0,3 and angle of repose, ψ, of 35° is to be assumed for this application.

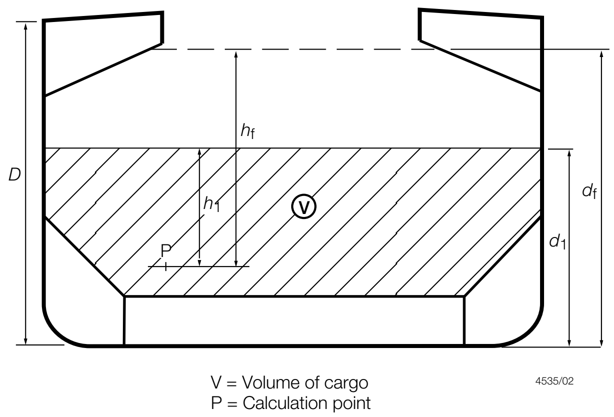


Figure 7.10.1 Cargo hold dimensions

10.4.5 An homogeneous load condition is defined as one where the ratio between the highest and the lowest filling levels, d_1, in adjacent holds does not exceed 1,20. For this purpose, where a loading condition includes cargoes of different densities, equivalent filling levels are to be calculated for all holds on the basis of a single reference value of cargo density, which can be the minimum to be carried.

10.4.6 The permeability, μ, may be taken as 0,3 for ore, coal and cement cargoes. The bulk density and angle of repose, ψ, may generally be taken as 3,0 tonne/m^3 and 35° respectively for iron ore and 1,3 tonne/m^3 and 25° respectively for cement.

10.4.7 The flooding head, h_f, *see Figure 7.10.1 Cargo hold dimensions*, is the distance, in metres, measured vertically with the ship in the upright position, from the location *P*, under consideration, to a position d_f, in metres, from the base line as given in *Table 7.10.1 Flooding head*.

10.4.8 In considering a flooded hold, the total load is to be taken as that of the cargo and flood water at the appropriate permeability. Where there is empty volume above the top of the cargo, this is to be taken as flooded to the level of the flooding head.

10.4.9 Corrugations may be constructed of flanged plates or fabricated from separate flange and web plates, which may be of different thicknesses. The corrugation angle is to be not less than 55°, *see Figure 7.10.2 Dimensions of bulkhead corrugation angles*.

10.4.10 The term net plate thickness is used to describe the calculated minimum thickness of plating of the web, t_w, or flange, t_f. The plate thickness to be fitted is the net plate thickness plus a corrosion addition of 3,5 mm.

10.5 Vertically corrugated transverse watertight bulkheads – Scantling assessment

10.5.1 The bending moment *M*, in kNm, for the bulkhead corrugations is given by:

$$M = \frac{Fl}{8}$$

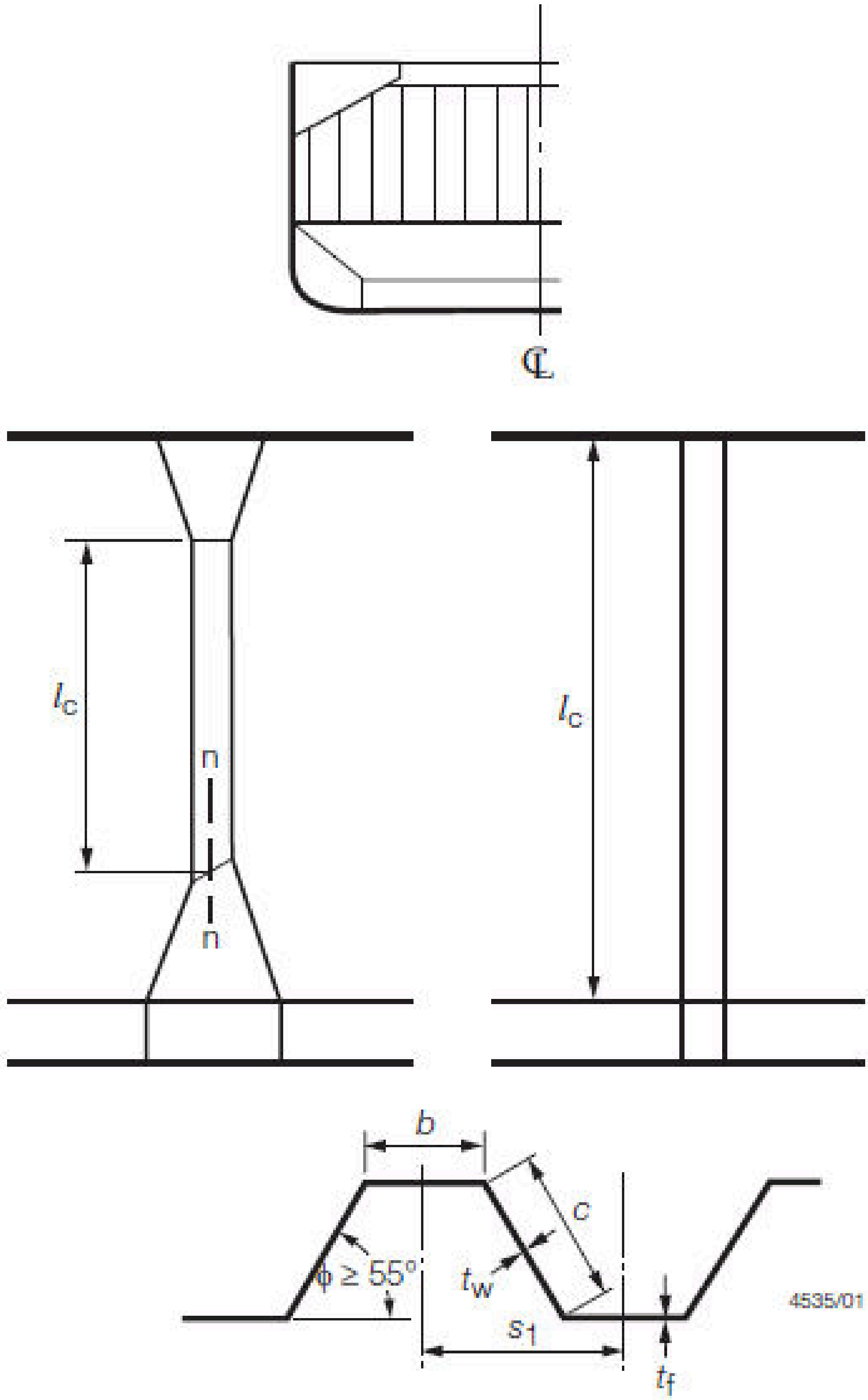
where

l = span of the corrugation, in metres, to be measured between the internal ends of the bulkhead upper and lower stools in way of the neutral axis of the corrugations or, where no stools are fitted, from inner bottom to deck, *see Figure 7.10.2 Dimensions of bulkhead corrugation angles* and *Figure 7.10.3 Scantling assessment*. The lower end of the upper stool is not to be taken greater than a distance from the deck at the centreline equal to:

= 3 times the depth of the corrugation, in general, or

= 2 times the depth of the corrugation, for rectangular stools

F = resultant force, in kN, *see Table 7.10.3 Resultant pressure and force*.



n = neutral axis of the corrugations
s = max (b; c)

Figure 7.10.2 Dimensions of bulkhead corrugation angles

10.5.2 The shear force, Q, in kN at the lower end of the bulkhead corrugation is given by:

$$Q = 0,8F$$

where F is defined in *Pt 4, Ch 7, 10.5 Vertically corrugated transverse watertight bulkheads – Scantling assessment 10.5.1*.

Table 7.10.1 Flooding head

Item	Bulkhead location	Bulk carriers with Type B freeboard and deadweight < 50 000 tonnes	Other bulk carriers
I (1)	Between holds 1 and 2	$d_f = 0{,}95D$	$d_f = D$
	Elsewhere	$d_f = 0{,}85D$	$d_f = 0{,}9D$
II (1)	Between holds 1 and 2	$d_f = 0{,}9D$	$d_f = 0{,}95D$
	Elsewhere	$d_f = 0{,}8D$	$d_f = 0{,}85D$

Note 1. Item **II** is to be used for non-homogeneous loading conditions where the bulk cargo density is less than 1,78 tonne/m^3. Otherwise, Item **I** is to be used.

Note 2. D = distance, in metres, from the base line to the freeboard deck at side amidships, *see* Fig 7.10.1.

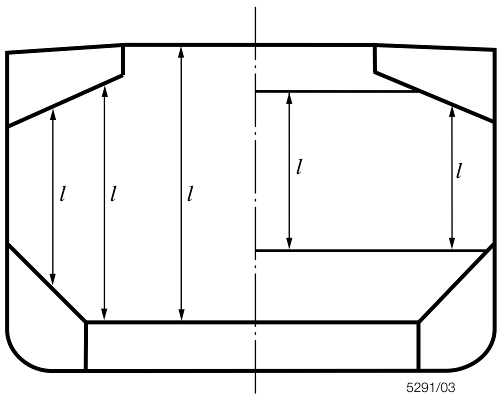


Figure 7.10.3 Scantling assessment

10.5.3 The section modulus of the corrugations is to be calculated using net plate thicknesses. At the lower end, the following requirements apply:

(a) An effective width of compression flange, b_{ef}, not greater than given in *Pt 4, Ch 7, 10.5 Vertically corrugated transverse watertight bulkheads – Scantling assessment 10.5.7*, is to be used.

(b) Where corrugation webs are not supported by local brackets below the shelf plate (or below the inner bottom if no lower stool is fitted), they are to be assumed 30 per cent effective in bending. Otherwise, the full area of web plates may be used, *see also Pt 4, Ch 7, 10.5 Vertically corrugated transverse watertight bulkheads – Scantling assessment 10.5.3.(e)*.

(c) Where effective shedder plates are fitted, *see Figure 7.10.4 Symmetric shedder plates* and *Figure 7.10.5 Asymmetric shedder plates*, the net area of the corrugation flange plates, in cm^2, may be increased by the lesser of:

$$2,5b\sqrt{(t_f\, t_{sh})} \text{ and } 2,5b\, t_f$$

where

b = width of corrugation flange, in metres, *see Figure 7.10.2 Dimensions of bulkhead corrugation angles*

t_f = net flange plate thickness, in mm

t_{sh} = net shedder plate thickness, in mm

A shedder plate is considered effective when it:

- is not knuckled; and
- is welded to the corrugations and the lower stool shelf plate by one-side penetration welds or equivalent; and
- has a minimum slope of 45° and lower edges in line with the stool side plating; and
- has a thickness not less than 0,75 times the thickness of the corrugation flanges; and
- has material properties at least equal to those of the corrugation flanges.

(d) Where effective gusset plates are fitted, *see Figure 7.10.6 Symmetric gusset/shedder plates* and *Figure 7.10.7 Asymmetric gusset/shedder plates* the net area of the corrugation flange plates, in cm^2, may be increased by:

$$7 h_g t_f$$

where

h_g = height of the gusset plate, in metres, but is not to be taken greater than $\frac{10}{7} s_{gu}$

t_f = net flange plate thickness, in mm

s_{gu} = width of the gusset plate, in metres

A gusset plate is considered effective when it:

- is fitted in combination with an effective shedder plate as defined in *Pt 4, Ch 7, 10.5 Vertically corrugated transverse watertight bulkheads – Scantling assessment 10.5.3.(c)*; and
- has height not less than half the flange plate width; and
- is fitted in line with the stool side plating; and
- has thickness and material properties at least equal to those of the flanges; and
- is welded to the top of the lower stool by full penetration welds and to the corrugations and shedder plates by one-side penetration welds or equivalent.

(e) Where the corrugation is welded to a sloping stool shelf plate, set at an angle of not less than 45° to the horizontal, the corrugation webs may be taken as fully effective in bending. Where the slope is less than 45°, the effectiveness is to be assessed by linear interpolation between fully effective at 45° and the appropriate value from *Pt 4, Ch 7, 10.5 Vertically corrugated transverse watertight bulkheads – Scantling assessment 10.5.3.(b)* at 0°. Where effective gusset plates are also fitted, the area of the flange plates may be increased in accordance with *Pt 4, Ch 7, 10.5 Vertically corrugated transverse watertight bulkheads – Scantling assessment 10.5.3.(d)*. No increase is permitted in the case where shedder plates are fitted without gussets.

Table 7.10.2 Bulkhead pressure and force

Item	Pressure, kN/m^2 (tonne-f/m^2)	Force, kN (tonne-f)
(1) In non-flooded bulk cargo holds	$p_c = g \rho_c h_1 \tan^2 \theta$ ($p_c = \rho_c h_1 \tan^2 \theta$)	$F_c = 0{,}5 \rho_c g s_1 (d_1 - h_{DB} - h_{LS})^2 \tan^2 \theta$ ($F_c = 0{,}5 \rho_c s_1 (d_1 - h_{DB} - h_{LS})^2 \tan^2 \theta$)

(2) In flooded bulk cargo holds, when $d_f \geq d_1$ (a) For positions between d_1 and d_f from base line	$p_{cf} = g\rho h_f$ $(p_{cf} = \rho h_f)$	$F_{cf} = 0{,}5 s_1(\rho g(d_f - d_1)^2 + (\rho g(d_f - d_1) + p_{le})(d_1 - h_{DB} - h_{LS}))$
(b) For positions at a distance lower than d_f from base line	$p_{cf} = g(\rho h_f + (\rho_c - \rho(1-\mu))h_1 \tan^2 \theta$ $(p_{cf} = (\rho h_f + (\rho_c - \rho(1-\mu))h_1 \tan^2 \theta)$	$(F_{cf} = 0{,}5 s_1(\rho(d_f - d_1)^2 + (\rho(d_f - d_1) + p_{le})(d_1 - h_{DB} - h_{LS})))$
(3) In flooded bulk cargo holds, when $d_f < d_1$ (a) For positions between d_1 and d_f from base line	$p_{cf} = g\rho_c h_1 \tan^2 \theta$ $(p_{cf} = \rho_c h_1 \tan^2 \theta)$	$F_{cf} = 0{,}5 s_1(\rho_c g(d_1 - d_f)^2 \tan^2 \theta + (\rho_c g(d_1 - d_f)\tan^2 \theta + p_{le})(d_f - h_{DB} - h_{LS}))$
(b) For positions at a distance lower than d_f from base line	$p_{cf} = g(\rho h_f + (\rho_c h_1 - \rho(1-\mu)h_f)\tan^2 \theta)$ $(p_{cf} = (\rho h_f + (\rho_c h_1 - \rho(1-\mu)h_f)\tan^2 \theta))$	$(F_{cf} = 0{,}5 s_1(\rho_c(d_1 - d_f)^2 \tan^2 \theta + (\rho_c(d_1 - d_f)\tan^2 \theta + p_{le})(d_f - h_{DB} - h_{LS})))$
(4) In flooded empty holds	$p_f = g\rho h_f$ $(p_f = \rho h_f)$	$F_f = 0{,}5 s_1 \rho g(d_f - h_{DB} - h_{LS})^2$ $(F_f = 0{,}5 s_1 \rho(d_f - h_{DB} - h_{LS})^2)$

Symbols		
d_f *see Pt 4, Ch 7, 10.4 Vertically corrugated transverse watertight bulkheads – Application and definitions 10.4.7*		
d_1	=	vertical distance, in metres, from the base line to the top of the cargo, *see Figure 7.10.1 Cargo hold dimensions*
g	=	gravitational constant, 9,81 m/sec^2
h_{DB}	=	height of double bottom, in metres
h_f	=	flooding head, *see Pt 4, Ch 7, 10.4 Vertically corrugated transverse watertight bulkheads – Application and definitions 10.4.7*
h_{LS}	=	mean height of lower stool, in metres
h_1	=	vertical distance, in metres, from the calculation point to the top of the cargo, *see Figure 7.10.1 Cargo hold dimensions*
p_c, p_{cf}, p_f	=	pressure on the bulkhead at the point under consideration, in kN/m^2
p_{le}	=	pressure at the lower end of the corrugation, in kN/m^2
s_1	=	spacing of the corrugations, in metres, *see Figure 7.10.2 Dimensions of bulkhead corrugation angles*
ρ	=	density of sea water = 1,025 tonne/m^3
ρ_c	=	bulk cargo density, in tonne/m^3
θ	=	45° - (ψ/2)
ψ	=	angle of repose of the cargo, in degrees
μ	=	permeability of cargo, *see Pt 4, Ch 7, 10.4 Vertically corrugated transverse watertight bulkheads – Application and definitions 10.4.6*

Table 7.10.3 Resultant pressure and force

Loading condition	Resultant pressure kN/m^2	Resultant force kN
Homogeneous	$p_r = p_{cf} – 0,8 p_c$	$F = F_{cf} – 0,8 F_c$
Non-homogeneous	$p_r = p_{cf}$	$F = F_{cf}$
Flood water alone (adjacent holds empty)	$p_r = p_f$	$F = F_f$
NOTE For symbols, *see* Table 7.10.2.		

10.5.4 The section modulus of corrugations at cross-sections other than the lower end is to be calculated with fully effective webs and an effective compression flange width, b_{ef} not greater than given in *Pt 4, Ch 7, 10.5 Vertically corrugated transverse watertight bulkheads – Scantling assessment 10.5.7*.

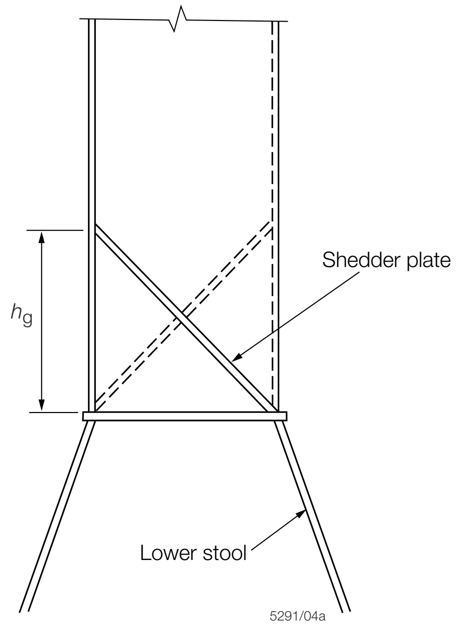


Figure 7.10.4 Symmetric shedder plates

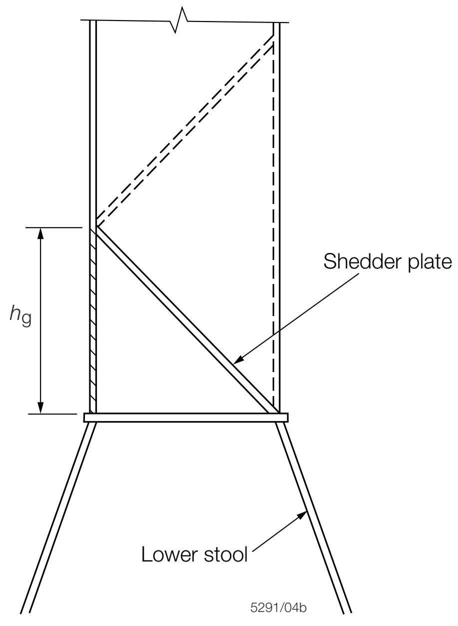


Figure 7.10.5 Asymmetric shedder plates

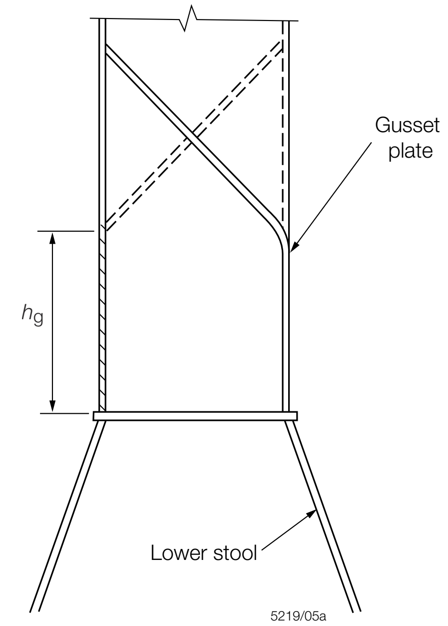


Figure 7.10.6 Symmetric gusset/shedder plates

10.5.5 The bending capacity of the bulkhead corrugations is to comply with the following relationship:

$$\frac{1000M}{0,5Z_{\text{le}}\,\sigma_{\text{p,le}} + Z_{\text{m}}\,\sigma_{\text{p,m}}} \leq 0,95$$

where

M = bending moment, in kNm, *see Pt 4, Ch 7, 10.5 Vertically corrugated transverse watertight bulkheads – Scantling assessment 10.5.1*

Z_{le} = section modulus at the lower end of the corrugations, in cm^3

Z_{m} = section modulus at mid-span of the corrugations, in cm^3

$\sigma_{\text{p,le}}$ = permissible bending stress at the lower end of the corrugations, in N/mm^2

$\sigma_{\text{p,m}}$ = permissible bending stress at mid-span of the corrugations, in N/mm^2

In the above expression Z_{le}, in cm^3, is not to be taken greater than Z'_{le} where

$$Z'_{\text{le}} = Z_{\text{g}} + \left(\frac{1000\,Q\,h_{\text{g}} - 0,5h^2_{\text{g}}\,s_1\,p_{\text{g}}}{\sigma_{\text{p,le}}}\right)$$

and Z_{m} is not to exceed the lesser of $1,15Z_{\text{le}}$ and $1,15Z'_{\text{le}}$

where

h_{g} = height of the gusset plate, in metres

p_{g} = resultant pressure calculated in way of the middle of the shedder or gusset plates as appropriate, in kN/m^2

s_1 = spacing of the corrugations, in metres

Q = shear force, in kN, *see Pt 4, Ch 7, 10.5 Vertically corrugated transverse watertight bulkheads – Scantling assessment 10.5.2*

where

Z_g = section modulus of the corrugations in way of the upper end of shedder or gusset plates as appropriate, in cm^3.

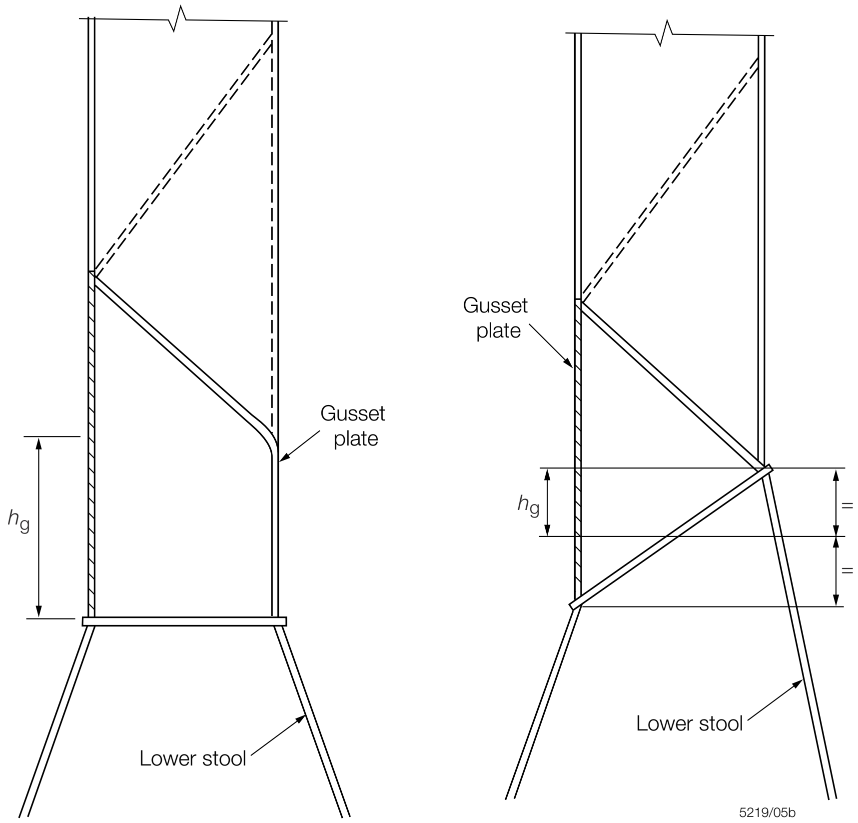


Figure 7.10.7 Asymmetric gusset/shedder plates

10.5.6 The applied shear stress, in N/mm^2, is determined by dividing the shear force derived from *Pt 4, Ch 7, 10.5 Vertically corrugated transverse watertight bulkheads – Scantling assessment 10.5.2* by the shear area of the corrugation, calculated using the net plate thickness. The shear area is to be reduced to account for non- perpendicularity between the corrugation webs and flanges. In general, the reduced area may be obtained by multiplying the web sectional area by sin φ, where φ is the angle between the web and the flange, *see Figure 7.10.2 Dimensions of bulkhead corrugation angles*. The applied shear stress is not to exceed the permissible shear stress or the shear buckling stress given in *Table 7.10.4 Permissible shear and buckling stresses*.

Table 7.10.4 Permissible shear and buckling stresses

Bending, N/mm²	Shear, N/mm²	Shear buckling, N/mm²
$\sigma_p = \sigma_0$	$\tau_p = 0{,}5\sigma_0$	$\tau_{cr} = \tau_E$ when $\tau_E \le \frac{\tau_0}{2}$ $= \tau_0\left(1 - \frac{\tau_0}{4\tau_E}\right)$ when $\tau_E \le \frac{\tau_0}{2}$

Symbols
b = width of corrugation flange, in metres, *see Figure 7.10.2 Dimensions of bulkhead corrugation angles*
c = width of corrugation web, in metres, *see Figure 7.10.2 Dimensions of bulkhead corrugation angles*
t_f = net flange plate thickness, in mm
t_w = web plate net thickness, in mm
E = modulus of elasticity
= 206 000 N/mm^2
σ_0 = specified minimum yield stress, in N/mm^2
τ_E = 5,706 E (t_w/1000c)^2 N/mm^2
τ_0 = $\dfrac{\sigma_0}{\sqrt{3}}$ N/mm^2

10.5.7 The width of the compression flange, in metres, to be used for calculating the effective modulus is:

$$b_{ef} = C_{ef} b$$

where

$$= \quad C_{ef} = \frac{2,25}{\beta} - \frac{1,25}{\beta^2} \quad \text{for } \beta > 1,25$$

$$C_{ef} = 1,0 \quad \text{for } \beta \le 1,25$$

$$\beta = 10^3 \left(\frac{b}{t_f}\right) \sqrt{\frac{\sigma_0}{E}}$$

Other symbols are as defined in *Table 7.10.4 Permissible shear and buckling stresses*.

10.5.8 The corrugation flange and web local net plate thickness are not to be less than:

$$t = 14,9 s_w \sqrt{1,05 \frac{p_r}{\sigma_0}} \text{ mm}$$

where

s_w = plate width, in metres, to be taken equal to the width of the corrugation flange or web, whichever is the greater

p_r = resultant pressure, in kN/m^2, as defined in *Table 7.10.3 Resultant pressure and force*, at the lower edge of each strake of plating. 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 the shedders, if effective shedder or gusset and shedder plates are fitted

σ_0 = specified minimum yield stress of the material, in N/mm^2.

10.5.9 For built-up corrugations, where the thickness of the flange and of the web are different, the net thickness of the narrower plating is to be not less than:

$$t_n = 14,9 s_n \sqrt{1,05 \frac{p_r}{\sigma_0}} \text{ mm}$$

where

s_n = width of the narrower plating, in metres.

The net thickness, in mm, of the wider plating is not to be taken less than the greater of:

$$t_{wp} = 14,9 s_w \sqrt{1,05 \frac{p_r}{\sigma_0}} \text{ mm or}$$

$$t_{wp} = \sqrt{\frac{462 s_w^2 p_r}{\sigma_0} - t_{np}^2} \text{ mm}$$

where

$\boldsymbol{t}_{\mathbf{np}}$ ≤ actual net thickness of the narrower plating but not greater than:

$$14,9 s_w \sqrt{1,05 \frac{p_r}{\sigma_0}} \text{ mm}$$

10.5.10 The required thickness of plating is the net thickness plus the corrosion addition given in *Pt 4, Ch 7, 10.4 Vertically corrugated transverse watertight bulkheads – Application and definitions 10.4.10*.

10.5.11 Scantlings required to meet the bending and shear strength requirements at the lower end of the bulkhead corrugation are to be maintained for a distance of 0,15*l* from the lower end, where *l* is as defined in *Pt 4, Ch 7, 10.5 Vertically corrugated transverse watertight bulkheads – Scantling assessment 10.5.1*. Scantlings required to meet the bending requirements at mid-height are to be maintained to a location no greater than 0,3*l* from the top of the corrugation. The section modulus of the remaining upper part of the corrugation is to be not less than 0,75 times that required for the middle part, corrected for differences in yield stress.

10.6 Vertically corrugated transverse bulkheads – Support structure at ends

10.6.1 The requirements of *Pt 4, Ch 7, 10.2 Bulkheads supported by stools* are to be complied with as applicable, together with the following.

10.6.2 **Lower stool**:

(a) The height of the lower stool is generally to be not less than three times the depth of the corrugations.
(b) The thickness and steel grade of the stool shelf plate are to be not less than those required for the bulkhead plating above.
(c) The thickness and steel grade of the upper portion of vertical or sloping stool side plating, within the depth equal to the corrugation flange width from the stool top, are to be not less than the flange plate thickness and steel grade needed to meet the bulkhead requirements at the lower end of the corrugation.
(d) The thickness of the stool side plating and the section modulus of the stool side stiffeners are to be not less than those required by *Pt 4, Ch 1, 9 Bulkheads* for a plane transverse bulkhead and stiffeners using the greater of the pressures determined from the head, h_4, in *Table 1.9.1 Watertight and deep tank bulkhead scantlings* and the expressions given in *Table 7.10.2 Bulkhead pressure and force*.
(e) The ends of stool side vertical stiffeners are to be attached to brackets at the upper and lower ends of the stool.
(f) The width of the shelf plate is to be in accordance with *Figure 7.10.8 Width of shelf plate*.
(g) The stool bottom is to have a width not less than 2,5 times the mean depth of the corrugation.
(h) Scallops in the brackets and diaphragms in way of connections to the stool shelf plate are to be avoided.
(i) Where corrugations are terminated on the bottom stool, corrugations 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 partial penetration welds, *see Figure 7.10.9 Partial penetration welding*. The supporting floors are to be connected to the inner bottom by either full penetration or partial penetration welds.

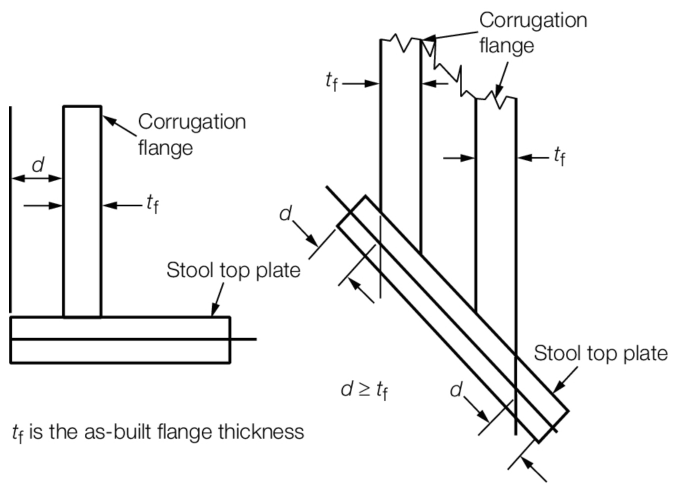


Figure 7.10.8 Width of shelf plate

10.6.3 **Upper stool**:

(a) The upper stool, where fitted, is to have a height generally between two and three times the depth of corrugations.

(b) Rectangular stools are to have a height generally equal to twice the depth of corrugations, measured from the deck level and at hatch side girder.

(c) The upper stool is to be properly supported by girders or deep brackets between the adjacent hatch-end beams.

(d) The width of the shelf plate is generally to be the same as that of the lower stool shelf plate.

(e) The upper end of a non-rectangular stool is to have a width not less than twice the depth of corrugations.

(f) The thickness and steel grade of the shelf plate are to be the same as those of the bulkhead plating below.

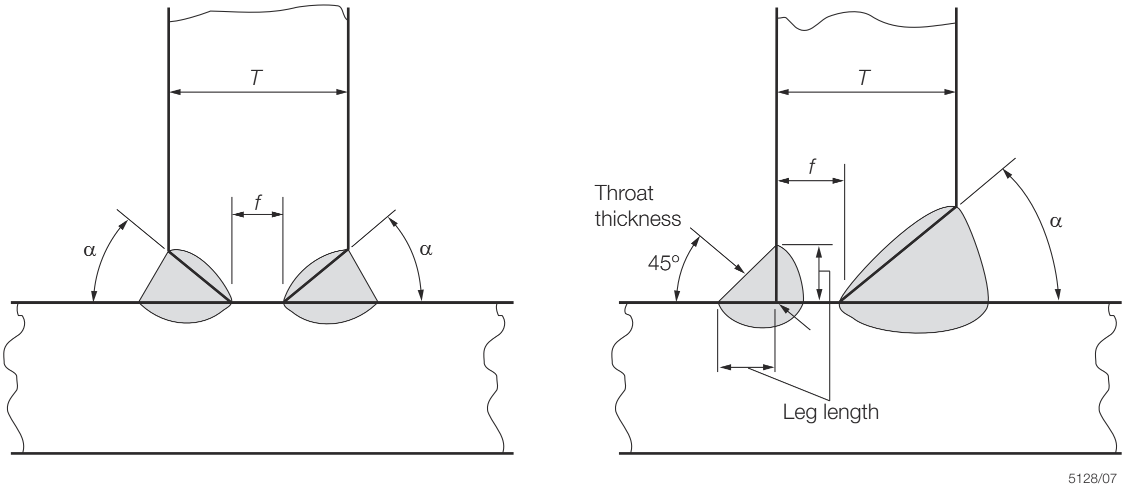
(g) The thickness of the lower portion of stool side plating is to be not less than 80 per cent of that required for the upper part of the bulkhead plating where the same materials are used.

(h) The thickness of the stool side plating and the section modulus of the stool side stiffeners are to be not less than those required by Ch 1,9 for plane transverse bulkheads and stiffeners using the greater of the pressures determined from the head, h_4, in *Table 1.9.1 Watertight and deep tank bulkhead scantlings* and the expressions given in *Table 7.10.2 Bulkhead pressure and force*.

(i) Where vertical stiffening is fitted, the ends of stool side stiffeners are to be attached to brackets at the upper and lower end of the stool.

(j) 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.

(k) Scallops in the brackets and diaphragms in way of the connection to the stool shelf plate are to be avoided.



Root face f = 3 mm to T/3 mm
Groove angle α = 40 to 60
Throat thickness = } *See* Pt 3, Ch 10
Leg length = }

Figure 7.10.9 Partial penetration welding

10.6.4 If no upper stool is fitted, two transverse reinforced beams are to be fitted in line with the corrugation flanges.

10.6.5 If no bottom stool is fitted, the corrugation flanges are to be in line with the supporting floors. Corrugations are to be connected to the inner bottom plating by full penetration welds. The thickness and steel grades of the supporting floors are to be at least equal to those provided for the corrugation flanges. The plating of supporting floors is to be connected to the inner bottom by either full penetration or deep penetration welds, *see Figure 7.10.9 Partial penetration welding*. The cut-outs for connections of the inner bottom longitudinals to double bottom floors are to be closed by collar plates. The supporting floors are to be connected to each other by suitably designed shear plates.

10.6.6 Stool side plating is to align with the corrugation flanges. Stool side vertical stiffeners and their brackets in the lower stool are to align with the inner bottom longitudinals to provide appropriate load transmission between these stiffening members. The lower stool side plating is not to be knuckled.

10.6.7 The design of local details is to take into account the transfer of the bulkhead forces and moments to the boundary structures and particularly to the double bottom and cross-deck structures.

■ *Section 11*
Direct calculation

11.1 Application

11.1.1 Direct calculations are to be employed in derivation of scantlings where required by the preceding Sections of this Chapter or by related provisions included in *Pt 3 Ship Structures (General)*.

11.1.2 Direct calculation methods are also generally to be used where additional calculations are required by the Rules in respect of unusual structural arrangements.

11.2 Procedures

11.2.1 For details of LR's direct calculation procedures see *Pt 3, Ch 1, 2 Direct calculations*. For requirements concerning use of other calculation procedures, *see Pt 3, Ch 1, 3 Equivalents*.

Section 12
Steel hatch covers

12.1 General

12.1.1 These requirements apply to hatch covers on exposed decks in Position 1, *see Pt 3, Ch 1, 6.6 Position 1 and Position 2 6.6.1*, and are in addition to the following requirements:

(a) *Pt 3, Ch 11, 4.2 Steel covers – Clamped and gasketed 4.2.14*, *Pt 3, Ch 11, 4.2 Steel covers – Clamped and gasketed 4.2.16*, *Pt 3, Ch 11, 4.2 Steel covers – Clamped and gasketed 4.2.17*, *Pt 3, Ch 11, 4.2 Steel covers – Clamped and gasketed 4.2.25*, *Pt 3, Ch 11, 4.2 Steel covers – Clamped and gasketed 4.2.27*, and *Pt 3, Ch 11, 4.2 Steel covers – Clamped and gasketed 4.2.29*.

(b) *Pt 3, Ch 11, 4.2 Steel covers – Clamped and gasketed 4.2.5* for the vertical weather pressure load case and cargo load, if carried on the hatch covers.

Note When cargo is carried on the hatch covers, *Pt 3, Ch 11, 4.2 Steel covers – Clamped and gasketed 4.2.8* to *Pt 3, Ch 11, 4.2 Steel covers – Clamped and gasketed 4.2.10* are also to be complied with. Cargo loads are to be in accordance with *Pt 3, Ch 11, 2.3 Load model 2.3.4* and *Pt 3, Ch 11, 2.3 Load model 2.3.5*. *Pt 4, Ch 8, 11.2 Direct calculations* is to be considered for compliance with *Pt 3, Ch 11, 2.4 Allowable stress and deflection 2.4.1*, *Pt 3, Ch 11, 2.4 Allowable stress and deflection 2.4.2*, *Pt 3, Ch 11, 2.5 Local net plate thickness 2.5.1*, *Pt 3, Ch 11, 2.8 Net scantling of secondary stiffeners 2.8.1*, *Pt 3, Ch 11, 2.8 Net scantling of secondary stiffeners 2.8.4*, *Pt 3, Ch 11, 2.8 Net scantling of secondary stiffeners 2.8.5*, *Pt 3, Ch 11, 2.9 Net scantling of primary supporting members 2.9.1* and *Pt 3, Ch 11, 2.9 Net scantling of primary supporting members 2.9.2*. The vertical weather design load needs not to be combined with the cargo load.

(c) For hatch covers subject to wheel loading or helicopter landing, *Pt 3, Ch 9, 3 Decks loaded by wheeled vehicles* and *Pt 3, Ch 9, 5 Helicopter landing areas* are to be complied with.

12.1.2 The net plate thickness, t_{net}, is the calculated minimum thickness of the plating and stiffeners. The required thickness is the net thickness plus a corrosion addition, t_c, given in *Table 7.12.1 Corrosion addition t_c*.

Table 7.12.1 Corrosion addition t_c

Hatch cover type			t_c, in mm
(a)	Single skin		2,0
(b)	Pontoon (double skin)		
	(i)	for the top and bottom plating	2,0
	(ii)	for the internal structures	1,5

12.1.3 Material for the hatch covers is to be steel according to the requirements for ship's hull.

12.2 Stiffener arrangement

12.2.1 The secondary stiffeners and primary supporting members of the hatch covers are to be continuous over the breadth and length of the hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to ensure sufficient load carrying capacity.

12.2.2 The spacing of primary supporting members parallel to the direction of secondary stiffeners is not to exceed $\frac{1}{3}$ of the span of primary supporting members.

12.3 Closing arrangements

12.3.1 Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced alongside the coamings and between cover elements.

12.3.2 Arrangement and spacing are to be determined with due attention to the effectiveness for weather-tightness, depending upon the type and the size of the hatch cover, as well as on the stiffness of the cover edges between the securing devices.

12.3.3 The net sectional area of each securing device is not to be less than:

A = 1,4 a/f cm^2

where

a = spacing in m of securing devices, not being taken less than 2 m

f = $(\sigma_Y/235)^e$

σ_Y = specified minimum upper yield stress in N/mm^2 of the steel used for fabrication, not to be taken greater than 70 per cent of the ultimate tensile strength

e = 0,75 for $\sigma_Y > 235$

= 1,0 for $\sigma_Y \leq 235$

12.3.4 Rods or bolts are to have a net diameter not less than 19 mm for hatchways exceeding 5 m^2 in area.

12.3.5 Between cover and coaming and at cross-joints, a packing line force sufficient to obtain weathertightness is to be maintained by the securing devices. For packing line forces exceeding 5 N/mm, the cross section area is to be increased in direct proportion. The packing line force is to be specified.

12.3.6 The cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices. The moment of inertia, $\boldsymbol{I}$, of edge elements is not to be less than:

$\boldsymbol{I}$ = 6p a^4 cm^4

where

p = packing line pressure in N/mm, minimum 5 N/mm

a = spacing in m of securing devices.

12.3.7 Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or covers. Individual securing devices on each cover are to have approximately the same stiffness characteristics.

12.3.8 Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

12.3.9 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.

12.3.10 Hatch covers are to be effectively secured, by means of stoppers, against transverse and longitudinal forces (acting on the forward end) arising from a pressure of 175 kN/m^2.

12.3.11 The equivalent stress:

- in stoppers and their supporting structures; and
- calculated in the throat of the stopper welds; is not to exceed the allowable value of 0,8σ_Y.

12.4 Load model

12.4.1 The pressure, p, in kN/m^2, acting on the hatch covers is given by:

(a) For ships of length 100 m or greater, for hatchways located on the freeboard deck, p is to be the greater of 34,3 or the following:

$$p = 34,3 + \frac{p_{FP} - 34,3}{0,25}\left(0,25 - \frac{x}{L}\right)$$

Where a hatchway is located in position 1 and at least one superstructure standard height higher than the freeboard deck, the pressure p may be 34,3 kN/m^2.

(b) For ships less than 100 m in length, for hatchways located at the freeboard deck, p is to be the greater of 0,195L + 14,9 or the following:

$$p = 15,8 + \frac{L}{3}\left(1 - \frac{5}{3}\frac{x}{L}\right) - 3,6\frac{x}{L}$$

Where two or more panels are connected by hinges, each individual panel is to be considered separately.

where

p_{FP} = pressure at the forward perpendicular

= 49,1 + (L – 100) a

a = 0,0726 for type B freeboard ships

= 0,356 for ships with reduced freeboard

L = Freeboard length, in metres, as defined in *Regulation 3 - Definitions of terms used in the Annexes* of Annex I to the 1966 Load Line Convention as modified by the Protocol of 1988, to be taken not greater than 340 m

x = distance, in metres, of the mid length of the hatch cover under examination from the forward end of L.

(c) For weather deck covers for holds which may be flooded and used as ballast tanks and holds in OBO, ore or oil and similar types of ship, the pressure p, in kN/m^2, due to the internal load for a member and position under consideration is to be taken as:

$$p = 5{,}53 Y \sin q \text{ kN/m}^2$$

where

$$\sin q = \left(0{,}45 + \frac{L}{10B}\right)\left(0{,}54 - \frac{L}{1270}\right)$$

q = roll angle, in degrees, but need not exceed 25° and is not to be taken as less than 22°

Y = transverse distance, in metres, from the side coaming at the coaming top to the member and position under consideration. Both sides of roll are to be considered.

In way of holds for oil cargo, a load equivalent to the inert gas pressure is to be applied over the full breadth of the cover and added to the load corresponding to the liquid pressure. However, where the rolling angle has been determined by direct calculations, the load may be derived accordingly.

12.5 Allowable stress

12.5.1 The normal and shear stresses calculated for the net section hatch cover structures are not to exceed the values given in *Table 7.12.2 Permissible stresses*.

Table 7.12.2 Permissible stresses

Failure mode	Permissible stress, in N/mm^2
Bending	$\sigma_a = 0{,}80\sigma_F$
Shear	$\tau_a = 0{,}46\sigma_F$
Symbols	
σ_F = minimum upper yield stress, in N/mm^2	

12.5.2 The normal stress in compression of the attached flange of primary supporting members is not to exceed 0,8 times the critical buckling stress of the structure according to the buckling check as given in *Pt 4, Ch 7, 12.10 Hatch cover plating*, *Pt 4, Ch 7, 12.11 Hatch cover secondary stiffeners* and *Pt 4, Ch 7, 12.12 Web panels of hatch cover primary supporting members*.

12.5.3 The stresses in hatch covers that are designed as a grillage of longitudinal and transverse primary supporting members are to be determined by a grillage or a FE analysis. When such an analysis is used the secondary stiffeners are not to be included in the attached flange area of the primary members.

12.5.4 When calculating the stresses σ and τ as defined in *Table 7.12.2 Permissible stresses*, the net scantlings are to be used.

12.6 Effective cross-sectional area of panel flanges for primary supporting members

12.6.1 The effective flange area, A_f, in cm^2, of the attached plating, to be considered for the yielding and buckling checks of primary supporting members, when calculated by means of a beam or grillage model, is obtained as the sum of the effective flange areas of each side of the girder web as appropriate:

$$A_f = \sum_{nf} \left(10 b_{ef} t \right)$$

where

nf = 2 if attached plate flange extends on both sides of girder web

= 1 if attached plate flange extends on one side of girder web only

t = net thickness of considered attached plate, in mm

b_{ef} = effective breadth of attached plate flange on each side of girder web, in metres

= b_p, but not to be taken greater than $0{,}165 l$

b_p = half distance between the considered primary supporting member and the adjacent one, in metres

l = span of primary supporting members, in metres.

12.7 Local net plate thickness

12.7.1 The local net plate thickness of the hatch cover top plating is to be not less than:

$$t = F_p 15{,}8 s \sqrt{\frac{p}{0{,}95 \sigma_F}}$$

or 1 per cent of the spacing of the stiffeners or 6 mm, whichever is greater

where

F_p = factor for combined membrane and bending response

= 1,50 in general

= $1{,}90\sigma/\sigma_a$, where $\sigma/\sigma_a \geq 0{,}8$, for the attached plate flange of primary supporting members

s = stiffener spacing, in metres

p = pressure, in kN/m^2, as defined in *Pt 4, Ch 7, 12.4 Load model*

σ = as defined in *Pt 4, Ch 7, 12.9 Net scantlings of primary supporting members*

σ_a = as defined in *Pt 4, Ch 7, 12.5 Allowable stress*.

12.7.2 For double skin hatch covers, when the lower plating is taken into account as a strength member of the hatch cover, the local net plate thickness of the hatch cover bottom plating is to be not less than:

t = 6,5s mm, or

t = 5,0 mm, whichever is the greater

where

s = stiffener spacing, in metres.

12.8 Net scantlings of secondary stiffeners

12.8.1 The required minimum section modulus, Z, in cm^3, of secondary stiffeners of the hatch cover top plate, based on stiffener net member thickness, is given by:

$$Z = \frac{1000 l^2 s\, p}{12 \sigma_a}$$

where

l = secondary stiffener span, in metres, to be taken as the spacing, in metres, of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all secondary stiffener spans, the secondary stiffener span may be reduced by an amount equal to $\frac{2}{3}$ of the minimum bracket arm length, but not greater than 10 per cent of the gross span, for each bracket

s = secondary stiffener spacing, in metres

p = pressure, in kN/m^2, as defined in *Pt 4, Ch 7, 12.4 Load model*

σ_a = as defined in *Pt 4, Ch 7, 12.5 Allowable stress*.

12.8.2 The net section modulus of the secondary stiffeners is to be determined based on an attached plate width assumed equal to the stiffener spacing.

12.9 Net scantlings of primary supporting members

12.9.1 The section modulus and web thickness of primary supporting members, based on member net thickness, are to be such that the normal stress σ in both flanges and the shear stress τ, in the web, do not exceed the allowable values σ_a and τ_a, respectively, defined in *Pt 4, Ch 7, 12.5 Allowable stress*.

12.9.2 The breadth of the primary supporting member flange is to be not less than 40 per cent of their depth for laterally unsupported spans greater than 3,0 m. Tripping brackets attached to the flange may be considered as a lateral support for primary supporting members.

12.9.3 The flange outstand is not to exceed 15 times the flange thickness.

12.10 Hatch cover plating

12.10.1 The compressive stress, σ, in N/mm^2, in the hatch cover plate panels, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, is not to exceed 0,8 times the critical buckling stress σ_{C1}, to be evaluated as defined below:

$\sigma_{C1} = \sigma_{E1}$ when $\sigma_{E1} \le \sigma_F/2$

$= \sigma_F\,[1 - \sigma_F/(4\sigma_{E1})]$ when $\sigma_{E1} > \sigma_F/2$

where

σ_F = minimum upper yield stress, in N/mm^2, of the material

$$\sigma_{E1} = 3,6\,E\left(\frac{t}{1000_s}\right)^2$$

E = modulus of elasticity, in N/mm^2

= 2,06 x 10^5 for steel

t = net thickness, in mm, of plate panel

s = spacing of secondary stiffeners, in metres

12.10.2 The mean compressive stress σ in each of the hatch cover plate panels, induced by the bending of primary supporting members perpendicular to the direction of secondary stiffeners, is not to exceed 0,8 times the critical buckling stress σ_{C2}, to be evaluated as defined below:

$\sigma_{C2} = \sigma_{E2}$ when $\sigma_{E2} \le \sigma_F/2$

$= \sigma_F\,[1 - \sigma_F/(4\sigma_{E2})]$ when $\sigma_{E2} > \sigma_F/2$

where

σ_F = minimum upper yield stress, in N/mm^2, of the material

σ_{E2} = $0,9m\,E\left(\frac{t}{1000 s_s}\right)^2$

m = $c\left[1+\left(\frac{s_s}{l_s}\right)^2\right]^2 \frac{2,1}{\psi + 1,1}$

E = modulus of elasticity, in N/mm^2

= 2,06 x 10^5 for steel

t = net thickness of plate panel, in mm

s_s = length of the shorter side of the plate panel, in metres

l_s = length of the longer side of the plate panel, in metres

Ψ = ratio between smallest and largest compressive stress

c = 1,3 when plating is stiffened by primary supporting members

= 1,21 when plating is stiffened by secondary stiffeners of angle or T type

= 1,1 when plating is stiffened by secondary stiffeners of bulb type

= 1,05 when plating is stiffened by flat bar.

12.10.3 The biaxial compressive stress in the hatch cover panels, when calculated by means of FEM shell element model, is to comply with *Pt 3, Ch 11, 2.11 Buckling strength of hatch cover structures 2.11.2*, using S = 1,25.

12.11 Hatch cover secondary stiffeners

12.11.1 The compressive stress σ, in N/mm^2, in the top flange of secondary stiffeners, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, is not to exceed 0,8 times the critical buckling stress σ_{CS}, to be evaluated as defined below:

$\sigma_{CS} = \sigma_{ES}$ when $\sigma_{ES} \le \sigma_F/2$

$= \sigma_F\,[1 - \sigma_F/(4\sigma_{ES})]$ when $\sigma_{ES} > \sigma_F/2$

where

σ_F = minimum upper yield stress, in N/mm^2, of the material

σ_{ES} = ideal elastic buckling stress, in N/mm^2, of the secondary stiffener

= minimum between σ_{E3} and σ_{E4}

σ_{E3} = $0,001E\,\boldsymbol{I}_a/(A\,l^2)$

E = modulus of elasticity, in N/mm^2

= 2,06 x 10^5 for steel

$\boldsymbol{I}_a$ = moment of inertia of the secondary stiffener, including a top flange equal to the spacing of secondary stiffeners, in cm^4

A = cross-sectional area of the secondary stiffener, including a top flange equal to the spacing of secondary stiffeners, in cm^2

l = span of the secondary stiffener, in metres

σ_{E4} = $\frac{\pi^2 E\, I_w}{10^4 I_p l^2}\left(m^2 + \frac{K}{m^2}\right) + 0,385E\frac{I_t}{I_p}$

where

K = $\frac{C\,l^4}{\pi^4 E\, I_w} 10^6 \; m$

m = number of half waves, given in *Table 7.12.3 Number of half waves*

I_w = sectorial moment of inertia (warping constant) of the secondary stiffener about its connection with the plating, in cm^6

= $\frac{h^3_w t^3_w}{36} 10^{-6}$ for flat bar secondary stiffeners

= $\frac{t_f b^3_f h^2_w}{12} 10^{-6}$ 'Tee' secondary stiffeners

= $\frac{b_f h^2_w{}^3}{12(b_f + h_w)^2} [t_f(b_f^2 + 2b_f h_w + 4h_w^2) + 3t_w b_f h_w] 10^{-6}$

= for angles and bulb secondary stiffeners

I_p = polar moment of inertia of the secondary stiffener about its connection with the plating, in cm^4

= $\frac{h^3_w t_w}{3} 10^{-4}$ for flat bar secondary stiffeners

= $\left(\frac{h^3_w t_w}{3} + h^2_w b_f t_f\right) 10^{-4}$

= for flanged secondary stiffeners

I_t = St.Venant's moment of inertia of the secondary stiffener without top flange, in cm^4

= $\frac{h^3_w t_w}{3} 10^{-4}$ for flat secondary stiffeners

= $\frac{1}{3}\left[h_w t^3_w + b_f t^3_f \left(1 - 0,63 \frac{t_f}{b_f}\right)\right] 10^{-4}$

= for flanged secondary stiffeners

h_w, t_w = height and net thickness of the secondary stiffener, respectively, in mm

b_f, t_f = width and net thickness of the secondary stiffener bottom flange, respectively, in mm

s = spacing of secondary stiffeners, in metres

C = spring stiffness exerted by the hatch cover top plating

= $\frac{k_p E\, t^3_p}{3s\left[1 + \frac{1,33 k_p h_w t^3_p}{1000 s\, t^3_w}\right]} 10^{-3}$

k_p = $1 - \eta_p$ to be taken not less than zero; for flanged secondary stiffeners, k_p need not be taken less than 0,1

η_p = $\frac{\sigma}{\sigma_{E1}}$

σ = as defined in *Pt 4, Ch 7, 12.9 Net scantlings of primary supporting members*

σ_{E1} = as defined in *Pt 4, Ch 7, 12.10 Hatch cover plating*

where

t_p = net thickness of the hatch cover plate panel, in mm.

Table 7.12.3 Number of half waves

K	m
$0 < K < 4$	1
$4 < K < 36$	2
$36 < K < 144$	3
$(m - 1)^2 m^2 < K \leq m^2 (m + 1)^2$	m

12.11.2 For flat bar secondary stiffeners and buckling stiffeners, the ratio h/t_W is to be not greater than $15k^{0,5}$

where

h, t_W = height and net thickness of the stiffener, respectively

k = $235/\sigma_F$

σ_F = minimum upper yield stress, in N/mm^2, of the material.

12.12 Web panels of hatch cover primary supporting members

12.12.1 This check is to be carried out for the web panels of primary supporting members formed by web stiffeners or by the crossing with other primary supporting members, the face plate (or the bottom cover plate) or the attached top cover plate.

12.12.2 The shear stress τ in the hatch cover primary supporting members web panels is not to exceed 0,8 times the critical buckling stress τ_C, to be evaluated as defined below:

$\tau_C = \tau_E$ when $\tau_E \leq \tau_F/2$

$= \tau_F [1 - \tau_F/(4\tau_E)]$ when $\tau_E > \tau_F/2$

where

σ_F = minimum upper yield stress of the material, in N/mm^2

$\tau_F = \dfrac{\sigma_F}{\sqrt{3}}$

$\tau_E = 0,9 k_t E \left(\dfrac{t_{pr,n}}{1000d}\right)^2$

E = modulus of elasticity, in N/mm^2

= $2,06 \times 10^5$ for steel

$t_{pr,n}$ = net thickness of primary supporting member, in mm

k_t = $5,35 + 4,0/(a/d)^2$

a = greater dimension of web panel of primary supporting member, in metres

d = smaller dimension of web panel of primary supporting member, in metres.

12.12.3 For primary supporting members parallel to the direction of secondary stiffeners, the actual dimensions of the panels are to be considered.

12.12.4 For primary supporting members perpendicular to the direction of secondary stiffeners or for hatch covers built without secondary stiffeners, a presumed square panel of dimension d is to be taken for the determination of the stress τ_C. In such a case, the average shear stress τ between the values calculated at the ends of this panel is to be considered.

12.13 Deflection limit and connections between hatch cover panel

12.13.1 Load bearing connections between the hatch cover panels are to be fitted with the purpose of restricting the relative vertical displacements.

12.13.2 The vertical deflection of primary supporting members is to be not more than 0,0056*l*, where *l* is the greatest span of primary supporting members.

■ *Section 13* Hatch coamings

13.1 General

13.1.1 The height and construction of forward and side hatch coamings are to comply with the following requirements. All hatch coamings are to comply with the requirements of *Pt 3, Ch 11, 5.1 General 5.1.1*, *Pt 3, Ch 11, 5.1 General 5.1.4*, *Pt 3, Ch 11, 5.2 Construction 5.2.1*, *Pt 3, Ch 11, 5.2 Construction 5.2.2*, *Pt 3, Ch 11, 5.2 Construction 5.2.4* to *Pt 3, Ch 11, 5.2 Construction 5.2.12*, *Pt 3, Ch 11, 5.2 Construction 5.2.16* to *Pt 3, Ch 11, 5.2 Construction 5.2.18* and *Pt 3, Ch 11, 5.4 Rest bars in hatchways 5.4.1*.

13.1.2 For the structure of hatch coamings and coaming stays, the corrosion addition t_c is to be 1,5 mm.

13.1.3 Material for the hatch coamings is to be steel according to the requirements for the ship's hull.

13.1.4 The secondary stiffeners of the hatch coamings are to be continuous over the breadth and length of the hatch coamings.

13.2 Load model

13.2.1 The pressure p_{coam}, on hatch coamings is to be taken as 220 kN/m^2.

13.3 Local net plate thickness

13.3.1 The local net plate thickness, *t*, in mm, of the hatch coaming plating is to be the greater of 9,5 mm or the following:

$$t = 14,9s\sqrt{\frac{p_{coam}}{\sigma_{a,coam}}S_{coam}}$$

where

s = secondary stiffener spacing, in metres

P_{coam} = pressure, in kN/m^2, as defined in *Pt 4, Ch 7, 13.2 Load model 13.2.1*

S_{coam} = safety factor to be taken equal to 1,15

$\sigma_{a,coam}$ = 0,95σ_F.

σ_F = minimum upper yield stress, in N/mm^2, of the material.

13.4 Net scantlings of longitudinal and transverse secondary stiffeners

13.4.1 The required section modulus, *Z*, in cm^3, of the longitudinal or transverse secondary stiffeners of the hatch coamings, based on net member thickness, is given by:

$$Z = \frac{1000S_{coam}\, l^2\, s\, p_{coam}}{m\, c_p\, \sigma_{a,coam}}$$

where

m = 16 in general

= 12 for the end spans of stiffeners sniped at the coaming corners

where

S_{coam} = safety factor to be taken equal to 1,15

l = span of secondary stiffeners, in metres

s = spacing of secondary stiffeners, in metres

p_{coam} = pressure in kN/m^2 as defined in *Pt 4, Ch 7, 13.2 Load model 13.2.1*

c_p = ratio of the plastic section modulus to the elastic section modulus of the secondary stiffeners with an attached plate breadth equal to 40*t*, where *t* is the plate net thickness, in mm

= 1,16 in the absence of more precise evaluation

$\sigma_{a,coam}$ = $0{,}95\sigma_F$

σ_F = minimum upper yield stress, in N/mm^2, of the material.

13.5 Net scantlings of coaming stays

13.5.1 The required minimum section modulus, Z, in cm^3, and web thickness, t_w, in mm of coaming stays designed as beams with flange connected to the deck or sniped and fitted with a bracket (*see Figure 7.13.1 Typical coaming stays*, Type A and B) at their connection with the deck, based on member net thickness, are given by:

$$Z = \frac{1000 H^2_c \, s \, p_{coam}}{2 \, \sigma_{a,coam}}$$

$$t_w = \frac{1000 H_c \, s \, p_{coam}}{h \, \tau_{a,coam}}$$

where

H_C = stay height, in metres

s = stay spacing, in metres

h = stay depth at the connection with the deck, in mm

p_{coam} = pressure, in kN/m^2, as defined in *Pt 4, Ch 7, 13.2 Load model 13.2.1*

$\sigma_{a,coam}$ = $0{,}95\sigma_F$

$t_{a,coam}$ = $0{,}5\sigma_F$

σ_F = minimum upper yield stress, in N/mm^2, of the material.

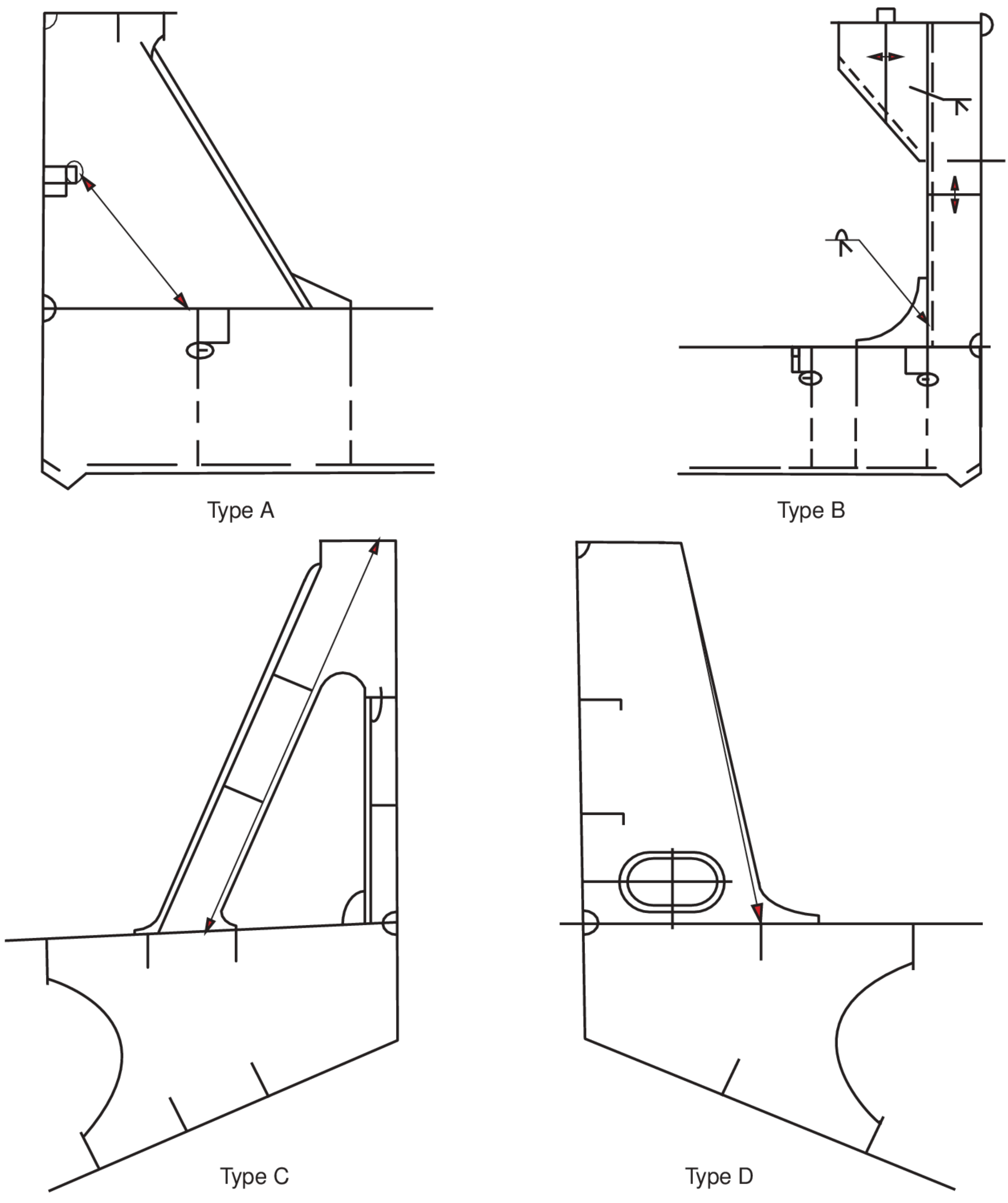


Figure 7.13.1 Typical coaming stays

13.5.2 For calculating the section modulus of coaming stays, their face plate area is to be taken into account only when it is welded with full penetration welds to the deck plating and adequate underdeck structure is fitted to support the stresses transmitted by it.

13.5.3 For other designs of coaming stays, such as those shown in *Figure 7.13.1 Typical coaming stays* Type C and D, the stress levels in 12.5 apply and are to be checked at the highest stressed locations.

13.6 Local details

13.6.1 The design of local details is to comply with *Pt 3, Ch 11, 5 Hatch coamings* for the purpose of transferring the pressures on the hatch covers to the hatch coamings and, through them, to the deck structures below. Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.

13.6.2 Underdeck structures are to be checked against the load transmitted by the stays, adopting the same allowable stresses specified in *Pt 4, Ch 7, 13.5 Net scantlings of coaming stays 13.5.1*.

13.6.3 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 $0{,}44t_W$, where t_W is the gross thickness of the stay web.

13.6.4 Toes of stay webs are to be connected to the deck plating with deep penetration double bevel welds extending over a distance not less than 15 per cent of the stay width.

■ *Section 14* Forecastles

14.1 Arrangement

14.1.1 An enclosed forecastle is to be fitted on the freeboard deck.

14.1.2 The aft bulkhead of the forecastle is to be fitted in way or aft of the forward bulkhead in the foremost cargo hold. *See Figure 7.14.1 Forecastle arrangement*. However, 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 per cent of ship length abaft the forward perpendicular where the ship length and forward perpendicular are defined in the *International Convention on Load Lines 1966* and its Protocol of 1988.

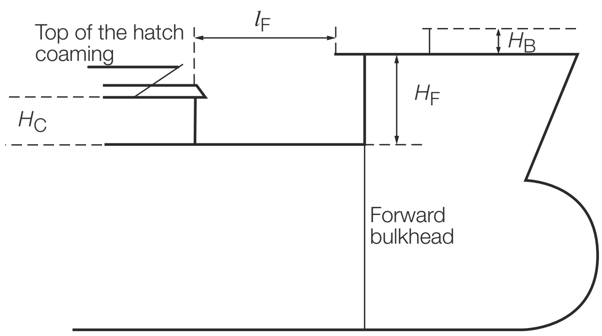


Figure 7.14.1 Forecastle arrangement

14.1.3 The forecastle height H_F, in metres, above the main deck is to be not less than the greater of:

- the standard height of a superstructure as specified in the *Load Lines, 1966/1988 - International Convention on Load Lines, 1966, as Amended by the Protocol of 1988* ; or
- H_C + 0,5 m

where

H_C = the height, in metres, of the forward transverse hatch coaming of cargo hold No.1.

14.1.4 All points of the aft edge of the forecastle deck are to be located at a distance:

$$l_f < 5\sqrt{(H_F - H_C)}$$

from the hatch coaming, *see Figure 7.14.1 Forecastle arrangement*.

14.1.5 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 upper edge at centre line is not less than:

$$H_B/\tan 20°$$

forward of the aft edge of the forecastle deck.

where

H_B = the height, in metres, of the breakwater above the forecastle, *see Figure 7.14.1 Forecastle arrangement*.

14.2 Construction

14.2.1 The construction of the forecastle is to comply with the requirements of *Pt 3, Ch 8, 4 Forecastles*.