RULES AND REGULATIONS FOR THE CLASSIFICATION OF SHIPS

SHIP STRUCTURES (GENERAL)

JULY 2007

PART 3

Lloyd's Register

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Section

■ *Section 1* Rule application

1.1 General

1.1.1 The Rules apply in general to single hull ships of normal form, proportions and speed. Relevant parameters to define what is regarded as normal are given by limitations specified at the beginning of individual ship type Chapters. Although the Rules are, in general, for steel ships of all welded construction, other materials for use in hull construction will be considered.

1.2 Exceptions

1.2.1 Ships of unusual form, proportions or speed, intended for the carriage of special cargoes, or for special or restricted service, not covered by Parts 3 and 4, will receive individual consideration based on the general standards of the Rules.

1.2.2 The requirements of 7.1 and 8.3 are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation (*see* Pt 1, Ch 2,2.3).

1.3 Loading

1.3.1 The Rules are framed on the understanding that ships will be properly loaded and handled; they do not, unless it is stated or implied in the class notation, provide for special distributions or concentrations of loading other than those included in the approved Loading Manual. The Committee may require additional strengthening to be fitted in any ship which, in their opinion, would otherwise be subjected to severe stresses due to particular features of the design, or where it is desired to make provision for exceptional load or ballast conditions.

1.4 Advisory services

1.4.1 The Rules do not cover certain technical characteristics, such as stability, trim, vibration, docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

1.5 Intact stability

1.5.1 New ships to which the Load Lines Conventions are applicable will be assigned Class only after it has been demonstrated that the level of intact stability is adequate, *see* Pt 1, Ch 2,1.1.9.

■ *Section 2* Direct calculations

2.1 General

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

2.1.2 Where model testing is undertaken to complement direct calculations the following details would normally be required to be submitted:

- Schedule of tests;
- details of test equipment;
- input data;
- analysis; and
- calibration procedure together with tabulated and plotted output.

2.2 ShipRight – Design, construction and lifetime ship care procedures

2.2.1 LR’s direct calculation procedures and facilities are summarized in two documents entitled *ShipRight Procedures Manual* and *Marine Software Guide*.

2.3 Submission of direct calculations

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

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

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

2.3.3 The responsibility for error free specification and input of program data and the subsequent correct transposal of output rests with the Builder.

■ *Section 3* Equivalents

3.1 Alternative arrangements and scantlings

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

3.1.2 Where calculation procedures other than those available within ShipRight are employed, supporting documentation is to be submitted for appraisal and this is to include details of the following:

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

3.1.3 LR will be ready to consider the use of Builders' programs for direct calculations in the following cases:

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

■ *Section 4* National and International Regulations

4.1 International Conventions

4.1.1 The Committee, when authorized, will act on behalf of Governments and, if requested, LR will certify compliance in respect of National and International statutory safety and other requirements for passenger and cargo ships.

4.1.2 In satisfying the Load Line Conventions, the general structural strength of the ship is required to be sufficient for the draught corresponding to the freeboards to be assigned. Ships built and maintained in accordance with LR's Rules and Regulations possess adequate strength to satisfy the Load Line Conventions. However, some National Authorities may, in addition, require to be supplied with calculations of bending moments and shear forces for certain conditions of loading.

4.2 International Association of Classification Societies (IACS)

4.2.1 Where applicable, the Rules take into account unified requirements and interpretations established by IACS.

4.3 International Maritime Organization (IMO)

4.3.1 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside classification as defined in these Rules and Regulations.

■ *Section 5* Information required

5.1 General

5.1.1 The categories and lists of information required are given in 5.2.

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

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

5.1.4 Additional requirements for individual ship types are given in subsequent Chapters.

5.2 Plans and supporting calculations

5.2.1 Plans covering the following items are to be submitted:

- Midship sections showing longitudinal and transverse material.
- Profile and decks.
- Shell expansion.
- Oiltight and watertight bulkheads.
- Propeller brackets.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Hatch coamings.
- Hatch cover construction.
- Deckhouses and superstructures.
- Sternframe.
- Rudder, stock and tiller.
- Equipment.
- Loading Manuals, preliminary and final.
- Ice strengthening.
- Welding.
- Hull penetration plans.
- Support structure for masts, derrick posts or cranes.
- Bilge keels showing material grades, welded connections and detail design.
- Supporting structure of deck fittings used for towing and mooring.

5.2.2 The following supporting documents are to be submitted:

- General arrangement.
- Capacity plan.
- Lines plan or equivalent.
- Dry-docking plan.
- Freeboard plan or equivalent showing freeboards and items relative to the conditions of assignment.
- Towing and mooring arrangements plan as defined in 5.3.8.
- When the ship is required to comply with statutory damage stability criteria:

  Watertight Integrity plan or equivalent showing watertight boundaries and associated design head necessary to satisfy damage stability criteria.

5.2.3 The following supporting calculations are to be submitted:

- Calculation of Equipment Number.
- Calculation of hull girder still water bending moment and shear force as applicable.
- Calculation of midship section modulus.
- Calculations for structural items in the aft end, midship and fore end regions of the ship.
- Preliminary freeboard calculation.

5.2.4 Where an ***IWS** (In-water Survey) notation is to be assigned (*see* Pt 1, Ch 2,2.3.11), plans and information covering the following items are to be submitted:

- Details showing how rudder pintle and bush clearances are to be measured and how the security of the pintles in their sockets are to be verified with the vessel afloat.
- Details showing how stern bush clearances are to be measured with the vessel afloat.
- Details of high resistant paint, for information only.

5.2.5 Where it is intended to exchange ballast water at sea resulting in the partial filling of the ballast spaces, the scantlings and structural arrangements of the tank boundaries are to be capable of withstanding the loads imposed by the movement of the ballast water in those spaces. The magnitude of the predicted loadings, together with the scantling calculations, may require to be submitted.

5.2.6 Ships that are required to comply with SOLAS Regulation 3-6 in chapter II-1 for 'Access to and within spaces in the cargo area of oil tankers and bulk carriers' are to supply information showing attachment of the access arrangements to the ship structure. This is to include necessary strength calculations, local detail and any reinforcements.

5.3 Plans to be supplied to the ship

5.3.1 To facilitate the ordering of materials for repairs, plans are to be carried in the ship indicating the disposition and grades (other than Grade A) of hull structural steel, the extent and location of higher tensile steel together with details of specification and mechanical properties, and any recommendations for welding, working and treatment of these steels.

5.3.2 Similar information is to be provided when aluminium alloy or other materials are used in the hull construction.

5.3.3 A copy of the final Loading Manual, when approved, and details of the loadings applicable to approved decks, hatch covers and inner bottom are to be placed on board the ship.

5.3.4 Details of any corrosion control system fitted are to be placed on board the ship.

5.3.5 Copies of main scantling plans are to be placed on board.

5.3.6 Where an ***IWS** (In-water Survey) notation is to be assigned, approved plans and information covering the items detailed in 5.2.4 are to be placed on board.

5.3.7 Where a ShipRight **CM** (Construction Monitoring) notation or descriptive note is to be assigned, the approved Construction Monitoring Plan (CMP), as detailed in the ShipRight Construction Monitoring Procedures, is to be maintained on board the ship.

5.3.8 The towing and mooring arrangements plan is to be provided on board for the guidance of the Master. The information provided on the plan is to include the following in respect of each shipboard fitting:

- Location on the ship.
- Fitting type.
- Safe working load (SWL).
- Purpose of fitting (mooring/harbour towing/escort towing).
- Manner of applying towing or mooring line load, including limiting fleet angles.

This information is to be incorporated into the pilot card in order to provide the pilot with the necessary information on harbour/escorting operations.

5.4 Fire protection, detection and extinction

5.4.1 For information and plans required, *see* Pt 6, Ch 4.

■ *Section 6* Definitions

6.1 Principal particulars

6.1.1 Rule length, L, is the distance, in metres, on the summer load waterline from the forward side of the stem to the after side of the rudder post or to the centre of the rudder stock if there is no rudder post. L is to be not less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on the summer load waterline. In ships with unusual stem or stern arrangements the Rule length, L, will be specially considered.

6.1.2 Amidships is to be taken as the middle of the Rule length, L, measuring from the forward side of the stem.

6.1.3 Breadth, B, is the greatest moulded breadth, in metres.

6.1.4 Depth, D, is measured, in metres, at the middle of the length, L, from top of keel to top of the deck beam at side on the uppermost continuous deck, or as defined in appropriate Chapters. When a rounded gunwale is arranged, the depth, D, is to be measured to the continuation of the moulded deck line.

6.1.5 Draught, T, is the summer draught, in metres, measured from top of keel.

6.1.6 The block coefficient, C_b, is the moulded block coefficient at draught, T, corresponding to summer load waterline, based on Rule length, L, and moulded breadth, B, as follows:

$$C_b = \frac{\text{moulded displacement (m}^3\text{) at draught } T}{LBT}$$

6.1.7 Length between perpendiculars, L_{pp}, is the distance, in metres, on the summer load waterline from the fore side of the stem to the after side of the rudder post, or to the centre of the rudder stock if there is no rudder post. In ships with unusual stern arrangements the length, L_{pp}, will be specially considered. The forward perpendicular, F.P., is the perpendicular at the intersection of the summer load waterline with the fore side of the stem. The after perpendicular, A.P., is the perpendicular at the intersection of the summer load waterline with the after side of the rudder post. For ships without a rudder post, the A.P. is the perpendicular at the intersection of the waterline with the centreline of the rudder stock.

6.1.8 Load line length, L_L, is to be taken as 96 per cent of the total length on a waterline at 85 per cent of the least moulded depth measured from the top of the keel, or as the length from the fore side of the stem to the axis of the rudder stock on that waterline, if that is greater. In ships designed with a rake of keel, the waterline on which this length is measured is to be parallel to the designed waterline. The length L_L is to be measured in metres.

6.1.9 Load line block coefficient, C_{bL}, is defined as:

$$C_{bL} = \frac{\nabla}{L_L\, B T_L}$$

where

∇ = volume of the moulded displacement, in m^3, excluding appendages, taken at draught T_L

T_L = moulded draught, in metres, measured to the waterline at 85 per cent of the least moulded depth.

6.1.10 Maximum service speed, V, means the maximum ahead service speed, in knots, which the ship is designed to maintain, at the summer load waterline at maximum propeller RPM and corresponding MCR.

6.1.11 Bow reference height, H_b, is defined as:
For ships less than 250 m in length:

$$H_b = 0{,}056 L_L \left(1 - \frac{L_L}{500}\right)\left(\frac{1{,}36}{C_{bL} + 0{,}68}\right) \text{ m}$$

For ships 250 m or greater in length:

$$H_b = 7\left(\frac{1{,}36}{C_{bL} + 0{,}68}\right) \text{ m}$$

where

L_L is defined in 6.1.8
C_{bL} is defined in 6.1.9.

6.2 Freeboard deck

6.2.1 The freeboard deck is normally the uppermost complete deck exposed to weather and sea, which has permanent means of closing all openings in the weather part, and below which all openings in the sides of the ship are fitted with permanent means of watertight closing.

6.2.2 For the purposes of the Load Lines Conventions, as applicable, where the assigned summer freeboard is increased such that the resulting draught is not more than that corresponding to a minimum summer freeboard for the same ship, but with an assumed freeboard deck located a distance below the actual freeboard deck at least equal to the standard superstructure height, the related items for the conditions of assignment to the actual freeboard deck may be as required for a superstructure deck.

6.3 Weathertight

6.3.1 A closing appliance is considered weathertight if it is designed to prevent the passage of water into the ship in any sea conditions.

6.3.2 Generally, all openings in the freeboard deck and in enclosed superstructures are to be provided with weathertight closing appliances.

6.4 Watertight

6.4.1 A closing appliance is considered watertight if it is designed to prevent the passage of water in either direction under a head of water for which the surrounding structure is designed.

6.4.2 Generally, all openings below the freeboard deck in the outer shell/envelope (and in main bulkheads) are to be fitted with permanent means of watertight closing.

6.5 Position 1 and Position 2

6.5.1 For the purpose of Load Line conditions of assignment, there are two basic positions of hatchways, doorways and ventilators defined as follows:

Position 1 – Upon exposed freeboard and raised quarterdecks, and exposed superstructure decks within the forward 0,25 of the load line length.

Position 2 – Upon exposed superstructure decks abaft the forward 0,25 of the load line length and located at least one standard height of superstructure above the freeboard deck. Upon exposed superstructure decks situated within the forward 0,25 of the Load Line length and located at least two standard heights of superstructure above the freeboard deck.

6.6 Passenger ship

6.6.1 A passenger ship is a ship which carries more than 12 passengers.

6.7 Reference system

6.7.1 For hull reference purposes, the ship is divided into 21 equally spaced stations where Station 0 is the after perpendicular, Station 20 is the forward perpendicular, and Station 10 is mid–L_{pp}.

6.8 Co-ordinate system

6.8.1 Unless otherwise stated, the co-ordinate system is as shown in Fig. 1.6.1, that is, a right-hand co-ordinate system with the X axis positive forward, the Y axis positive to port and the Z axis positive upwards. Angular motions are considered positive in a clockwise direction about the X, Y or Z axes.

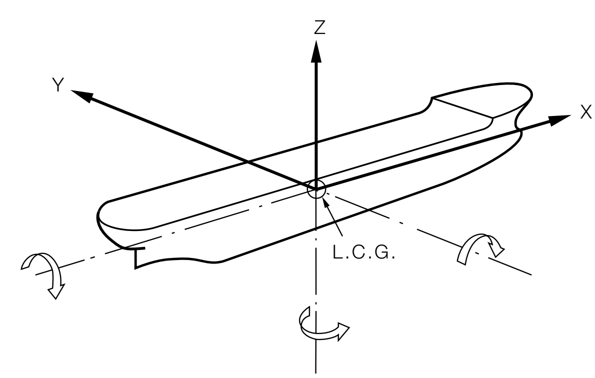


Fig. 1.6.1 Co-ordinate system

■ *Section 7* Equipment Number

7.1 Calculation of Equipment Number

7.1.1 The equipment of anchors and chain cables specified in Ch 13,7 is based on an 'Equipment Number' which is to be calculated as follows:

$$\text{Equipment Number} = \Delta^{2/3} + 2BH + \frac{A}{10}$$

where

A = area, in m^2, in profile view of the hull, within the Rule length of the vessel, and of superstructures and houses above the summer load waterline, which are within the Rule length of the vessel, and also having a breadth greater than $\frac{B}{4}$

See also 7.1.3 and 7.1.4

B = greatest moulded breadth, in metres

H = freeboard amidships, in metres, from the summer load waterline to the upper deck, plus the sum of the heights at the centreline, in metres, of each tier of houses having a breadth greater than $\frac{B}{4}$

See also 7.1.2, 7.1.3 and 7.1.4

Δ = moulded displacement, in tonnes, to the summer load waterline.

7.1.2 In the calculation of H and A, sheer and trim are to be ignored. Where there is a local discontinuity in the upper deck, H is to be measured from a notional deckline.

7.1.3 If a house having a breadth greater than $\frac{B}{4}$ is above a house with a breadth of $\frac{B}{4}$ or less, then the wide house is to be included, but the narrow house ignored.

7.1.4 Screens and bulwarks more than 1,5 m in height are to be regarded as parts of houses when determining H and A. Where a screen or bulwark is of varying height, the portion to be included is to be that length, the height of which exceeds 1,5 m.

7.1.5 The Equipment Number for tugs is to be calculated as follows:

$$\text{Equipment Number} = \Delta^{2/3} + 2(Bf + \Sigma bh) + \frac{A}{10}$$

where

Δ, B and A are defined in 7.1.1

b = breadth, in metres, of the widest superstructure or deckhouse on each tier

f = freeboard amidships, in metres, from the summer load waterline

h = the height, in metres, of each tier of superstructure or deckhouse at side having a breadth of $\frac{B}{4}$ or greater. In the calculation of h, sheer and trim are to be ignored.

■ *Section 8* Inspection, workmanship and testing procedures

8.1 Inspection

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

8.2 Workmanship

8.2.1 All workmanship is to be of good quality and in accordance with good shipbuilding practice. Any defect is to be rectified to the satisfaction of the Surveyor before the material is covered with paint, cement or other composition. The materials and welding are to be in accordance with the requirements of the Rules for Materials (Part 2). The assembly sequence and welding sequence are to be agreed prior to construction and are to be to the satisfaction of the Surveyor. Plates which have been subjected to excessive heating while being worked are to be satisfactorily heat treated before being erected in the hull.

8.2.2 **Wood sheathing on decks**. Where plated decks are sheathed with wood, the sheathing is to be efficiently attached to the deck, caulked and sealed, to the satisfaction of the Surveyor.

8.2.3 **Rudder and sternframe**. The final boring out of the propeller boss and sternframe skeg or solepiece, and the fit-up and alignment of the rudder, pintles and axles, are to be carried out after completing the major part of the welding of the after part of the ship. The contacts between the conical surfaces of pintles, rudder stocks and rudder axles are to be checked before the final mounting.

8.3 Testing procedures

8.3.1 **Definitions**. For the purpose of these procedures the following definitions apply:

(a) **Protective coating** is the coating system applied to protect the structure from corrosion. This excludes the prefabrication primer.

(b) **Structural testing** is a hydrostatic test carried out to demonstrate the tightness of the tanks and the structural adequacy of the design. Where practical limitations prevail and hydrostatic testing is not feasible, hydropneumatic testing (*see* 8.3.1(e)), may be carried out instead.

(c) **Leak testing** is an air or other medium test carried out to demonstrate the tightness of the structure.

(d) **Hose testing** is carried out to demonstrate the tightness of structural items not subjected to hydrostatic or leak testing, and other components which contribute to the watertight or weathertight integrity of the hull.

(e) **Hydropneumatic testing** is a combination of hydrostatic and air testing, consisting of filling the tank with water and applying an additional air pressure. The conditions are to simulate, as far as practicable, the actual loading of the tank and in no case is the air pressure to be less than given in 8.3.4.

8.3.2 **Application**. The testing requirements for gravity tanks including independent tanks of 5 m^3 or more in capacity, watertight and weathertight compartments, are listed in Table 1.8.1. Tests are to be carried out in the presence of the Surveyor at a stage sufficiently close to completion such that the strength and tightness are not subsequently impaired.

Table 1.8.1 Testing requirements (*to be continued*)

Item to be tested	Testing procedure	Testing requirement
Double bottom tanks	Structural (1)	The greater of: • head of water up to the top of the overflow • head of water up to the margin line • head of water representing the maximum pressure experienced in service
Combined double bottom and lower hopper side tanks	Structural (1)	The greater of: • head of water representing the maximum pressure experienced in service • head of water up to the top of the overflow
Combined double bottom, lower hopper and topside tanks	Structural (1)	The greater of: • head of water up to the top of the overflow • 2,4 m head of water above highest point of tank (4)
Double side tanks	Structural (1)	
Topside tanks	Structural (1)	
Cofferdams	Structural (1)	
Forepeak and aft peak used as tank(3)	Structural	
Tank bulkheads	Structural (1)	The greater of: • head of water up to the top of the overflow • 2,4 m head of water above the highest point of tank (4) • setting pressure of the safety valves, where relevant (10) • 2,0ρ m above the top of the tank, where ρ is the relative density of any intended cargo
Deep tanks	Structural (1)	
Fuel oil bunkers	Structural	
Scupper and discharge pipes in way of tanks	Structural (1)	
Cargo holds with trunks fitted	Structural (1)	The greater of test heads given in Table 1.8.2
Water ballast holds in bulk carriers (*see* 1.2.2)	Structural (1)	The tank testing requirement is not to be less than the head up to the top of the hatch coaming (11) & (12)
Double plate rudders	Structural (1), (5)	2,4 m head of water, and rudder should normally be tested while laid on its side
Steel hatch covers fitted to the cargo oil tanks and cargo holds of ships used for the alternate carriage of oil cargo and dry bulk cargo (6)	Structural (1)	The greater of: • 2,4 m head of water above the top of hatch cover • setting pressure of the safety valves (10)
Watertight bulkheads, shaft tunnels, flats and recesses, etc.	Hose (2)	*See* 8.3.5
Watertight doors (below freeboard or bulkhead deck) when fitted in place	Hose (9)	
Weathertight hatch covers and closing appliances	Hose	
Fore peak not used as tank	Hose (2)	
Shell doors	Hose	
Chain locker, if aft of collision bulkhead	Structural	Head of water up to the top
Independent tanks	Structural	Head of water up to the top of overflow, but not less than 0,9 m
Ballast ducts	Structural	Ballast pump maximum pressure
Pump-rooms, shell plating in way	Visual examination	(7)
Pump-room bulkheads not forming tank boundaries	Leak	*See* 8.3.4 (8)
After peak not used as tank	Leak	*See* 8.3.4

Table 1.8.1 Testing requirements (*continuation*)

NOTES
1. Leak or hydropneumatic testing may be accepted, provided that at least one tank of each of structural configuration is structurally tested, to be selected in connection with the approval of the design. For chemical tankers, all cargo tank boundaries are to be structurally tested from at least one side, *see also* 8.3.8.
2. When hose testing cannot be performed without damaging possible outfittings already installed, it may be replaced by a careful visual inspection of all the crossings and welded joints. Where necessary, dye penetrant test or ultrasonic leak test may be required.
3. Testing of the aft peak is to be carried out after the sterntube has been fitted.
4. The highest point of the tank is generally to exclude hatchways. In holds for liquid cargo or ballast with large hatch openings, the highest point of the tank is to be taken to the top of the hatch.
5. If leak or hydropneumatic testing is carried out, arrangements are to be made to ensure that no pressure in excess of 0,30 bar (0,30 kgf/cm^2) can be applied.
6. A minimum of every second hatch cover is to be tested.
7. To be carefully examined with the vessel afloat.
8. Alternative methods of testing will be considered.
9. *See also* SOLAS Reg. II-1/18. Where the door has had the full hydrostatic test before installation, the hose test may be replaced by careful visual examination after full operational tests.
10. Pressure/vacuum relief valve head to be taken as 12,0 p_V m above the top of the tanks, where p_V is the maximum positive pressure/vacuum relief valve setting, in bar (kgf/cm^2).
11. Prior to performing the test, small access hatches having a smaller coaming height than the main hatch are to be fully closed.
12. For those designs unable to apply the tank test requirements up to the top of the hatch coaming, the applied head is to be as close to the hatch coaming top level as is reasonably practical.

Table 1.8.2 Required test heads where a trunk is fitted

Depth of midship tank to top of trunk centre where fitted metres	Test heads	
	Above trunk metres	Above deck metres
> 5,0	1,50	2,45
> 4,25 ≤ 5,0	1,20	2,15
> 3,75 ≤ 4,25	0,90	1,85
> 3,0 ≤ 3,75	0,60	1,50
≤ 3,0	0,60	1,20

8.3.3 **Structural testing**:

(a) Structural testing may be carried out afloat where testing using water is undesirable in dry-dock or on the building berth. The testing afloat is to be carried out by separately filling each tank and cofferdam to the test head. For tankers and ore or oil ships (*see* 1.2.2), the testing afloat is to be carried out by separately filling each tank and cofferdam to the test head given in Table 1.8.1. With about half the number of tanks full, the bottom and lower side shell in the empty tanks is to be examined and the remainder of the bottom and lower side shell examined when the water is transferred to the remaining tanks.

(b) The attachment of fittings to oiltight surfaces is to be completed before tanks are structurally tested. Where it is intended to carry out structural tests after the protective coating has been applied, welds are generally to be leak tested prior to the coating application.

(c) For welds other than manual and automatic erection welds, manual fillet welds on tank boundaries and manual penetration welds, the leak test may be waived provided that careful visual inspection is carried out, to the satisfaction of the Surveyor, before the coating is applied. The cause of any discolouration or disturbance of the coating is to be ascertained, and any deficiencies repaired.

8.3.4 **Leak testing**.

(a) This is carried out by applying an efficient indicating liquid (e.g. soapy water solution), to the weld or outfitting penetration being tested, while the tank or compartment is subject to an air pressure of at least 0,15 bar (0,15 kgf/cm^2).

(b) It is recommended that the air pressure be raised to 0,2 bar (0,2 kgf/cm^2) and kept at this level for about one hour to reach a stabilized state, with a minimum number of personnel in the vicinity, and then lowered to the test pressure prior to inspection. A U-tube filled with water to a height corresponding to the test pressure is to be fitted for verification and to avoid overpressure. The U-tube is to have a cross-section larger than that of the air supply pipe. In addition, the test pressure is to be verified by means of a pressure gauge, or alternative equivalent system.

(c) Leak testing is to be carried out, prior to the application of a protective coating, on all fillet welds and erection welds on tank boundaries, and on all outfitting penetrations. Automatic and Flux Core Arc Welding (FCAW) semi-automatic butt welds of the erection joints need not be tested, provided that careful visual inspections show continuous uniform weld profile shape, free from repairs, and the results of selected NDE testing show no significant defects.

(d) Selected locations of automatic erection welds and pre-erection manual or automatic welds may also be required to be tested before coating, at the discretion of the Surveyor, taking account of the quality control procedures of the shipyard. Where exempt from this requirement, leak testing may be carried out after the protective coating has been applied, provided that the welds have been carefully inspected to the satisfaction of the Surveyor.

8.3.5 **Hose testing**. This is to be carried out at a maximum distance of 1,5 m with a hose pressure not less than 2,0 bar (2,0 kgf /cm^2). The nozzle diameter is not to be less than 12 mm. The jet is to be targeted directly onto the weld or seal being tested.

8.3.6 **Hydropneumatic testing**. When this is performed, the safety precautions identified in 8.3.4 are to be followed.

8.3.7 Equivalent proposals for testing will be considered.

8.3.8 **Trial trip and operational tests**. The items listed in Table 1.8.3 are to be tested on completion of the installation or at sea trials.

Table 1.8.3 Trial trip and operational tests

Item	Requirement
Sliding watertight doors	To be operated under working conditions.
Windlass	An anchoring test is to be carried out in the presence of the Surveyor. The test should demonstrate that the windlass with brakes, etc., functions satisfactorily, and that the power to raise anchor can be developed and satisfies the Rule requirements. For Rule requirements, *see* Ch 13,7.
Steering gear, main and auxiliary	To be tested under working conditions, to the satisfaction of the Surveyors,to demonstrate that the Rule requirements are met. For Rule requirements, *see* Pt 5, Ch 19.
Bilge suctions in holds, and hand pumps in peak spaces	To be tested under working conditions to the satisfaction of the Surveyors.

Section 1 Materials of construction

1.1 General

1.1.1 The Rules relate in general to the construction of steel ships, although consideration will be given to the use of other materials.

1.1.2 The materials used in the construction of the ship are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials (Part 2)). Materials for which provision is not made therein may be accepted, provided that they comply with an approved specification and such tests as may be considered necessary.

1.1.3 The requirements in this Chapter are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation (*see* Pt 1, Ch 2,2.3) with the exception of 1.2.5, 2.3 and 3.2 which are to be complied with.

1.2 Steel

1.2.1 Steel having a specified minimum yield stress of 235 N/mm^2 (24 kgf/mm^2) is regarded as mild steel. Steel having a higher specified minimum yield stress is regarded as higher tensile steel.

1.2.2 For the determination of the hull girder section modulus, where higher tensile steel is used, a higher tensile steel factor, k_L, is given in Table 2.1.1.

Table 2.1.1 Values of k_L

Specified minimum yield stress in N/mm^2 (kgf/mm^2)	k_L
235 (24)	1,0
265 (27)	0,92
315 (32)	0,78
355 (36)	0,72
390 (40)	0,68

NOTES
1. Intermediate values by linear interpolation.
2. For the purpose of calculating hull moment of inertia as specified in Ch 4,5.7.1, k_L = 1,0.

1.2.3 The local scantling requirements of higher tensile steel plating, longitudinals, stiffeners and girders may be based on a *k* factor determined as follows:

$$k = \frac{235}{\sigma_o} \quad \left(k = \frac{24}{\sigma_o}\right)$$

or 0,66, whichever is the greater,
where
σ_o = specified minimum yield stress in N/mm^2 (kgf/mm^2).

1.2.4 For the application of the requirements of 1.2.2 and 1.2.3, special consideration will be given to steel where $\sigma_o \geq 355$ N/mm^2 (36 kgf/mm^2). Where such steel grades are used in areas which are subject to fatigue loading, the structural details are to be verified using fatigue design assessment methods.

1.2.5 Where steel castings or forgings are used for stern-frames, rudder frames, rudder stocks, propeller shaft brackets and other major structural items, they are to comply with Chapter 4 or Chapter 5 of the Rules for Materials (Part 2), as appropriate.

1.3 Aluminium

1.3.1 The use of aluminium alloy is permitted for special purpose craft, and for superstructures, deckhouses, hatch covers, helicopter platforms, or other local components on board ships.

1.3.2 Aluminium is not to be used for the crowns or casings of Category A machinery spaces, *see* Pt 5, Ch 1,4.8.1.

1.3.3 Except where otherwise stated, equivalent scantlings are to be derived as follows:

Plating thickness;

$$t_a = t_s \sqrt{k_a c}$$

Section modulus of stiffeners;

$$Z_a = Z_s k_a c$$

where
c = 0,95 for high corrosion resistant alloy
= 1,00 for other alloys

$$k_a = \frac{245}{\sigma_a}$$

t_a = thickness of aluminium plating
t_s = thickness of mild steel plating
Z_a = section modulus of aluminium stiffener
Z_s = section modulus of mild steel stiffener
σ_a = 0,2 per cent proof stress or 70 per cent of the ultimate strength of the material, whichever is the lesser.

1.3.4 In general, for welded structure, the maximum value of σ_a to be used in the scantlings derivation is that of the aluminium in the welded condition. However, consideration will be given to using unwelded values depending upon the weld line location, other heat affected zones, in relation to the maximum applied stress on the member (e.g. extruded sections).

Table 2.1.2 Minimum mechanical properties for aluminium alloys

Alloy	Condition		0,2% proof stress, N/mm^2		Ultimate tensile strength, N/mm^2	
			Unwelded	Welded (*see* Note 4)	Unwelded	Welded (*see* Note 4)
5083	O/H111		125	125	275	275
5083	H112		125	125	275	275
5083	H116/H321		215	125	305	275
5383	O/H111		145	145	290	290
5383	H116/H321		220	145	305	290
5086	O/H111		100	95	240	240
5086	H112		125 (*see* Note 2)	95	250 (*see* Note 2)	240
5086	H116/H321		195	95	275	240
5059	O/H111		160	160	330	330
5059	H116/H321		260	160	360	300
5456	O		125	125	285	285
5456	H116		200 (*see* Note 5)	125	290 (*see* Note 5)	285
5456	H321		215 (*see* Note 5)	125	305 (*see* Note 5)	285
5754	O/H111		80	80	190	190
6005A (*see* Note 1)	T5/T6	Extruded: Open Profile Extruded: Closed Profile	215 215	100 100	260 250	160 160
6061 (*see* Note 1)	T5/T6	Rolled Extruded: Open Profile Extruded: Closed Profile	240 240 205	125 125 125	290 260 245	160 160 160
6082	T5/T6	Rolled Extruded: Open Profile Extruded: Closed Profile	240 260 240	125 125 125	280 310 290	190 190 190

NOTES
1. These alloys are not normally acceptable for application in direct contact with sea-water.
2. *See also* Table 8.1.4 in Pt 2, Ch 8.
3. The mechanical properties to be used to determine scantlings in other types and grades of aluminium alloy manufactured to National or proprietary standards and specifications are to be individually agreed with LR, *see also* Pt 2, Ch 8,1.1.5.
4. Where detail structural analysis is carried out, 'Unwelded' stress values may be used away from heat affected zones and weld lines, *see also* 1.3.3.
5. For thickness less than 12,5 mm the minimum unwelded 0,2% proof stress is to be taken as 230 N/mm^2 and the minimum tensile strength is to be taken as 315 N/mm^2.

1.3.5 A comparison of the mechanical properties for selected welded and unwelded alloys is given in Table 2.1.2.

1.3.6 Where strain hardened grades (designated Hxxx) are used, adequate protection by coating is to be provided to avoid the risk of stress corrosion cracking.

■ *Section 2* Fracture control

2.1 Grades of steel

2.1.1 The resistance to fracture is controlled, in part, by the notch toughness of the steel used in the structure. Steels with different levels of notch toughness are specified in the Rules for Materials (Part 2). The grade of steel to be used is, in general, related to the thickness of the material and the stress pattern associated with its location.

2.1.2 In order to distinguish between the material grade requirements for different hull members, material classes are assigned as given in Table 2.2.1. Steel grades are to be not lower than those corresponding to the material classes as given in Table 2.2.2.

2.1.3 Where tee or cruciform connections employ full penetration welds, and the plate material is subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, as detailed in Ch 3,8 of the Rules for Materials (Part 2).

2.1.4 The material grade of exposed structure of ships intended to operate in temperatures below minus 20°C will be specially considered. The design air temperature is to be taken as the lowest mean daily average air temperature in the area of operation:

where

Mean = statistical mean over a minimum of 20 years (MDHT)

Average = average during one day and one night (MDAT)

Lowest = lowest during the year (MDLT)

Fig. 2.1.1 shows the definition graphically.

Table 2.2.1 Material classes and grades

Structural member category	Within 0,4*L* amidships	Outside 0,4*L* amidships
SECONDARY: • Lower strake in longitudinal bulkhead • Deck plating exposed to weather, in general • Side plating	I	A/AH
PRIMARY: • Bottom plating, including keel plate • Strength deck plating, excluding those belonging to the special category • Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings • Upper strake in longitudinal bulkhead • Vertical strake (hatch side girder) and upper sloped strake in top wing tank	II	A/AH
SPECIAL: • Sheerstrake or rounded gunwale, *see* Note 1 • Stringer plate at strength deck, *see* Note 1 • Strength deck plating at outboard corners of cargo hatch openings in container carriers and other ships with similar hatch opening configurations, *see* Note 2 • Strength deck plating at corners of cargo hatch openings in bulk carriers (*see* 1.1.3), or carriers, combination carriers and other ships with similar hatch opening configuration, *see* Note 3 • Deck strake at longitudinal bulkhead, *see* Note 4 • Bilge strake, *see* Notes 5 and 6 • Longitudinal hatch coaming of length greater than 0,15*L*, *see* Note 7 • End brackets and deckhouse transition of longitudinal cargo hatch coamings, *see* Note 7	III	II, in general I, outside 0,6*L*

NOTES
1. In ships with length exceeding 250 m, sheerstrake or rounded gunwale and stringer plate at strength deck are not to be less than Grade E/EH within 0,4*L* amidships.
2. Plating at outboard corners of cargo hatch opening and plating intersections of the longitudinal underdeck girders and the cross-deck strips are not to be less than Class III within the length of the cargo region.
3. Not to be less than Class III within 0,6L amidships and Class II within the remaining length of the cargo region.
4. Excluding deck plating in way of inner-skin bulkhead of double hull ships.
5. In ships with a double bottom over the full breadth and with length less than 150 m, bilge strake may be of Class II within 0,4*L* amidships.
6. In ships with length exceeding 250 m, bilge strake is not to be less than Grade D/DH within 0,6*L* amidships.
7. Grade is not to be less than D/DH.
8. Corner inserts in way of any complex openings such as for lifts and side doors which may impinge on the deck plating or stringer plate are to be of Grade D/DH for $t \leq 20$ mm and Grade E/EH for $t > 20$ mm.
9. For strength members not mentioned, Grade A/AH may generally be used.
10. Within 0,4*L* amidships, single strakes required to be of Class III or of Grade E/EH are to have breadths not less than 800 + 5*L* mm, but need not be greater than 1800 mm.
11. The material class used for reinforcement and the quality of material (i.e. whether mild or higher tensile steel) used for welded attachments, such as waterway bars and bilge keels, is to be similar to that of the hull envelope plating in way. Where attachments are made to rounded gunwale plates, special consideration will be given to the required grade of steel, taking account of the intended structural arrangements and attachment details.
12. The material class for deck plating, sheerstrake and upper strake of longitudinal bulkhead within 0,4*L* amidships is also to be applied at structural breaks of the superstructure, irrespective of position.
13. Engine seat top plates outside 0,6*L* amidships may be Grade A/AH. Steel grade requirement for top plates within 0,6*L* amidships will be specially considered.
14. Steel grade is to correspond to the as-fitted thickness.
15. Plating materials for sternframes, rudders, rudder horns and shaft brackets are, in general, not to be of lower Grades than corresponding to Class II. For rudder and rudder body plates subjected to stress concentrations (e.g. in way of lower support of semi-spade rudders or at upper part of spade rudders) Class III is to be applied.

Table 2.2.2 Steel grades

Thickness, *t*, in mm	Material class					
	I		II		III	
	Mild steel	H.T. steel	Mild steel	H.T. steel	Mild steel	H.T. steel
$t \leq 15$	A	AH	A	AH	A	AH
$15 < t \leq 20$	A	AH	A	AH	B	AH
$20 < t \leq 25$	A	AH	B	AH	D	DH
$25 < t \leq 30$	A	AH	D	DH	D	DH
$30 < t \leq 35$	B	AH	D	DH	E	EH
$35 < t \leq 40$	B	AH	D	DH	E	EH
$t > 40$	D	DH	E	EH	E	EH

NOTE
See Notes under Table 2.2.1

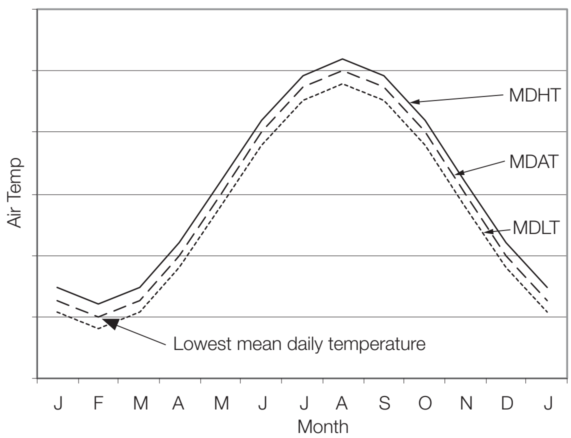


Fig. 2.1.1 Design air temperature

2.2 Refrigerated spaces

2.2.1 Where the minimum design temperature of the steel falls below 0°C in refrigerated spaces, in addition to the requirements of 2.1.2, the grade of steel for the following items is to comply, in general, with the requirements of Table 2.2.3:

- Deck plating.
- Webs of deck girders.
- Longitudinal bulkhead strakes attached to deck.
- Shelf plates and their face bars supporting hatch covers.

Table 2.2.3 Grades of steel for minimum design temperatures below 0°C

Minimum design temperature, in °C	Thickness, in mm	Grades of steel
0 to –10	$t \leq 12,5$ $12,5 < t \leq 25,5$ $t > 25,5$	B/AH D/DH E/EH
–10 to –25	$t \leq 12,5$ $t > 12,5$	D/DH E/EH
–25 to –40	$t \leq 12,5$ $t > 12,5$	E/EH FH/LT–FH, *see also* Pt 2, Ch 3,6

2.2.2 Unless a temperature gradient calculation is carried out to assess the design temperature in the items defined in 2.2.1, the temperature to which the steel deck may be subjected is to be assessed as shown in Table 2.2.4.

Table 2.2.4 Assessment of deck temperature

Arrangement	Deck temperature
(1) Deck not covered with insulation in the refrigerated space	Temperature of the refrigerated space
(2) Deck covered with insulation in the refrigerated space and not insulated on the other side	Temperature of the space on the uninsulated side
(3) Deck covered with insulation on both sides	
(a) Temperature difference not greater than 11°C	Mean of the temperatures of the spaces above and below the deck
(b) Temperature difference greater than 11°C but not greater than 33°C	Mean of the temperatures of the spaces above and below the deck less 3°C
(c) Temperature difference greater than 33°C	Deck temperature will be specially assessed

NOTE
Where one of the internal spaces concerned is not refrigerated, the temperature of the space is to be taken as 5°C.

2.3 Grades of steel for ice-breaking ships designed to operate in low ambient temperatures

2.3.1 These requirements are intended for ships strengthened in accordance with the requirements stated in Ch 9,8 and designed to operate for long periods in low air temperatures.

2.3.2 The grade of steel to be used is related to the anticipated operating temperature, T_0, degree of ice induced dynamic loading and the thickness of material. In no case should the grade of steel be less than that required by 2.1 or 2.2.

2.3.3 In order to establish the anticipated operating temperature, T_0, for a given structural member, it is assumed that the minimum design air temperature, *T*, for ships designed to operate in Arctic or Antarctic conditions, is not lower than –45°C and should not be taken as higher than –35°C. It is the responsibility of the Owner to specify the design air temperature *T*. Where reliable environment records for contemplated operational areas exist, the minimum design air temperature can be obtained after the exclusion of all recorded values having a probability of occurrence of less than 3 per cent. If *T* is lower than –45°C then the steel grades to be used will be specially considered.

2.3.4 The operating temperature T_0 relevant for the selection of steel grades is given in Table 2.2.5.

2.3.5 Steel grades for plating forming the outer shell and deck boundaries are obtained from the figures specified in Table 2.2.5. The strakes of shell plating to which the bilge keels or ground bars are attached are to be made of Grade D steel over the forward 0,5*L* but may be of Grade B steel elsewhere.

2.3.6 In general, longitudinal frames and longitudinal bulkhead strakes attached to deck and shell and outboard strakes of horizontal stringers are to be of the same steel grade as the hull envelope plating to which they are connected, but the grade may be adjusted to take account of difference in thickness.

2.3.7 The outer strake of web plating of web frames is to be constructed of material of the same steel grade as the shell plating to which they are attached, but the grade may be adjusted to take account of difference in thickness.

2.3.8 The steel grade of transverse side frames and the strakes of transverse bulkhead plating directly attached to the shell in Region A, *see* Table 2.2.5, are to be determined from Fig. 2.2.2 in conjunction with an operating temperature of (*T* + 10)°C.

2.3.9 Steel grades for rudder horn, stern frame and stem (including the adjacent strake of shell plating), are given in Table 2.2.6. The steel grades of internal members attached to these items are to be of the same grade (or equivalent) with due account taken of difference in thickness.

Table 2.2.5 **Steel grades and operating temperatures for ships intended to navigate in Arctic and Antarctic conditions**

Region	Position	Operating temp. T_0°C	Steel grade Fig. No.
A	Region between a line set at a distance 0,1*D* or 2 m (whichever is less) below the Ice Light Waterline and a line set the same distance above the Ice Load Waterline:		
	Forward of 0,3*L* from the F.P. Abaft 0,3*L* from the F.P.	*T* + 10 *T* + 10	2.2.1 2.2.2
B	Region between the keel and a line set at the lesser of 0,1*D* or 2 m below the Ice Light Waterline		
	Forward of 0,3*L* from the F.P. Permanently immersed parts of the welded stern frame	*T* + 20 *T* + 20	2.2.1 2.2.2
C	Exposed portions of side shell, main deck, stem and stern, excluding coamings, protected positions and forecastle sides:		
	Forward of 0,3*L* from the F.P. Abaft of 0,3*L* from the F.P.	*T*, *see* Note *T*, *see* Note	2.2.1 2.2.2
D	Main deck protected from open environment, i.e. within accommodation block or forecastle, etc., but excluding a 1 m wide strip adjacent to boundaries which are to be treated as exposed:		
	Permanently heated spaces Permanently unheated spaces	0 –15	2.2.2 2.2.2
E	Deck coamings, hatch covers, crane pedestals	*T* + 5	2.2.2
F	External bulkheads of accommodation block (the lowest strake is not to be less than Grade D), and forecastle sides	*T* + 20 but not greater than –10ºC	2.2.2
G	Forecastle deck	*T* + 10, *see* Note	2.2.2
H	All other permanently immersed structure	—	Normal Rule Requirement

NOTE
For ships intended to operate only during the summer period and to be laid up in winter the operating temperature T_0 may be taken as *T* + 20 but need not be taken lower than –18°C.

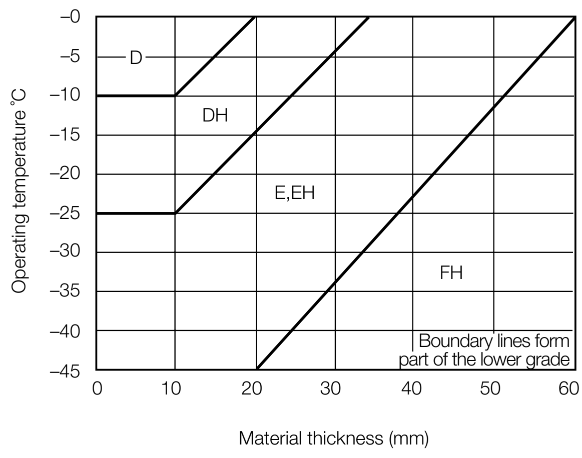


Fig. 2.2.1
Steel grade (Forward of 0,3*L* from the F.P.)

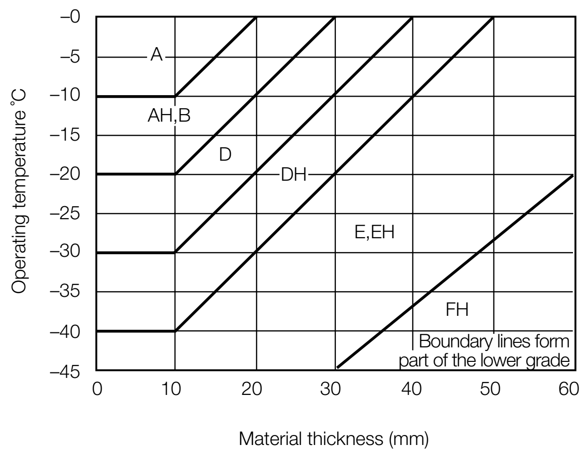


Fig. 2.2.2 Steel grade (Remaining positions)

Table 2.2.6 Steel grades for rudder horn, stern frame and stem for ships intended to navigate in Arctic or Antarctic conditions

Item	Condition	Construction	Steel grade(2)(3)	
			f < 25(1)	$f \geq$ 25(1)
Rudder horn	Fully immersed	Cast steel	Carbon manganese steel Grade 400	Carbon manganese steel Grade 400
		Fabricated	Grade EH	Grade EH
	Periodically immersed or exposed	Cast steel	Carbon manganese steel Grade 460	$2\frac{1}{4}$ Ni steel or equivalent
		Fabricated	Grade FH	$1\frac{1}{2}$ Ni steel or equivalent
Stern frame	Fully immersed	Cast steel	Normal Rule requirement	Normal Rule requirement
		Fabricated	Table 2.2.5 Region B	Table 2.2.5 Region B
	Periodically immersed or exposed	Cast steel	Carbon manganese steel Grade 400	Carbon manganese steel Grade 460
		Fabricated	Table 2.2.5 Region C	Grade FH
Stem including adjacent strake of shell plating	Fully immersed	Fabricated	Table 2.2.5 Region B	Table 2.2.5 Region B
		Cast steel	Carbon manganese steel Grade 400	Carbon manganese steel Grade 400
	Periodically immersed or exposed	Fabricated	Table 2.2.5 Region C	Table 2.2.5 Region C
		Cast steel	$2\frac{1}{4}$ Ni steel	$2\frac{1}{4}$ Ni steel

NOTES

1. $f = \sqrt{P_o \Delta} \times 10^{-3} \left(= 0{,}858 \sqrt{H_o \Delta} \times 10^{-3}\right)$

   where P_o (H_o) is the maximum propulsion shaft power for which the machinery is classed
   Δ is displacement, in tonnes, at Ice Load Waterline or Deepest Ice Operation Waterline when floating in water of relative density of 1,0.
2. For cast steel, *see* Pt 2, Ch 4,7.
3. For C–Mn LT60 and Ni plates, *see* Pt 2, Ch 3,6.

■ *Section 3* Corrosion protection

3.1 General

3.1.1 Where bimetallic connections are made, measures are to be incorporated to preclude galvanic corrosion.

3.2 Prefabrication primers

3.2.1 Where a primer is used to coat steel after surface preparation and prior to fabrication, the composition of the coating is to be such that it will have no significant deleterious effect on subsequent welding work and that it is compatible with the paints or other coatings subsequently applied in association with an approved system of corrosion control.

3.2.2 To determine the influence of the primer coating on the characteristics of welds, tests are to be made as detailed in 3.2.3 and 3.2.5.

3.2.3 Three butt weld assemblies are to be tested using plate material 20 to 25 mm thick. A 'V' preparation is to be used and, prior to welding, the surfaces and edges are to be treated as follows:

(a) Assembly 1 – Coated in accordance with the manufacturer's instructions.
(b) Assembly 2 – Coated to a thickness approximately twice the manufacturer's instructions.
(c) Assembly 3 – Uncoated.

3.2.4 Tests as follows are to be taken from each test assembly:

(a) Radiographs. These are to have a sensitivity of better than two per cent of the plate thickness under examination, as shown by an image quality indicator.
(b) Photo-macrographs. These may be of actual size and are to be taken from near each end and from the centre of the weld.
(c) Face and reverse bend test. The test specimens are to be bent by pressure or hammer blows round a former of diameter equal to three times the plate thickness.
(d) Impact tests. These are to be carried out at ambient temperature on three Charpy V-notch test specimens prepared in accordance with Ch 2,3 of the Rules for Materials (Part 2). The specimens are to be notched at the centreline of the weld, perpendicular to the plate surface.

3.2.5 The tests are to be carried out in the presence of a Surveyor to Lloyd's Register (hereinafter referred to as 'LR') or by an independent laboratory specializing in such work. A copy of the test report is to be submitted, together with radiographs and macrographs.

3.2.6 In ships intended for the carriage of oil cargoes having a flash point not exceeding 60°C (closed cup test), paint containing aluminium should not, in general, be used in positions where cargo vapours may accumulate, unless it has been shown by appropriate tests that the paint to be used does not increase the incendive sparking hazard.

3.3 Internal cathodic protection

3.3.1 When a cathodic protection system is to be fitted in tanks for the carriage of liquid cargo with flash point not exceeding 60°C, a plan showing details of the locations and attachment of anodes is to be submitted. The arrangements will be considered for safety against fire and explosion aspects only. Impressed current cathodic protection systems are not permitted in any tank.

3.3.2 Particular attention is to be given to the locations of anodes in relation to the structural arrangements and openings of the tank.

3.3.3 Anodes are to be of approved design and sufficiently rigid to avoid resonance in the anode support. Steel cores are to be fitted, and these are to be so designed as to retain the anode even when the latter is wasted.

3.3.4 Anodes are to be attached to the structure in such a way that they remain secure both initially and during service. The following methods of attachment would be acceptable:

(a) Steel core connected to the structure by continuous welding of adequate section.
(b) Steel core bolted to separate supports, provided that a minimum of two bolts with lock nuts is used at each support. The separate supports are to be connected to the structure by continuous welding of adequate section.
(c) Approved means of mechanical clamping.

3.3.5 Anodes are to be attached to stiffeners, or may be aligned in way of stiffeners on plane bulkhead plating, but they are not to be attached to the shell. The two ends are not to be attached to separate members which are capable of relative movement.

3.3.6 Where cores or supports are welded to the main structure, they are to be kept clear of the toes of brackets and similar stress raisers. Where they are welded to asymmetrical stiffeners, they are to be connected to the web with the welding kept at least 25 mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the face plate but well clear of the free edges. However, it is recommended that anodes are not fitted to face plates of higher tensile steel longitudinals.

3.4 Aluminium and magnesium anodes

3.4.1 Aluminium and aluminium alloy anodes are permitted in tanks used for the carriage of oil, but only at locations where the potential energy does not exceed 275 J (28 kgf m). The weight of the anode is to be taken as the weight at the time of fitting, including any inserts and fitting devices.

3.4.2 The height of the anode is, in general, to be measured from the bottom of the tank to the centre of the anode. Where the anode is located on, or closely above, a horizontal surface (such as a bulkhead girder) not less than 1 m wide, provided with an upstanding flange or face plate projecting not less than 75 mm above the horizontal surface, the height of the anode may be measured above that surface.

3.4.3 Aluminium anodes are not to be located under tank hatches or Butterworth openings unless protected by adjacent structure.

3.4.4 Magnesium or magnesium alloy anodes are permitted only in tanks intended solely for water ballast.

3.5 External hull protection

3.5.1 Suitable protection of the underwater portion of the hull is to be provided.

3.5.2 Where an impressed current cathodic protection system is fitted, plans showing the proposed layout of anodes and hull penetrations are to be submitted.

3.5.3 The arrangements for glands, where cables pass through the shell, are to include a small cofferdam. Cables to anodes are not to be led through tanks intended for the carriage of low flash point oils. Where cables are led through cofferdams or clean ballast tanks of tankers, they are to be enclosed in a substantial steel tube of about 10 mm thickness, *see also* Pt 6, Ch 2,13.9.

3.5.4 Where an ***IWS** (In-water Survey) notation is to be assigned, *see* Pt 1, Ch 2,2.3.11, protection of the underwater portion of the hull is to be provided by means of a suitable high resistant paint applied in accordance with the manufacturer's requirements. Details of the high resistant paint are to be submitted for information.

3.6 Corrosion protection coatings for salt-water ballast spaces

3.6.1 At the time of new construction, all salt-water ballast spaces having boundaries formed by the hull envelope shall have an efficient protective coating, epoxy or equivalent, applied in accordance with the manufacturer's recommendations. The durability of the coatings could affect the frequency of survey of the spaces and light coloured coatings would assist in improving the effectiveness of subsequent surveys. It is therefore recommended that these aspects be taken into account by those agreeing the specification for the coatings and their application.

3.6.2 For further information and recommendations regarding the coating of salt-water ballast spaces *see* the *List of Paints, Resins, Reinforcements and Associated Materials*, published by LR.

■ *Section 4* Deck covering

4.1 General

4.1.1 Where plated decks are sheathed with wood or an approved composition, reductions in plate thickness may be allowed.

4.1.2 The steel deck is to be coated with a suitable material in order to prevent corrosive action, and the sheathing or composition is to be effectively secured to the deck.

4.1.3 Primary deck coverings within accommodation spaces, control stations or service spaces are to be of a type which will not readily ignite or give rise to smoke or toxic or explosive hazards at elevated temperatures in accordance with the requirements of the *International Code for the Application of Fire Test Procedures*.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter illustrates the general principles to be adopted in applying the Rule structural requirements given in Parts 3 and 4. In particular, consideration has been given to the layout of the Rules as regards the different regions of the ship, principles for taper of hull scantlings, definition of span point, derivation of section moduli and basic design loading for deck structures. Principles for subdivision are also covered.

1.1.2 Where additional requirements relating to particular ship types apply, these are, in general, dealt with under the relevant ship type Chapter in Part 4.

1.1.3 The requirements in this chapter are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation (*see* Pt 1, Ch 2,2.3) with the exception of 4.7 which is to be complied with.

■ *Section 2* Rule structural concepts

2.1 Definition of requirements

2.1.1 In Fig. 3.2.1 the breakdown of the ship into regions is shown. Within each region, the applicable Parts and Chapters of the Rules are indicated.

2.2 Definition of fore end region

2.2.1 The fore end region structure is considered to include structure forward of the midship 0,4*L* region.

2.3 Definition of aft end region

2.3.1 The aft end region structure is considered to include all structure aft of the midship 0,4*L* region.

2.4 Symbols

2.4.1 The symbols used in this Section are defined as follows:

F_D, F_B = local scantling reduction factor as defined in Ch 4,5.6

k_L, k = higher tensile steel factor, *see* Ch 2,1.2

z_D, z_B = vertical distance, in metres, from the hull transverse neutral axis to the moulded deck line at side and to the top of keel respectively

Z_{ht} = vertical extent of higher tensile steel.

2.5 Taper requirements for hull envelope

2.5.1 The thickness of the shell envelope and strength deck plating, and the modulus and sectional area of strength deck longitudinals are to taper gradually from the midship region to the fore and aft ends. For the requirements, *see* Table 3.2.1.

2.5.2 Outside the line of openings where higher tensile steel is used amidships and mild steel at the ends, the equivalent mild steel midship thickness for plating, equivalent mild steel midship deck longitudinal area and equivalent mild steel midship total deck area, for taper purposes are to be determined as follows:

(a) Equivalent mild steel value

$$= \frac{\text{H.T. steel value}}{k_L}$$

(b) If the higher tensile steel plating is based on minimum thickness requirements, then:
Equivalent mild steel midship plating thickness determined from Pt 4, Ch 1 and Ch 9.

2.5.3 The transition from higher tensile steel to mild steel is to be as shown in Fig. 3.2.2 for the forward region. The transition in the aft region is to be similar to the forward region.

2.5.4 Where the higher tensile steel longitudinals extend beyond the point of transition from higher tensile to mild steel plating, the modulus of the composite section is not to be taken less than the required mild steel value at the deck plate flange, and *k* times the mild steel value at the higher tensile flange.

2.6 Vertical extent of higher tensile steel

2.6.1 Higher tensile steel may be used for both deck and bottom structures or deck structure only. Where fitted, it is to be used for the whole of the longitudinal continuous material for the following vertical distances:

(a) from the line of deck at side

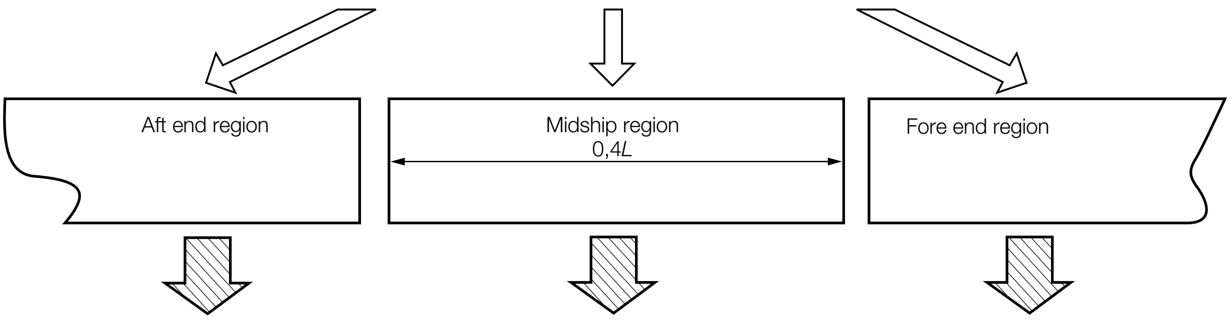
$$z_{ht} = \left(1 - \frac{k_L}{F_D}\right) z_D$$

(b) from the top of keel

$$z_{ht} = \left(1 - \frac{k_L}{F_B}\right) z_B$$

In the above formulae F_D and F_B are to be taken not less than k_L.

Sections covered	Part	Chapter
Rule applicability, general	3	1
Structural arrangement and taper, general	3	3
Longitudinal strength	3	4
Material and grades of steel	3	2
Corrosion control	3	2
Ice strengthening	3	9
Decks, special features	3	9



Sections covered	Part	Ch
Deck structure	3	6
Shell structure	3	6
Strengthening in panting region	3	6
After peak structure	3	6
Sternframes, shaft brackets and bossings	3	6
Rudder	3	13
Propeller hull clearances	3	6

Sections covered	Part	Ch
Deck structure	4	–
Shell structure	4	–
Hull girder section modulus	3	4
Longitudinal bulkheads	4	–
Deck girders and supporting structure	4	–
Transverse bulkheads	4	–
Inner bottom	4	–

Sections covered	Part	Ch
Deck structure	3	5
Shell structure	3	5
Stems	3	5
Deep tank forward	3	5
Strengthening in panting region	3	5
Bottom strengthening forward	3	5
Fore peak structure	3	5

Sections covered	Part	Chapter
Control systems	3	13
Superstructures, deckhouses and forecastles	3	8
Welding and structural details	3	10
Machinery space additional requirement	3	7
Hatch covers	3	11
Scuppers and sanitary discharges	3	12
Testing	3	1

Fig. 3.2.1 Rule scantlings – Schematic layout of requirements

Table 3.2.1 Taper requirements for hull envelope

Item	Location	Requirement
Plating		
(1) Shell envelope plating, *see* Notes 1 and 2	Fore and aft ends	The thickness, in mm, is to be the greater of the following: (a) $t_t = \left[(t_c - t_{e1})\left(1 - \dfrac{d}{0{,}225L}\right) + t_{e1}\right]$ (*see* Note 3) (b) $t_t = (6{,}5 + 0{,}033L)\sqrt{\dfrac{k\,s_1}{s_b}}$
(2) Strength deck plating, *see* Notes 1 and 2	Fore and aft ends	The thickness, in mm, is to be the greater of the following: (a) $t_t = \left[(t_c - t_{e2})\left(1 - \dfrac{d}{0{,}225L}\right) + t_{e2}\right]$ (*see* Note 3) (b) $t_t = (5{,}5 + 0{,}02L)\sqrt{\dfrac{k\,s_1}{s_b}}$
Longitudinals outside 0,4*L* amidships		
(3) Strength deck, *see* Notes 1 and 2	Fore and aft ends	MODULUS The section modulus in association with deck plating, in cm^3, is to be the greater of the following: (a) $Z_t = \left[(Z_c - Z_e)\left(1 - \dfrac{d}{0{,}225L}\right) + Z_e\right]$ (*see* Note 3) (b) As determined by Table 5.2.3 in Chapter 5, Table 6.2.3 in Chapter 6, and Pt 4, Ch 9, as appropriate
		SECTIONAL AREA The deck longitudinals may be gradually tapered outside the 0,4*L* midships region in association with the deck plating on the basis of area. The sectional area of one longitudinal without plating, in cm^2, is to be not less than the following: $A_t = \left[(A_c - A_e)\left(1 - \dfrac{d}{0{,}225L}\right) + A_e\right]$ (*see* Note 3)
Strength deck area		
(4) Deck area taper, *see* Notes 1 and 2	Fore and aft ends	The total area of longitudinals and deck plating outside line of openings at midship region should have a linear taper from 0,2*L* from midships to 0,075*L* from F.P. or A.P. such that the area at 0,075*L* and 0,15*L* from F.P. or A.P. is not less than 30 and 50 per cent respectively of the total midships area, *see* Note 3.

Symbols

L, *k*, *s* as defined in Ch 5,1.4.1
- d = distance, in m, from 0,2*L* forward or aft of amidships to the mid-length of the building block, strake, or longitudinal under consideration
- s_b = standard frame spacing, in mm, as given in Tables 5.2.1 and 5.3.1 in Chapter 5, and Tables 6.2.1 and 6.3.1 in Chapter 6, as appropriate
- s_1 = s, but is to be taken not less than s_b
- t_c = actual thickness of deck or shell plating within the 0,4*L* midships region
- t_{e1} = basic shell end thickness for taper and is $(6{,}5 + 0{,}033L)\sqrt{k}$ at 0,075*L* from the A.P. or F.P.
- t_{e2} = basic strength deck end thickness for taper and is $(5{,}5 + 0{,}02L)\sqrt{k}$ at 0,075*L* from the A.P. or F.P.
- t_t = taper thickness for strength deck and shell plating
- Z_c = section modulus of deck longitudinal in association with deck plating, in cm^3, within the 0,4*L* midships region
- Z_e = section modulus of deck longitudinal in association with deck plating, in cm^3, at 0,075*L* from the ends
- Z_t = taper section modulus of deck longitudinal in association with deck plating, in cm^3
- A_c = cross sectional area of one longitudinal without attached plating, in cm^2, within the 0,4*L* midships region
- A_e = cross sectional area of one longitudinal without attached plating, in cm^2, at 0,075*L* from the ends
- A_t = taper cross-sectional area of one longitudinal without attached plating, in cm^2

NOTES
1. For thickness of strength deck and shell plating in way of cargo tanks of double hull oil tankers, single hull oil tankers or ore carriers, *see also* Pt 4, Ch 9, Ch 10, or Ch 11 as appropriate.
2. The taper requirement does not apply to container ships or open type ships, *see* Ch 4,2.3, where the requirements of Pt 4, Ch 8,3.2 are applicable, nor to fast cargo ships where the requirements of Pt 4, Ch 1,3 are applicable. *See also* Ch 4,5 for hull section modulus requirement away from the midship area.
3. The formulae for the taper values are based on the assumption that the quality of steel is the same at amidships and ends. Where higher tensile steel is used in the midship region and mild steel at the ends, the taper values should be calculated for both qualities of steel in way of the transition from higher tensile to mild steel, and applied as determined by 2.5.2 and 2.5.3.

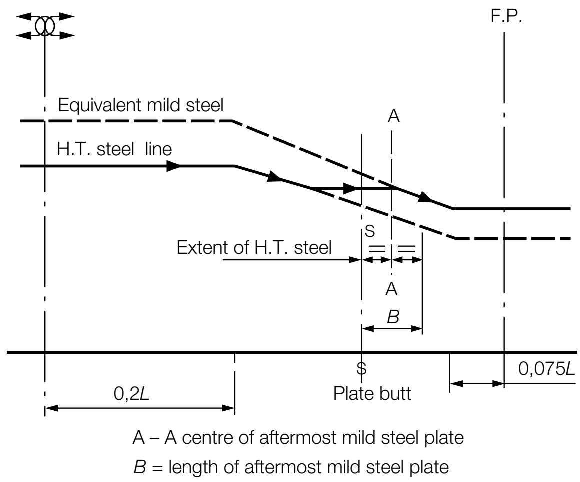


Fig. 3.2.2 Transition of steel grades

2.7 Grouped stiffeners

2.7.1 Where stiffeners are arranged in groups of the same scantling, the section modulus requirement of each group is to be based on the greater of the following:

(a) the mean value of the section modulus required for individual stiffeners within the group;

(b) 90 per cent of the maximum section modulus required for individual stiffeners within the group.

■ *Section 3* Structural idealization

3.1 General

3.1.1 For derivation of scantlings of stiffeners, beams, girders, etc., the formulae in the Rules are normally based on elastic or plastic theory using simple beam models supported at one or more points and with varying degrees of fixity at the ends, associated with an appropriate concentrated or distributed load.

3.1.2 Apart from local requirement for web thickness or flange thicknesses, the stiffener, beam or girder strength is defined by a section modulus and moment of inertia requirement.

3.2 Geometric properties of section

3.2.1 The symbols used in this sub-Section are defined as follows:

b = the actual width, in metres, of the load-bearing plating, i.e. one-half of the sum of spacings between parallel adjacent members or equivalent supports

f = $0{,}3\left(\dfrac{l}{b}\right)^{2/3}$, but is not to exceed 1,0. Values of this factor are given in Table 3.3.1

l = the overall length, in metres, of the primary support member, *see* Fig. 3.3.3

t_p = the thickness, in mm, of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

Table 3.3.1 Load bearing plating factor

$\dfrac{l}{b}$	f	$\dfrac{l}{b}$	f
0,5	0,19	3,5	0,69
1,0	0,30	4,0	0,76
1,5	0,39	4,5	0,82
2,0	0,48	5,0	0,88
2,5	0,55	5,5	0,94
3,0	0,62	6 and above	1,00
NOTE Intermediate values to be obtained by linear interpolation.			

3.2.2 The effective geometric properties of rolled or built sections may be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the attached plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

3.2.3 The geometric properties of rolled or built stiffener sections and of swedges are to be calculated in association with effective area of attached load bearing plating of thickness t_p mm and of width 600 mm or $40t_p$ mm, whichever is the greater. In no case, however, is the width of plating to be taken as greater than either the spacing of the stiffeners or the width of the flat plating between swedges, whichever is appropriate. The thickness, t_p, is the actual thickness of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

3.2.4 The effective section modulus of a corrugation over a spacing p is to be calculated from the dimensions and, for symmetrical corrugations, may be taken as:

$$Z = \frac{d_w}{6000}(3bt_p + ct_w) \quad \text{cm}^3$$

where d_w, b, t_p, c and t_w are measured, in mm, and are as shown in Fig. 3.3.1. The value of b is to be taken not greater than:

$50t_p\sqrt{k}$ for welded corrugations

$60t_p\sqrt{k}$ for cold formed corrugations

The value of θ is to be not less than 40°. The moment of inertia is to be calculated from:

$$I = \frac{Z}{10}\left(\frac{d_w}{2}\right) \text{cm}^4$$

3.2.5 The section modulus of a double plate bulkhead over a spacing b may be calculated as:

$$Z = \frac{d_w}{6000}(6f\,b\,t_p + d_w\,t_w) \quad \text{cm}^3$$

where d_w, b, t_p and t_w are measured, in mm, and are as shown in Fig. 3.3.2.

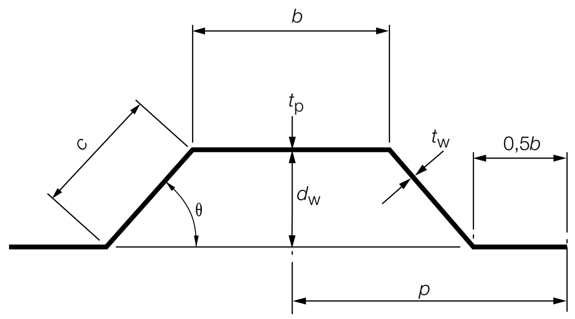


Fig. 3.3.1 Corrugation dimensions

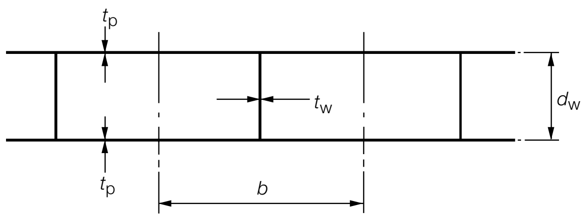


Fig. 3.3.2 Double plate bulkhead dimensions

3.2.6 The effective section modulus of a built section may be taken as:

$$Z = \frac{a d_w}{10} + \frac{t_w d_w^2}{6000}\left(1 + \frac{200\,(A - a)}{200A + t_w\,d_w}\right) \text{ cm}^3$$

where

a = the area of the face plate of the member, in cm^2

d_w = the depth, in mm, of the web between the inside of the face plate and the attached plating. Where the member is at right angles to a line of corrugations, the minimum depth is to be taken

t_w = the thickness of the web of the section, in mm

A = the area, in cm^2, of the attached plating, *see* 3.2.7. If the calculated value of A is less than the face area a, then A is to be taken as equal to a.

3.2.7 The geometric properties of primary support members (i.e. girders, transverses, webs, stringers, etc.) are to be calculated in association with an effective area of attached load bearing plating, A, determined as follows:

(a) For a member attached to plane plating:

$A = 10 f\, b\, t_p$ cm²

(b) For a member attached to corrugated plating and parallel to the corrugations:

$A = 10 b\, t_p$ cm²

See Fig. 3.3.1

(c) For a member attached to corrugated plating and at right angles to the corrugations:
A is to be taken as equivalent to the area of the face plate of the member.

3.3 Determination of span point

3.3.1 The effective length, l_e, of a stiffening member is generally less than the overall length, l, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined as follows:

(a) For rolled or built secondary stiffening members:
The span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member is equal to the depth of the member. Where there is no end bracket, the span point is to be measured between primary member webs. For double skin construction, the span may be reduced by the depth of primary member web stiffener, *see* Fig. 3.3.3.

(b) For primary support members:
The span point is to be taken at a point distant from the end of the member,

where $b_e = b_b\left(1 - \frac{d_w}{d_b}\right)$

See also Fig. 3.3.3.

3.3.2 Where the end connections of longitudinals are designed with brackets to achieve compliance with the ShipRight FDA Procedure, no reduction in span is permitted for such brackets unless the fatigue life is subsequently reassessed and shown to be adequate for the resulting reduced scantlings.

3.3.3 Where the stiffener member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

3.3.4 It is assumed that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, consideration will be given to the effective span to be used for the stiffener.

3.4 Calculation of hull section modulus

3.4.1 All continuous longitudinal structural material is to be included in the calculation of the inertia of the hull midship section, and the lever z is, except where otherwise specified for particular ship types, to be measured vertically from the neutral axis to the top of keel and to the moulded strength deck line at the side. The strength deck is to be taken as follows:

(a) Where there is a complete upper deck and no effective superstructure, the strength deck is the upper deck.

(b) Where the upper deck is stepped, as in the case of raised quarter deck ships, or there is an effective superstructure on the upper deck, the strength deck is stepped as shown in Fig. 3.3.4.

3.4.2 An effective superstructure is one which exceeds 0,15L in length and extends inside the midship 0,5L region. Superstructure decks less than 12 m in length are not to be considered as strength deck.

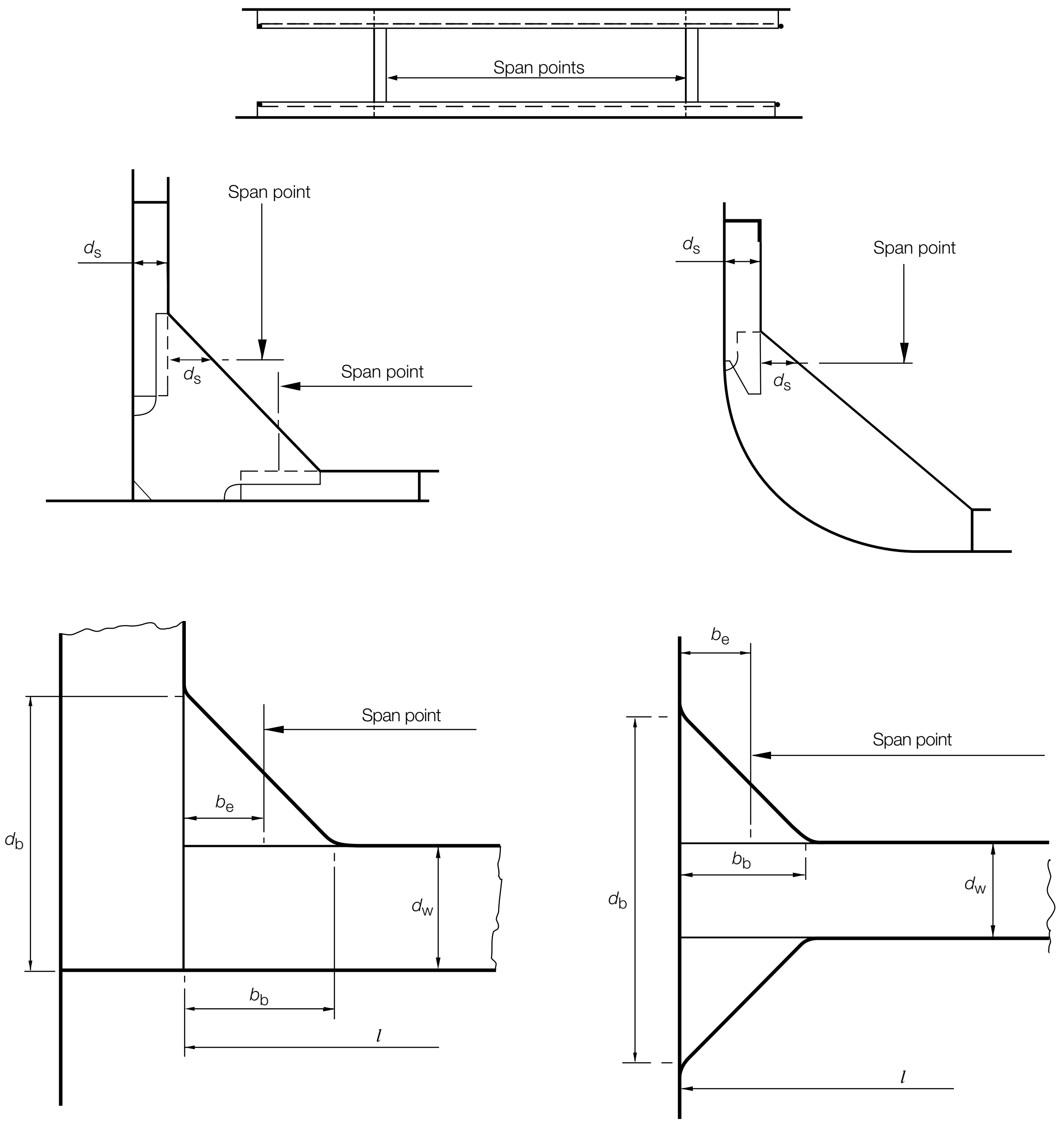


Fig. 3.3.3 Span points

3.4.3 Openings having a length in the fore and aft direction exceeding 2,5 m or 0,1*B* m or a breadth exceeding 1,2 m or 0,04*B* m, whichever is the lesser, are always to be deducted from the sectional areas used in the section modulus calculation.

3.4.4 Smaller openings (including manholes, lightening holes, single scallops in way of seams, etc.) need not be deducted provided they are isolated and the sum of their breadths or shadow area breadths (*see* 3.4.7), in one transverse section does not reduce the section modulus at deck or bottom by more than 3 per cent.

3.4.5 Where B_1 equals the breadth of the ship at the section considered and Σb_1 equals the sum of breadths of deductible openings, the expression 0,06 ($B_1 - \Sigma b$) may be used for deck openings in lieu of the 3 per cent limitation of reduction of section modulus in 3.4.4.

3.4.6 Where a large number of openings are proposed in any transverse space, special consideration will be required.

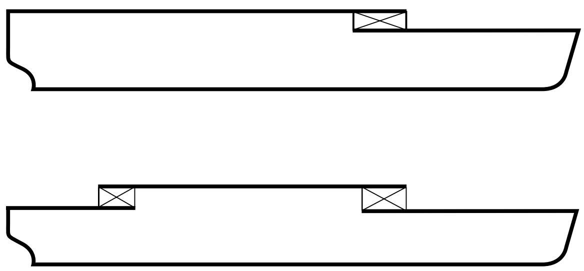


Fig. 3.3.4 Strength deck stepping

3.4.7 When calculating deduction-free openings, the openings are assumed to have longitudinal extensions as shown by the shaded areas in Fig. 3.3.5. The shadow area is obtained by drawing two tangent lines to an opening angle of 30°. The section to be considered should be perpendicular to the centreline of the ship and should result in the maximum deduction in each transverse space.

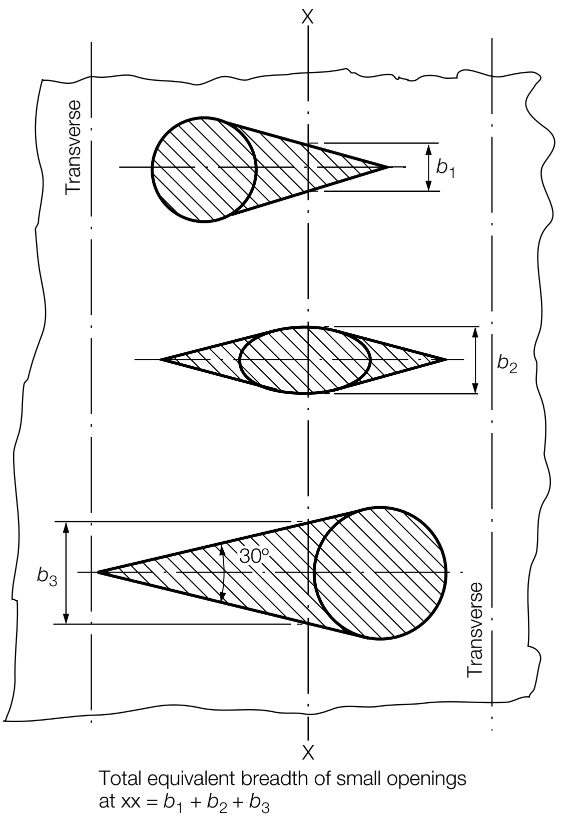


Fig. 3.3.5 Deduction free openings shadow areas

3.4.8 Isolated openings in longitudinals or longitudinal girders need not be deducted if their depth does not exceed 25 per cent of the web depth with a maximum depth for scallops of 75 mm.

3.4.9 Openings are considered isolated if they are spaced not less than 1 m apart.

3.4.10 For compensation that may be required for openings, *see* individual ship Chapters.

3.4.11 Where trunk decks or continuous hatch coamings are effectively supported by longitudinal bulkheads or deep girders, they are to be included in the longitudinal sectional area when calculating the hull section modulus. The lever z_t is to be taken as:

$$z_t = z_c \left(0{,}9 + 0{,}2 \frac{y}{B}\right) \text{ m but not less than } z$$

y = horizontal distance from top of continuous strength member to the centreline of the ship, in metres

z = vertical distance from the neutral axis to the moulded deck line at side, in metres

z_c = vertical distance from the neutral axis to the top of the continuous strength member, in metres

z_c and y are to be measured to the point giving the largest value of z_t.

3.4.12 Where continuous hatch coamings are effectively supported (except inboard coamings of multi-hatch arrangements, *see* 3.4.14), 100 per cent of their sectional area may be included in the calculation of the hull section modulus.

3.4.13 Where a continuous longitudinal underdeck girder, or girders, are arranged to support the inboard hatch coamings, 50 per cent of their sectional area may be included. If the girder is fitted in conjunction with a longitudinal centreline bulkhead, 100 per cent of the sectional area may be included. In cases where the girders are enclosed box sections, or where the girders are effectively tied to the bottom structure, the area to be included will be specially considered.

3.4.14 The percentage of the sectional area to be included for inboard continuous hatch side coamings should be the same percentage as that of the longitudinal girder under.

3.4.15 Where continuous deck longitudinals or deck girders are arranged above the strength deck, the sectional area may be included in the calculation of the hull section modulus. The lever is to be taken to a position corresponding to the depth of the longitudinal member above the moulded deckline at side amidships.

■ *Section 4* Bulkhead requirements

4.1 Number and disposition of bulkheads

4.1.1 All ships are to have a collision bulkhead, an after peak bulkhead, generally enclosing the sterntubes in a watertight compartment, and a watertight bulkhead at each end of the machinery space. Additional watertight bulkheads are to be fitted so that the total number of bulkheads is at least in accordance with Table 3.4.1.

Table 3.4.1 Total number of bulkheads

Length, L, in metres	Total number of bulkheads	
	Machinery amidships	Machinery aft, *see* Note
≤ 65	4	3
> 65 ≤ 85	4	4
> 85 ≤ 90	5	5
> 90 ≤ 105	5	5
> 105 ≤ 115	6	5
> 115 ≤ 125	6	6
> 125 ≤ 145	7	6
> 145 ≤ 165	8	7
> 165 ≤ 190	9	8
> 190	To be considered individually	
NOTE With after peak bulkhead forming after boundary of machinery space.		

4.1.2 The bulkheads in the holds should be spaced at reasonably uniform intervals. Where non-uniform spacing is unavoidable and the length of a hold is unusually great, the transverse strength of the ship is to be maintained by fitting web frames, increased framing, etc., and details are to be submitted.

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

4.1.4 Where applicable, the number and disposition of bulkheads are to be arranged to suit the requirements for subdivision, floodability and damage stability, and are to be in accordance with the requirements of the National Authority in the country in which the ship is registered.

4.2 Collision bulkhead

4.2.1 The collision bulkhead in all ships other than passenger ships is to be positioned as detailed in Table 3.4.2. Consideration will, however, be given to proposals for the collision bulkhead to be positioned slightly further aft on arrangement (b) ships, but not more than $0,08L_L$ from the fore end of L_L, provided that the application is accompanied by calculations showing that flooding of the space forward of the collision bulkhead will not result in any part of the freeboard deck becoming submerged, nor any unacceptable loss of stability.

4.2.2 The collision bulkhead in passenger ships is to be in accordance with the following:

(a) A ship shall have a forepeak or collision bulkhead, which shall be watertight up to the bulkhead deck. (The bulkhead deck is the uppermost deck up to which the transverse watertight bulkheads are carried, *see* 4.1.4). This bulkhead is to be positioned as detailed in Table 3.4.3.

Table 3.4.2 Collision bulkhead position (other than passenger ships)

Arrangement	Length L_L, in metres	Distance of collision bulkhead aft of fore end of L_L, in metres	
		Minimum	Maximum
(a)	≤ 200	$0,05L_L$	$0,08L_L$
	> 200	10	$0,08L_L$
(b)	≤ 200	$0,05L_L - f_1$	$0,08L_L - f_1$
	> 200	$10 - f_2$	$0,08L_L - f_2$
Symbols and definitions			

$f_1 = \frac{G}{2}$ or $0,015L_L$, whichever is the lesser

$f_2 = \frac{G}{2}$ or 3 m, whichever is the lesser

G = projection of bulbous bow forward of fore end of L_L, in metres

L_L is as defined in Ch 1,6.1

Arrangement (a) A ship that has no part of its underwater body extending forward of the fore end of L_L

Arrangement (b) A ship with part of its underwater body extending forward of the fore end of L_L (e.g. bulbous bow)

(b) If a ship has a long forward superstructure, the forepeak or collision bulkhead shall be extended weathertight to the deck next above the bulkhead deck. The extension need not be fitted directly over the bulkhead below, provided it is located within the limits specified in Table 3.4.3 with the exemption permitted by 4.5.3 and the part of the bulkhead deck which forms the step is made effectively weathertight.

Table 3.4.3 Collision bulkhead position for passenger ships

Arrangement	Distance of collision bulkhead aft of fore perpendicular, in metres	
	Minimum	Maximum
(a)	$0,05L_{pp}$	$3 + 0,05L_{pp}$
(b)	$0,05L_{pp} - f$	$3 + 0,05L_{pp} - f$
Symbols and definitions		

$f = \frac{G}{2}$ or $0,015L_{pp}$ or 3 m, whichever is the lesser

G = projection of bulbous bow forward of fore perpendicular, in metres

L_{pp} is to be taken as the length measured between the extremities of the deepest subdivision waterline

Arrangement (a) A ship that has no part of its underwater body extending forward of the fore perpendicular

Arrangement (b) A ship with part of its underwater body extending forward of the fore perpendicular, (e.g. bulbous bow)

4.3 After peak bulkhead

4.3.1 All ships are to have an after peak bulkhead generally enclosing the sterntube and rudder trunk in a water-tight compartment. In twin screw ships where the bossing ends forward of the after peak bulkhead, the sterntubes are to be enclosed in suitable watertight spaces inside or aft of the shaft tunnels. In passenger ships, the sterntubes are to be enclosed in watertight spaces of moderate volume. The stern gland is to be situated in a watertight shaft tunnel or other watertight space separate from the stern tube compartment and of such volume that, if flooded by leakage through the stern gland, the margin line will not be submerged. (The margin line is a line drawn at least 76 mm below the upper surface of the bulkhead deck at side).

4.4 Height of bulkheads

4.4.1 The collision bulkhead is normally to extend to the uppermost continuous deck or, in the case of ships with combined bridge and forecastle or a long superstructure which includes a forecastle, to the superstructure deck. However, if a ship is fitted with more than one complete superstructure deck, the collision bulkhead may be terminated at the deck next above the freeboard deck. Where the collision bulkhead extends above the freeboard deck, the extension need only be to weathertight standards.

4.4.2 The after peak bulkhead may terminate at the first deck above the load waterline, provided that this deck is made watertight to the stern or to a watertight transom floor. In passenger ships, the after peak bulkhead is to extend water-tight to the bulkhead deck. However, it may be stepped below the bulkhead deck provided the degree of safety of the ship as regards watertight subdivision is not thereby diminished.

4.4.3 The remaining watertight bulkheads are to extend to the freeboard deck. In passenger ships of restricted draught and all ships of unusual design, the height of the bulkheads will be specially considered.

4.5 Watertight recesses, flats and loading ramps

4.5.1 Watertight recesses in bulkheads are generally to be so framed and stiffened as to provide strength and stiffness equivalent to the requirements for watertight bulkheads.

4.5.2 In collision bulkheads, any recesses or steps in the bulkhead are to fall within the limits of bulkhead positions given in 4.2.1. Where the bulkhead is extended above the freeboard deck or bulkhead deck in passenger ships, the extension need only be to weathertight standards. If a step occurs at that deck, the deck need also only be to weather-tight standards in way of the step, unless the step forms the crown of a tank, *see* Pt 4, Ch 1,4.

4.5.3 In ships fitted with bow doors, in which a sloping loading ramp forms part of the collision bulkhead above the freeboard or bulkhead deck, that part of the ramp which is more than 2,30 m above the freeboard or bulkhead deck may extend forward of the minimum limit specified in Table 3.4.2 or Table 3.4.3 as appropriate. Such a ramp is to comply with Pt 4, Ch 2,8.2.5.

4.6 Longitudinal subdivision

4.6.1 When timber load lines are to be assigned, double bottom tanks within the midship half-length are to have adequate longitudinal subdivision.

4.7 Protection of tanks carrying oil fuel, lubricating oil, vegetable or similar oils

4.7.1 Tanks carrying oil fuel or lubricating oil are to be separated by cofferdams from those carrying feed water, fresh water, edible oil or similar oils. Similarly, tanks carrying vegetable or similar oils are to be separated from those carrying fresh or feed water.

4.7.2 Lubricating oil compartments are also to be separated by cofferdams from those carrying oil fuel. However these cofferdams need not be fitted provided that:

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

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

4.7.3 Cofferdams are not required between oil fuel double bottom tanks and deep tanks above, provided that the inner bottom plating is not subjected to a head of oil fuel.

4.7.4 Where fitted, cofferdams are to be suitably ventilated.

4.7.5 If oil fuel tanks are necessarily located within or adjacent to the machinery spaces, their arrangement is to be such as to avoid direct exposure of the bottom from rising heat resulting from an engine room fire, *see* SOLAS 1974 as amended Reg. II–2/B4.2.2.3.2.

4.7.6 In passenger ships, water ballast is, in general, not to be carried in tanks intended for oil fuel. Attention is drawn to the Statutory Regulations issued by National Authorities in connection with the *International Convention for the Prevention of Pollution of the Sea by Oil*, 1973/78.

4.8 Watertight tunnels and passageways

4.8.1 Where a machinery space is situated with a compartment or compartments between it and the after peak bulkhead, the shafting is to be enclosed in a watertight tunnel large enough to permit proper examination and repair of shafting. A sliding watertight door, capable of being operated locally from both sides, is to be provided at the forward end of the tunnel. Consideration may, however, be given to the omission of the watertight door, subject to satisfactory compliance with any relevant statutory requirements.

4.8.2 Pipe tunnels are to have dimensions adequate for reasonable access.

4.8.3 Where fore and aft underdeck passageways are arranged at the ship's side, the after access thereto is to be by a watertight trunk led to the upper deck. Alternative arrangements to prevent the engine room being flooded, in the event of a collision or if the passageway doors are left open, will be considered.

4.9 Means of escape

4.9.1 For the requirements for means of escape, *see* SOLAS 1974 as amended Reg. II–2/D,13.

4.10 Oil tankers

4.10.1 For subdivision requirements within the cargo tank region for oil tankers, *see* Pt 4, Ch 9,1.

■ *Section 5* Design loading

5.1 General

5.1.1 This Section contains the design heads/pressures to be used in the derivation of scantlings for decks, tank tops and transverse bulkheads. These are given in Table 3.5.1.

5.2 Symbols

5.2.1 The symbols used in this Section are defined as follows:

L, L_{pp}, C_b, B, D and T as defined in Ch 1,6.1

h_i = appropriate design head, in metres

l_e = span of stiffener

p = design loading, in kN/m^2 (tonne-f/m^2)

p_a = applied loading, in kN/m^2 (tonne-f/m^2)

C = stowage rate, in m^3/tonne

= $\dfrac{h_i}{p}$ generally

= volume of the hold, in m^3 excluding the volume contained within the depth of the cargo hatchway, divided by the weight of cargo, in tonnes, stowed in the hold, for inner bottom

E = correction factor for height of platform

$$\frac{0{,}0914 + 0{,}003L}{D - T} - 0{,}15$$, but not less than zero nor more than 0,147

H = height from tank top to deck at side, in metres

H_c = 'tween deck height measured vertically on the centreline of the ship from 'tween deck to underside of hatch cover stiffeners on deck above, in metres

H_{td} = cargo head in 'tween deck, in metres, as defined in Fig. 3.5.1.

5.2.2 The following symbols and definitions apply in particular to the design pressures for partially filled tanks:

L_{pp} and C_b as defined in Ch 1,6.1

b = height of internal primary bottom members, in metres

F = fill height, in metres

F_r = effective filling ratio

$$= \frac{\pi}{L_s}\left(F - b\sqrt{\frac{n}{n+1}}\right)$$

GM = transverse metacentric height, in metres, including free surface correction, for the loading condition under consideration

H_t = tank depth, in metres, measured from the bottom of the tank to the underside of the deck at side. In the case of holds, the depth is measured from the inner bottom to the underside of the deck at hatch side, except in double skin ships with hatch coaming in line with the inner skin, in which case, the depth is measured to the top of the hatch coaming

n = number of internal primary bottom members

L_s = the effective horizontal free surface length, in metres, in the direction of angular motion (i.e. tank breadth for roll, tank length for pitch)

S_{nr} = ship's natural rolling period

$$= \frac{2{,}35r}{\sqrt{GM}} \text{ seconds}$$

for ships for which either r or GM varies significantly between loading conditions (for example, bulk carriers and tankers, *see* 1.1.3), S_{nr} should be evaluated for each representative loading condition considered

r = radius of gyration of roll, in metres, and may be taken as 0,34B

S_{np} = ship's natural pitching period

$$= 3{,}5\sqrt{TC_b} \text{ seconds}$$

for ships for which either T or C_b varies significantly between loading conditions (for example, bulk carriers and tankers, *see* 1.1.3), S_{np} should be evaluated for each representative loading condition considered

T_{np} = fluid natural period of pitch

$$= \sqrt{\frac{4\pi L_s}{g.\tanh(F_r)}} \text{ seconds}$$

T_{nr} = fluid natural period of roll

$$= \sqrt{\frac{4\pi L_s}{g.\tanh(F_r)}} \text{ seconds}$$

θ_{max} = maximum 'lifetime' pitch angle, in degrees:

$$(32{,}7 - 8{,}2C_b)\; e^{-0{,}001L_{pp}(4{,}9 + 0{,}5C_b)}$$

ϕ_{max} = maximum 'lifetime' roll angle, in degrees:

$$\left(14{,}8 + 3{,}7\frac{L_{pp}}{B}\right) e^{-0{,}0023L_{pp}}$$

Table 3.5.1 Design heads and permissible cargo loadings (SI units) *(see continuation)*

Structural item and position	Component	Standard stowage rate C, in m^3/tonne	Design loading p, in kN/m^2	Equivalent design head h_i in metres	Permissible cargo loading in kN/m^2	Equivalent permissible head, in metres
Weather deck (general cargo)				h_1		
(a) Loading for minimum scantlings						
Forward of 0,075L from F.P.	Beams and longitudinals	1,39	12,73	1,8	8,5	1,2
	Primary structure		29,64 + 14,41E	4,2 + 2,04E		
Between 0,12L and 0,075L from F.P.	Beams and longitudinals	1,39	10,61	1,5	8,5	1,2
	Primary structure		22,59 + 14,41E	3,2 + 2,04E		
Aft of 0,12L from F.P.	Beams and longitudinals	1,39	8,5 + 14,41E	1,2 + 2,04E	8,5	1,2
	Primary structure					
(b) Specified cargo loading						
Forward of 0,075L from F.P.	Beams and longitudinals	1,39	2,47p_a + 14,41E or as (a), whichever is larger (Note 1)	0,35p_a + 2,04E (Note 1)	p_a	0,14p_a
	Primary structure		3,5p_a + 14,41E or as (a), whichever is larger (Note 1)	0,5p_a + 2,04E (Note 1)		
Between 0,12L and 0,075L from F.P.	Beams and longitudinals	1,39	1,98p_a + 14,41E or as (a), whichever is larger (Note 1)	0,28p_a + 2,04E (Note 1)	p_a	0,14p_a
	Primary structure		2,67p_a + 14,41E or as (a), whichever is larger (Note 1)	0,38p_a + 2,04E (Note 1)		
Aft of 0,12L from F.P.	Beams and longitudinals	1,39	p_a + 14,41E (Note1)	0,14p_a + 2,04E (Note 1)	p_a	0,14p_a
	Primary structure					
Cargo decks				h_2		
General cargo (standard loads)	All structure	1,39	7,07H_{td}	H_{td}	7,07H_{td}	H_{td}
Special cargo (specified loads)		C	p_a	$\frac{Cp_a}{9,82}$	p_a	$\frac{Cp_a}{9,82}$
Machinery space, workshop and stores		1,39	18,37	2,6	—	—
Ship stores		1,39	14,14	2,0	—	—
Accommodation decks (clear of tanks)	All structure	1,39	8,5	h_3 1,2	—	—

Table 3.5.1 Design heads and permissible cargo loadings (SI units) *(see continuation)*

Structural item and position	Component	Standard stowage rate C, in m^3/tonne	Design loading p, in kN/m^2	Equivalent design head h_i in metres	Permissible cargo loading in kN/m^2	Equivalent permissible head, in metres
Superstructure decks (Note 3)				h_3		
1st tier	Beams and longitudinals	—	—	0,9 — Where the deck is exposed to the weather, add 2,04E	—	—
2nd tier				0,6		
3rd tier and above				0,45		
Decks forming crown of tunnels and deep tanks	Plating and stiffeners	C	$\frac{9,82h}{C}$	h_4 h	—	—
			where h = 1/2 height of stand pipe above crown			
(c) Bulk carrier (see 1.1.3) with topside tanks						
Weather deck outside line of hatchways in way of cargo hold region, when topside tanks empty	Beams and longitudinals	1,39	—	—	7,06h	h = the lesser of (i) 0,22B (ii) $1,2 + 0,14\frac{W_b}{A}$ where W_b = weight of water ballast in the topside tank per frame space, in kN A = Corresponding area, (m^2), of deck in way over one hold frame space
	Primary structure	1,39	—	—		
Weather deck hatch covers (non-liquid cargo)	*see also* Pt 3, Ch 11, for weather loading			h_H		
Steel covers – Position 1 (Note 4)	Webs, stiffeners and plating	1,39	$\left(7,56 + \frac{L_L}{10,26}\right)$ Min. 10,59 Max. 17,17	$\left(1,07 + \frac{L_L}{72,5}\right)$ Min. 1,5 Max. 2,45	10,59 (Note 2)	1,5 (Note 2)
Steel covers – Position 2 (Note 4)			$\left(5,65 + \frac{L_L}{14,15}\right)$ Min. 8,47 Max. 12,77	$\left(0,8 + \frac{L_L}{100}\right)$ Min. 1,2 Max. 1,8	8,5 (Note 2)	1,2 (Note 2)
Wood covers	As for steel covers					

Table 3.5.1 Design heads and permissible cargo loadings (SI units) *(conclusion)*

Structural item and position	Component	Standard stowage rate C, in m^3/tonne	Design loading p, in kN/m^2	Equivalent design head h_i in metres	Permissible cargo loading in kN/m^2	Equivalent permissible head, in metres
Cargo hatch covers (standard loading)				h_H		
Steel cover	Webs, stiffeners and plating	1,39	$7,07H_{td}$	H_{td}	$7,07H_{td}$	H_{td}
Wood cover	—	1,39	—	—	$7,07H_{td}$	H_{td}
Inner bottom				H		
Ship without heavy cargo notation	Plating and stiffeners	1,39	—	—	$9,82T$	$1,39T$
Ship with heavy cargo notation		C but ≤ 0,865	$\frac{H}{C}$	H	$\frac{H}{C}$	H
Watertight bulkheads	Plating and stiffeners	0,975	$10,07h_4$	h_4 from Fig. 3.5.2	—	—
Deep tank bulkhead	Plating and stiffeners	C but ≤ 0,975	$\frac{9,82h_4}{C}$	h_4 from Fig. 3.5.2	—	—

NOTES
1. In the case of beams and longitudinals, the equivalent design head is to be used in conjunction with the appropriate formulae.
2. Where the scantlings of weather deck covers have been approved for the loading equal to or in excess of the minimum design loading and cargo is to be carried at this loading, the scantlings of the deck supporting structure are also to be suitable for this loading.
3. For forecastle decks forward of 0,12L from F.P., *see* Weather decks.
4. For definitions of Positions 1 and 2, and specified cargo loading, *see* Ch 11,1.1.

Table 3.5.1 Design heads and permissible cargo loadings (metric units) *(see continuation)*

Structural item and position	Component	Standard stowage rate C, in m^3/tonne	Design loading p, in tonne-f/m^2	Equivalent design head h_i in metres	Permissible cargo loading in tonne-f/m^2	Equivalent permissible head, in metres
Weather deck (general cargo)				h_1		
(a) Loading for minimum scantlings						
Forward of 0,075L from F.P.	Beams and longitudinals	1,39	1,296	1,8	0,865	1,2
	Primary structure		3,02 + 1,467E	4,2 + 2,04E		
Between 0,12L and 0,075L from F.P.	Beams and longitudinals	1,39	1,08	1,5	0,865	1,2
	Primary structure		2,30 + 1,467E	3,2 + 2,04E		
Aft of 0,12L from F.P.	Beams and longitudinals	1,39	0,865 + 1,467E	1,2 + 2,04E	0,865	1,2
	Primary structure					
(b) Specified cargo loading						
Forward of 0,075L from F.P.	Beams and longitudinals	1,39	2,5p_a + 1,467E or as (a), whichever is larger (Note 1)	3,5p_a + 2,04E (Note 1)	p_a	1,39p_a
	Primary structure		3,5p_a + 1,467E or as (a), whichever is larger (Note 1)	4,87p_a + 2,04E (Note 1)		
Between 0,12L and 0,075L from F.P.	Beams and longitudinals	1,39	2,0p_a + 1,467E or as (a), whichever is larger (Note 1)	2,78p_a + 2,04E (Note 1)	p_a	1,39p_a
	Primary structure		2,67p_a + 1,467E or as (a), whichever is larger (Note 1)	3,71p_a + 2,04E (Note 1)		
Aft of 0,12L from F.P.	Beams and longitudinals	1,39	p_a + 1,467E (Note 1)	1,39p_a + 2,04E (Note 1)	p_a	1,39p_a
	Primary structure		p_a + 1,467E (Note 1)	1,39p_a + 2,04E (Note 1)		
Cargo decks				h_2		
General cargo (standard loads)	All structure	1,39	$\frac{H_{td}}{1,39}$	H_{td}	$\frac{H_{td}}{1,39}$	H_{td}
Special cargo (specified loads)		C	p_a	Cp_a	p_a	Cp_a
Machinery space, workshop and stores		1,39	1,87	2,6	—	—
Ship stores		1,39	1,44	2,0	—	—
Accommodation decks (clear of tanks)	All structure	1,39	0,865	h_3	—	—
				1,2		

Table 3.5.1 Design heads and permissible cargo loadings (metric units) *(see continuation)*

Structural item and position	Component	Standard stowage rate C, in m^3/tonne	Design loading p, in tonne-f/m^2	Equivalent design head h_i in metres	Permissible cargo loading in tonne-f/m^2	Equivalent permissible head, in metres
Superstructure decks (Note 3)				h_3		
1st tier	Beams and longitudinals	—	—	0,9 Where the deck is exposed to the weather, add 2,04E	—	—
2nd tier				0,6		
3rd tier and above				0,45		
Decks forming crown of tunnels and deep tanks	Plating and stiffeners	C	$\frac{h}{C}$	h_4 h	—	—
			where h = $^1/_2$ height of stand pipe above crown			
(c) Bulk carrier (see 1.1.3) with topside tanks						
Weather deck outside line of hatchways in way of cargo hold region, when topside tanks empty	Beams and longitudinals	1,39	—	—	$\frac{h}{1,39}$	h = the lesser of (i) 0,22B (ii) $1,2 + 0,39 \frac{W_b}{A}$ where W_b = weight of water ballast in the topside tank per frame space, tonne-f A = Corresponding area, (m^2), of deck in way over one hold frame space
	Primary structure	1,39	—	—		
Weather deck hatch covers (non-liquid cargo)				h_H		
Steel covers – Position 1 (Note 4)	Webs, stiffeners and plating	1,39	$\left(0,77 + \frac{L_L}{100,8}\right)$ Min. 1,08 Max. 1,75	$\left(1,07 + \frac{L_L}{72,5}\right)$ Min. 1,5 Max. 2,45	1,08 (Note 2)	1,5 (Note 2)
Steel covers – Position 2 (Note 4)			$\left(0,575 + \frac{L_L}{139}\right)$ Min. 0,865 Max. 1,3	$\left(0,8 + \frac{L_L}{100}\right)$ Min. 1,2 Max. 1,8	0,865 (Note 2)	1,2 (Note 2)
Wood covers	As for steel covers					

Table 3.5.1 Design heads and permissible cargo loadings (metric units) *(conclusion)*

Structural item and position	Component	Standard stowage rate C, in m^3/tonne	Design loading p, in tonne-f/m^2	Equivalent design head h_i in metres	Permissible cargo loading in tonne-f/m^2	Equivalent permissible head, in metres
Cargo hatch covers (standard loading)				h_H		
Steel cover	Webs, stiffeners and plating	1,39	$\frac{H_{td}}{1,39}$	H_{td}	$\frac{H_{td}}{1,39}$	H_{td}
Wood cover	—	1,39	—	—	$\frac{H_{td}}{1,39}$	H_{td}
Inner bottom				H		
Ship without heavy cargo notation		1,39	—	—	T	1,39T
Ship with heavy cargo notation	Plating and stiffeners	C but ≤ 0,865	$\frac{H}{C}$	H	$\frac{H}{C}$	H
Watertight bulkheads	Plating and stiffeners	0,975	$\frac{h_4}{0,975}$	h_4 from Fig. 3.5.2	—	—
Deep tank bulkhead	Plating and stiffeners	C but ≤ 0,975	$\frac{h_4}{C}$	h_4 from Fig. 3.5.2	—	—

NOTES
1. In the case of beams and longitudinals, the equivalent design head is to be used in conjunction with the appropriate formulae.
2. Where the scantlings of weather deck covers have been approved for the loading equal to or in excess of the minimum design loading and cargo is to be carried at this loading, the scantlings of the deck supporting structure are also to be suitable for this loading.
3. For forecastle decks forward of 0,12L from F.P., *see* Weather decks.
4. For definitions of Positions 1 and 2, and specified cargo loading, *see* Ch 11,1.1.

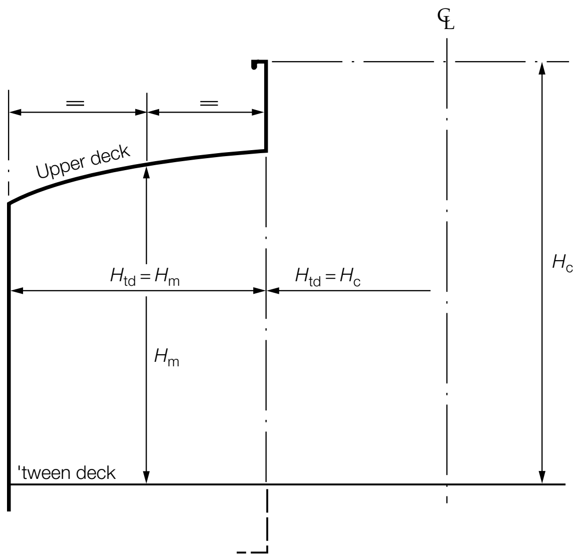


Fig. 3.5.1 Heads for 'tween decks

5.3 Stowage rate and design loads

5.3.1 Unless it is specifically requested otherwise, the following standard stowage rates are to be used:

(a) 1,39 m^3/tonne for weather or general cargo loading on deck and inner bottom.

(b) 0,975 m^3/tonne for liquid cargo of density 1,025 tonne/m^3 or less on watertight and tank divisions. For liquid of density greater than 1,025 tonne/m^3 the corresponding stowage rates are to be adopted.

5.3.2 Proposals to use a stowage rate greater than 1,39 m^3/tonne for permanent structure will require special consideration, and will normally be accepted only in the case of special purpose designs such as fruit carriers, etc.

5.3.3 The design head and permissible cargo loading are shown in Table 3.5.1.

5.4 Design pressure for partially filled tanks

5.4.1 When partial filling of tanks or holds is contemplated for sea-going conditions, the risk of significant loads due to sloshing induced by any of the ship motions is to be considered. An initial assessment is to be made to determine whether or not a higher level of sloshing investigation is required, using the following procedure which corresponds to the Level 1 Investigation outlined in the *SDA Procedure for Sloshing loads and scantling assessment,* on tanks partially filled with liquids.

5.4.2 In general, significant dynamic magnifications of the sloshing pressures are considered unlikely for the following cases:

(a) For internally stiffened tanks:

(i) where two (or more) deck girders (in the case of rolling) or deck transverses (in the case of pitching) are located not more than 25 per cent of the tank breadth or length respectively from the adjacent tank boundary, and the fill level is greater than the tank depth minus the height of the deck girders or transverses;

(ii) where the deck girders or transverses, at any location, are less than 10 per cent of the tank depth, and the fill level is greater than the tank depth minus the height of the deck girders or transverses;

(iii) where the fill level is less than the height of any bottom girders or transverses.

(b) For smooth tanks: where the fill level is less than 10 per cent or more than 97 per cent of the tank depth.

5.4.3 Significant dynamic magnification of the fluid motions, and hence the sloshing pressure, can occur if either of the following conditions exist:

(a) The natural rolling period, T_{nr}, of the fluid and the ship's natural rolling period, S_{nr}, are within five seconds of each other.

(b) The natural pitching period, T_{np}, of the fluid is greater than a value of three seconds below the ship natural pitching period, S_{np}.

These values define the limits of the critical fill range for each tank.

5.4.4 The critical fill range, F_{crit}, is to be determined using the following formula:

$$F_{crit} = \left(\frac{100}{H_t}\right)\left[\left(\frac{L_s}{2\pi}\right) \ln \left(\frac{(1+\eta)}{(1-\eta)}\right) + b\sqrt{\frac{n}{n+1}}\right]\%$$

where

$\ln$ = natural logarithm to base e

$\eta = \dfrac{4\pi L_s}{[(S_{nr} - 5)^2 g]}$ for fill level at S_{nr} – 5 seconds

upper bound roll critical fill level

or $\eta = \dfrac{4\pi L_s}{[(S_{nr} + 5)^2 g]}$ for fill level at S_{nr} + 5 seconds

lower bound roll critical fill level

or $\eta = \dfrac{4\pi L_s}{[(S_{np} - 3)^2 g]}$ for fill level at S_{np} – 3 seconds

upper bound pitch critical fill level

or $\eta = \dfrac{4\pi L_s}{[(S_{np})^2 g]}$ for fill level at S_{np} seconds

The lower bound pitch critical fill level is 0,1 per cent fill.

The value of F_{crit} is limited to the range 0 to 100 per cent, *see also* 5.4.6.

5.4.5 The natural periods of the ship for a given motion type are to be determined for the service loading conditions agreed between the Shipbuilder and Lloyd's Register (hereinafter referred to as 'LR'). From this aspect, the storm-ballast and the segregated ballast conditions and the condition with all tanks partially filled could be the most critical.

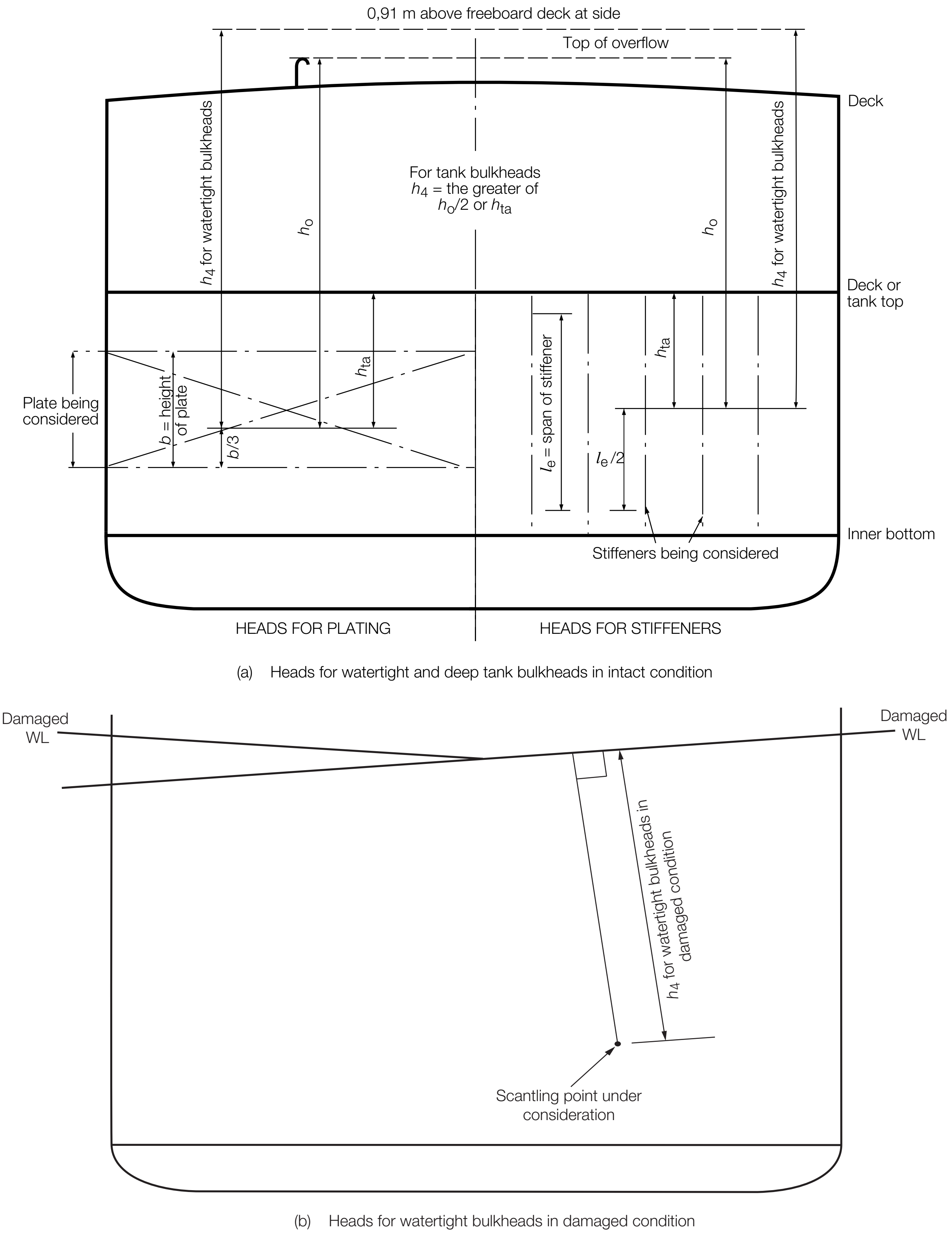


Fig. 3.5.2 Heads for watertight and deep tank bulkheads

5.4.6 When a ship is to be approved for Unrestricted Filling Levels – Unspecified Loading Conditions, many arbitrary ship loading conditions are possible. In order to cover the complete range of loading conditions, the fully loaded and ballast conditions are to be considered. These two conditions give an upper and lower limit for the possible range of natural periods of the ship as shown in Fig. 3.5.3. Both the roll and pitch motion modes are to be examined.

Because of the unrestricted filling level requirement, the critical sloshing ranges extend from [$S_{nrBallast}$ – 5] to [$S_{nrLoaded}$ + 5] seconds in roll and from [$S_{npBallast}$ – 3] to [$S_{npLoaded}$] in pitch. Also, because of unrestricted filling levels, the ship natural period range extends from [$S_{nBallast}$] to [$S_{nLoaded}$] for both pitch and roll.

For sloshing in the roll motion mode shown in Fig. 3.5.3(a), the critical fill range extends from F_1 to F_4. All fill levels between F_1 and F_4 are to be investigated:

- For fill levels between F_1 and F_2, $S_{nrBallast}$ is to be used.
- For fill levels between F_3 and F_4, $S_{nrLoaded}$ is to be used.
- For fill levels between F_2 and F_3, S_{nr} is to be equal to T_{nr}.

Similarly, for sloshing in the pitch motion mode shown in Fig. 3.5.3(b), the critical fill range extends from F_1 to F_4. All fill levels between F_1 and F_4 are to be investigated:

- For fill levels between F_1 and F_2, $S_{npBallast}$ is to be used.
- For fill levels between F_2 and F_3, S_{np} is to be equal to T_{np}.
- For fill levels between F_3 and F_4, $S_{npLoaded}$ is to be used.

5.4.7 When a ship is to be approved for Restricted Filling Levels – Unspecified Loading Conditions, many arbitrary ship loading conditions are possible within the restrictions imposed. In order to cover the complete range of loading conditions, the fully loaded and ballast conditions are to be considered. These two conditions give an upper and lower limit for the possible range of ship natural period. It is recognized that there might be ship natural period bands which will not be applicable as a result of the limitations on the fill levels. However, it is recommended that the Unrestricted Filling Levels – Unspecified Loading Conditions procedure outlined in 5.4.6 be applied.

5.4.8 When a ship is to be approved for Unrestricted Filling Levels – Specified Loading Conditions, each specified loading condition is to be examined for the complete fill ranges to determine the critical sloshing fill range for each tank in both roll and pitch motion modes.

5.4.9 When a ship is to be approved for Restricted Filling Levels – Specified Loading Conditions, each specified loading condition is to be examined for the restricted fill ranges to determine the critical sloshing fill range for each tank in both roll and pitch motion modes.

5.4.10 Where the assessment indicates that all the intended fill levels are outside the critical fill ranges and, therefore, significant sloshing will not occur, no further evaluation is required with regard to sloshing pressure. In such cases, the scantlings of the tank boundaries are to be determined in accordance with the relevant Rule requirements.

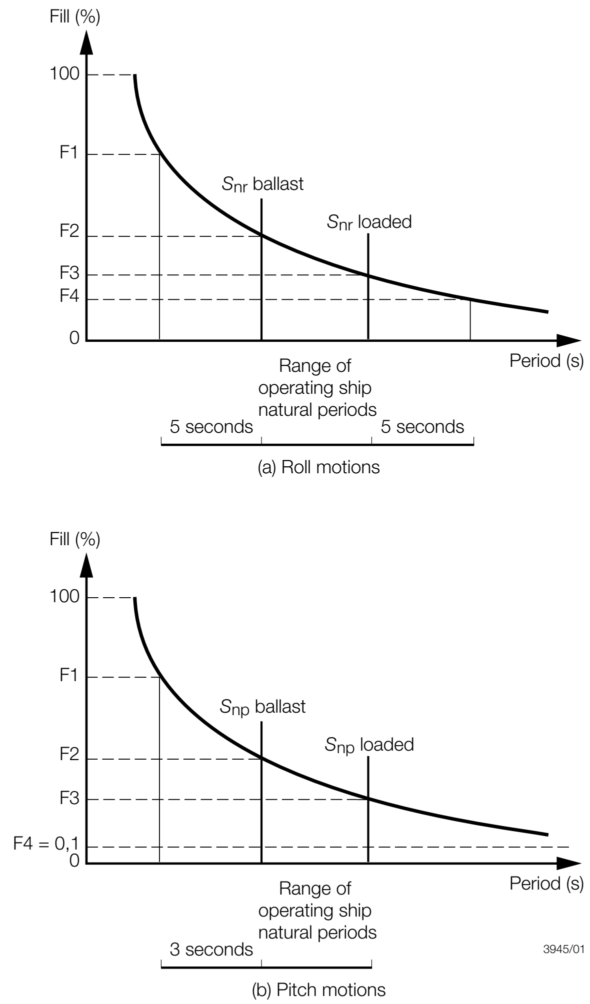


Fig. 3.5.3 Natural periods diagrams

5.4.11 Where the separation of periods defined in 5.4.3 is not met, other levels of assessment will be required as given in the *SDA Procedure for Sloshing loads and scantling assessment,* on tanks partially filled with liquids.

5.4.12 The structural capability of the tank boundaries to withstand the dynamic sloshing pressures is to be examined. The magnitude of the predicted loads, together with the scantling calculations may be required to be submitted.

■ *Section 6*
Minimum bow heights, reserve buoyancy and extent of forecastle

6.1 Minimum bow heights

6.1.1 Ships are to comply with the Load Lines conventions, so far as these are applicable.

6.1.2 Bulk carriers, ore carriers and combination carriers are also to comply with the requirements of Pt 4, Ch 7,14.

6.2 Extent of forecastle

6.2.1 Forecastles are to extend from the stem to a point at least $0{,}07L_L$ abaft the forward end of L_L (as defined in Ch 1,6.1). If the minimum bow height is obtained by increasing the sheer of the upper deck, the sheer is to extend for at least $0{,}15L_L$ abaft the forward end of L_L.

6.2.2 Bulk carriers, ore carriers and combination carriers are also to comply with the requirements of Pt 4, Ch 7,14.

6.2.3 Forecastles are to be enclosed; that is with enclosing bulkheads of efficient construction and access openings complying with Pt 3, Ch 11 and all other openings in sides or ends fitted with efficient weathertight means of closing.

Section

■ *Section 1* Definitions

1.1 List of symbols

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

L, B, D, C_b and V are as defined in Ch 1,6.1

k_L, k = higher tensile steel factor, *see* Ch 2,1.2.

■ *Section 2* General

2.1 Longitudinal strength calculations

2.1.1 Longitudinal strength calculations are to be carried out for all ships where L is greater than 65 m, covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. The calculations of still water shear forces and bending moments are to cover both departure and arrival conditions and any special mid-voyage conditions caused by changes in ballast distribution.

2.1.2 For ships where L is equal to or less than 65 m, longitudinal strength calculations may be required, dependent upon proposed loading.

2.1.3 Specific information regarding required loading conditions is given in the individual ship type Chapters.

2.2 Erections contributing to hull strength

2.2.1 In general, where a long superstructure or deckhouse of length greater than 0,15L is fitted, extending within the 0,5L amidships, the requirements for longitudinal strength in the hull and erection will be considered in each case.

2.3 Open type ships

2.3.1 For ships other than container ships which have large deck openings and where the structural configuration is such that warping stresses in excess of 14,7 N/mm^2 are likely to occur, local increases in section modulus, based normally on the combined stress diagram undertaken for container ships, may be required. For calculations for container ships, *see* Pt 4, Ch 8,3.

2.4 Ships with large flare

2.4.1 In ships of length between 120 and 170 m and maximum service speed greater than 17,5 knots, in association with a bow shape factor of more than 0,15, the Rule hull midship section modulus and the distribution of longitudinal material in the forward half-length will be specially considered, *see* Pt 4, Ch 1,3.

2.5 Direct calculation procedures

2.5.1 In direct calculation procedures capable of deriving the wave induced loads on the ship, and hence the required modulus, account is to be taken of the ship's actual form and weight distribution.

2.5.2 Lloyd's Register's (hereinafter referred to as 'LR') direct calculation method involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval should normally contain these three elements and produce similar and consistent results when compared with LR's methods.

2.6 Approved calculation systems

2.6.1 Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from LR, calculations using the system for a particular ship may be submitted.

■ *Section 3* Application

3.1 Symbols

3.1.1 The symbols used in this Section are defined as follows:

b = breadth, in metres, of the hatch opening. Where there are multiple openings abreast, these are regarded as a single opening, and b is to be the sum of the individual breadths of these openings

l_H = length of the hatch opening, in metres

l_{BH} = distance, in metres, between centres of the deck strip at each end of the hatch opening. Where there is no further opening beyond the one under consideration, the point to which l_{BH} is measured will be considered, *see also* Fig. 4.3.1

B_1 = extreme breadth of deck including hatch opening, measured at the mid-length of the opening, in metres.

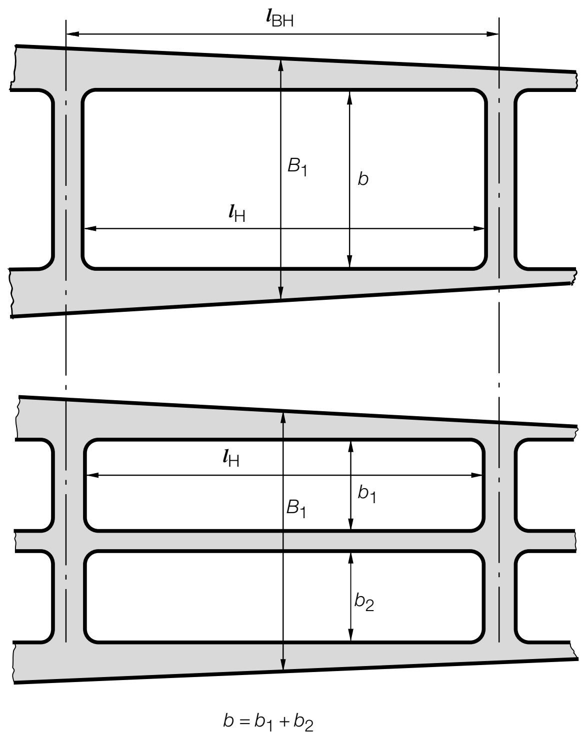


Fig. 4.3.1 Deck opening size

3.2 General

3.2.1 The requirements of this Chapter apply to sea-going steel ships, of normal form, proportions and speed, unless direct calculation procedures are adopted, in which case the assumptions made and the calculations performed are to be submitted for approval.

3.2.2 The requirements in this Chapter are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation. *See* Pt 1, Ch 2,2.3.

3.3 Exceptions

3.3.1 Individual consideration based on direct calculation procedures will generally be required for ships having one or more of the following characteristics:

- Length L greater than 400 m.
- Speed V greater than that defined in Table 4.3.1 for the associated block coefficient.
- Unusual type or design.
- Unusual hull weight distribution.
- $\frac{L}{B} \leq 5$, or $\frac{B}{D} \geq 2,5$
- Large deck openings, or where warping stresses in excess of 14,7 N/mm^2 (1,5 kgf/mm^2) are likely to occur.
- Openings for side loading in way of both sheerstrake and stringer.
- $C_b < 0,6$
- Carriage of heated cargo, *see* Pt 4, Ch 9,12.

Table 4.3.1 Ship speed criteria

Ship length L, m	C_b	Speed, knots
≤ 200	> 0,80 = 0,70 < 0,60	17 19,5 22
> 200	> 0,80 = 0,70 < 0,60	18 21,5 25
NOTE Intermediate values of speed to be obtained by linear interpolation for C_b.		

3.3.2 A ship is regarded as having large deck openings if both the following conditions apply to any one opening:

$$\frac{b}{B_1} > 0,6$$

$$\frac{l_H}{l_{BH}} > 0,7$$

See also Fig. 4.3.1.

■ *Section 4*
Information required

4.1 List of requirements

4.1.1 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in LR's standard format where appropriate.

(a) General arrangement and capacity plan or list, showing details of the volume and position of centre of gravity of all tanks and compartments.

(b) Bonjean data, in the form of tables or curves, for at least 21 equally spaced stations along the hull. A lines plan and/or tables of offsets may also be required.

(c) Details of the calculated lightweight and its distribution.

(d) Loading Manual.

(e) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions for individual ship types specified in Part 4. It is recommended that this information be submitted in the form of a preliminary Loading Manual, and that it includes the calculated still water bending moments and shear forces.

4.1.2 For final Loading Manual, *see* Section 8.

Section 5

Hull bending strength

5.1 Symbols

5.1.1 The symbols used in this Section are defined as follows:

f_1 = ship service factor
f_2 = wave bending moment factor
F_B = local scantling reduction factor for hull members below the neutral axis, *see* 5.6
F_D = local scantling reduction factor for hull members above the neutral axis, *see* 5.6
I_{min} = minimum moment of inertia, of the hull midship section about the transverse neutral axis, in m^4
M_s = design still water bending moment, sagging (negative) and hogging (positive), in kN m (tonne-f m), to be taken negative or positive according to the convention given in 5.3.2
$\overline{M}_s$ = maximum permissible still water bending moment, sagging (negative) and hogging (positive), in kN m (tonne-f m), *see* 5.4
M_w = design hull vertical wave bending moment amidships, sagging (negative) and hogging (positive), in kN m (tonne-f m), to be taken negative or positive according to the convention given in 5.3.2
Z_c = actual hull section modulus, in m^3, at continuous strength member above strength deck, calculated with the lever specified in Ch 3,3.4
Z_D, Z_B = actual hull section moduli, in m^3, at strength deck and keel respectively, *see* Ch 3,3.4
Z_{min} = minimum hull midship section modulus about the transverse neutral axis, in m^3
σ = permissible combined stress (still water plus wave), in N/mm^2 (kgf/mm^2), *see* 5.5
σ_D, σ_B = maximum hull vertical bending stress at strength deck and keel respectively, in N/mm^2 (kgf/mm^2)
z = vertical distance from the hull transverse neutral axis to the position considered, in metres
z_M = vertical distance, in metres, from the hull transverse neutral axis to the minimum limit of higher tensile steel, as defined in Ch 3,2.6, above or below the neutral axis as appropriate.

5.2 Design vertical wave bending moments

5.2.1 The appropriate hogging or sagging design hull vertical wave bending moment at amidships is given by the following:

$M_w = f_1 f_2 M_{wo}$

where

C_b is to be taken not less than 0,60
C_1 is given in Table 4.5.1
C_2 = 1, (also defined in 5.2.2 at other positions along the length L)
f_1 = ship service factor. To be specially considered depending upon the service restriction and in any event should be not less than 0,5. For unrestricted sea-going service f_1 = 1,0
f_2 = –1,1 for sagging (negative) moment
$f_2 = \dfrac{1,9C_b}{(C_b + 0,7)}$ for hogging (positive) moment
$M_{wo} = 0,1 C_1 C_2 L^2 B (C_b + 0,7)$ kN m
$(0,0102 C_1 C_2 L^2 B (C_b + 0,7)$ tonne-f m)

Consideration will be given to direct calculations of long-term vertical wave bending moments, *see* 2.6.

Table 4.5.1 Wave bending moment factor

Length L, in metres	Factor C_1
<90	$0,0412L + 4,0$
90 to 300	$10,75 - \left(\dfrac{300 - L}{100}\right)^{1,5}$
>300 ≤350	10,75
>350 ≤500	$10,75 - \left(\dfrac{L - 350}{150}\right)^{1,5}$

5.2.2 The longitudinal distribution factor, C_2, of wave bending moment is to be taken as follows:

- 0 at the aft end of L
- 1,0 between 0,4L and 0,65L from aft
- 0 at the forward end of L

Intermediate values are to be determined by linear interpolation.

5.2.3 For operation in sheltered water or short voyages, a higher permissible still water bending moment can be assigned based on a reduced vertical wave bending moment given by:

(a) For operating in sheltered water:
$M_w = 0,5 f_2 M_{wo}$

(b) For short voyages:
$M_w = 0,8 f_2 M_{wo}$

These expressions can only be used in the expression for permissible still water bending moment, *see* 5.4, and the relevant loading conditions are to be included in the Loading Manual, *see* 8.1.

5.2.4 'Short voyages' are defined as voyages of limited duration in reasonable weather. 'Reasonable weather' and 'sheltered water' are defined in Pt 1, Ch 2,2.

5.3 Design still water bending moments

5.3.1 The design still water bending moment, M_s, hogging and sagging is the maximum moment calculated from the loading conditions, given in 5.3.3, and is to satisfy the following relationship:

$|M_s| \leq |\overline{M}_s|$

5.3.2 Still water bending moments are to be calculated along the ship length. For these calculations, downward loads are to be taken as positive values and are to be integrated in the forward direction from the aft end of *L*. Hogging bending moments are positive.

5.3.3 In general, the following loading conditions, based on amount of bunkers, fresh water and stores at departure and arrival, are to be considered.

(a) General cargo ships, container ships, passenger ships, roll on-roll off ships and refrigerated cargo carriers:
  - (i) Homogeneous loading conditions, at maximum draught.
  - (ii) Ballast conditions.
  - (iii) Special loading conditions, e.g. container or light load conditions at less than the maximum draught, heavy cargo, empty holds or non-homogeneous cargo conditions, deck cargo conditions, etc., where applicable.

(b) Bulk carriers (*see* 3.2.2), ore carriers and combination carriers
  - (i) For ships of length, *L*, less than 150 m:
    Alternate hold loading conditions at maximum draught, where applicable.
    Homogeneous loading conditions at maximum draught.
    Ballast conditions, including intermediate conditions associated with ballast exchange at sea.
    Special conditions, e.g. deck cargo conditions.
    For combination carriers, the conditions as specified in (c) for oil tankers are also to be considered.
  - (ii) For ships of length, *L*, 150 m or above:
    Alternate light and heavy cargo loading conditions at maximum draught, where applicable.
    Homogeneous light and heavy cargo loading conditions at maximum draught.
    Ballast conditions. Where vessels are designed with a ballast hold adjacent to topside wing, hopper and double bottom tanks, the structure design is to be such that the ballast hold can be filled with all adjacent tanks empty.
    Short voyage conditions where the ship is loaded to maximum draught with reduced bunkers, where applicable.
    Multiple port loading/unloading conditions, where applicable.
    Deck cargo conditions, where applicable.
    Typical loading and discharging sequences from commencement to end of cargo operation, for homogeneous, alternate and part load conditions, where applicable.
    Typical sequences for exchange of ballast at sea, where applicable.
    For combination carriers, the conditions as specified in (c) for oil tankers are also to be considered.
    For bulk carriers, the conditions as specified in 5.4 for the relevant notation are also to be considered.

(c) Oil tankers (*see* 3.2.2):
  - (i) Homogeneous loading conditions (excluding dry and clean ballast tanks) and ballast or part loaded conditions.
  - (ii) Any specified non-uniform distribution of loading.
  - (iii) Mid-voyage conditions relating to tank cleaning or other operations where these differ significantly from the ballast conditions.

(d) Chemical tankers:
  - (i) Conditions as specified for oil tankers.
  - (ii) Conditions for high density or segregated cargo.

(e) Liquefied gas carriers:
  - (i) Homogeneous loading conditions for all approved cargoes.
  - (ii) Ballast conditions.
  - (iii) Cargo conditions where one or more tanks are empty or partially filled or where more than one type of cargo having significantly different densities is carried.

(f) All ships:
  - (i) Any other loading condition likely to result in high bending moments and/or shear forces (including docking conditions, as appropriate).

5.3.4 Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted in addition to those for departure and arrival conditions. Also, where any ballasting and/or de-ballasting is intended during voyage, calculations of the intermediate condition just before and just after ballasting and/or de-ballasting any tank are to be submitted and, where approved, included in the loading manual for guidance.

5.3.5 Ballast loading conditions involving partially filled peak and/or other ballast tanks at departure, arrival or during intermediate conditions are not permitted as design conditions unless the design stress limits are satisfied for all filling levels between empty and full, and for bulk carriers the requirements of Pt 4, Ch 7,3, as applicable, are to be complied with for all filling levels between empty and full. To demonstrate compliance with all filling levels between empty and full, it will be acceptable if, in each condition at departure, arrival and where required by 5.3.3, any intermediate condition, the tanks intended to be partially filled are assumed to be:

- empty
- full
- partially filled at intended level.

Where multiple tanks are intended to be partially filled, all combinations of empty, full or partially filled at intended level for those tanks are to be investigated. However, for conventional ore carriers with large wing water ballast tanks in cargo area, where empty or full ballast water filling levels of one or maximum two pairs of these tanks lead to the ship's trim exceeding one of the following conditions, it is sufficient to demonstrate compliance with maximum, minimum and intended partial filling levels of these one or maximum two pairs of ballast tanks such that the ship's condition does not exceed any of these trim limits. Filling levels of all other wing ballast tanks are to be considered between empty and full.

The trim conditions mentioned above are:

- trim by stern of 3% of the ship's length, or
- trim by bow of 1,5% of ship's length, or
- any trim that cannot maintain propeller immersion (I/D) not less than 25%, where;
  - I = the distance from propeller centreline to the waterline, *see* Fig. 4.5.1
  - D = propeller diameter, *see* Fig. 4.5.1

The maximum and minimum filling levels of the above mentioned pairs of side ballast tanks are to be indicated in the loading manual.

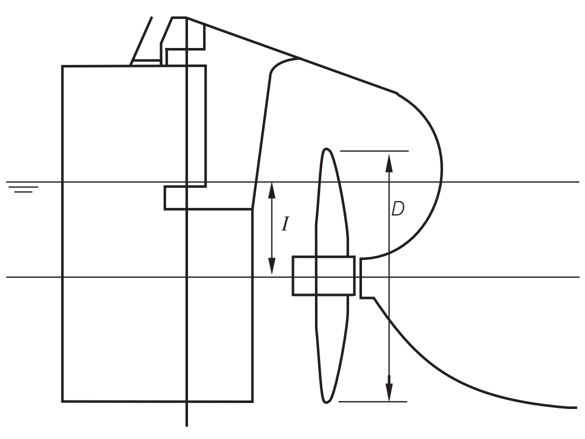


Fig 4.5.1 Propeller immersion

5.3.6 When considering cargo loading conditions, the requirements of 5.3.5 apply to peak tanks only.

5.3.7 When considering ballast water exchange using the sequential method, the requirements of 5.3.5 and 5.3.6 do not apply.

5.4 Minimum hull section modulus

5.4.1 The hull midship section modulus about the transverse neutral axis, at the deck or the keel, is to be not less than:

$Z_{min} = f_1 k_L C_1 L^2 B (C_b + 0,7) \times 10^{-6}$ m^3

and

f_1 is to be taken not less than 0,5.

5.4.2 For materials to be included in the calculation of actual hull section properties, *see* Ch 3,3.

5.4.3 The midship section modulus for ships with a service restriction notation is to be not less than half the minimum value required for unrestricted service.

5.4.4 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section modulus requirements given in 5.4.1 are to be maintained within 0,4*L* amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the 0,4*L* part, bearing in mind the desire not to inhibit the vessel's loading flexibility.

5.5 Permissible still water bending moments

5.5.1 The permissible still water bending moments sagging and hogging are to be taken as the lesser of the following:

(a) $|\overline{M}_s| = F_D \sigma Z_D \times 10^3 - |M_w|$ kN m (tonne-f m)

(b) $|\overline{M}_s| = F_B \sigma Z_B \times 10^3 - |M_w|$ kN m (tonne-f m)

where

σ = the permissible combined stress in N/mm^2 (kgf/mm^2) is given in 5.6 and F_D and F_B are defined in 5.7.2. M_w is the design wave bending moment, sagging or hogging as appropriate, in accordance with 5.2.

5.6 Permissible hull vertical bending stresses

5.6.1 The permissible combined (still water plus wave) stress for hull vertical bending, σ, is given by:

(a) Within 0,4*L* amidships

$$\sigma = \frac{175}{k_L} \text{ N/mm}^2 \left(\frac{17,84}{k_L} \text{ kgf/mm}^2\right)$$

(b) for continuous longitudinal structural members outside 0,4*L* amidships

$$\sigma = \left(75 + 543\frac{d}{L} - 699\left(\frac{d}{L}\right)^2\right)\frac{1}{k_L} \text{ N/mm}^2$$

$$\left(\sigma = \left(75 + 543\frac{d}{L} - 699\left(\frac{d}{L}\right)^2\right)\frac{0,102}{k_L} \text{ kgf/mm}^2\right)$$

where d is the distance, in metres, from the F.P. (for the fore end region) or from the A.P. (for the aft end region), as appropriate, to the location under consideration.

Special consideration will be given to increasing the permissible stress outside 0,4*L* amidships to

$$\frac{175}{k_L} \text{ N/mm}^2 \left(\frac{17,84}{k_L} \text{ kgf/mm}^2\right)$$

provided that sufficient buckling checks are carried out.

5.6.2 The requirements for ships of special or unusual design and for the carriage of special cargoes will be individually considered.

5.7 Local reduction factors

5.7.1 The maximum hull vertical bending stresses at deck, σ_D, and keel, σ_B, are given by the following, using the appropriate combination of bending moments to give sagging and hogging stresses:

$$\sigma_D = \frac{|\overline{M}_s + M_w|}{Z_D} \times 10^{-3} \text{ N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

$$\sigma_B = \frac{|\overline{M}_s + M_w|}{Z_B} \times 10^{-3} \text{ N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

Where the ship is always in the hogging condition, the sagging bending moment is to be specially considered.

5.7.2 Where the maximum hull vertical bending stress at deck or keel is less than the permissible combined stress, σ, reductions in local scantlings within 0,4*L* amidships may be permitted. The reduction factors applicable in Part 4 are defined as follows:

For hull members above the neutral axis

$$F_D = \frac{\sigma_D}{\sigma}$$

For hull members below the neutral axis

$$F_B = \frac{\sigma_B}{\sigma}$$

In general, the values of σ_D and σ_B to be used are the greater of the sagging or hogging stresses, and F_D and F_B are not to be taken less than 0,67 for plating and 0,75 for longitudinal stiffeners.

5.7.3 Where higher tensile steel is used in the hull structure, the values of F_D and F_B for the mild steel part are to be taken as not less than $\frac{z}{z_M}$.

5.8 Hull moment of inertia

5.8.1 The hull midship section moment of inertia about the transverse neutral axis is to be not less than the following using the maximum total bending moment, sagging or hogging:

$$I_{min} = \frac{3L\left(|\overline{M}_s + M_w|\right)}{k_L\,\sigma} \times 10^{-5} \text{ m}^4$$

where values of σ are given in 5.6.1.

5.9 Continuous strength members above strength deck

5.9.1 Where trunk decks or continuous hatch coamings are effectively supported or deck longitudinals or girders are fitted above the strength deck, the modulus Z_c is to be not less than Z_{min}. The scantling reduction factor, F_D, referred to strength deck at side, is applicable and, in addition to the requirement given in 5.5.1, the permissible still water bending moments, sagging and hogging, are not to exceed:

$$|\overline{M}_s| = \sigma Z_c \times 10^3 - |M_w| \text{ kN m (tonne-f m)}$$

where

M_w is the design wave bending moment sagging or hogging, as appropriate, in accordance with 5.2.

■ *Section 6*
Hull shear strength

6.1 Symbols

6.1.1 The symbols used in this Section are defined as follows:

I = the inertia of the hull about the horizontal neutral axis at the section concerned, in cm^4

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_s = design hull still water shear force, in kN (tonne-f), to be taken as negative or positive according to the convention given in 6.4.2

$\overline{Q}_s$ = permissible hull still water shear force, in kN (tonne-f), *see* 6.5

Q_w = design hull wave shear force, in kN (tonne-f), to be taken as negative or positive according to the convention given in 6.4.2

τ = permissible combined shear stress (still water plus wave), in N/mm^2 (kgf/mm^2), *see* 6.6

τ_A = design shear stress, in N/mm^2 (kgf/mm^2), as given in 6.7.1 for use in 7.4.

6.2 General

6.2.1 For ships with length *L* greater than 65 m, the shear forces on the hull structure are to be investigated.

6.2.2 For *L* greater than 200 m, where double skin construction of the side shell in association with topside and hopper tanks is proposed, shear flow calculations may be required to be submitted.

6.2.3 Where shear flow calculation procedures other than those available within ShipRight are employed, the requirements of Ch 1,3 are to be complied with.

6.2.4 For passenger ships, the assessment of permissible still water shear forces is to take into consideration the effectiveness of the continuous superstructures and the sizes and arrangements of window and door openings.

6.2.5 Where longitudinal bulkheads are perforated by cut-outs, the assessment of permissible still water shear forces is to take into consideration the loss of material.

6.3 Design wave shear force

6.3.1 The design hull wave shear force, Q_w, at any position along the ship is given by:

$$Q_w = K_1 K_2 Q_{wo} \text{ kN (tonne-f)}$$

where

Q_{wo} = $0,3C_1\,LB\,(C_b + 0,7)$ kN
($0,0306C_1\,LB\,(C_b + 0,7)$ tonne-f)

and C_b is to be taken not less than 0,6

K_1 is to be taken as follows, *see also* Fig. 4.6.1:

(a) Positive shear force

K_1 = 0 at aft end of L

= $\frac{1,589C_b}{(C_b + 0,7)}$ between 0,2L and 0,3L from aft

= 0,7 between 0,4L and 0,6L from aft

= 1,0 between 0,7L and 0,85L from aft

= 0 at forward end of L

(b) Negative shear force

K_1 = 0 at aft end of L

= –0,92 between 0,2L and 0,3L from aft

= –0,7 between 0,4L and 0,6L from aft

= $\frac{-1,727C_b}{(C_b + 0,7)}$ between 0,7L and 0,85L from aft

= 0 at forward end of L

Intermediate values to be determined by linear interpolation

K_2 = 1,0 for unrestricted sea-going service conditions

= 0,8 for short voyages

= 0,5 for operating in sheltered water.

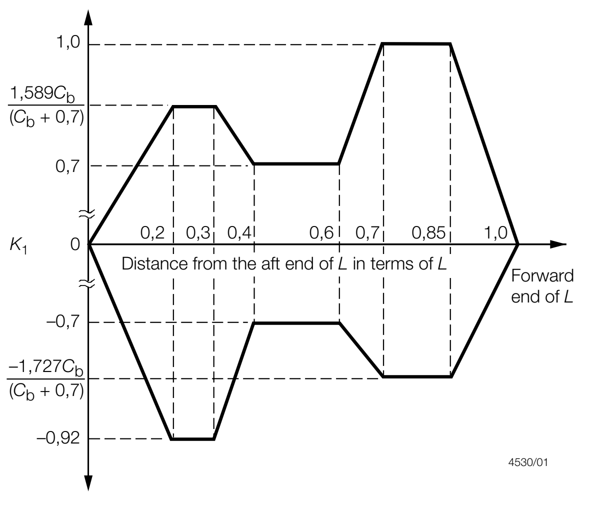


Fig. 4.6.1 Shear force factor K_1

6.4 Design still water shear force

6.4.1 The design still water shear force, Q_s, at each transverse section along the hull is to be taken as the maximum positive and negative value found from the longitudinal strength calculations for each of the loading conditions given in 5.3.3 and is to satisfy the following relationship:

$$|Q_s| \leq |\overline{Q_s}|$$

6.4.2 Still water shear forces are to be calculated at each section along the ship length. For these calculations, downward loads are to be taken as positive values and are to be integrated in a forward direction from the aft end of L. The shear force is positive when the algebraic sum of all vertical forces aft of the section is positive.

6.4.3 For hull configuration Types A, D, G, H and I, as indicated in Table 4.6.1, where loading conditions are featuring either:

- cargo loading with specified or alternate cargo holds (or cargo tanks) empty; or
- ballasting of cargo hold(s);

the actual shear forces obtained from the longitudinal strength calculations may be corrected for the effect of local forces at the transverse bulkheads. The calculation of these local forces is to be submitted for approval or, alternatively, the proportion of the double bottom load carried by the transverse bulkhead may be arrived at by using the following bulkhead factor F:

$$F = \frac{1}{1 + 1,5\alpha^{1,65}}$$

where

l_F = span of floors measured to intersection of hopper side or ship's side, and inner bottom, in metres

S_H = length of hold measured between bulkhead stools, where fitted, at the level of the inner bottom on the centreline, in metres

$$\alpha = \frac{S_H}{l_F}$$

6.4.4 If the hull shear forces in kN (tonne-f) at transverse bulkheads A and B are calculated to be Q_A and Q_B respectively (with appropriate algebraic signs), the excess load or buoyancy over hold AB is given by $Q_B - Q_A$ and the load transmitted to each bulkhead is:

$0,5F\,(Q_B - Q_A)$ kN (tonne-f)

where F is the bulkhead factor as given in 6.4.3.

See Fig. 4.6.2.

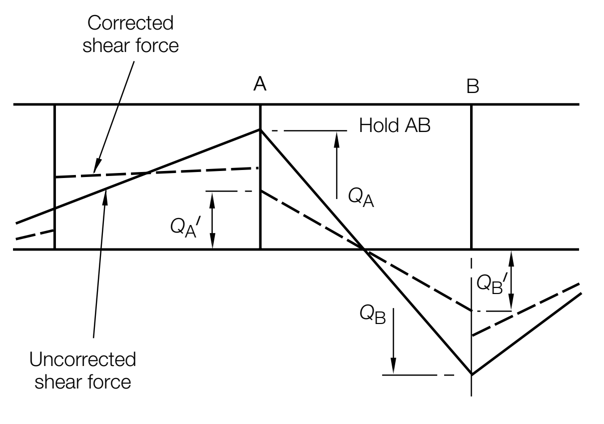


Fig. 4.6.2 Shear force correction

6.4.5 The corrected shear forces, Q_A' and Q_B', at bulkheads A and B with respect to hold AB are then obtained from:

$Q_A' = Q_A + 0{,}5F(Q_B - Q_A)$ kN (tonne-f)

$Q_B' = Q_B - 0{,}5F(Q_B - Q_A)$ kN (tonne-f)

6.5 Permissible still water shear force

6.5.1 The permissible hull still water shear force is given by the minimum value obtained from:

$$|Q_s| = \tau \frac{I\,\delta_i}{100Az} - |Q_w| \quad \text{kN (tonne-f)}$$

when

$$\delta_i = \frac{t_i}{f_i + m_i}$$

i = structural member index for the hull configuration under consideration, *see* Table 4.6.1

t_i = the plate thickness of the structural member at the vertical level and section under consideration, in mm

f_i, m_i = factors determined from Tables 4.6.1 and 4.6.2 respectively, for the hull configuration under consideration.

6.5.2 The permissible shear forces assigned for approved loading instruments will normally be based on 6.5.1. However, where use is made of an approved loading instrument incorporating a facility to calculate the transverse distribution of shear forces, separate permissible still water shear forces, Q_{si} may be assigned for the structural members indicated in Table 4.6.1 for the hull configuration under consideration.

$$|Q_{si}| = (f_i + m_i)\,|Q_s| \quad \text{kN (tonne-f)}$$

6.5.3 Individual loading conditions in the ship's loading manual may be specially considered on a similar basis to that in 6.5.2 with the factors being determined by direct calculation.

6.5.4 For hull configuration types B and E (*see* Table 4.6.1), where loading conditions are such that hull girder torsion may be induced, direct calculations may be required.

6.5.5 The calculation of shear forces immediately beyond the ends of the longitudinal bulkheads will be considered in relation to the arrangement of structure in these regions.

6.6 Permissible shear stress

6.6.1 The permissible combined shear stress (still water plus wave) is to be taken as:

$$\tau = \frac{110}{k_L} \text{ N/mm}^2 \quad \left(\frac{11{,}2}{k_L} \text{ kgf/mm}^2\right)$$

6.6.2 Where a plate is tapered, the permissible combined shear stress is not to be exceeded at any point in way of the taper, *see* Fig. 4.6.3.

6.7 Design shear stress

6.7.1 The design shear stress for use in 7.4 is to be taken as:

$$\tau_A = 100Az \frac{|Q_s| + |Q_w|}{I\,\delta_i} \text{ N/mm}^2$$

$$= \left(10{,}2Az \frac{|Q_s| + |Q_w|}{I\,\delta_i} \text{ kgf/mm}^2\right)$$

Table 4.6.1 **f_i factors** *(see continuation)*

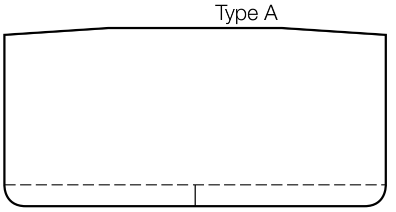
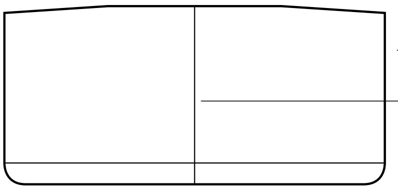
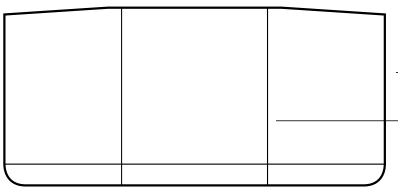
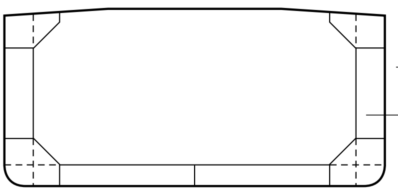
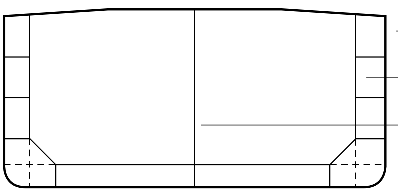
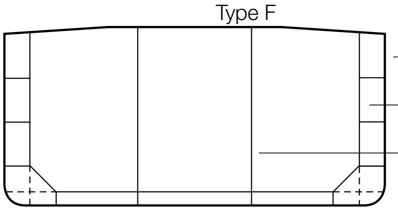
Hull configuration	f_i factors
Type A 	Member 1 $f_1 = 0{,}5$
Type B 	Member 1 $f_1 = 0{,}231 + 0{,}076\, A_1/A_2$ Member 2 $f_2 = 0{,}538 - 0{,}152\, A_1/A_2$
Type C 	Member 1 $f_1 = 0{,}135 + 0{,}088\, A_1/A_2$ Member 2 $f_2 = 0{,}365 - 0{,}088\, A_1/A_2$
Type D 	Member 1 $f_1 = 0{,}128 + 0{,}105\, A_1/A_2$ Member 2 $f_2 = 0{,}372 - 0{,}105\, A_1/A_2$
Type E 	Member 1 $f_1 = 0{,}055 + 0{,}097\, A_1/A_2 + 0{,}020\, A_2/A_3$ Member 2 $f_2 = 0{,}193 - 0{,}059\, A_1/A_2 + 0{,}058\, A_2/A_3$ Member 3 $f_3 = 0{,}504 - 0{,}076\, A_1/A_2 - 0{,}156\, A_2/A_3$
Type F 	Member 1 $f_1 = 0{,}028 + 0{,}087\, A_1/A_2 + 0{,}023\, A_2/A_3$ Member 2 $f_2 = 0{,}119 - 0{,}038\, A_1/A_2 + 0{,}072\, A_2/A_3$ Member 3 $f_3 = 0{,}353 - 0{,}049\, A_1/A_2 - 0{,}095\, A_2/A_3$

Table 4.6.1 **f_i factors** *(continued)*

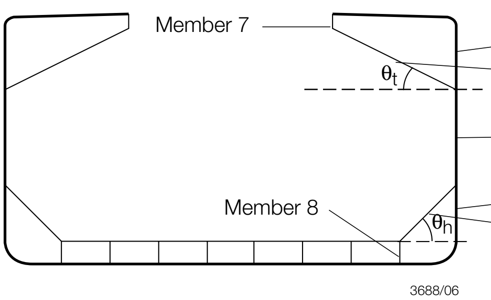
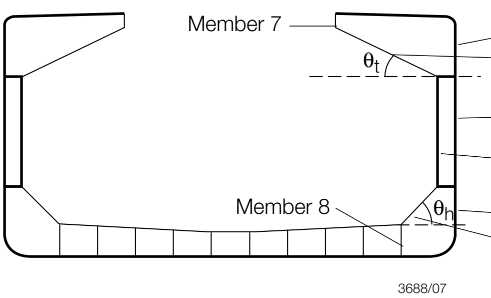
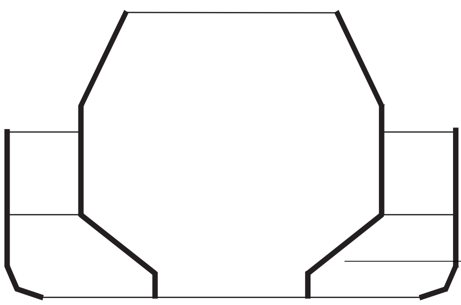
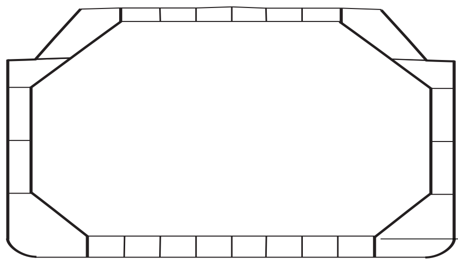
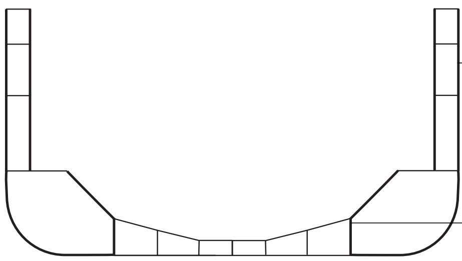
Hull configuration	f_i factors
Type G 	Member 1 $f_1 = 0,139 + 0,099\ A_1/A_2$ Member 2 $f_2 = 0,361 - 0,099\ A_1/A_2$
Type H 	Member 1 $f_1 = 0,216 + 0,087\ A_1/(A_7 + A_2 \sin \theta_t)$ Member 2 $f_2 = 0,284 - 0,087\ A_1/(A_7 + A_2 \sin \theta_t)$ Member 3 $f_3 = 0,5$ Member 5 $f_5 = 0,155 + 0,087\ A_5/(A_8 + A_6 \sin \theta_h)$ Member 6 $f_6 = 0,345 - 0,087\ A_5/(A_8 + A_6 \sin \theta_h)$ $f_7 = f_2, \quad f_8 = f_6$
Type I 	Member 1 $f_1 = 0,216 + 0,087\ A_1/(A_7 + A_2 \sin \theta_t)$ Member 2 $f_2 = 0,284 - 0,087\ A_1/(A_7 + A_2 \sin \theta_t)$ Member 3 $f_3 = 0,143 + 0,104\ A_3/A_4$ Member 4 $f_4 = 0,357 - 0,104\ A_3/A_4$ Member 5 $f_5 = 0,155 + 0,087\ A_5/(A_8 + A_6 \sin \theta_h)$ Member 6 $f_6 = 0,345 - 0,087\ A_5/(A_8 + A_6 \sin \theta_h)$ $f_7 = f_2, \quad f_8 = f_6$
Type J 	Member 1 $f_1 = 0,153 + 0,105\ A_1/A_2$ Member 2 $f_2 = 0,347 - 0,105\ A_1/A_2$

Table 4.6.1 f_i **factors** *(conclusion)*

Hull configuration	f_i factors
Type K 	Member 1 $f_1 = 0{,}128 + 0{,}105\ A_1/A_2$ Member 2 $f_2 = 0{,}372 - 0{,}105\ A_1/A_2$
Type L 	Member 1 $f_1 = 0{,}093 + 0{,}162\ A_1/A_2$ Member 2 $f_2 = 0{,}407 - 0{,}162\ A_1/A_2$

Symbols

i = structural member index for different hull configurations
for types A, B, C, D, E, F and G, *i* may take the value of 1, 2 or 3.
for *i* = 1, the side shell at the section is under consideration
for *i* = 2 and 3, the longitudinal bulkheads at the section are under consideration
for types H and I, *i* may take the value of 1, 2, 3, 4, 5, 6, 7 or 8
for *i* = 1, the part of side shell in way of topside tank is under consideration
for *i* = 2, the topside slope is under consideration
for *i* = 3, the part of side shell between topside tank and hopper tank is under consideration
for *i* = 4, the inner hull is under consideration
for *i* = 5, the part of side shell in way of hopper tank is under consideration
for *i* = 6, the hopper slope is under consideration
for *i* = 7, the vertical strake at topside tank is under consideration
for *i* = 8, the double bottom girder at hopper tank is under consideration
for types J, K and L, *i* may take the value of 1 or 2:
for *i* = 1, the side shell at the section is under consideration
for *i* = 2, the longitudinal bulkheads at the section are under consideration

A_i = the area of structural member *i* at the section under consideration, in cm^2
In the event of part of the structural member being non-vertical, A_i is to be calculated using the projected area in the vertical direction, *see* Fig. 4.6.4, except for members 2 and 6 for types H and I, where the inclined area is to be applied.

NOTES
1. For hull configurations not included above, f_i factors are to be specially considered.
2. Where it is necessary to increase the thickness of the side shell or longitudinal bulkhead(s) to meet these requirements, the original thicknesses are to be used in the calculation of the cross-sectional areas A_i.

Table 4.6.2 m_i factors

Hull configuration, *see* Table 4.6.1	m_i factors
Type A	$m_1 = 0$
Type B	$m_1 = \frac{m_2}{2}$, $m_2 = (0{,}1 + r)\, 0{,}5$
Type C	$m_1 = m_2$, $m_2 = (0{,}1 + r) \frac{b_2}{B}$
Type D	$m_i = 0$
Type E	$m_1 = \frac{m_3}{4}$, $m_2 = \frac{m_3}{4}$, $m_3 = (0{,}1 + r)\, 0{,}5 \left(1 - \frac{b_2}{B}\right)$
Type F	$m_1 = \frac{m_3}{2}$, $m_2 = \frac{m_3}{2}$, $m_3 = (0{,}1 + r) \left(\frac{b_3 - 0{,}5 b_2}{B}\right)$
Type G	$m_i = 0$
Type H	$m_i = 0$
Type I	$m_i = 0$
Type J	$m_i = 0$
Type K	$m_i = 0$
Type L	$m_i = 0$

Symbols

i = structural member index for different hull configurations, *see* Table 4.6.1
b_i = the horizontal distance of the structural member *i* from the side shell, at the section under consideration, in metres
r = 0,15 within $0{,}20L_T$ from the transverse bulkhead position for loading conditions where the cargo region between two consecutive bulkheads is unevenly loaded in the transverse direction
= 0 within $0{,}20L_T$ from the transverse bulkhead position for loading conditions where the cargo region between two consecutive bulkheads is evenly loaded in the transverse direction
= 0 elsewhere
L_T = cargo hold length, in metres

NOTE
For hull configurations not included above, m_i factors are to be specially considered.

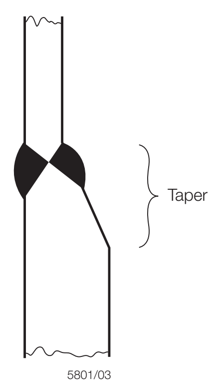


Fig. 4.6.3 Tapered plates

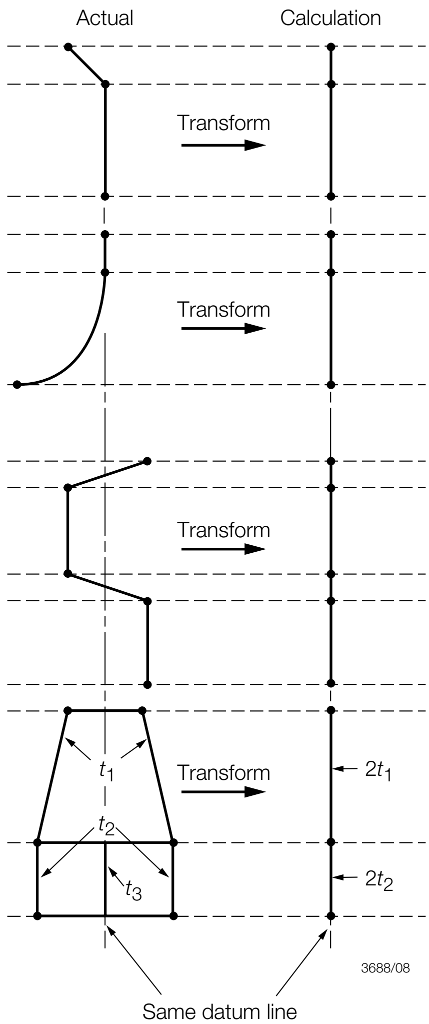


Fig. 4.6.4
Calculation of A_i for non-vertical parts of structural members

■ *Section 7*

Hull buckling strength

7.1 Application

7.1.1 These requirements apply to plate panels and longitudinals subjected to hull girder compression and shear stresses based on design values for still water and wave bending moments and shear forces.

7.1.2 The hull buckling strength requirements are applicable within 0,4*L* amidships to ships of 90 m or greater in length.

7.1.3 Hull buckling strength outside 0,4*L* amidships and hull buckling strength for ships less than 90 m in length will be specially considered.

7.2 Symbols

7.2.1 The symbols used in this Section are defined as follows:

d_t = standard deduction for corrosion, *see* Table 4.7.1
s = spacing of secondary stiffeners, in mm. In the case of symmetrical corrugations, s is to be taken as b or c in Fig. 3.3.1 in Chapter 3, whichever is the greater
t = as built thickness of plating, stiffener flange and web used in Table 4.7.1 in calculating standard deduction d_t, in mm
t_p = as built thickness of plating less standard deduction d_t, in mm, (i.e. $t_p = t - d_t$)
E = modulus of elasticity, in N/mm^2 (kgf/mm^2)
= 206000 N/mm^2 (21000 kgf/mm^2) for steel
S = spacing of primary members, in metres
σ_o = specified minimum yield stress, in N/mm^2 (kgf/mm^2)
σ_A = design longitudinal compressive stress in N/mm^2 (kgf/mm^2)
σ_{CRB} = critical buckling stress in compression, in N/mm^2 (kgf/mm^2) corrected for yielding effects
σ_E = elastic critical buckling stress in compression, in N/mm^2 (kgf/mm^2)
τ_A = design shear stress, in N/mm^2 (kgf/mm^2)
τ_{CRB} = critical buckling stress in shear, in N/mm^2 (kgf/mm^2) corrected for yielding effects
τ_E = elastic critical buckling stress in shear, in N/mm^2 (kgf/mm^2)

$$\tau_o = \frac{\sigma_o}{\sqrt{3}}$$

7.3 Elastic critical buckling stress

7.3.1 The elastic critical buckling stress of plating is to be determined from Table 4.7.2.

7.3.2 The elastic critical buckling stress of longitudinals is to be determined from Table 4.7.3.

Table 4.7.1 Standard deduction for corrosion, d_t

Structure		d_t mm	d_t range mm min. – max.
(a) Compartments carrying dry bulk cargoes		0,05*t*	0,5 – 1
(b) One side exposure to water ballast and/or liquid cargo.	Vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line.		
(c) One side exposure to water ballast and/or liquid cargo.	Horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line.	0,10*t*	2 – 3
(d) Two side exposure to water ballast and/or liquid cargo.	Vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line.		
(e) Two side exposure to water ballast and/or liquid cargo.	Horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line.	0,15*t*	2 – 4

NOTES
1. The standard deduction d_t is to be taken as appropriate and within the range given above.
2. For direct calculation purposes, standard deductions will be specially considered.

Table 4.7.2 Elastic critical buckling stress of plating

Mode	Elastic critical buckling stress, N/mm² (kgf/mm²)
(a) Compression of plating with longitudinal stiffeners (parallel to compressive stress), *see* Note	$\sigma_E = 3{,}6E\left(\frac{t_p}{s}\right)^2$
(b) Compression of plating with transverse stiffeners (perpendicular to compressive stress), *see* Note	$\sigma_E = 0{,}9c\left[1 + \left(\frac{s}{1000S}\right)^2\right]^2 E\left(\frac{t_p}{s}\right)^2$ where c = 1,3 when plating stiffened by floors or deep girders = 1,21 when stiffeners are built up profiles or rolled angles = 1,10 when stiffeners are bulb plates = 1,05 when stiffeners are flat bars
(c) Shear, *see* Note	$\tau_E = 3{,}6\left[1{,}335 + \left(\frac{s}{1000S}\right)^2\right] E\left(\frac{t_p}{s}\right)^2$

NOTE
Where the elastic critical buckling stress, as evaluated from (a), (b) or (c), exceeds 50 per cent of specified minimum yield stress of the material, the corrected critical buckling stresses in compression (σ_{CRB}) and shear (τ_{CRB}) are given by:

$$\sigma_{CRB} = \sigma_E \quad \text{when } \sigma_E \le \frac{\sigma_o}{2}$$

$$= \sigma_o\left(1 - \frac{\sigma_o}{4\sigma_E}\right) \quad \text{when } \sigma_E > \frac{\sigma_o}{2} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

$$\tau_{CRB} = \tau_E \quad \text{when } \tau_E \le \frac{\tau_o}{2}$$

$$= \tau_o\left(1 - \frac{\tau_o}{4\tau_E}\right) \quad \text{when } \tau_E > \frac{\tau_o}{2} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

Table 4.7.3 **Elastic critical buckling stress of longitudinals** (*see continuation*)

Mode	Elastic critical buckling stress, N/mm^2 (kgf/mm^2)
(a) Column buckling (perpendicular to plane of plating) without rotation of cross section, *see* Note 1	$\sigma_E = 0{,}001E \dfrac{I_a}{A_t S^2}$
(b) Torsional buckling, *see* Note 1	$\sigma_E = \dfrac{0{,}001\, E\, I_w}{I_p S^2}\left(m^2 + \dfrac{K}{m^2}\right) + 0{,}385E \dfrac{I_t}{I_p}$
(c) Web buckling, *see* Notes 1 and 3 (flat bars are excluded)	$\sigma_E = 3{,}8E \left(\dfrac{t_w}{d_w}\right)^2$

Symbols and Parameters

d_w = web depth, in mm

t_w = as built web thickness less standard deduction d_t as specified in Table 4.7.1, in mm, (i.e. $t_w = t - d_t$). For webs in which the thickness varies, a mean thickness is to be used

b_f = flange width, in mm

t_f = as built flange thickness less standard deduction d_t as specified in Table 4.7.1, in mm, (i.e. $t_f = t - d_t$). For bulb plates, the mean thickness of the bulb may be used, *see* Fig. 4.7.1

A_t = cross-sectional area, in cm^2, of longitudinal, including attached plating, taking account of standard deductions, *see* Note 4

I_a = moment of inertia, in cm^4, of longitudinal, including attached plating, taking account of standard deductions, *see* Note 4

I_t = St.Venant's moment of inertia, in cm^4, of longitudinal (without attached plating)

$= \dfrac{d_w\, t_w^3}{3}\, 10^{-4}$ for flat bars

$= \dfrac{1}{3}\left[d_w\, t_w^3 + b_f\, t_f^3 \left(1 - 0{,}63 \dfrac{t_f}{b_f}\right)\right] 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_p = polar moment of inertia, in cm^4, of profile about connection of stiffener to plating

$= \dfrac{d_w^3\, t_w}{3}\, 10^{-4}$ for flat bars

$= \left(\dfrac{d_w^3\, t_w}{3} + d_w^2\, b_f\, t_f\right) 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_w = sectorial moment of inertia, in cm^6, of profile about connection of stiffener to plating

$= \dfrac{d_w^3\, t_w^3}{36}\, 10^{-6}$ for flat bars

$= \dfrac{t_f\, b_f^3\, d_w^2}{12}\, 10^{-6}$ for 'Tee' profiles

$= \dfrac{b_f^3\, d_w^2}{12\,(b_f + d_w)^2}\left[t_f\left(b_f^2 + 2b_f\, d_w + 4d_w^2\right) + 3t_w\, b_f\, d_w\right] 10^{-6}$ for 'L' profiles, rolled angles and bulb plates

$K = \dfrac{1{,}03C\, S^4}{E\, I_w}\, 10^4$

7.4 Design stress

7.4.1 Design longitudinal compressive stress, σ_A, is to be determined in accordance with Section 5:

minimum $\sigma_A = \dfrac{30}{k_L}$ N/mm^2 $\left(\dfrac{3{,}06}{k_L}\right.$ kgf/mm$^2\left.\right)$

for structural members above the neutral axis,

$$\sigma_A = \sigma_D \frac{z}{z_D}$$

for structural members below the neutral axis,

$$\sigma_A = \sigma_B \frac{z}{z_B}$$

σ_D based on sagging moment and σ_B based on hogging moment are determined in 5.6.1.

where

z = vertical distance from the hull transverse neutral axis to the position considered, excluding deck camber, in metres

z_D, z_B = vertical distances from the hull transverse neutral axis to the deck and keel respectively, in metres

Table 4.7.3 Elastic critical buckling stress of longitudinals (*conclusion*)

m is determined as follows:

m	*K* range
1	$0 < K \le 4$
2	$4 < K \le 36$
3	$36 < K \le 144$
4	$144 < K \le 400$
5	$400 < K \le 900$
6	$900 < K \le 1764$
m	$(m-1)^2\, m^2 < K \le m^2\,(m+1)^2$

C = spring stiffness exerted by supporting plate panel

$$= \frac{k_p\, E\, t_p^3}{3s\left(1 + \dfrac{1{,}33 k_p\, d_w\, t_p^3}{s\, t_w^3}\right)}$$

k_p = $1 - \eta_p$, and is not to be taken less than zero. For built up profiles, rolled angles and bulb plates, k_p need not be taken less than 0,1

$\eta_p = \dfrac{\sigma_A}{\sigma_{Ep}}$ where σ_{Ep} = elastic critical buckling stress (σ_E) of supporting plate derived from Table 4.7.2

All other symbols as defined in 7.2.1.

NOTES

1. Where the elastic critical buckling stress, as evaluated from (a), (b) or (c), exceeds 50 per cent of specified minimum yield stress of the material, the corrected critical buckling stress in compression (σ_{CRB}) is given by:

$$\sigma_{CRB} = \sigma_o \left(1 - \frac{\sigma_o}{4\sigma_E}\right) \text{ N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

2. Fig. 4.7.1 shows the dimensions of longitudinals.
3. For flanges on angles and T-sections of longitudinals, the following requirement is to be satisfied:

$\dfrac{b_f}{t} \le 15$ for angles, $\dfrac{b_f}{t} \le 30$ for 'Tee' profiles,

where

t = as built flange thickness, in mm

4. The area of attached plating is to be calculated using actual spacing of secondary stiffeners.

For initial design purposes, the hull transverse neutral axis may be taken at a distance $\dfrac{D}{2}$ above keel, where D is the depth of the ship, in metres, as defined in Ch 1,6.

7.4.2 Design shear stress, τ_A, is to be determined in accordance with Section 6.
For initial design purposes, τ_A may be taken as:

$$\tau_A = \frac{110}{k_L} \text{ N/mm}^2 \left(\frac{11{,}2}{k_L} \text{ kgf/mm}^2\right)$$

7.5 Scantling criteria

7.5.1 The corrected critical buckling stress in compression, σ_{CRB}, of plate panels and longitudinals, as derived from Tables 4.7.2 and 4.7.3, is to satisfy the following:

$$\sigma_{CRB} \ge \beta\, \sigma_A$$

where

β = 1 for plating and for web plating of longitudinals (local buckling)

β = 1,1 for longitudinals

7.5.2 The corrected critical buckling stress in shear, τ_{CRB}, of plate panels, as derived from Table 4.7.2(c), is to satisfy the following:

$$\tau_{CRB} \ge \tau_A$$

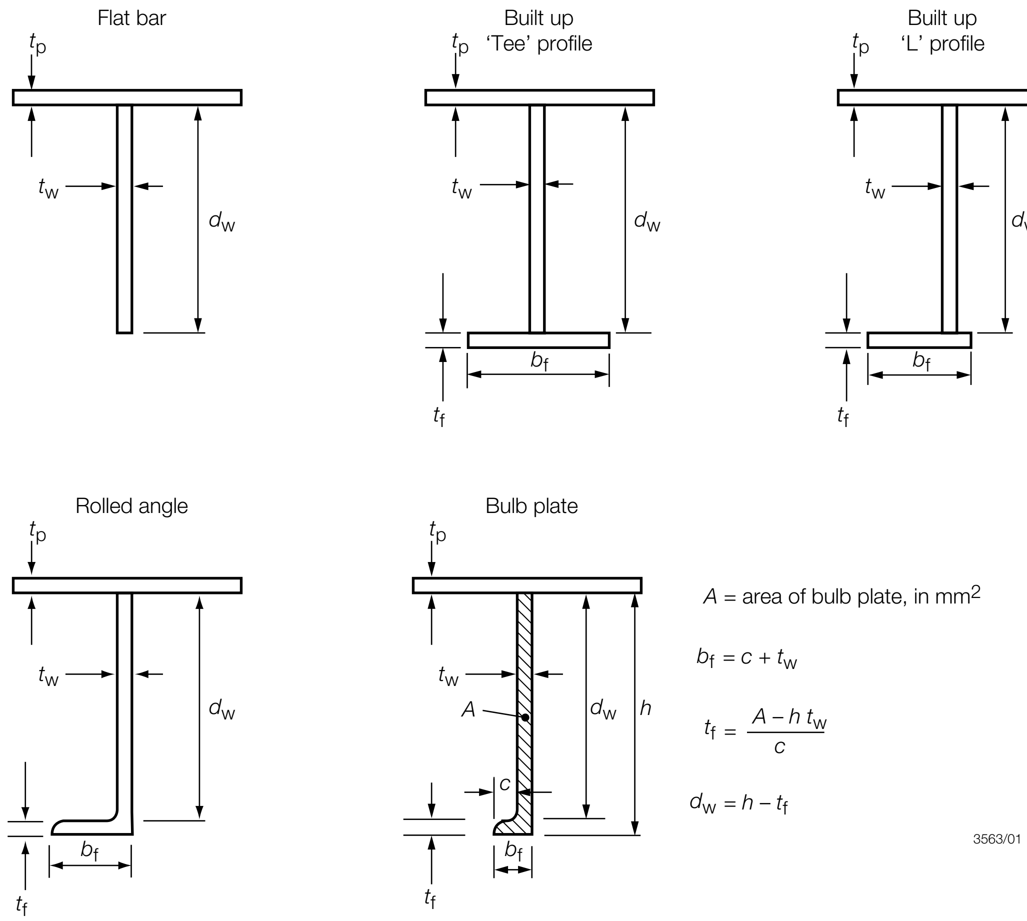


Fig. 4.7.1 Dimensions of longitudinals

■ *Section 8*
Loading guidance information

8.1 General

8.1.1 Sufficient information is to be supplied to the Master of every ship to enable him to arrange loading and ballasting in such a way as to avoid the creation of unacceptable stresses in the ship's structure.

8.1.2 This information is to be provided by means of a Loading Manual and in addition, where required, by means of an approved loading instrument.

8.2 Loading Manual

8.2.1 A Loading Manual is to be supplied to all ships where longitudinal strength calculations have been required, *see* Section 2. The Manual is to be submitted for approval in respect of strength aspects. Where both Loading Manual and loading instrument are supplied, the Loading Manual must nevertheless be approved from the strength aspect. In this case, the Manual is to be endorsed to the effect that any departures from these conditions in service are to be arranged on the basis of the loading instrument and the allowable local loadings shown in the Manual, *see* 8.2.4.

8.2.2 The Manual is to be based on the final data of the ship and is to include well-defined lightweight distribution and buoyancy data.

8.2.3 Details of the loading conditions given in 5.3.3 are to be included in the Manual as applicable.

8.2.4 The Manual is also to contain the following:

(a) Values of actual and permissible still water bending moments and shear forces and, where applicable, limitations due to torsional loads.

(b) The allowable local loadings for the structure such as the hatch covers, decks and double bottoms. If the ship is not approved to carry load on the deck or hatch covers, this is to be clearly stated.

(c) Details of cargo carriage constraints imposed by the use of an accepted coating in association with a system of corrosion control, *see* Ch 2,3.6.

(d) A note saying:

'Scantlings approved for minimum draught forward of …m with ballast tanks No… filled. In heavy weather conditions the forward draught should not be less than this value. If, in the opinion of the Master, sea conditions are likely to cause regular slamming, then other appropriate measures such as change in speed, heading or an increase in draught forward may also need to be taken.'

(e) The maximum unladen weight, in tonnes, of grab that is considered suitable for the approved thickness of the hold inner bottom for bulk carriers and ore or oil carriers that are regularly discharged by grabs. This maximum unladen weight may differ for adjacent holds, *see* Ch 9,13.2 and Pt 4, Ch 7,8.1. This weight does not preclude the use of heavier grabs, but 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.

8.2.5 In addition to the requirements of 8.2.4, the Manual is to contain the following information for bulk carriers (*see* 3.2.2), ore carriers and combination carriers of length, *L*, 150 m or above:

(a) The cargo hold(s) or combination of cargo holds that may be empty at maximum draught. If no cargo hold is permitted to be empty at maximum draught, this is to be clearly stated in the Manual.

(b) Maximum allowable and minimum required mass of cargo and double bottom ballast for each hold as a function of the draught at mid-hold position.

(c) Maximum allowable and minimum required mass of cargo and double bottom ballast for any two adjacent holds as a function of the mean draught in way of these holds. The mean draught may be calculated by averaging the draught at the two mid-hold positions.

(d) Maximum allowable inner bottom loading together with specification of the nature of the cargo, for cargoes other than bulk cargoes.

(e) The maximum rate of ballast exchange, together with advice that a load plan is to be agreed with the terminal on the basis of achievable rates of exchange.

For bulk carriers for which it is required to undertake longitudinal strength calculations in the flooded condition, *see* Pt 4, Ch 7,1.2.2, the Manual is also to contain envelope results and permissible limits of still water bending moments and shear forces for hold flooded conditions, *see* Pt 4, Ch 7,3.4.

8.2.6 Where applicable, the Manual is also to contain the procedure for ballast exchange and sediment removal at sea.

8.2.7 Where alteration to structure, lightweight, cargo distribution or draught is proposed, revised information is to be submitted for approval.

8.3 Loading instrument

8.3.1 In addition to a Loading Manual, an approved type loading instrument is to be provided for all ships where *L* is greater than 65 m and which are approved for non-uniform distribution of loading. The following ships are exempt from this requirement:

(a) Ships with very limited possibilities for variations in the distribution of cargo and ballast.

(b) Ships with a regular or fixed trading pattern.

(c) Ships exempt by individual Chapters in Part 4.

8.3.2 The loading instrument is to be capable of calculating shear forces and bending moments, in any load or ballast condition at specified readout points and is to indicate the permissible values. On container ships and other ships with large deck openings (*see* 3.3.2), cargo torque is also to be calculated.

8.3.3 For bulk carriers, ore carriers and combination carriers of length, *L*, 150 m or above, the loading instrument is to be additionally capable of verifying that the following are within permissible limits:

(a) the mass of cargo and double bottom ballast in way of each hold as a function of the draught at the mid-hold position.

(b) the mass of cargo and double bottom ballast for any two adjacent holds as a function of the mean draught in way of these holds. The mean draught may be calculated by averaging the draught at the two mid-hold positions.

For bulk carriers for which it is required to undertake longitudinal strength calculations in the flooded condition, *see* Pt 4, Ch 7,1.2.2, the loading instrument is also to be capable of verifying that the still water bending moments and shear forces in hold flooded conditions (*see* Pt 4, Ch 7,3.4), are within permissible limits.

8.3.4 If the approved loading manual utilises bulkhead correction factors for shear force distribution, then the loading instrument must also have the capability to account for the bulkhead correction factors.

8.3.5 The instrument is to be certified in accordance with LR's document entitled *Approval of Longitudinal Strength and Stability Calculations Programs*.

8.3.6 The instrument readout points are usually selected at the position of the transverse bulkheads or other obvious boundaries. As many readout points as considered necessary by LR are to be included, e.g., between bulkheads.

8.3.7 A notice is to be displayed on the loading instrument stating:

> 'Scantlings approved for minimum draught forward of …m with ballast tanks No… filled. In heavy weather conditions, the forward draught should not be less than this value. If, in the opinion of the Master, sea conditions are likely to cause regular slamming, then other appropriate measures such as change in speed, heading or an increase in draught forward may also need to be taken.'

8.3.8 Where alteration to structure, lightweight or cargo distribution is proposed, the loading instrument is to be modified accordingly and details submitted for approval.

8.3.9 The operation of the loading instrument is to be verified by the Surveyors upon installation and at Annual and Periodical Surveys as required in Pt 1, Ch 3. An Operation Manual for the instrument is to be verified as being available on board.

8.3.10 Where an onboard computer system having a strength computation capability is provided as an Owner's option, it is recommended that the system be certified in accordance with LR's document entitled *Approval of Longitudinal Strength and Stability Calculations Programs*. For systems having a stability computation capability and installed on a new ship, *see also* Pt 1, Ch 2,1.1.11. For systems having a stability computation capability and installed on an existing ship, it is recommended that the system be certified in accordance with LR's document entitled *Approval of Longitudinal Strength and Stability Calculation Programs.*

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all types of ship covered by Part 4 except where specifically stated otherwise.

1.1.2 The requirements given are those specific to fore ends and relate to structure situated in the region forward of 0,3*L* from the forward perpendicular.

1.1.3 Requirements for cargo space structure within this region not dealt with in this Chapter are to be as detailed in the relevant Chapter of Part 4 for the particular ship type.

1.1.4 The requirements in this chapter are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation. *See* Pt 1, Ch 2,2.3.

1.2 Structural configuration

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

1.2.2 In the case of container ships and open type ships, additional requirements may apply as detailed in Pt 4, Ch 8.

1.2.3 In the case of fast cargo ships, the additional requirements given in Pt 4, Ch 1,3 are to be complied with where applicable.

1.2.4 The requirements regarding minimum bow height given in Ch 3,6 are to be complied with where applicable.

1.3 Structural continuity

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

1.3.2 Where longitudinal framing terminates and is replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover. Where a forecastle is fitted extending aft of 0,15*L* from the F.P., longitudinal framing at the upper deck and topsides is generally to be continued forward of the end bulkhead of this superstructure. In bulk carriers and oil tankers (*see* 1.1.4) the longitudinal framing at the upper deck is to be maintained over the cargo space region and continued over the fore peak region.

1.3.3 In container or similar ships having continuous side tanks or double skin construction in way of the cargo spaces, the longitudinal bulkheads are to be continued as far forward as is practicable and are to be suitably tapered at their ends. Where, due to the ship's form, such bulkheads are stepped, suitable scarfing is to be arranged.

1.3.4 In bulk carriers (*see* 1.1.4) the topside tank and double bottom hopper tank structures are to be maintained over the cargo space region, and suitable taper brackets are to be arranged in line with the end of these tank structures in the fore peak region. In addition, in way of the cargo space forward bulkhead, a girder or intercostal bulb plate stiffeners (fitted between and connected to the bulkhead vertical stiffeners), are to be arranged on the forward side in line with the sloped bulkheads of the topside and hopper tanks clear of the taper brackets.

1.4 Symbols and definitions

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

L, *B*, *D*, *T*, C_b and *V* as defined in Ch 1,6.1

k_L, k = higher tensile steel factor, *see* Ch 2,1.2
l = overall length of stiffening member, in metres, *see* Ch 3,3.3
l_e = effective length of stiffening member, in metres, *see* Ch 3,3.3
s = spacing of secondary stiffeners, in mm
t = thickness of plating, in mm
I = inertia of stiffening member, in cm^4, *see* Ch 3,3.2
S = spacing, or mean spacing, of primary members, in metres
Z = section modulus of stiffening member, in cm^3, *see* Ch 3,3.2
ρ = relative density (specific gravity) of liquid carried in a tank and is to be taken not less than 1,025.

1.4.2 For the purpose of this Chapter the forward perpendicular, F.P., is defined as the forward limit of the Rule length *L*.

1.5 Strengthening of bottom forward

1.5.1 The bottom forward of a sea-going ship is to be additionally strengthened, except where the ship is so designed that a minimum draught forward, T_{FB}, of 0,045*L* can be achieved for any ballast or part loaded condition. This draught is to be indicated on the shell expansion plan, the plan showing the internal strengthening, the Loading Manual and loading instrument, where fitted, *see* Ch 4,8.

1.5.2 The requirements for the additional strengthening apply to ships where L is greater than 65 m. Where a ship is classed for service in protected waters or extended protected waters, compliance with the requirements of this Section may be modified or waived altogether.

1.5.3 The additional strengthening is to extend forward of 0,3L from the F.P. over the flat of bottom and adjacent plating with attached stiffeners up to a height of 0,002L above the base line or 300 mm whichever is the lesser.

1.5.4 The scantling requirements outside the areas defined in 1.5.3 are to be suitably tapered to maintain adequate continuity of strength in both longitudinal and transverse directions.

1.5.5 The requirements for the additional strengthening within the region defined in 1.5.3 are given in Table 5.1.1, or may be obtained by direct calculation. Where T_{FB} is less than 0,01L, the additional strengthening is to be specially considered.

1.5.6 Bottom longitudinals are to pass through and be supported by the webs of primary members. The vertical web stiffeners are to be connected to the bottom longitudinals. The cross-sectional area of the connections is to comply with the requirements given in Table 5.1.1.

1.5.7 The scantlings required by this Section must in no case be less than those required by the remaining Sections in Chapter 5.

1.5.8 For minimum draught forward, T_{FB} between 0,01L and 0,045L, the equivalent slamming pressure expressed as a head of water, h_s, is to be obtained from Fig. 5.1.1, where h_{max} is calculated from the following expressions:

$$65 < L \leq 169 \text{ m}, \quad h_{max} = 10\sqrt{L}\, F \text{ m}$$
$$169 < L \leq 180 \text{ m}, \quad h_{max} = 130\, F \text{ m}$$
$$L > 180 \text{ m}, \quad h_{max} = 130\, F e^{-0{,}0125(L-180)^{0{,}705}} \text{ m}$$

where

$$F = 5{,}95 - 10{,}5 \left(\frac{T_{FB}}{L}\right)^{0{,}2}$$

and

e = base of natural logarithm, 2,7183

(a) The application of the maximum pressure for forward of 0,3L from the F.P. is as indicated in Fig. 5.1.1. For C_b between 0,70 and 0,80 its position may be obtained by linear interpolation.

(b) Where the bottom plating forms the boundary of a double bottom tank, deep tank or double skin tank which is full in all ballast conditions, then for such conditions the head, h_s, may be reduced by 1,25 times the head, in metres, of ballast water to top of tank.

(c) For bulk carriers (*see* 1.1.4) the reduction to the head, h_s, is not to exceed the head, in metres, of ballast water to the top of the hopper tank or 1,25 times the depth, in metres, of the double bottom tank, whichever is the greater.

(d) For ballast and part loaded conditions where the draught forward is less than 0,045L and the reduction to the head, h_s, has been applied, the ballast tanks are to be filled and a note added to the loading booklet to this effect, *see* Ch 4,8.2.4(d).

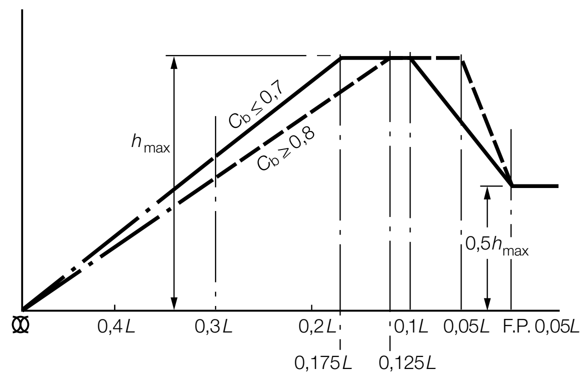


Fig. 5.1.1 Pressure heads

1.6 Strengthening against bow flare slamming

1.6.1 The requirements of this Section apply to all ships except those defined in Pt 4, Ch 2 and Pt 4, Ch 8.

1.6.2 The side structure in the area forward of 0,075L from the F.P. and above the summer load waterline is to be strengthened against bow flare impact pressure. The strengthening is to extend vertically to the uppermost deck level, including the forecastle deck, if fitted, but need not exceed the level of T + 1,65H_b above the base line, where H_b is the minimum bow height, in metres, as derived in Ch 3,6.1.

1.6.3 The flare angle, α, is the angle between the vertical axis and the tangent of the outer shell measured normal to the shell in a vertical plane, at the point under consideration. The entry angle, β, is the angle between the longitudinal axis and the waterplane tangent measured on the outer shell, at the point under consideration. The flare angle may normally be derived in accordance with Fig. 5.1.2.

1.6.4 The equivalent bow flare slamming head, h_S, is to be taken as:

$$h_S = 0{,}8\left(0{,}2 + 1{,}5 \tan\alpha\right)\left(0{,}51 V \sin\beta \cos\alpha + \frac{\pi}{\sqrt{L}}\,\delta\right)^2 \text{ m}$$

where

V = as defined in 1.4.1

α = flare angle, in degrees, at the point under consideration

β = entry angle, in degrees, at the point under consideration

$\delta = \left(\frac{\pi}{30} L e^{-0{,}0033L} - 0{,}5d\right)$ and is not to be taken less than zero

e = base of natural logarithms 2,7183

d = vertical distance, in metres, between the waterline at draught T and the point under consideration.

Table 5.1.1 Additional strengthening of bottom forward (*see continuation*)

Item	Requirements	
(1) Longitudinally framed bottom shell plating (including keel), *see* Notes 1 and 2	$t = 0{,}003 s f \sqrt{h_s k}$	
(2) Bottom longitudinals – other than flat bars	$\dfrac{d_w}{t_w} \leq 55\sqrt{k}$ $\dfrac{d_w t_w}{100} \geq 0{,}00033\, k\, h_s\, s\, c \left(S - \dfrac{s}{2000}\right)$ cm^2 $Z \geq 6{,}8 \times 10^{-6} h_s\, s\, k \left[(17{,}5 l_s)^2 - (0{,}01 s)^2 + d_w c \left(S - \dfrac{s}{2000}\right)\right]$ cm^3 $\dfrac{(A_1 \overline{\tau} + \alpha)}{\overline{p}} \times 10^{-1} \geq 1$ $A_w \geq 0{,}84 A_1$	
(3) Bottom longitudinals – flat bars	Will be specially considered	
(4) Primary structure in way of single bottoms	Transverse framing	Longitudinal framing
	(a) Centre girder: Scantlings as required by item (1) in Table 5.5.1,except that in determining Z in way of a deep tank forward of 0,2L from the F.P. the value of h_5 is to be increased by the following percentages: where $T_{FB} \leq 0{,}03L_2$, 30 per cent where $T_{FB} \geq 0{,}04L_2$, 0 per cent The increase in h_5 for intermediate values of T_{FB} is to be obtained by interpolation (b) Floors: Scantlings as required by item (2) in Table 5.5.1, except that in way of dry cargo spaces the minimum face area is to be increased by the following percentages: where $T_{FB} \leq 0{,}03L_2$, 50 per cent where $T_{FB} \geq 0{,}04L_2$, 0 per cent The increase of minimum face area for intermediate values of T_{FB} is to be obtained by interpolation (c) Side girders: Arrangement and scantlings as required by 5.2.2 and 5.2.3, with the addition of intermediate half-height girders or equivalent fore and aft stiffening	(a) Ships having one or more longitudinal bulkheads: (i) Centre girder Scantlings as required by item (4) in Table 5.5.1 and (iii) (ii) Bottom transverses Maximum spacing As for midships region Scantlings as required by Pt 4, Ch 9,9 or Pt 4, Ch 10,2 (iii) For horizontally stiffened longitudinal bulkheads and girders the depth to thickness ratio of the panel attached to the bottom shell plate is not to exceed $55\sqrt{k}$ (iv) Where T_{FB}, < 0,025L_2 the scantlings and arrangements will receive individual consideration (b) Other ship arrangements will receive individual consideration
(5) Primary structure in way of double bottoms, *see* Note 3	(a) Plate floors: Maximum spacing, every frame Scantlings as required by Pt 4, Ch 1,8 (b) Centre and side girders: Maximum spacing, 0,003s_F m Scantlings as required by Pt 4, Ch 1,8 (c) Intermediate half-height girders to be arranged midway between side girders: Scantlings as required for non watertight side girders by Pt 4, Ch 1,8	(a) Plate floors: Maximum spacing: 0,002s_F m for $T_{FB} < 0{,}04L_2$ 0,003s_F m for $T_{FB} \geq 0{,}04L_2$ but not to exceed that required by item (2) in Table 5.5.2 Scantlings as required by Pt 4, Ch 1,8 (b) Centre and side girders: Maximum spacing: 0,003s_L m for $T_{FB} < 0{,}04L_2$ 0,004s_L m for $T_{FB} > 0{,}04L_2$ but not to exceed that required by item (4) in Table 5.5.2 Scantlings as required by Pt 4, Ch 1,8
(6) Primary structure in way of double bottoms supported by longitudinal bulkheads	—	The scantlings and arrangements will receive individual consideration on the basis of direct calculations using, if necessary, a suitably defined two-dimensional grillage model, *see* Ch 1,3

Table 5.1.1 Additional strengthening of bottom forward (*conclusion*)

Symbols

L,T, s, k as defined in 1.4.1

c = 1,0 for $S \leq 2,5$ m
= $(0,87 + 0,16S)\, c_1$ for $S > 2,5$ m

c_1 = 1,0 for $S \leq 1,0$ m
= $(1,14 - 0,14S)$ for $1,0 \text{ m} < S \leq 4,0$ m
= $\dfrac{2,32}{S}$ for $S > 4,0$ m

d_w = web depth, in mm, which for bulb flats may be taken as 0,9 times the section height

f = $\left(1,1 - \dfrac{s}{2500S}\right)$ but not greater than 1,0

h_s = equivalent slamming pressure, in metres obtained from 1.5.8

l_s = l_e, in metres, as defined in 1.4.1 where in way of a double bottom
= S, in metres, where in way of a single bottom

S = spacing of primary members, in metres

p = $9,81\, h_s\, s\, c_1 \left[S - \dfrac{s}{2000}\right] \times 10^{-3}$ kN
= $\left(h_s\, s\, c_1 \left[S - \dfrac{s}{2000}\right] \times 10^{-3} \text{ tonne-f}\right)$

s_F = spacing of transverse frames, in mm, for longitudinally framed side and bottom construction s_F may be taken as s_L

s_L = spacing of bottom longitudinals, in mm

t_w = web thickness, in mm

A_f = cross-sectional area of primary member web stiffener, in cm²

A_{fc} = effective area of primary member web stiffener in way of butted end connection to the longitudinal, in cm²

A_L = area of weld of lapped connection, in cm², calculated as total length of weld, in cm x throat thickness, in cm

A_w = area of weld of lug and web connection to the longitudinal, in cm², calculated as total length of weld in cm x throat thickness, in cm

A_1 = effective total cross-sectional area of the lug and web connection to the longitudinal, in cm²

L_2 = L but need not be taken greater than 215 m

T_{FB} = draught, in metres, at the F.P., as defined in 1.5.1

α = $A_f \bar{\sigma}$ for the web stiffeners
= $A_{fc} \bar{\sigma}$ for a butted connection to the longitudinals
= $A_L \bar{\tau}$ for a lapped connection

$\bar{\sigma}$ = permissible direct stress, in N/mm² (kgf/mm²), given in Table 5.1.2

$\bar{\tau}$ = permissible shear stress, in N/mm² (kgf/mm²), given in Table 5.1.2

NOTES
1. If intermediate stiffening is fitted the thickness of the bottom shell plating may be 80 per cent of that required by (1) but is to be not less than the normal taper thickness.
2. For transverse framing the bottom shell plating is to be specially considered.
3. Particular care is to be taken to limit the size and number of openings in way of the ends of floors or girders or to fit suitable reinforcement where such openings are essential.
4. The welding requirements of Ch 10, and in cargo oil tanks of tankers, the requirements of Pt 4, Ch 9,10.14 or Pt 4, Ch 10,7.14, are also to be complied with.

1.6.5 The thickness of the side shell is to be not less than:

$t = 3,2 s_C \sqrt{k\, h_s}\; C_R \times 10^{-2}$ mm

where

s_C = spacing of secondary stiffeners, in mm, measured along a chord between parallel adjacent members or equivalent supports, as shown in Fig. 5.1.3

h_S = bow flare slamming head, in metres, as defined in 1.6.4

C_R = panel ratio factor
= $\left(\dfrac{l}{s_c}\right)^{0,41}$ but is not to be taken less than 0,06 or greater than 0,1

l = overall panel length, in metres, measured along a chord between the primary members.

1.6.6 The scantlings of secondary stiffeners are not to be less than:

(a) Section modulus of secondary stiffeners
$Z = 3,6 s_{CM}\, k\, h_S\, l_e^2 \times 10^{-3}$ cm³

(b) Web area of secondary stiffeners
$A = 3,7 s_{CM}\, k\, h_S\, (l_e - s_{CM}/2000) \times 10^{-4}$ cm²

where

s_{CM} = mean spacing of secondary stiffeners, in mm, measured along a chord between parallel adjacent members or equivalent supports, as shown in Fig. 5.1.3

h_S = bow flare slamming head, in metres, as defined in 1.6.4

Other symbols are as defined in 1.4.1.

1.6.7 The scantlings of primary members are not to be less than:

(a) Section modulus of primary members
$Z = 2 S_{CM}\, k\, h_S\, l_e^2$ cm³

(b) Web area of primary members
$A = 0,2 S_{CM}\, k\, h_S\, l_e$ cm²

where

S_{CM} = mean spacing of primary members, in metres, measured along a chord between parallel adjacent members or equivalent supports, as shown in Fig. 5.1.4

h_S = bow flare slamming head, in metres, as defined in 1.6.4

Other symbols are as defined in 1.4.1.

Table 5.1.2 Permissible stresses

Item		Direct stress, $\bar{\sigma}$ in N/mm^2 (kgf/mm^2) *see* Note	Shear stress, $\bar{\tau}$ in N/mm^2 (kgf/mm^2)
Primary member web stiffener on area A_f	(a) Flat bars, *see* Note	$\frac{10,3}{k}\left[33-\frac{d}{t\sqrt{k}}\right]$	—
		$\left(\frac{1,05}{k}\left[33-\frac{d}{t\sqrt{k}}\right]\right)$	—
	(b) Bulb plates, *see* Note	$\frac{8,6}{k}\left[40-\frac{d}{\left(\frac{100A_f}{d}-\frac{t}{6}\right)\sqrt{k}}\right]$	—
		$\left(\frac{0,88}{k}\left[40-\frac{d}{\left(\frac{100A_f}{d}-\frac{t}{6}\right)\sqrt{k}}\right]\right)$	—
	(c) Inverted angles	$\frac{220}{k}\left(\frac{22,4}{k}\right)$	—
Primary member web stiffener on area A_{fc}		$\frac{245}{k}\left(\frac{25}{k}\right)$	—
Primary member web stiffener lapped to secondary member on area A_L		—	$\frac{167}{k}\left(\frac{17}{k}\right)$
Lug or web connection on area A_1	Single	—	$\frac{124}{k}\left(\frac{12,6}{k}\right)$
	Double	—	$\frac{141}{k}\left(\frac{14,4}{k}\right)$
Symbols			
A_f, A_L, A_1 as defined in Table 5.1.1 d = stiffener depth, in mm k = as defined in 1.4.1 t = stiffener web thickness, in mm			
NOTE $\bar{\sigma}$ to be taken not greater than $\frac{220}{k}\left(\frac{22,4}{k}\right)$			

1.6.8 For primary members with cut-outs for the passage of secondary stiffeners, and which may have web stiffeners connected to the secondary stiffener, buckling checks are to be carried out to ensure that the primary member web plating and web stiffener will not buckle under the design load. The buckling procedure to be followed is given in Table 5.1.3. Where the web stiffener is fitted with a bracket, the buckling capability of the web stiffener in way of the cut-out is to take account of the bracket. Where no web stiffener is fitted, the buckling capability of the primary member web plating is to be checked for the total load transmitted to the connection.

1.6.9 The structural scantlings required in areas strengthened against bow flare slamming are to be tapered from 0,075*L* aft of fore perpendicular to meet the normal requirements at 0,15*L* aft of the fore perpendicular.

1.6.10 Where the stiffener web is not perpendicular to the plating, tripping brackets may need to be fitted in order to obtain adequate lateral stability.

1.6.11 For stiffeners and primary structure, where the angle between the stiffener web and the plating is less than 70°, the effective section modulus and shear area are to take account of the non-perpendicularity.

1.6.12 The side structure scantlings required by this Section must in no case be taken less than those required by the remaining Sections of Chapter 5.

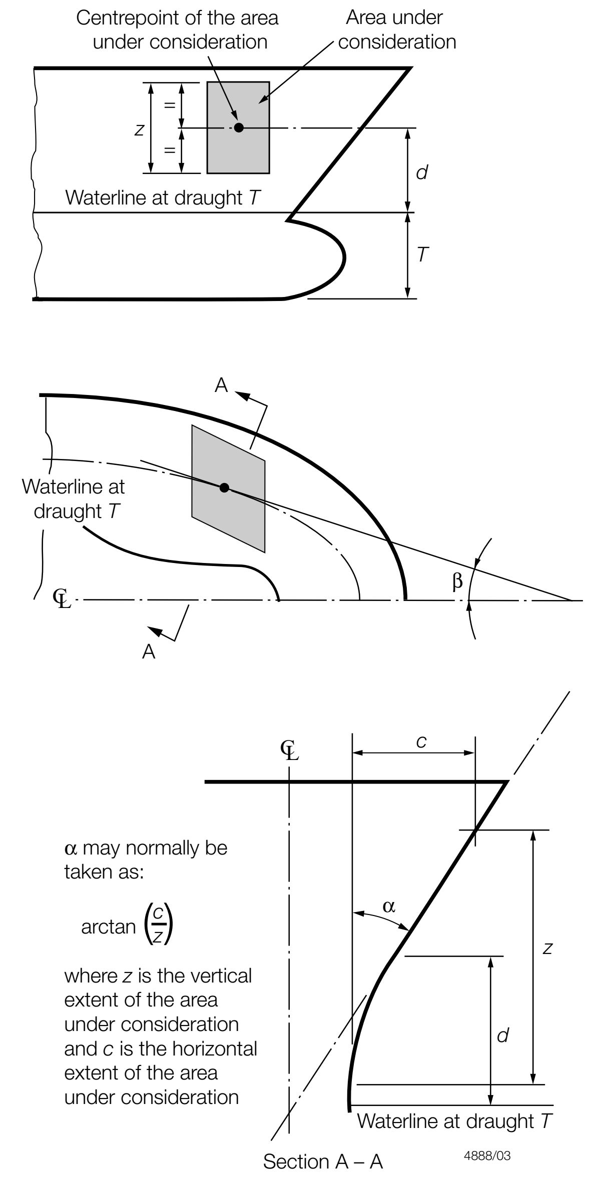


Fig. 5.1.2 Flare angle determination

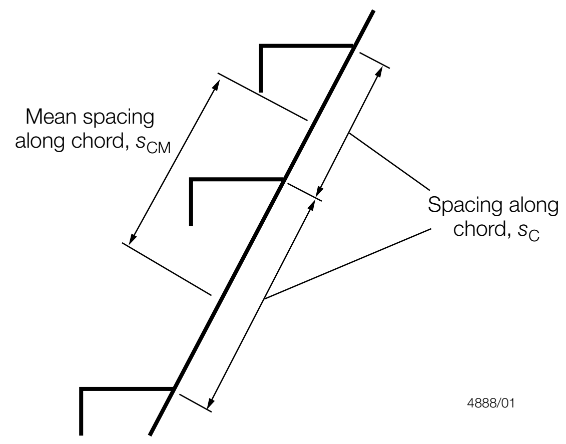


Fig. 5.1.3
Chord spacing and mean chord spacing for secondary members

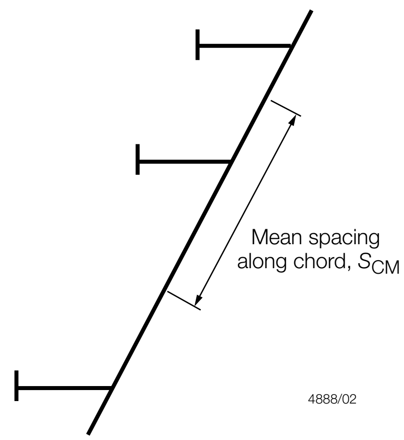


Fig. 5.1.4
Mean chord spacing for primary members

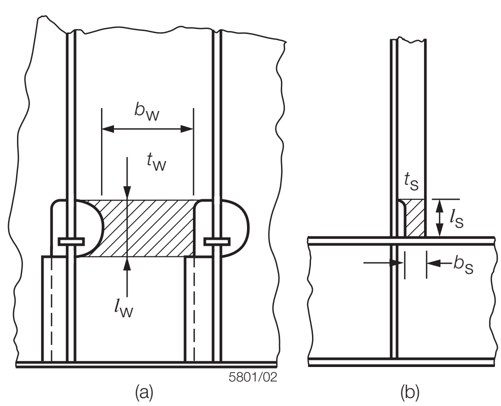


Fig. 5.1.5
Dimensions of critical areas of (a) primary member web plating and (b) primary web stiffener

Table 5.1.3 Buckling procedure for primary member web plating and web stiffener

Steps	Members	
	Primary member web plating	Primary member web stiffener
Determination of the design compressive stress, σ_A, N/mm^2 (kgf/mm^2)	$\sigma_A = \dfrac{1000 P_W}{A_W}$	$\sigma_A = \dfrac{1000 P_S}{A_S}$
Determination of the elastic critical buckling stress, σ_E, in compression, N/mm^2 (kgf/mm^2)	$\sigma_E = \dfrac{9{,}87 E\, I_W}{l_W^2 A_W}$	$\sigma_E = \dfrac{9{,}87 E\, I_S}{l_S^2 A_S}$
Determination of the corrected critical buckling stress, σ_{CR}, in compression, N/mm^2 (kgf/mm^2)	$\sigma_{CR} = \sigma_o \left(1 - \dfrac{\sigma_o}{4\,\sigma_E}\right)$ where $\sigma_E > \dfrac{\sigma_o}{2}$ $\sigma_{CR} = \sigma_E$ where $\sigma_E \leq \dfrac{\sigma_o}{2}$	
Requirement	$\sigma_{CR} \geq \sigma_A$	

Symbols

b_W, b_S, l_W, and l_S are dimensions, in mm, as shown in Fig. 5.1.5

h_S = equivalent bow flare slamming head, in metres, as defined in 1.6.4

s_{CM} = mean spacing of secondary stiffeners, in mm, as defined in 1.6.6

t_W = thickness of primary member web plating, in mm

t_S = thickness of primary member web stiffener, in mm

A_W = $b_W\, t_W$ mm^2

A_S = $b_S\, t_S$ mm^2

E = modulus of elasticity, in N/mm^2 (kgf/mm^2)
= 206000 N/mm^2 (21000 kgf/mm^2) for steel

$$I_W = \frac{b_W\, t_W^3}{12} \text{ mm}^4$$

$$I_S = \frac{b_S\, t_S^3}{12} \text{ mm}^4$$

P = total load transmitted to the connection
= 10,06 $S_{CM}\, s_{CM}\, h_S \times 10^{-3}$ kN

(P = 1,025 $S_{CM}\, s_{CM}\, h_S \times 10^{-3}$ tonne-f)

P_W = load transmitted through the primary member web plating, in kN (tonne-f)
= $P - P_S$, or by direct calculations

P_S = load transmitted through the primary member web stiffener, in kN (tonne-f), to be determined from Ch 10,5.2.7(b), or by direct calculations

S_{CM} = mean spacing of primary members, in metres, as defined in 1.6.7

σ_o = specified minimum yield stress, in N/mm^2 (kgf/mm^2)

■ *Section 2* Deck structure

2.1 General

2.1.1 Where the upper deck is longitudinally framed outside the line of openings in the midship region, this system of framing is to be carried as far forward as possible. In the case of oil tankers (*see* 1.1.4), longitudinal framing is to extend to at least the forward end of the cargo tank section.

2.2 Deck plating

2.2.1 The thickness of strength/weather deck plating is to comply with the requirements of Table 5.2.1.

2.2.2 The thickness of lower deck plating is to comply with the requirements of Table 5.2.2.

2.2.3 The taper thickness of the strength deck stringer plate is to be increased by 20 per cent at the end of a forecastle or bridge where the end bulkhead is situated aft of 0,25L from the F.P. No increase is required where the end bulkhead lies forward of 0,2L from the F.P. The increase at intermediate positions is to be determined by interpolation.

2.2.4 The deck plating thickness and supporting structure are to be suitably reinforced in way of the anchor windlass and other deck machinery, and in way of cranes, masts or derrick posts.

2.2.5 Where long, wide hatchways are arranged at lower decks, it may be necessary to increase the deck plating thickness to ensure effective support for side framing.

Table 5.2.1 Strength/weather deck plating forward (excluding forecastle deck)

Symbols	Location	Thickness, in mm
L, D, T, s, S, k, ρ as defined in 1.4.1 $C = \left(\dfrac{D + 2,3 - T}{\text{height of deck above load waterline at F.P.}}\right)$ but is to be taken not greater than 1,0 nor less than 0,9 s_1 = *s*, but to be taken not less than s_b s_b = standard frame spacing as follows: (a) forward of 0,05*L* from the F.P.: $s_b = \left(470 + \dfrac{L}{0,6}\right)$ mm or 600 mm, whichever is the lesser (b) between 0,05*L* and 0,2*L* from the F.P.: $s_b = \left(470 + \dfrac{L}{0,6}\right)$ mm or 700 mm, whichever is the lesser $f = 1,1 - \dfrac{s}{2500S}$ but to be taken not greater than 1,0 h_4 = tank head, in metres, as defined in Ch 3,5	(1) Forward of 0,075*L* from the F.P.	$t = (6,5 + 0,02L)\, C \sqrt{\dfrac{ks_1}{s_b}}$
	(2) Between 0,075*L* and 0,2*L* from the F.P.	The greater of the following: (a) $t = (5,5 + 0,02L)\, C \sqrt{\dfrac{ks_1}{s_b}}$ (b) the taper thickness (*see* Notes 1, 2 and 3) (c) for oil tankers, the thickness is also to be in accordance with Pt 4, Ch 9,4.3.3
	(3) Aft of 0,2*L* from the F.P.	The taper thickness (*see* Notes 1, 2 and 3) or as (2) (c) whichever is the greater
	(4) Inside forecastle extending aft of 0,15*L* from the F.P.	As for a lower deck (*see* Note 4)
	(5) In way of crown of a tank	$t = 0,004s\, f \sqrt{\dfrac{\rho\, k\, h_4}{1,025}} + 3,5$ or as in (1) to (4) as applicable, whichever is the greater but not less than: 7,5 mm where $L \geq 90$ m, or 6,5 mm where $L < 90$ m

NOTES
1. The taper thickness is to be determined from Table 3.2.1 in Chapter 3.
2. For taper area requirements, *see* Table 3.2.1 in Chapter 3.
3. For thickness of upper deck plating in way of the cargo and fore peak tanks of oil tankers or ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11, as applicable.
4. The exposed deck taper thickness is to extend into a forecastle or bridge for at least one-third of the breadth of the ship from the superstructure end bulkhead.

Table 5.2.2 Lower deck plating forward

Symbols	Location	Thickness, in mm
L, s, S, k, ρ as defined in 1.4.1 *b* = breadth of increased plating, in mm $f = 1,1 - \dfrac{s}{2500S}$ but is to be taken not greater than 1,0 h_4 = tank head, in metres, as defined in Ch 3,5 K_2 = 2,5 mm at bottom of tank, or = 3,5 mm at crown of tank s_1 = *s*, but is to be taken not less than $\left(470 + \dfrac{L_1}{0,6}\right)$ mm A_f = girder face area, in cm[2] L_1 = *L* but need not be taken greater than 190 m	(1) Forward of 0,075*L* from the F.P.	$t = 0,01\, s_1 \sqrt{k}$ but not less than 6,5 mm
	(2) Aft of 0,075*L* from the F.P., inside line of openings	$t = 0,01\, s_1 \sqrt{k}$ but not less than 6,5 mm
	(3) Aft of 0,075*L* from the F.P., outside line of openings	As determined by a taper line from the midship thickness to the end thickness given by (1)
	(4) In way of crown or bottom of tank	$t = 0,004\, f\, s \sqrt{\dfrac{\rho\, k\, h_4}{1,025}} + K_2$ or as in (1), (2) or (3) as applicable, whichever is the greater but not less than: 7,5 mm where $L \geq 90$ m, or 6,5 mm where $L < 90$ m
NOTES 1. Where the deck loading exceeds 43,2 kN/m^2 (4,4 tonne-f/m^2), the thickness of plating will be specially considered. This is equivalent to a 'tween deck height of 6,1 m in association with the standard stowage rate of 1,39 m^3/tonne. 2. For minimum thickness of deck plating in oil tankers, *see* Pt 4, Ch 9,10.2.	(5) Plating forming the upper flange of underdeck girders	Clear of cargo hatches: $t = \sqrt{\dfrac{A_f}{1,8k}}$ In way of hatch side girders: $t = 1,1\sqrt{\dfrac{A_f}{1,8k}}$ Minimum breadth: $b = 760$ mm

2.3 Deck stiffening

2.3.1 The scantlings of strength/weather deck longitudinals are to comply with the requirements of Table 5.2.3.

2.3.2 The scantlings of cargo and accommodation deck longitudinals are to comply with the requirements given in Table 1.4.4 in Pt 4, Ch 1.

2.3.3 End connections of longitudinals to bulkheads are to provide adequate fixity, lateral support and, so far as practicable, direct continuity of longitudinal strength.

2.3.4 The scantlings of weather deck beams are to comply with the requirements of Table 5.2.4.

2.3.5 The scantlings of lower deck beams are to comply with the requirements of Table 1.4.5 in Pt 4, Ch 1.

2.3.6 End connections of beams are to be in accordance with the requirements of Ch 10,3.

Table 5.2.3 Strength/weather deck longitudinals forward

Location	Modulus, cm^3	Inertia, cm^4
(1) Forward of 0,075*L* from the F.P.	The greater of the following: (a) $Z = s\,k\,(635h_1 + 0{,}0078\,(l_e\,L_1)^2) \times 10^{-4}$ (b) $Z = 0{,}0127s\,k\,h_1\,l_e^2$	–
(2) At 0,075*L* from the F.P., for end modulus for taper	The greater of the following: (a) $Z_e = s\,k\,(485h_o + 0{,}0062\,(l_{e1}\,L_1)^2) \times 10^{-4}$ (b) $Z_e = 0{,}009s\,k\,h_o\,l_{e1}^2$	–
(3) Aft of 0,075*L* from the F.P., outside line of openings	As given by (4) or as determined from Table 3.2.1 in Chapter 3 whichever is the greater, *see* Note 1	–
(4) At 0,075*L* and between 0,075*L* and 0,12*L* from the F.P.	The greater of the following: (a) $Z = s\,k\,(570h_1 + 0{,}0072\,(l_e\,L_1)^2) \times 10^{-4}$ (b) $Z = 0{,}0127s\,k\,h_1\,l_e^2$	–
(5) Aft of 0,12*L* from the F.P., inside line of main cargo hatchways openings	The greater of the following: (a) $Z = s\,k\,(400h_1 + 0{,}005\,(l_e\,L_1)^2) \times 10^{-4}$ (b) $Z = 0{,}007s\,k\,h_1\,l_e^2$	–
(6) In way of the crown of a tank	As (1) to (5), as applicable, or $Z = \dfrac{0{,}0113\rho\,s\,k\,h_4\,l_e^2}{b}$ whichever is the greater	$I = \dfrac{2{,}3}{k}\,l_e\,Z$

Symbols

L, s, k_L, k, ρ as defined in 1.4.1
b = 1,4 for rolled or built sections
= 1,6 for flat bars
d_w = web depth of longitudinal, in mm
h_o = 1,2 m for dry cargo ships
= $\dfrac{L_1}{56}$ m for oil tankers (*see* 1.1.4)
h_1 = weather head, in metres, as defined in Ch 3,5 for dry cargo ships
= $\dfrac{L_1}{70}$ m for oil tankers (*see* 1.1.4)
h_4 = tank head, in metres, as defined in Ch 3,5
l_e as defined in 1.4.1, but is to be taken not less than 1,5 m
l_{e1} is to be taken as the maximum span in metres in the midship cargo tank region for oil tankers (*see* 1.1.4) and equal to l_e for dry cargo ships
L_1 = L but need not be taken greater than 190 m

NOTES
1. For area taper requirements, *see also* Table 3.2.1 in Chapter 3.
2. Where weather decks are intended to carry deck cargo and the loading is in excess of 8,5 kN/m^2 (0,865 tonne-f/m^2), the scantlings of longitudinals may be required to be increased to comply with the requirements for location (1) in Table 1.4.4 in Pt 4, Ch 1 using the equivalent design head, for specified cargo loadings, for weather decks given in Table 3.5.1 in Chapter 3.
3. For the scantlings of deck longitudinals forward in way of the cargo tanks of oil tankers (*see* 1.1.4) or ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11, as applicable.
4. The thickness of flat bar longitudinals situated outside the line of openings is to be not less than the following:
   (a) $t = \dfrac{d_w}{18\sqrt{k_L}}$ mm
   where longitudinal continuous through bulkhead
   (b) $t = \dfrac{d_w}{15\sqrt{k_L}}$ mm
   where longitudinal cut at bulkhead
5. The web depth of longitudinal, d_w, is to be not less than 60 mm.

Table 5.2.4 Weather deck beams forward

Location	Modulus, cm^3	Inertia, cm^4
(1) Forward of 0,075*L* from the F.P.	The lesser of the following: (a) $Z = k\,(800K_1\,T\,D + 5{,}4B_1 s\,h_1\,l_e^2) \times 10^{-4}$ (b) $Z = 10{,}8B_1\,s\,k\,h_1\,l_e^2 \times 10^{-4}$	—
(2) Between 0,075*L* and 0,12*L* from the F.P.	The lesser of the following: (a) $Z = k\,(800K_1\,T\,D + K_3\,B_1\,s\,h_1\,l_e^2) \times 10^{-4}$ (b) $Z = 2K_3\,B_1\,s\,k\,h_1\,l_e^2 \times 10^{-4}$	—
(3) Aft of 0,12*L* from the F.P.	As required for location (1) of Table 1.4.5 in Pt 4, Ch 1	—
(4) In way of the crown of a tank	As (1), (2) or (3), as applicable, or $Z = \dfrac{0{,}0113\rho\,s\,k\,h_4\,l_e^2}{b}$ whichever is the greater	$I = \dfrac{2{,}3}{k}\,l_e\,Z$

Symbols

B, D, T, s, ρ, *k* as defined in 1.4.1

b = 1,4 for rolled or built sections
= 1,6 for flat bars

h_1 = weather head, in metres, as defined in Ch 3,5

h_4 = tank head, in metres, as defined in Ch 3,5

l_e as defined in 1.4.1, but is to be taken not less than 1,83 m

K_1 = a factor dependent on the number of decks (including a bridge superstructure) at the position of the beam under consideration as follows:

1 deck	20,0
2 decks	13,3
3 decks	10,5
4 decks or more	9,3

For a forecastle deck, K_1 is to be taken as 13,3

K_3 = a factor dependent on the location of the beam as follows:

Span adjacent to ship's side	3,6
Elsewhere	3,3

B_1 = *B*, but need not be taken greater than 21,5 m

NOTES
1. Beams at the upper deck inside superstructures are to have scantlings determined as for a lower deck, *see* Table 1.4.5 in Pt 4, Ch 1.
2. Where weather decks are intended to carry deck cargo and the loading is in excess of 8,5 kN/m^2 (0,865 tonne-f/m^2), the scantlings of beams are also to comply with the requirements for location (2) in Table 1.4.5 of Pt 4, Ch 1 using the equivalent design head, for specified cargo loadings, for weather decks given in Table 3.5.1 in Chapter 3.
3. The web depth of beams, d_w, is to be not less than 60 mm.
4. The scantlings of deck beams forward in way of the cargo tanks of oil tankers or ore carriers will be specially considered, *see* Pt 4, Ch 9,1.3.10.

2.4 Deck supporting structure

2.4.1 The arrangements and scantlings of supporting structure are generally to be in accordance with the requirements given in Pt 4, Ch 1,4 using the heads given in Ch 3,5 for the particular region concerned, except as required by 2.4.2 to 2.4.4.

2.4.2 The spacings of girders and transverses are generally not to exceed the values given in Table 5.2.5.

2.4.3 Primary structure in the topside tanks of bulk carriers is to comply with the requirements of Pt 4, Ch 7,7.

2.4.4 Primary structure in the cargo tanks of oil tankers and ore carriers is to be determined from Pt 4, Ch 9, Ch 10 or Ch 11, as applicable.

2.5 Deck openings

2.5.1 In dry cargo ships the requirements for deck openings given in Pt 4, Ch 1,4 are generally applicable throughout the forward region, except that forward of 0,25*L* from the F.P.:

(a) The radii or dimensions of the corners of main cargo hatchway openings on the strength deck are to be in accordance with the requirements of Pt 4, Ch 1,4.5. The thickness of the insert plates, where required, is not to be less than 20 per cent greater than the adjacent deck thickness outside the line of openings, with a minimum increase of 3 mm.

(b) Insert plates will be required at lower decks in way of any rapid change in hull form to compensate for loss of deck cross-sectional area. Otherwise, insert plates will not normally be required.

(c) Compensation and edge reinforcement for openings outside the line of main hatchways will be considered, bearing in mind their position, the deck arrangements and the type of ship concerned.

Table 5.2.5 Spacing of girders and transverses under strength/weather decks forward

Location	Maximum spacing	
	Girders in association with transverse framing system	Transverses in association with longitudinal framing system
(1) Forward of the collision bulkhead	3,7 m	2,5 m where $L \leq 100$ m 3,5 m where $L \geq 300$ m Intermediate values by interpolation
(2) Between the collision bulkhead and 0,075*L* from the F.P.	3,7 m	
(3) In way of a deep tank, forward of 0,2*L* from the F.P.	–	3,0 m where $L \leq 100$ m 4,2 m where $L \geq 300$ m Intermediate values by interpolation
(4) Elsewhere in way of dry cargo spaces or deep tanks, *see* Note 1	–	3,8 m where $L \leq 100$ m (3,2 + 0,006*L*) m where $L > 100$m

NOTES
1. For the maximum spacing of transverses in the cargo tanks of oil tankers or ore carriers, *see* Pt 4, Ch 9,9.
2. For the maximum spacing of transverses in dredgers, *see* Pt 4, Ch 12,5.

2.5.2 For deck openings in way of the cargo tanks in oil tankers and ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11, as applicable. For main cargo hatchway openings on bulk carriers and container ships, *see also* Pt 4, Ch 7 and Ch 8, as applicable.

■ *Section 3*
Shell envelope plating

3.1 General

3.1.1 Where the shell is longitudinally framed in the midship region, this system of framing is to be carried as far forward as practicable. In the case of oil tankers (*see* 1.1.4), longitudinal framing is to extend at least to the forward end of the cargo tanks.

3.2 Keel

3.2.1 The scantlings of bar keels at the fore end are to be the same as in the midship region as required by Pt 4, Ch 1,5.

3.2.2 The thickness and width of plate keels in the forward region are to be the same as required in the midship region for the particular type of ship concerned, *see* Part 4.

3.3 Stem

3.3.1 Bar stems may be either steel castings or steel forgings complying with the requirements of Chapter 3 of the Rules for Materials (Part 2) for rolled steel flat bars or Chapter 5 of the Rules for Materials (Part 2) for solid round bars. The scantlings of bar stems are to comply with Table 5.3.1.

3.3.2 The scantlings of plate stems are to be determined from Table 5.3.1. Plate stems are to be supported by horizontal diaphragms positioned in line with the side stringers or perforated flats with intermediate breasthook diaphragms. Diaphragms are to be spaced not more than 1,5 m apart, measured along the stem. Where the stem plate radius is large, a centreline stiffener or web will be required.

3.4 Bottom shell and bilge

3.4.1 The thickness of bottom shell and bilge plating in the forward region for ships not requiring additional strengthening of bottom is to comply with Table 5.3.1.

3.4.2 For thickness of bottom shell and keel when additional bottom strengthening is required, *see* 1.5.

3.4.3 Where longitudinals are omitted in way of radiused bilge plating amidships, the plating thickness forward will be considered in relation to the support derived from the hull form and internal stiffening arrangements.

3.5 Side shell and sheerstrake

3.5.1 The thickness of side shell and sheerstrake plating in the forward region is to be not less than the values given in Table 5.3.1, but may be required to be increased locally on account of high shear forces, in accordance with Ch 4,6.5.

3.5.2 For transversely framed side shells where panting stringers are omitted, *see* 4.4, the side shell plating in the region concerned is to be increased in thickness by the percentages given below:
(a) 15 per cent, where $L \leq 150$ m
(b) 5 per cent, where $L \geq 215$ m
For intermediate values of *L*, the percentage increase is to be obtained by interpolation.

Table 5.3.1 Shell plating forward

Location	Thickness, in mm
(1) Bottom shell and bilge, *see also* 1.5 and Note 5: (a) Forward of 0,075*L* from the F.P. (b) Between 0,075*L* and 0,25*L* from the F.P., *see* Note 7 (c) Aft of 0,25*L* from the F.P., *see* Note 7	$t = (6{,}5 + 0{,}033L)\sqrt{\frac{k\,s_1}{s_b}}$ (*see* Note 1) As (1)(a) or the taper thickness, whichever is the greater The taper thickness (*see* Note 2)
(2) Side shell, *see* Notes 4 and 5: (a) Forward of 0,075*L* from the F.P. (b) Between 0,075*L* and 0,2*L* from the F.P., *see also* 3.5.2 (c) Aft of 0,2*L* from the F.P.	$t = (6{,}5 + 0{,}033L)\sqrt{\frac{k\,s_1}{s_b}}$ (*see* Note 1) As (2)(a) or the taper thickness, whichever is the greater The taper thickness (*see* Note 2)
(3) Sheerstrake, *see* Notes 4 and 5: (a) Forward of 0,075*L* from the F.P.: where $\frac{T}{D} > 0{,}7$ where $\frac{T}{D} \leq 0{,}7$ (b) Between 0,075*L* and 0,2*L* from the F.P., *see* Note 7 (c) Aft of 0,2*L* from the F.P., *see* Note 7	 As (2)(a) for side shell As (4) for a forecastle As (3)(a) or as determined from Table 3.2.1 in Chapter 3 The taper thickness (*see* Note 2)
(4) Forecastle, *see* Notes 4 and 5	$t = (7{,}0 + 0{,}02L)\sqrt{\frac{k\,s_1}{s_b}}$
(5) Stem, *see* Notes 4 and 5: (a) Bar stem: below load waterline at stem head (b) Plate stem: below load waterline at stem head	 A_1 = (1,6*L* – 32) cm^2 or *L* cm^2 whichever is the greater $A_2 = 0{,}75\,A_1$ cm^2 $t = (5{,}0 + 0{,}083L_2)\sqrt{k}$ mm *t* = as (2)(a) for side shell

NOTES
1. For ships where $L \leq 70$ m this thickness may be reduced by 1 mm, but it is to be not less than 6 mm.
2. The taper thickness is to be determined from Table 3.2.1 in Chapter 3.
3. For thickness of shell plating in way of the cargo and fore peak tanks of oil tankers or ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11, as appropriate.
4. In offshore supply ships the thickness of side shell is to be not less than 9 mm.
5. For trawlers and fishing vessels, *see* Pt 4, Ch 6,5.
6. For fast cargo ships, *see* Pt 4, Ch 1,3.
7. For oil tankers the thickness is also to be in accordance with Pt 4, Ch 9,4.3.3.

Symbols

L, B, D, T, s, k as defined in 1.4.1
s_1 = *s*, but to be taken as not less than s_b
s_b = standard frame spacing, in mm, as follows:

Region	Bottom shell s_b	Side shell s_b
Forward of 0,05*L* from the F.P.	$\left(470 + \frac{L}{0{,}6}\right)$ or 600*	$\left(470 + \frac{L}{0{,}6}\right)$ or 600*
Between 0,05*L* and 0,2*L* from the F.P.	$\left(470 + \frac{L}{0{,}6}\right)$ or 700*	$\left(470 + \frac{L}{0{,}6}\right)$ or 700*
Between 0,2*L* and 0,25*L* from the F.P.	$\left(510 + \frac{L_2}{0{,}6}\right)$	

*whichever is the lesser

A_1 = cross-sectional area of bar stem below load waterline, in cm^2
A_2 = cross-sectional area of bar stem at stem head, in cm^2
L_2 = *L*, but need not be taken greater than 215 m

3.5.3 The side shell plating of increased thickness required by 3.5.2 is to be continued forward past the fore peak or collision bulkhead. In addition, horizontal brackets in line with the fore peak stringers are to be fitted at the aft side of the bulkhead where practicable. The brackets are to be the same thickness as the side shell and are to extend from the bulkhead to the adjacent shell frame and be connected thereto. Transversely the toes of the brackets are to extend past the outboard stiffener of the bulkhead to clear any cut out in the bulkhead stringer.

3.5.4 The sheerstrake taper thickness is to be increased by 20 per cent at the ends of a bridge superstructure extending out to the ship's side irrespective of position. Similar strengthening is to be fitted in way of the end of a forecastle if this occurs at a position aft of 0,25*L* from the F.P. No increase is required if the forecastle end bulkhead lies forward of 0,2*L* from the F.P. The increase at intermediate positions of end bulkhead is to be obtained by interpolation.

3.5.5 The shell plating may be required to be increased in thickness locally in way of hawse pipes, *see* Ch 13,7.8.

3.5.6 The shell plating is to be increased in thickness locally in way of a bulbous bow, *see* 6.5.6.

3.6 Shell openings

3.6.1 In general, compensation will not be required for holes in the sheerstrake which are clear of the gunwale, or for any deck openings situated outside the line of main hatchways and whose depth does not exceed 20 per cent of the depth of the sheerstrake or 380 mm, whichever is the lesser. Openings are not to be cut in a rounded gunwale. Cargo door openings are to have well rounded corners, and the proposed compensation for the door openings will be individually considered.

3.6.2 Sea inlet and other openings are to have well rounded corners. The thickness of sea inlet box plating is generally to be the same as the adjacent shell. It is however, to be not less than 12,5 mm, and need not exceed 25 mm.

■ *Section 4* Shell envelope framing

4.1 General

4.1.1 Requirements are given in this Section for both longitudinal and transverse framing systems. Where longitudinal framing is adopted in the midship region it is to be carried as far forward as practicable. In the case of oil tankers (*see* 1.1.4), longitudinal framing is to be continued at least to the fore end of the cargo tanks.

4.1.2 End connections of longitudinals to bulkheads are to provide adequate fixity, lateral support and, so far as practicable, direct continuity of longitudinal strength, *see also* Ch 10,3. Where *L* exceeds 215 m, the bottom longitudinals are to be continuous in way of both watertight and non-watertight floors, but alternative arrangements will be considered. Higher tensile steel longitudinals within 10 per cent of the ship's depth at the bottom and deck are to be continuous irrespective of the ship length.

4.1.3 Stiffeners and brackets on side transverses, where fitted on one side and connected to higher tensile steel longitudinals between the base line and 0,8*D* above the base line, are to have their heels well radiused to reduce stress concentrations. Where a symmetrical arrangement is fitted, i.e. bracket or stiffening on both sides, and it is connected to higher tensile steel longitudinals, the toes of the stiffeners or brackets are to be well radiused. Alternative arrangements will be considered if supported by appropriate direct calculations.

4.1.4 Where higher tensile steel side longitudinals pass through transverse bulkheads in the cargo area, well radiused brackets of the same material are to be fitted on both the fore and aft side of the connection between the upper turn of bilge and 0,8*D* above the base line. Particular attention is to be given to ensuring the alignment of these brackets. Alternative arrangements will be considered if supported by appropriate direct calculations.

4.1.5 For ships intended to load or unload while aground, *see* Ch 9,12.

4.2 Shell longitudinals

4.2.1 The scantlings of bottom and side shell longitudinals in the forward region are to comply with the requirements given in Table 5.4.1. For the scantlings of bottom shell longitudinals where additional bottom strengthening is required, *see* 1.5.

4.2.2 End connections of longitudinals to bulkheads are to provide adequate fixity, lateral support and so far as practicable, direct continuity of longitudinal strength, *see also* Ch 10,3.

4.3 Shell framing

4.3.1 The scantlings of side frames in the forward region are to comply with the requirements given in Table 5.4.2.

4.3.2 The scantlings of main frames are normally to be based on Rule standard brackets at top and bottom, whilst the scantlings of 'tween deck frames are normally to be based on a Rule standard bracket at the top only.

Table 5.4.1 Shell framing (longitudinal) forward

Location	Modulus, in cm^3
(1) Side longitudinals in forecastle	$Z = 0{,}0075 s\, k\, l_e^2\, (0{,}6 + 0{,}167 D_1)$
(2) Side longitudinals in way of dry spaces including double skin construction:	
(a) Forward of the collision bulkhead	$Z = 0{,}007 s\, k\, h_{T1}\, l_e^2\, F_s$ but not to be less than as required by (1)
(b) Between the collision bulkhead and 0,2*L* from the F.P.	As (a) above or as required in the midship region for the particular type of ship concerned, whichever is the greater. However, not to be taken less than as required by (1).
(c) Aft of 0,2*L* from the FP	As required in the midship region for the particular type of ship concerned.
(3) Side longitudinals in way of double skin tanks or deep tanks	The greater of the following: (a) *Z* as from (2) (b) As required by Pt 4, Ch 1,9 for deep tanks.
(4) Bottom and bilge longitudinals	The greater of the following: (a) As required in the midship region for the particular type of ship concerned. (b) As required by 1.5, strengthening of bottom forward, where applicable.

Symbols

L, *D*, *T*, *s*, *k*, as defined in 1.4.1

l_e = as defined in 1.4.1, but is to be taken not less than 1,5 m

L_1 = *L* but need not be taken greater than 190 m

F_s is a fatigue factor to be taken as follows:

(a) For built sections and rolled angle bars:

$$F_s = \frac{1{,}1}{k}\left[1 - \frac{2b_{f1}}{b_f}(1-k)\right] \text{ at } 0{,}6D_1 \text{ above the base line}$$

= 1,0 at D_1 and above, and F_{sb} at the base line intermediate values by linear interpolation

F_{sb} is a fatigue factor for bottom longitudinals

= $0{,}5\,(1 + F_s$ at $0{,}6D_1)$

(b) For flat bars and bulb plates $\frac{b_{f1}}{b_f}$ may be taken as 0,5

where

b_{f1} = the minimum distance, in mm, from the edge of the face plate of the side longitudinal under consideration to the centre of the web plate, *see* Fig. 9.5.1 in Pt 4, Ch 9

b_f = the width of the face plate, in mm, of the side longitudinal under consideration, *see* Fig. 9.5.1 in Pt 4, Ch 9

T_1 = *T* but not to be taken less than $0{,}65D_1$

D_1 = $T + H_b$ metres, where H_b is the minimum bow height, in metres, obtained from Ch 3,6.1

$$h_{T1} = f_w\, C_w \left(1 - \frac{h_6}{D_1 - T_1}\right) F_\lambda$$, in metres, for longitudinals above the waterline at draught T_1 where

$f_w \left(1 - \frac{h_6}{D_1 - T_1}\right)$ is not to be taken less than 0,7

$$= \left[h_6 + f_w\, C_w \left(1 - \frac{h_6}{2T_1}\right)\right] F_\lambda$$, in metres, for longitudinals below the waterline at draught T_1

where

f_w = 1,0 at 0,2*L* from F.P. and 1,71 at, and forward of, 0,15*L* from F.P. Intermediate positions by interpolation

h_6 = vertical distance, in metres, from the waterline at draught T_1, to the longitudinal under consideration

F_λ = 1,0 for $L \le 200$ m

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

C_w = a wave head, in metres = $7{,}71 \times 10^{-2}\, L e^{-0{,}0044L}$

where

e = base of natural logarithms 2,7183

NOTE

Where struts are fitted midway between transverses in double skin construction, the modulus of the side longitudinals may be reduced by 50*k* per cent from that obtained for locations (2) and (3) as applicable.

4.3.3 End connections of transverse main and 'tween deck frames are to be in accordance with Ch 10,3. For bulk carriers the end connections of main frames in cargo holds are to be in accordance with Pt 4, Ch 7,6.2.5 to 6.2.12. Where brackets are omitted at the foot of main frames in cargo spaces, small easing brackets are to be fitted forward of 0,15*L* from the F.P.

4.4 Panting stringers in way of transverse framing

4.4.1 In lower hold or deep tank spaces panting stringers are generally to be fitted in line with each stringer or flat in the fore peak space and extending back to 0,15*L* from the F.P. These stringers may be omitted if the shell plating is increased in thickness as required by 3.5.2. Where the span of the main frames exceeds 9 m, panting stringers are to be fitted irrespective of whether the shell plating is increased in thickness or not. These stringers are to be arranged in line with alternate stringers or flats in the fore peak and are to extend back to 0,2*L* from the F.P.

Table 5.4.2 Shell framing (transverse) forward

Location	Modulus, in cm^3	Inertia, in cm^4
(1) Frames in fore peak spaces and lower 'tween decks over, *see* Note 1	$Z = K_1\, s\, k\, T\, D_2\, S_1 \times 10^{-3}$	$I = \dfrac{3{,}5}{k} S_1 Z$
(2) Frames in upper 'tween decks and forecastles forward of the collision bulkhead, *see* Notes 1, 2 and 8	The greater of the following: (a) $Z = C\, s\, k\, h_{T1}\, H^2 \times 10^{-3}$ (b) $Z = 9{,}1\, s\, k\, D_1 \times 10^{-3}$	$I = \dfrac{3{,}5}{k} HZ$
(3) Main and 'tween deck frames (including forecastle) between the collision bulkhead and 0,15*L* from the F.P., *see* Notes 1 to 4 and 8	The greater of the following: (a) $Z = C\, s\, k\, h_{T1}\, H^2 \times 10^{-3}$ (b) $Z = 9{,}1\, s\, k\, D_1 \times 10^{-3}$	$I = \dfrac{3{,}5}{k} HZ$
(4) Main and 'tween deck frames between 0,15*L* and 0,2*L* from the F.P. in dry cargo spaces, *see* Notes 1 to 4 and 8	The greater of the following: (a) $Z = C\, s\, k\, h_{T1}\, H^2 \times 10^{-3}$ (b) $Z = 9{,}1\, s\, k\, D_1 \times 10^{-3}$	$I = \dfrac{3{,}2}{k} HZ$
(5) Panting stringers, *see* Note 5	Web depth, d_w, same depth as frames Web thickness, $t = 6 + 0{,}025L_2$ mm Face area, $A = kS_2\,(H + 1)$ cm^2	
(6) Main and 'tween deck frames elsewhere, *see* Notes 1 to 4	As required in the midship region for the particular type of ship concerned	

Symbols

L, *D*, *T*, *s*, *k* as defined in 1.4.1

L_2 = *L* but need not be taken greater than 215 m

D_1 = $T + H_b$, in metres, where H_b is defined in Ch 1,6.1.11

D_2 = D_1, but is to be taken not greater than 16 m, nor less than 6,0 m

H = H_{MF} or H_{TF} as applicable, *see* Note 7

H_{MF} = vertical framing depth, in metres, of main frames as shown in Fig. 5.4.1 but is to be taken not less than 3,5 m, *see* Note 6

H_{TF} = vertical framing depth, in metres, of 'tween deck frames as shown in Fig. 5.4.1 but is to be taken not less than 2,5 m

K_1 = 2,3 for peak tanks
= 1,87 for 'tween decks over peak tanks

S_1 = vertical spacing of peak stringers or height of lower 'tween deck above the peak, in metres, as applicable

S_2 = vertical spacing of panting stringers, in metres

C = end connection factor
= 3,4 where two Rule standard brackets fitted
= 3,4 (1,8 – 0,8(l_a/l)) where one Rule standard bracket and one reduced bracket is fitted
= 3,4 (2,15 – 1,15 (l_{amean}/l)) where two reduced brackets are fitted
= 6,1 where one Rule standard bracket is fitted
= 6,1 (1,2 – 0,2 (l_a/l)) where one reduced bracket is fitted
= 7,3 where no brackets are fitted.
The requirements for frames where brackets larger than Rule standard are fitted will be specially considered

l = length, in mm, as derived from Pt 3, Ch 10,3.4.1

l_a = equivalent arm length, in mm, as derived from Pt 3, Ch 10,3.4.1

l_{amean} = mean equivalent arm length, in mm, for both brackets

T_1 = *T* but not to be taken less than $0{,}65D_1$

h_{T1} = head, in metres, at mid-length of *H*
$= f_w\, C_w \left(1 - \dfrac{h_6}{D_1 - T}\right) F_\lambda$, in metres for frames where the mid-length of frame is above the waterline at draught T_1
where $f_w \left(1 - \dfrac{h_6}{D_1 - T_1}\right)$ is not to be taken less than 0,7
$= \left[h_6 + f_w\, C_w \left(1 - \dfrac{h_6}{2T_1}\right)\right] F_\lambda$, in metres for frames where the mid-length of frame is below the waterline at draught T_1

where

f_w = 1,0 at 0,2*L* from F.P. and 1,71 at, and forward of, 0,15*L* from F.P. Intermediate positions by interpolation

h_6 = vertical distance, in metres, from the waterline at draught T_1 to the mid-length of *H*

F_λ = 1,0 for $L \le 200$ m
= [1,0 + 0,0023 (*L* – 200)] for $L > 200$ m

C_w = a wave head , in metres
= $7{,}71 \times 10^{-2}\, L e^{-0{,}0044L}$
where *e* = base of natural logarithms 2,7183

NOTES
1. For framing in the fore end of fishing vessels, *see* Pt 4, Ch 6,6.
2. In offshore supply ships the moduli of main and 'tween deck frames are to be 25 per cent greater than given in (2), (3) and (4).
3. In way of the cargo tanks of oil tankers or ore carriers, the scantlings of frames are also to comply with the requirements for frames in the midship region of such ships, *see* Pt 4, Ch 9, Ch 10 or Ch 11, as applicable.
4. In bulk carriers the scantlings of frames are also to comply with the requirements of Pt 4, Ch 7,6 in which the requirements of Table 7.6.1 location (1) are to be multiplied by the following factor:
Between 0,15*L* and 0,2*L* from the F.P., $C_1 = (0{,}018D_2 + 0{,}82)$, but not to be taken less than 1,0.
Between collision bulkhead and 0,15*L* from the F.P., $C_1 = (0{,}021D_2 + 0{,}96)$.
5. Panting stringers are not required in tugs less than 46 m in length, *see* Pt 4, Ch 3,4.
6. Where the frames are supported by fully effective horizontal stringers, these may be considered as decks for the purpose of determining H_{MF}.
7. Where frames are inclined at more than 15° to the vertical, H_{MF} or H_{TF} is to be measured along a chord between span points of the frame.
8. Except for main frames the modulus for these members need not exceed that derived from (1) using H_{TF} in place of S_1.

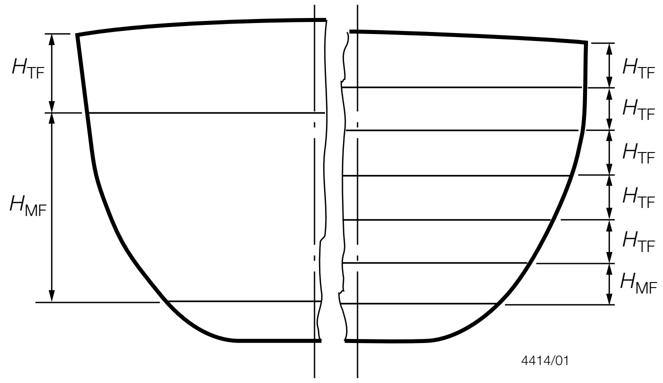


Fig. 5.4.1 Framing depths for transverse frames

4.4.2 In 'tween deck spaces in the region forward of 0,15*L* from the F.P., where the unsupported length of frame exceeds 2,6 m in a lower 'tween deck or 3,0 m in an upper 'tween deck, intermediate panting stringers are generally to be fitted. These stringers may be omitted if the shell plating is increased in thickness as required by 3.5.2.

4.4.3 The scantlings of panting stringers are to be determined from Table 5.4.2.

4.5 Primary structure at sides

4.5.1 For the arrangement of primary structure in peak tanks and deep tanks forward, *see also* Sections 6 and 7.

4.5.2 The spacing of side transverses and web frames is generally not to exceed the values given in Table 5.4.3.

4.5.3 The scantlings of side transverses supporting longitudinal framing and stringers and webs supporting transverse framing in the forward region are to be determined from Table 5.4.4.

4.5.4 The web thickness, stiffening arrangements and end connections of primary supporting members are to be in accordance with the requirements of Ch 10,4.

Table 5.4.3 Spacing of side transverses and web frames forward

Location	Maximum spacing	
	Web frames in association with transverse framing system	Side transverses in association with longitudinal framing system
(1) Forward of the collision bulkhead	5 frame spaces	2,5 m where $L \leq 100$ m 3,5 m where $L \geq 300$ m Intermediate values by interpolation
(2) In way of a forward deep tank adjacent to the collision bulkhead	5 frame spaces	3,0 m where $L \leq 100$ m 4,2 m where $L \geq 300$ m Intermediate values by interpolation
(3) Elsewhere in way of dry cargo spaces or deep tanks	*See* Note 1	3,8 m where $L \leq 100$ m $(0{,}006L + 3{,}2)$ m where $L > 100$m
(4) In way of the cargo tanks of oil tankers, chemical tankers or ore or oil carriers	–	3,6 m where $L \leq 180$ m $0{,}02L$ where $L > 180$ m

NOTES
1. In 'tween decks above deep tanks situated adjacent to the collision bulkhead, web frames are to be fitted in line with those in the tanks.
2. For the maximum spacing of transverses in dredgers, *see* Pt 4, Ch 12,5.

Table 5.4.4 Primary structure forward

Item and location	Modulus, in cm^3	Inertia, in cm^4
Longitudinal framing system		
(1) Side transverses in dry spaces forward of 0,2*L* from the F.P., *see* Note 5: (a) Holds (b) 'tween decks	 $Z = 10\,k\,S\,h_{T1}\,l_e^2$ $Z = C_2\,k\,S\,T\,H_{TF}\sqrt{D}$	—
(2) Side transverses in peak and deep tanks forward of 0,2*L* from the F.P., *see* Notes 1 and 4: (a) where no struts fitted (b) where struts fitted	 $Z = 14{,}1\rho\,k\,S\,h_4\,l_e^2\,\gamma$ or as (1) above, whichever is the greater As in Pt 4, Ch 9,9	$I = \dfrac{2{,}5}{k}\,l_e\,Z$
(3) Side transverses in dry spaces and deep tanks aft of 0,2*L* from the F.P.	As in Pt 4, Ch 1,6, *see* Notes 1 and 2	
Transverse framing system		
(4) Side stringers supported by webs in dry spaces forward of 0,2*L* from the F.P., *see* Note 3	$Z = 7{,}75\,k\,S\,h_{T1}\,l_e^2$	—
(5) Side stringers supported by webs in peak or deep tanks forward of 0,2*L* from the F.P., *see* Notes 1 and 3	$Z = 11{,}7\rho\,k\,S\,h_4\,l_e^2$ or as (4) above, whichever is the greater	$I = \dfrac{2{,}5}{k}\,l_e\,Z$
(6) Web frames supporting side stringers forward of 0,2*L* from the F.P., *see* Notes 1, 2 and 3	Z to be determined from the calculations based on the following assumptions: (a) Fixed ends (b) Point loadings from stringers (c) Head γh_4 or γh_{T1} as applicable (d) Bending stress $\dfrac{93{,}2}{k}$ N/mm^2 $\left(\dfrac{9{,}5}{k}\text{ kgf/mm}^2\right)$ (e) Shear stress $\dfrac{83{,}4}{k}$ N/mm^2 $\left(\dfrac{8{,}5}{k}\text{ kgf/mm}^2\right)$	In deep tanks $I = \dfrac{2{,}5}{k}\,l_e\,Z$
(7) Web frames in 'tween decks, not supporting side stringers, forward of 0,2*L* from the F.P.	$Z = C_3\,k\,S\,T\,H_{TF}\sqrt{D}$	—
(8) Side stringers and web frames in dry spaces and deep tanks aft of 0,2*L* from the F.P.	As in Pt 4, Ch 1,6, *see* Notes 1 and 2	

Symbols

D, T, S, l_e, k, ρ as defined in 1.4.1

B_f = bow fullness factor determined from Fig. 5.4.3 to be taken as 1,0 for framing members located at and abaft 0,2*L* from the forward perpendicular

h_4 = tank head, in metres, as defined in Ch 3,5

h_{T1} = head, in metres, at mid-length of span

$= f_w\,C_w\left(1 - \dfrac{h_6}{D_1 - T_1}\right)F_\lambda$, in metres, where the mid-length of span is above the waterline at draught T_1

where $f_w\left(1 - \dfrac{h_6}{D_1 - T_1}\right)$ is not to be taken less than 0,7

$= \left[h_6 + f_w\,C_w\left(1 - \dfrac{h_6}{2T_1}\right)\right]F_\lambda$, in metres, where the mid-length of span is below the waterline at draught T_1

where

f_w = 1,0 at 0,2*L* from F.P. and 1,71 at, and forward of, 0,15*L* from F.P. Intermediate positions by interpolation

h_6 = vertical distance, in metres, from the waterline at draught T_1 to the mid-length of span

F_λ = 1,0 for $L \le 200$ m

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

C_w = a wave head, in metres

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

where e = base of natural logarithms 2,7183

D_1 = $T + H_b$, in metres, where H_b is defined in Ch 1,6.1.11

T_1 = T but not to be taken less than $0{,}65D_1$

C_2, C_3 = factors obtained from Fig. 5.4.2

H_{TF} = vertical height of 'tween decks, in metres, as shown in Fig. 5.4.1

γ is to be measured at the mid-span of the member as follows:

γ_1 = 1,0 at base line

γ_2 = bow fullness factor (B_f) at 0,6*D* above base

$\gamma_3 = \left(\dfrac{B_f - 1}{2}\right) + 1{,}0$ at depth *D* above base

Intermediate values are to be determined by interpolation.
Minimum value = 1,0

NOTES

1. In way of the cargo tanks, fore peak tanks and dry spaces of oil tankers or ore carriers the scantlings of primary structure are to comply with the requirements of Pt 4, Ch 9, Ch 10 or Ch 11, as appropriate.
2. For bulk carriers *see* Pt 4, Ch 7,6.2.
3. For stringers and webs in fore peaks or deep tanks, *see* also 6.3 and 7.3.
4. In the fore peak, the breadth *S* should be measured along the line of shell. The effective length l_e of the vertical webs should be measured along the line of shell from horizontal flat to horizontal flat, except that it may be taken to the underside of a transverse or strut where fitted.
5. The web depth of side transverses forward of 0,2*L* from the F.P. is to be not less than 2,5 times the depth of the longitudinals supported. The web depth of stringers forward of 0,2*L* is to be not less than 2,2 times the depth of the frames supported.
6. For the primary structure at sides in dredgers with restricted service notations, *see* Table 12.5.2 in Pt 4, Ch 12.

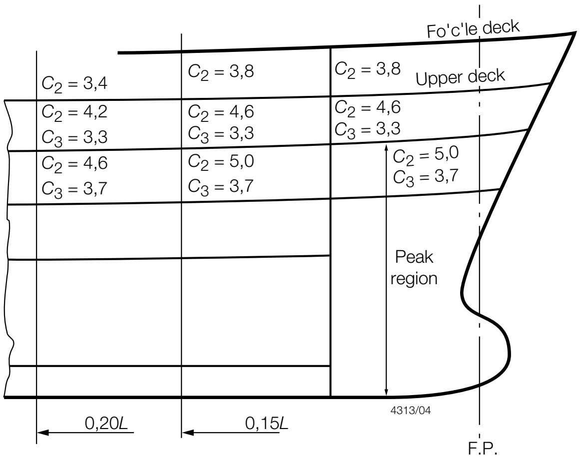


Fig. 5.4.2
Framing factors for primary members

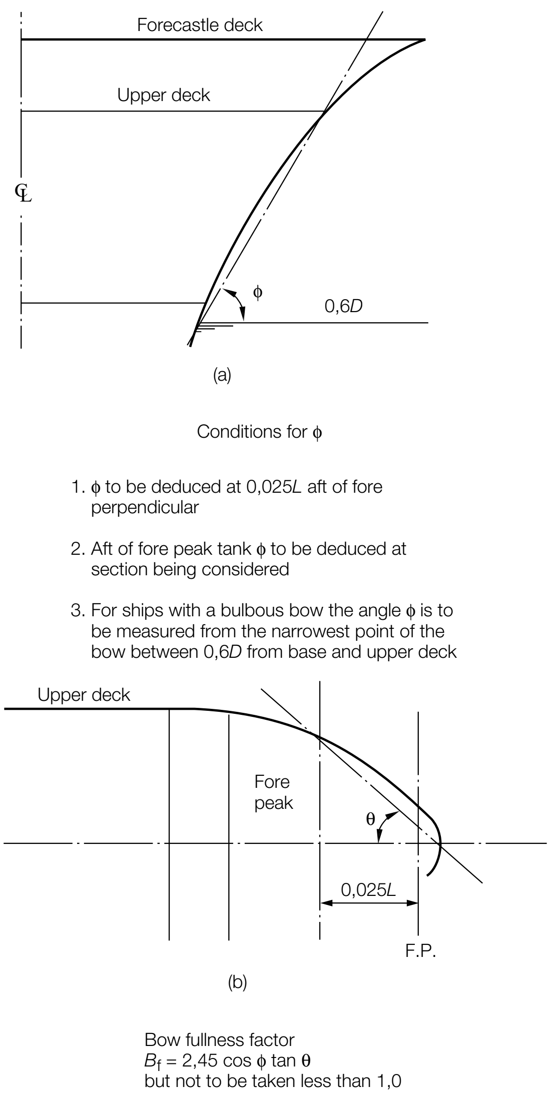


Fig. 5.4.3
Illustration of bow fullness factor determination

■ *Section 5*
Single and double bottom structure

5.1 General

5.1.1 For dry cargo ships exceeding 120 m in length and for all ships which have the notation 'strengthened for heavy cargoes', longitudinal framing is, in general, to be adopted, *see also* Pt 4, Ch 9,1.3 and Pt 4, Ch 10.

5.1.2 For ships requiring additional strengthening of bottom forward the requirements given in 1.5 are also to be complied with, as applicable.

5.1.3 For ships having the notation 'strengthened for heavy cargoes' the requirements of Pt 4, Ch 7,8 are also to be complied with, as applicable.

5.1.4 For ships intended to load or unload while aground, *see* Ch 9,13.

5.1.5 Provision is to be made for the free passage of water and/or air from all parts of single or double bottoms to bilge or tank suctions, account being taken of the pumping rates required.

5.1.6 For passenger ships, *see* Pt 4, Ch 2,6.

5.2 Single bottoms – Transverse framing

5.2.1 In fore peak spaces, for ships of full form the floors are to be supported by a centreline girder or a centreline wash bulkhead. In other cases the centreline girder is to be carried as far forward as practicable. The arrangement and scantlings of the floors and centreline girder are to be sufficient to give adequate stiffness to the structure, but are to be not less than required by Table 5.5.1. The floor panels and the upper edges of the floors and centreline girder are to be suitably stiffened.

5.2.2 In deep tanks forward of 0,2*L* from the F.P. floors are to be supported by a primary centreline girder or centreline bulkhead together with intercostal side girders. In the case of an oil tanker (*see* 1.1.4) or similar ship having longitudinal bulkheads port and starboard, these may be extended to the fore end of the deep tank in lieu of a centreline bulkhead. The arrangement and scantlings of centreline girder, floors and side girders are to be determined from Table 5.5.1, but in way of web frames the depth of the floor and size of the face bar are to be not less than those of the web frame. In general, floors are not to be flanged.

5.2.3 In way of dry cargo spaces forward, the arrangement and scantlings of transversely framed single bottoms are to be generally as required in the midship region as given in Pt 4, Ch 1,7, except as required by Table 5.1.1. The girders forward are to scarf into the normal girder arrangement in the midship region. In ships having considerable rise of floor towards the fore end, the depth of the floors may be required to be increased or the top edge sloped upwards towards the outboard end. In general, floors are not to be flanged.

Table 5.5.1 Single bottom construction forward

Item	Parameter	Requirement
Transverse framing system		
(1) Centre girder: (a) In fore peak tank, or deep tank, forward of 0,2L from the F.P.	Modulus Inertia Web thickness	The greater of the following: $Z = 8{,}5\, k\, S\, h_5\, l_e^2$ cm^3, or $Z = 9{,}75\, \rho\, k\, S\, h_4\, l_e^2$ cm^3 $I = \frac{2{,}5}{k} l_e Z$ cm^4 $t = t_w$ as in Ch 10,4.4
(b) In dry spaces	Web thickness Web depth and face area	Forward of 0,075L from the F.P., $t = (\sqrt{Lk} + 0{,}5)$ mm or 6 mm, whichever is the greater. Between 0,075L and 0,3L from the F.P. the thickness may taper from the midship thickness to the end thickness above As in Pt 4, Ch 1,7
(2) Floors: (a) In fore peak tank, or deep tank, forward of 0,2L from the F.P.	Maximum spacing Web depth (at centreline) Web thickness Minimum face plate area in deep tank	Every frame d_f = (83D + 150) mm or 1400 mm, whichever is the lesser $t = (6{,}0 + 0{,}025L_2)\sqrt{\frac{s_2}{800}}$ mm $A_f = 0{,}85kB$ cm^2
(b) In dry cargo spaces	Maximum spacing Scantlings	Every frame As in Pt 4, Ch 1,7.2
(3) Intercostal side girders: (a) In deep tank, forward of 0,2L from the F.P.	Maximum spacing Web depth Web thickness Minimum face plate area	0,003s_F m As floors $t = t_w$ as in Ch 10,4.4 Suitable stiffener
(b) In dry cargo spaces	Maximum spacing Scantlings	0,003s_F m As in Pt 4, Ch 1,7
Longitudinal framing system		
(4) Centre girder: (a) In deep tanks forward of 0,2L from the F.P.	Scantlings	As in Pt 4, Ch 9,9
(b) In dry spaces	Scantlings	To be specially considered
(5) Bottom transverses: (a) In deep tanks forward of 0,2L from the F.P., *see* Note 4	Maximum spacing Scantlings	3,0 m for $L \leq 100$ m 4,2 m for $L \geq 300$ m Spacing at intermediate lengths by interpolation As in Pt 4, Ch 9,9
(b) In dry spaces	Scantlings	To be specially considered
(6) Intercostal side girders	Scantlings	To be specially considered

Symbols

L, B, D, S, s, l_e, k, ρ as defined in 1.4.1
h_4 = tank head, in metres, as defined in Ch 3,5
h_5 = distance, in metres, from mid-point of span to the following positions:
(a) forward of 0,15L from the F.P., 3 m above the deck height obtained from Ch 3,6.1
(b) at 0,2L from the F.P., the upper deck at side
(c) between 0,15L and 0,2L from the F.P., by interpolation between (a) and (b)
s_F = transverse frame spacing, in mm
s_2 = spacing of stiffener, in mm, but to be taken not less than 800 mm
L_2 = L but need not be taken greater than 215 m

NOTES
1. For single bottom construction in way of the cargo tanks of oil tankers, *see* Pt 4, Ch 9,1.3 and Pt 4, Ch 10.
2. For minimum thickness of structure within cargo tanks and fore peak tanks in oil tankers, *see* Pt 4, Ch 9,10.2 and Pt 4, Ch 10,7.2
3. For single bottom construction in dredgers, *see* Pt 4, Ch 12,6.
4. For ships having one or more longitudinal bulkheads the maximum spacing may be increased but is not to exceed that for the midship region.

5.3 Single bottoms – Longitudinal framing

5.3.1 In deep tanks forward of 0,2*L* from the F.P., bottom transverses are to be supported by a primary centreline girder or a centreline bulkhead. In addition, an intercostal side girder is generally to be fitted port and starboard. In the case of an oil tanker (*see* 1.1.4) or similar ship having longitudinal bulkheads port and starboard, these may be extended to the fore end of the deep tank in lieu of a primary centreline support and intercostal girders. The spacing of bottom transverses and scantlings of the centreline girder, bottom transverses and side girders are to be as required by Table 5.5.1.

5.3.2 The requirements for longitudinally framed single bottoms in way of dry cargo spaces will be specially considered.

5.4 Double bottoms

5.4.1 The minimum depth of centre girder forward is generally to be the same as that required in the midship region by Part 4 for the particular type of ship concerned, but in ships with considerable rise of floor, a greater depth may be required at the fore end to provide adequate access throughout the double bottom tank.

5.4.2 Where the height of the double bottom varies, this variation is generally to be made gradual by sloping the inner bottom over an adequate longitudinal extent. Knuckles in the plating are to be arranged close to plate floors. Otherwise, suitable scarfing arrangements are to be made.

5.4.3 The arrangement and scantlings of girders, floors and inner bottom plating and the section modulus of inner bottom stiffening are to be determined from Table 5.5.2. In other respects the structural arrangements are to be as detailed in Part 4 for the particular type of ship concerned.

5.4.4 For double bottom construction in way of the cargo tanks of oil tankers or ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11, as appropriate.

Table 5.5.2 Double bottom construction forward

Item and parameter	Requirements: Transverse framing	Requirements: Longitudinal framing
(1) Centre girder: (a) Thickness forward of 0,075*L* from the F.P. (b) Thickness between 0,075*L* and 0,3*L* from the F.P.	$t = (0{,}008\, d_{DB} + 2)\sqrt{k}$ mm As determined by a taper line from the midship thickness given in Pt 4, Ch 1,8 to the end thickness as for (1) (a)	
(2) Plate floors: (a) Maximum spacing forward of 0,2*L* from the F.P. (b) Maximum spacing aft of 0,2*L* from the F.P. (c) Scantlings	$0{,}002 s_F$ m As for midship region As in Pt 4, Ch 1,8	2,5 m As for midship region, *see* Note 5 As in Pt 4, Ch 1,8
(3) Watertight floors and bracket floors	As in Pt 4, Ch 1,8	As in Pt 4, Ch 1,8
(4) Side girders, *see* Note 1: (a) Maximum spacing forward of 0,2*L* from the F.P. (b) Maximum spacing aft of 0,2*L* from the F.P. (c) Scantlings	$0{,}003 s_F$ m As for midship region As in Pt 4, Ch 1,8	$0{,}004 s_L$ or 3,7 m whichever is the lesser As for midship region, *see* Note 5 As in Pt 4, Ch 1,8
(5) Inner bottom plating, *see* Note 2: (a) Thickness at or forward of 0,075*L* from the F.P. (b) Thickness between 0,075*L* and 0,3*L* from the F.P. (c) In way of deep tanks or holds used for the carriage of water ballast or where the double bottom tank is common with a wing ballast tank	$t = (0{,}00127(s + 660)\sqrt[4]{k^2 LT})$ mm or 6,5 mm, whichever is the greater, *see* Notes 3, 4 and 5 As determined by a taper line from the midship thickness given in Pt 4, Ch 1,8 to the end thickness as for (5) (a), but not less than 6,5 mm, *see* Notes 3, 4 and 5 $t = \left(0{,}004\, s\, f \sqrt{\frac{\rho\, k\, h_4}{1{,}025}} + 2{,}5\right)$ mm or 6,5 mm, whichever is the greater	
(6) Inner bottom longitudinals	As in Pt 4, Ch 1,8, *see* Notes 2 and 5	

Symbols

L, *T*, *S*, *s*, *k*, ρ as defined in 1.4.1

d_{DB} = minimum depth of centre girder as required by Pt 4, Ch 1,8

$f = 1{,}1 - \frac{s}{2500S}$ but to be taken not greater than 1,0

h_4 = tank head, in metres, as defined in Ch 3,5

s_F = transverse frame spacing, in mm

s_L = spacing of bottom longitudinals, in mm

NOTES

1. The girders forward of 0,2*L* are to be suitably scarfed into the midship girder arrangement.
2. For double bottom construction in way of the cargo tanks of oil tankers or ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11, as appropriate.
3. In way of hatches the tank top taper thickness is to be increased by 2 mm if no ceiling is fitted, but is to be taken not less than 7,5 mm.
4. Where cargo is to be regularly discharged by grabs the tank top taper thickness is to be increased by 5,0 mm if no ceiling is fitted, or by 3,0 mm where ceiling is fitted.
5. For ships having the notation 'strengthened for heavy cargoes', the requirements of Pt 4, Ch 7,8 are also to be complied with.

■ *Section 6* Fore peak structure

6.1 General

6.1.1 The requirements given in this Section apply to the arrangement of primary structure supporting the peak side framing and bulbous bow, the arrangement and scantlings of wash bulkheads and perforated flats, and the scantlings of collision bulkheads.

6.1.2 In ships of very full form it is recommended that transverse framing and side transverses supporting longitudinal framing, together with attached floors and beams, be inclined at an angle to the centreline of ship so that the frames or transverses lie as near normal to the shell plating as possible.

6.2 Bottom structure

6.2.1 The bottom of the peak space is generally to be transversely framed with arrangements and scantlings as detailed in 5.2.1. Longitudinally framed bottom structure will be specially considered.

6.3 Side structure – Transverse framing

6.3.1 Above the floors, transverse side framing is to be supported by one of the following arrangements:

(a) Side stringers spaced about 2,0 m apart and supported by struts fitted at alternate frames. The struts are to be bracketed to the frames and where the span is long, supported at the centreline by a complete or partial wash bulkhead or equally effective structure. Intermediate frames are to be bracketed to the stringer plates.

(b) Side stringers spaced about 2,0 m apart and supported by web frames. The upper ends of the web frames are to be supported under the tank top by suitable deep beams or buttresses which should generally form a ring structure.

(c) Perforated flats spaced not more than 2,5 m apart. The area of perforations in each flat is to be not less than 10 per cent of the total area of the flat. The plating is to be suitably framed in way of openings.

(d) A combination of the above arrangements.

6.3.2 Where the depth of the peak space exceeds 10 m, a perforated flat is to be arranged at about mid-depth.

6.3.3 Where the length of the space exceeds 10 m and the side framing is supported as required by 6.3.1(a) or (c), additional transverse strengthening in the form of transverse wash bulkheads or web frames is to be provided.

6.3.4 The scantlings of side stringers supported by struts, and also of the struts and their brackets, are to be determined from Table 5.6.1.

6.3.5 The scantlings of side stringers supported by web frames, and also of the web frames, are to be determined from 4.5.

6.3.6 The scantlings of perforated flats are to be determined from Table 5.6.1.

6.4 Side structure – Longitudinal framing

6.4.1 The spacing and scantlings of side transverses supporting longitudinal framing are to be as required by 4.5.

6.4.2 Where the depth of a tank exceeds 10 m, side transverses are generally to be supported by one or more perforated flats or an arrangement of struts.

6.4.3 Suitable transverses or deep beams are to be arranged at the top of the tank and at perforated flats to provide end rigidity to the side transverses.

6.5 Bulbous bow

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

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

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

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

6.5.5 In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or substantial web frames spaced about five frame spaces apart are generally to be fitted.

6.5.6 The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness is to be the same as that required for plated stems by 3.3.2.

6.6 Wash bulkhead

6.6.1 Where a fore peak space is used as a tank and the breadth of the tank at its widest point exceeds 0,5B, a complete or partial centreline wash bulkhead is to be fitted.

6.6.2 Wash bulkheads are to have an area of perforations not less than five per cent nor more than 10 per cent of the area of the bulkhead. The plating is to be suitably stiffened in way of openings.

6.6.3 The scantlings of wash bulkheads are to be determined from Table 5.6.1. Stiffeners are to be bracketed at top and bottom.

6.7 Collision bulkhead

6.7.1 The position and height of the collision bulkhead are to be in accordance with the requirements of Ch 3,4.

6.7.2 The scantlings are to comply with the requirements of Pt 4, Ch 1,9 except that the thickness of plating and modulus of stiffeners are to be not less than 12 per cent greater and 25 per cent greater, respectively, than would be required for a dry space. If the collision bulkhead forms the boundary of a cargo tank or cofferdam in an oil tanker or ore carrier the minimum thickness requirements of Pt 4, Ch 9,10 are also to be complied with.

Table 5.6.1 Fore peak structure

Item	Parameter	Requirement
(1) Unflanged stringers supported by panting beams at alternate frames	Web thickness Web depth	$t = (6{,}0 + 0{,}025L_2)\sqrt{\dfrac{s_1}{600}}$ mm $d_w = (400 + 3{,}3L)\dfrac{S_1}{2{,}0}$ mm
(2) Struts	Cross-sectional area Least inertia	$A = (2{,}5B_1 - 0{,}04L_2)\,k$ cm^2 $I = S_1\,S_2\,h_5\,l_e^2$ cm^4
(3) Brackets supporting stringers and beams	Thickness Arm length	$t = (6{,}0 + 0{,}025L_2)\sqrt{\dfrac{s_1}{600}}$ mm $l_e = \dfrac{150A}{t}$ mm in way of struts $l_e = 0{,}5d_w$ mm at intermediate frames
(4) Perforated flats and wash bulkheads (excluding lowest strake of plating), *see* Notes 1, 2 and 3	Plating thickness Stiffener modulus	$t = (6{,}0 + 0{,}015L)\sqrt{\dfrac{s_2}{800}}$ mm $Z = \dfrac{0{,}0057\,s\,k\,h_6\,l_e^2}{b}$ cm^3
(5) Diaphragms in bulbous bows and lowest strake of wash bulkhead	Plating thickness	$t = (6{,}0 + 0{,}025L_2)\sqrt{\dfrac{s_2}{800}}$ mm

Symbols

L, B, S, s, k as defined in 1.4.1
b = 1,4 for rolled or built sections
= 1,6 for flat bars
h_5 = vertical distance, in metres, from the stringer to a position 3 m above the deck height obtained from Ch 3,6.1
h_6 = vertical distance, in metres, from mid-depth of tank to top of tank
l_e = effective length of stiffening member, in metres, *see* Tables 1.9.1 and 1.9.3 in Pt 4, Ch 1
s_1 = spacing of peak frames, in mm, but to be taken not less than 600 mm
s_2 = spacing of stiffeners, in mm, but to be taken not less than 800 mm
B_1 = B but need not be taken greater than 32 m
L_2 = L but need not be taken greater than 215 m
S_1 = vertical spacing or mean spacing of stringers, in metres
S_2 = horizontal spacing of struts, in metres

NOTES
1. For oil tankers, *see also* Pt 4, Ch 9,10.7.
2. For horizontal flats supporting vertical webs in the fore peak tank, the thickness of the flat in way of the web is to comply with Table 9.7.1(b)(ii) in Pt 4, Ch 9.
3. For minimum thickness within fore peak tanks of oil tankers, *see also* Pt 4, Ch 9,10.2.

6.7.3 Doors, manholes, permanent access openings or ventilation ducts are not to be cut in the collision bulkhead below the freeboard deck, *see also* Pt 5, Ch 13,3. The number of openings in collision bulkheads above the freeboard deck is to be kept to a minimum compatible with the design and proper working of the ship. All such openings are to be fitted with means of closing to weathertight standards.

■ *Section 7* **Forward deep tank structure**

7.1 General

7.1.1 The requirements given in this Section apply to the arrangement of primary structure supporting the side framing, the arrangement and scantlings of wash bulkheads and perforated flats, and the scantlings of boundary bulkheads in way of deep tanks situated forward of 0,2L from the F.P.

7.1.2 For deep tanks situated aft of this position, *see* Pt 4, Ch 1,9.

7.2 Bottom structure

7.2.1 The bottom structure is to comply with the requirements given in 5.2.2, 5.3.1 and 5.4, as applicable.

7.3 Side structure – Transverse framing

7.3.1 Above the floors, transverse framing is to be supported by one of the following arrangements:

(a) Side stringers spaced not more than 5 m apart and supported by web frames. The upper ends of the web frames are to be supported under the tank top by suitable deep beams or buttresses which should generally form a ring system.
(b) Side stringers spaced not more than 5 m apart and spanning from bulkhead to bulkhead. The ends of these stringers are to be connected to horizontal stringers on the transverse bulkheads to form a ring system.
(c) In the case of narrow tanks, perforated flats spaced not more than 5 m apart. The area of perforations is to be not less than 10 per cent of the area of the flat, and the plating is to be suitably stiffened in way of openings.

7.3.2 Where the side framing is supported as required by 7.3.1(a) and the depth of the tank exceeds 16 m, the web frames are to be supported by one of the following:

(a) One or more side stringers spanning from bulkhead to bulkhead.
(b) One or more perforated flats having deep beams or transverses in way of the web frames.
(c) One or more cross ties.

7.3.3 Where the side framing is supported as required by 7.3.1(c) and the length of the tank exceeds 14 m, additional transverse strengthening in the form of transverse wash bulkheads or web frames is to be provided.

7.3.4 The scantlings of stringers and web frames as required by 7.3.1(a) are to be determined from 4.5.

7.3.5 The scantlings of side stringers supporting framing as required by 7.3.1(b) are to be determined from Item (5) in Table 5.4.4.

7.3.6 The scantlings of side stringers supporting web frames as required by 7.3.2(a) are to be determined from Item (6) in Table 5.4.4.

7.3.7 The scantlings of perforated flats as required by 7.3.1(c) or 7.3.2(b) are to be determined from Table 5.6.1.

7.3.8 The scantlings of cross ties are to be determined as for cross ties in the cargo tanks of oil tankers, *see* Pt 4, Ch 9.9. Where the span between the side shell and longitudinal bulkhead exceeds 0,3*B*, additional fore and aft or vertical support for the struts may be required.

7.4 Side structure – Longitudinal framing

7.4.1 The spacing and scantlings of side transverses supporting longitudinal framing are to be as required by 4.5.

7.4.2 Where the depth of the tank exceeds 16 m, the side transverses are to be supported as required by 7.3.2.

7.5 Wash bulkheads

7.5.1 Where the breadth of the tank at its widest point exceeds 0,5*B*, a centreline wash bulkhead is generally to be fitted. If the maximum breadth of tank exceeds 0,7*B*, it is recommended that the centreline bulkhead be made intact. In the case of an oil tanker or similar ship having longitudinal bulkheads port and starboard, these may be extended to the fore end of the deep tank in lieu of a centreline bulkhead.

7.5.2 Wash bulkheads are to have an area of perforations not less than 5 per cent nor more than 10 per cent of the area of the bulkhead. The plating is to be suitably stiffened in way of openings.

7.5.3 The scantlings of wash bulkheads are generally to be as required by Table 5.6.1, but *see also* 7.5.4 to 7.5.6. Stiffeners are to be bracketed at top and bottom.

7.5.4 The thickness of longitudinal bulkheads may be required to be increased to ensure compliance with the shear strength requirements of Ch 4,6. In the case of a centreline or perforated wing bulkhead, the proportion of the total shear force absorbed by the bulkhead will be specially considered.

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

7.5.6 Where longitudinal wash bulkheads support bottom transverses, the lower section of the bulkhead is to be kept free of non-essential openings for a depth equal to 1,75 times the depth of the transverses, and the plating thickness may be required to be increased to meet local buckling requirements.

7.6 Transverse boundary bulkheads

7.6.1 The transverse bulkheads forming the forward and after boundaries of the tank are generally to comply with the requirements of Pt 4, Ch 1,9, except that when the after bulkhead forms the boundary of a cargo tank or cofferdam in an oil tanker or ore carrier, the minimum thickness requirements of Pt 4, Ch 9,10 are also to be complied with.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all types of ship covered by Part 4, except where specifically stated otherwise.

1.1.2 The requirements given are those specific to aft ends and relate to structure situated in the region aft of 0,3*L* from the after perpendicular.

1.1.3 Requirements for cargo space structure within this region not dealt with in this Chapter are to be as detailed in the relevant Chapter of Part 4 for the particular ship type.

1.1.4 The requirements in this chapter are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation. *See* Pt 1, Ch 2,2.3.

1.2 Structural configuration

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

1.2.2 In the case of container ships and open type ships additional requirements may apply as detailed in Pt 4, Ch 8.

1.3 Structural continuity

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

1.3.2 Where longitudinal framing terminates and is replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover. Where a poop is fitted extending forward of 0,15*L* from the A.P., longitudinal framing at the upper deck and topsides is generally to be continued aft of the forward bulkhead of this superstructure. In bulk carriers and oil tankers (*see* 1.1.4) the longitudinal framing at the upper deck is to be maintained over the cargo space region and continued over the aft end region.

1.3.3 In oil tankers (*see* 1.1.4) with machinery aft, continuity of the longitudinal bulkheads is to be maintained as far as is practicable into the machinery space, and suitable taper brackets are to be fitted at their ends.

1.3.4 In bulk carriers (*see* 1.1.4) with machinery aft, continuity of the topside tank and double bottom hopper tank structure is to be maintained over the cargo space region and as far as is practicable continued into the machinery space, and suitable taper brackets are to be arranged at their ends. Also a vertical taper bracket in line with the vertical strake of the topside tank is to be fitted at the forward side of the aft bulkhead of the cargo space region. Where the topside tank and double bottom hopper tank structures terminate at the cargo space aft bulkhead, the vertical strake of the topside tank is to be arranged with an integral taper bracket and continued through the bulkhead into the machinery space for a distance of 0,2*B*, and the ends of the hopper and topside structures are to be arranged with suitable taper brackets. In addition, in way of the cargo space aft bulkhead, a girder or intercostal bulb plate stiffeners (fitted between and connected to the bulkhead vertical stiffeners), are to be arranged on the aft side in line with the sloped bulkheads of the topside and hopper tanks clear of the taper brackets.

1.3.5 In container or similar ships having continuous side tanks or double skin construction in way of the cargo spaces, the longitudinal bulkheads are to be continued as far aft as is practicable and are to be suitably tapered at their ends. Where, due to the ship's form, such bulkheads are stepped, suitable scarfing is to be arranged.

1.4 Symbols and definitions

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

L, B, D, T as defined in Ch 1,6.1

k_L, k = higher tensile steel factor as defined in Ch 2,1.2

l = overall length of stiffening member, in metres, *see* Ch 3,3.3

l_e = effective length of stiffening member, in metres, *see* Ch 3,3.3

s = spacing of secondary stiffeners, in mm

t = thickness of plating, in mm

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

Z = section modulus of stiffening member, in cm^3, *see* Ch 3,3.2

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

I = inertia of stiffening member, in cm^4, *see* Ch 3,3.2.

1.4.2 For the purpose of this Chapter, the after perpendicular, A.P., is defined as the after limit of the Rule length *L*.

Section 2
Deck structure

2.1 General

2.1.1 Where the upper deck is longitudinally framed outside the line of openings in the midship region, this system of framing is to be carried as far aft as possible, *see also* Pt 4, Ch 9,1.3.

2.2 Deck plating

2.2.1 The thickness of strength/weather deck plating is to comply with the requirements of Table 6.2.1.

2.2.2 The thickness of lower deck plating is to comply with the requirements of Table 6.2.2.

2.2.3 The taper thickness of the strength deck stringer plate is to be increased by 20 per cent at the ends of a poop or bridge where the end bulkhead is situated forward of 0,25*L* from the A.P. No increase is required where the end bulkhead lies aft of 0,2*L* from the A.P. The increase at intermediate positions is to be determined by interpolation.

2.2.4 The deck plating thickness and supporting structure are to be suitably reinforced in way of deck machinery, and in way of cranes, masts or derrick posts.

2.2.5 Where long, wide hatchways are arranged at lower decks it may be necessary to increase the deck plating thickness to ensure effective support for side framing.

2.3 Deck stiffening

2.3.1 The scantlings of strength/weather deck longitudinals are to comply with the requirements of Table 6.2.3.

2.3.2 The scantlings of cargo and accommodation deck longitudinals are to comply with the requirements given in Table 1.4.4 in Pt 4, Ch 1.

2.3.3 End connections of longitudinals to bulkheads are to provide adequate fixity, lateral support and so far as practicable, direct continuity of longitudinal strength.

2.3.4 The scantlings of weather deck beams are to comply with the midship requirements for the particular ship type.

2.3.5 The scantlings of lower deck beams are to comply with the requirements of Table 1.4.5 in Pt 4, Ch 1.

2.3.6 End connections of beams are to be in accordance with the requirements of Ch 10,3.

Table 6.2.1 Strength/weather deck plating aft (excluding poop deck)

Symbols	Location	Thickness, in mm
L, s, S, k, ρ as defined in 1.4.1 $f = 1,1 - \frac{s}{2500S}$ but is to be taken not greater than 1,0 h_4 = tank head, in metres, as defined in Ch 3,5 s_b = standard frame spacing as follows: Aft of 0,15*L* from the A.P.: $s_b = \left(510 + \frac{L}{0,6}\right)$ mm or 850 mm, whichever is the lesser s_1 = *s*, but is to be taken not less than s_b	(1) Aft of 0,075*L* from the A.P.	$t = (5,5 + 0,02L)\sqrt{\frac{ks_1}{s_b}}$
	(2) Between 0,075*L* and 0,15*L* from the A.P.	The greater of the following: (a) $t = (5,5 + 0,02L)\sqrt{\frac{ks_1}{s_b}}$ (b) the taper thickness, see Notes 1, 2 and 3 (c) for oil tankers, the thickness is also to be in accordance with Pt 4, Ch 9,4.3.3
	(3) Forward of 0,15*L* from the A.P.	The taper thickness, *see* Notes 1, 2 and 3, or as 2(c) whichever is the greater
	(4) Inside poop extending forward of 0,15*L*	As for a lower deck, *see* Note 4
	(5) In way of the crown of a tank	$t = 0,004sf\sqrt{\frac{\rho k h_4}{1,025}} + 3,5$ or (1) to (4) as applicable, whichever is the greater but not less than 7,5 mm where $L \geq 90$ m, or 6,5 mm where $L < 90$ m

NOTES
1. The taper thickness is to be determined from Table 3.2.1 in Chapter 3.
2. For taper area requirements, *see* Table 3.2.1 in Chapter 3.
3. For thickness of upper deck plating in way of the cargo tanks of oil tankers or ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11.
4. The exposed weather deck taper thickness is to extend into a poop or bridge for at least one-third of the breadth of the ship from the superstructure end bulkhead.

Table 6.2.2 Lower deck plating aft

Symbols	Location	Thickness, in mm
L, s, S, k, ρ as defined in 1.4.1 b = breadth of increased plating, in mm $f = 1,1 - \frac{s}{2500S}$ but is to be taken not greater than 1,0 h_4 = tank head, in metres, as defined in Ch 3,5 K_2 = 2,5 mm at bottom of tank or 3,5 mm at crown of tank s_1 = s, but is to be taken not less than $\left(470 + \frac{L_1}{0,6}\right)$ mm A_f = girder face area, in cm^2 L_1 = L, but need not be taken greater than 190 mm	(1) Aft of 0,075L from the A.P.	$t = 0,01s_1\sqrt{k}$ but not less than 6,5 mm
	(2) Forward of 0,075L from the A.P., inside line of openings	$t = 0,01s_1\sqrt{k}$ but not less than 6,5 mm
	(3) Forward of 0,075L from the A.P., outside line of openings	As determined by a taper line from the midship thickness to the end thickness given by (1)
	(4) In way of the crown or bottom of a tank	$t = 0,004sf\sqrt{\frac{\rho k h_4}{1,025}} + K_2$ or (1), (2) or (3) as applicable, whichever is the greater but not less than 7,5 mm where $L \geq 90$ m, or 6,5 mm where $L < 90$ m
NOTE Where the deck loading exceeds 43,2 kN/m^2, (4,4 tonne-f/m^2), the thickness of plating will be specially considered. This is equivalent to a 'tween deck height of 6,1 m in association with the standard stowage rate of 1,39 m^3/tonne.	(5) Plating forming upper flange of underdeck girders	Clear of cargo hatches $t = \sqrt{\frac{A_f}{1,8k}}$ In way of hatch side girders $t = 1,1\sqrt{\frac{A_f}{1,8k}}$ Minimum breadth b = 760 mm

Table 6.2.3 Strength/weather deck longitudinals aft

Location	Modulus, in cm^3	Inertia, in cm^4
(1) Aft of 0,075L from the A.P.	The greater of the following: (a) $Z = s\,k\,(400h_1 + 0,005\,(l_e\,L_1)^2) \times 10^{-4}$ (b) $Z = 0,0074s\,k\,h_1\,l_e^2$	–
(2) Forward of 0,075L from the A.P., inside line of openings	As (1)	–
(3) Forward of 0,075L from the A.P., outside line of openings	As determined from Table 3.2.1 in Chapter 3, *see* Note 1 For oil tankers (*see* 1.1.4) and dry cargo ships the end modulus for taper at 0,075L from the A.P. is to be derived from Table 5.2.3 item (2)	–
(4) In way of the crown of a tank	$Z = \frac{0,0113\rho\,s\,k\,h_4\,l_e^2}{b}$ or as (1) to (3) as applicable, whichever is the greater	$I = \frac{2,3}{k} l_e Z$

Symbols

L, s, k_L, k, ρ as defined in 1.4.1
b = 1,4 for rolled or built sections
= 1,6 for flat bars
d_w = web depth of longitudinal, in mm
h_1 = weather head, in metres, as defined in Ch 3,5
h_4 = tank head, in metres, as defined in Ch 3,5
l_e = as defined in 1.4.1 but is to be taken not less than 1,5 m
L_1 = L but need not be taken greater than 190 m

NOTES
1. For taper area requirements, *see* Table 3.2.1 in Chapter 3.
2. Where weather decks are intended to carry deck cargo and the loading is in excess of 8,5 kN/m^2 (0,865 tonne-f/m^2) the scantlings of longitudinals are also to comply with the requirements for location (1) in Table 1.4.4 in Pt 4, Ch 1 using the equivalent design head, for specified cargo loadings, for weather decks given in Table 3.5.1 in Chapter 3.
3. For the scantlings of deck longitudinals aft in way of the cargo tanks of oil tankers (*see* 1.1.4) or ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11, as applicable.
4. The thickness of flat bar longitudinals, situated outside the line of openings is to be not less than the following:
   (a) $t = \frac{d_w}{18\sqrt{k_L}}$ mm
   where longitudinal continuous through bulkhead
   (b) $t = \frac{d_w}{15\sqrt{k_L}}$ mm
   where longitudinal cut at bulkhead
5. The web depth of longitudinal, d_w, to be not less than 60 mm.

2.4 Deck supporting structure

2.4.1 The arrangements and scantlings of supporting structure are generally to be in accordance with the requirements given in Pt 4, Ch 1,4 except as required by 2.4.2 to 2.4.4.

2.4.2 At upper and lower decks above the after peak, deep beams are generally to be fitted in way of web frames. Deck girders are generally to be spaced not more than 3,0 m apart.

2.4.3 Primary structure in the topside tanks of bulk carriers is to comply with the requirements of Pt 4, Ch 7,7.

2.4.4 Primary structure in the cargo tanks of oil tankers, or ore carriers, is to be determined from Pt 4, Ch 9, Ch 10 or Ch 11, as applicable.

2.5 Deck openings

2.5.1 In dry cargo ships, the requirements for deck openings given in Pt 4, Ch 1,4 are generally applicable throughout the aft region except that aft of 0,25*L* from the A.P.:

(a) The radii or dimensions of the corners of main cargo hatchway openings of the strength deck are to be in accordance with the requirements of Pt 4, Ch 1,4.5. The thickness of the insert plates, where required, is not to be less than 20 per cent greater than the adjacent deck thickness outside the line of openings, with a minimum increase of 3 mm.

(b) Insert plates will be required at lower decks in way of any rapid change in hull form to compensate for loss of deck cross-sectional area. Otherwise, insert plates will not normally be required.

(c) Compensation and edge reinforcement for openings outside the line of main hatchways will be considered, bearing in mind their position, the deck arrangements and the type of ship concerned.

2.5.2 For deck openings in way of cargo tanks in oil tankers and ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11, as applicable. For main cargo hatchway openings on bulk carriers and container ships, *see also* Pt 4, Ch 7 and Ch 8, as applicable.

■ *Section 3* Shell envelope plating

3.1 General

3.1.1 Where the shell is longitudinally framed in the midship region, this system of framing is to be carried as far aft as practicable.

3.2 Keel

3.2.1 The scantlings of bar keels at the aft end are to be the same as in the midship region as required by Pt 4, Ch 1,5.

3.2.2 The thickness and width of plate keels in the aft region are to be the same as required in the midship region for the particular type of ship concerned, *see* Part 4.

3.3 Bottom shell and bilge

3.3.1 The thickness of bottom shell and bilge plating in the aft region is to comply with the requirements of Table 6.3.1.

3.3.2 Where the bottom is transversely framed and there are large flat areas of shell plating, the buckling stability of the plating will be specially considered, and increased plate thickness or additional stiffening may be required, *see also* 5.2.3.

3.3.3 Where longitudinals are omitted in way of radiused bilge plating amidships, the plating thickness aft will be considered in relation to the support derived from the hull form and internal stiffening arrangements.

3.4 Side shell and sheerstrake

3.4.1 The thickness of side shell and sheerstrake plating in the aft region is to be not less than the values given in Table 6.3.1, but may be required to be increased locally on account of high shear forces, in accordance with Ch 4,6.5.

3.4.2 Increased shell plate thickness may be required where the panting stringers required by 4.4.1 are omitted. The extent and amount of the increase will be specially considered.

3.4.3 The thickness of shell plating is to be increased locally in way of the sternframe, propeller brackets or rudder horn. The increased plate thickness is to be not less than 50 per cent greater than the basic shell end thickness.

3.4.4 The sheerstrake thickness is to be increased by 20 per cent at the ends of a bridge superstructure extending out to the ship's side, irrespective of position. Similar strengthening is to be fitted in way of the end of a poop if this occurs at a position forward of 0,25*L* from the A.P. No increase is required if the poop end bulkhead lies aft of 0,2*L* from the A.P. The increase at intermediate positions of end bulkhead is to be obtained by interpolation.

3.5 Shell openings

3.5.1 In general, compensation will not be required for holes in the sheerstrake which are clear of the gunwale, or for any deck openings situated outside the line of main hatchways and whose depth does not exceed 20 per cent of the depth of the sheerstrake or 380 mm, whichever is the lesser. Openings are not to be cut in a rounded gunwale. Cargo door openings are to have well rounded corners, and the proposed compensation for the door openings will be individually considered.

Table 6.3.1 Shell plating aft

Location	Thickness, in mm	NOTES
(1) Bottom shell and bilge, *see* Notes 4 and 5: (a) Aft of 0,075*L* from the A.P. (b) Between 0,075*L* and 0,15*L* from the A.P., *see* Note 6 (c) Forward of 0,15*L* from the A.P., *see* Note 6	$t = (6{,}5 + 0{,}033L)\sqrt{\frac{k\,s_1}{s_b}}$ (*see* Note 1) As (1) (a) or the taper thickness, whichever is the greater, *see* Note 2 The taper thickness, *see* Note 2	1. For ships where $L \leq 70$ m this thickness may be reduced by 1 mm, but it is to be not less than 6 mm. 2. The taper thickness is to be determined from Table 3.2.1 in Chapter 3. 3. For thickness of shell plating in way of the cargo tanks of oil tankers or ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11, as applicable. 4. In offshore supply ships the thickness of side shell is to be not less than 9 mm. 5. For trawlers and fishing vessels *see* Pt 4, Ch 6,5. 6. For oil tankers the thickness is also to be in accordance with Pt 4, Ch 9,4.3.3.
(2) Side shell, *see* Notes 4 and 5: (a) Aft of 0,075*L* from the A.P. (b) Between 0,075*L* and 0,15*L* from the A.P., *see also* 3.4.2 (c) Forward of 0,15*L* from the A.P.	$t = (6{,}5 + 0{,}033L)\sqrt{\frac{k\,s_1}{s_b}}$ (*see* Note 1) As (2) (a) or the taper thickness, whichever is the greater, *see* Note 2 The taper thickness, *see* Note 2	
(3) Sheerstrake, *see* Notes 4 and 5 (a) Aft of 0,075*L* from the A.P.: where $\frac{T}{D} > 0{,}7$ where $\frac{T}{D} \leq 0{,}7$ (b) Between 0,075*L* and 0,15*L* from the A.P., *see* Note 6 (c) Forward of 0,15*L* from the A.P., *see* Note 6	 As (2) (a) for side shell As (4) for a poop As (3) (a) or as determined from Table 3.2.1 in Chapter 3 The taper thickness, *see* Note 2	
(4) Poop, *see* Notes 4 and 5	$t = (6{,}5 + 0{,}017L)\sqrt{\frac{k\,s_1}{s_b}}$	

Symbols

L, B, D, T, s, k as defined in 1.4.1
s_1 = *s* but to be taken as not less than s_b
s_b = standard frame spacing, in mm, as follows:

Region	Bottom shell s_b	Side shell s_b
Aft of 0,05*L* from the A.P.	$\left(470 + \frac{L}{0{,}6}\right)$ or 600*	$\left(470 + \frac{L}{0{,}6}\right)$ or 600* below the deck next above the load waterline or $\left(470 + \frac{L}{0{,}6}\right)$ or 700* above the deck next above the load waterline
Between 0,05*L* and 0,15*L* from the A.P.	$\left(510 + \frac{L}{0{,}6}\right)$ or 850*	$\left(510 + \frac{L}{0{,}6}\right)$ or 850*

*whichever is the lesser

3.5.2 Sea inlet and other openings are to have well rounded corners and so far as possible, should be kept clear of the bilge radius. The thickness of sea inlet box plating is generally to be the same as the adjacent shell. It is not, however, to be less than 12,5 mm, and need not exceed 25 mm.

■ *Section 4*
Shell envelope framing

4.1 General

4.1.1 Requirements are given in this Section for both longitudinal and transverse framing systems. Where longitudinal framing is adopted in the midship region, it is to be carried as far aft as practicable.

4.1.2 End connections of longitudinals to bulkheads are to provide adequate fixity, lateral support and, so far as practicable, direct continuity of longitudinal strength, *see also* Ch 10,3. Where *L* exceeds 215 m, the bottom longitudinals are to be continuous in way of both watertight and non-watertight floors, but alternative arrangements will be considered. Higher tensile steel longitudinals within 10 per cent of the ship's depth at the bottom and deck are to be continuous irrespective of the ship length.

4.1.3 Stiffeners and brackets on side transverses, where fitted on one side and connected to higher tensile steel longitudinals between the base line and 0,8*D* above the base line, are to have their heels well radiused to reduce stress concentrations. Where a symmetrical arrangement is fitted, i.e. bracket or stiffening on both sides, and it is connected to higher tensile steel longitudinals, the toes of the stiffeners or brackets are to be well radiused. Alternative arrangements will be considered if supported by appropriate direct calculations.

4.1.4 Where higher tensile steel side longitudinals pass through transverse bulkheads in the cargo area, well radiused brackets of the same material are to be fitted on both the fore and aft side of the connection between the upper turn of bilge and 0,8D above the base line. Particular attention is to be given to ensuring the alignment of these brackets. Alternative arrangements will be considered if supported by appropriate direct calculations.

4.1.5 For ships intended to load or unload while aground, *see* Ch 9,13.

4.2 Shell longitudinals

4.2.1 The scantlings of bottom and side shell longitudinals in the aft region are to comply with the requirements given in Table 6.4.1.

4.3 Shell framing

4.3.1 The scantlings of side frames in the aft region are to comply with the requirements given in Table 6.4.2.

Table 6.4.1 Shell framing (longitudinal) aft

Location	Modulus, in cm^3
(1) Side longitudinals in poop	$Z = 0{,}0065\, s\, k\, l_e^2\, (0{,}6 + 0{,}167 D_2)$
(2) Side longitudinals in way of dry spaces including double skin construction:	
(a) Aft of the after peak bulkhead	$Z = 0{,}0085\, s\, k\, h_{T1}\, l_e^2\, F_s$ but not to be less than as required by (1)
(b) Between the after peak bulkhead and 0,2L from the A.P.	$Z = 0{,}007\, s\, k\, h_{T1}\, l_e^2\, F_s$ or as required in the midship region for the particular type of ship concerned, whichever is the greater
(c) Forward of 0,2L from the A.P.	As required in the midship region for the particular type of ship concerned
(3) Side longitudinals in way of double skin tanks or deep tanks	The greater of the following: (a) Z as from (2) (b) As required by Pt 4, Ch 1,9 for deep tanks
(4) Bottom and bilge longitudinals	As required in the midship region for the particular type of ship concerned

Symbols

L, D, T, s, k, as defined in 1.4.1

l_e = as defined in 1.4.1, but is to be taken not less than 1,5 m

D_2 = D_1 but need not be taken greater than 20 m

L_1 = L but need not be taken greater than 190 m

F_s is a fatigue factor to be taken as follows:

(a) For built sections and rolled angle bars

$$F_s = \frac{1{,}1}{k}\left[1 - \frac{2b_{f1}}{b_f}(1-k)\right] \text{ at } 0{,}6D_1 \text{ above the base line}$$

= 1,0 at D_1 and above, and F_{sb} at the base line intermediate values by linear interpolation

F_{sb} is a fatigue factor for bottom longitudinals = 0,5 (1 + F_s at 0,6D_1)

(b) For flat bars and bulb plates $\frac{b_{f1}}{b_f}$ may be taken as 0,5

where

b_{f1} = the minimum distance, in mm, from the edge of the face plate of the side longitudinal under consideration to the centre of the web plate, *see* Fig. 9.5.1 in Pt 4,Ch 9

b_f = the width of the face plate, in mm, of the side longitudinal under consideration, *see* Fig. 9.5.1 in Pt 4, Ch 9

D_1 = D but need not exceed $T + H_b$, in metres, where H_b is the minimum bow height, in metres, obtained from Ch 3,6.1

T_1 = T but not to be taken less than 0,65D_1

h_{T1} = $f_w C_w \left(1 - \frac{h_6}{D_1 - T_1}\right) F_\lambda$, in metres, for longitudinals above the waterline at draught T_1 where $f_w\left(1 - \frac{h_6}{D_1 - T_1}\right)$ is not to be taken less than 0,7

= $\left[h_6 + f_w C_w \left(1 - \frac{h_6}{2T_1}\right)\right] F_\lambda$, in metres, for longitudinals below the waterline at draught T_1

where

f_w = 1,0 at 0,2L from A.P. and 1,32 at and aft of aft peak bulkhead. Intermediate positions by interpolation.

h_6 = vertical distance, in metres, from the waterline at draught T_1, to the longitudinal under consideration

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_λ = 1,0 for $L \leq 200$ m

= [1,0 + 0,0023 (L – 200)] for $L > 200$ m

NOTES

1. Where struts are fitted midway between transverses in double skin construction, the modulus of the side longitudinals may be reduced by 50k per cent from that obtained for locations (2) and (3) as applicable.
2. For modulus and area of side longitudinals in way of a machinery space, *see* Ch 7,3.1.

Table 6.4.2 Shell framing (transverse) aft

Location	Modulus, in cm^3	Inertia, in cm^4
(1) Frames in after peak spaces and lower 'tween decks over	$Z = 1{,}85 s\,k\,T\,D_2\,S_1 \times 10^{-3}$	$I = \frac{3{,}2}{k} S_1 Z$
(2) Frames in upper 'tween decks and poops aft of the after peak bulkhead, *see* Notes 1, 2 and 6	The greater of the following: (a) $Z = C\,s\,k\,h_{T1}\,H^2 \times 10^{-3}$ (b) $Z = 9{,}1 s\,k\,D_1 \times 10^{-3}$	$I = \frac{3{,}2}{k} HZ$
(3) Main and 'tween deck frames (including poop) between the after peak bulkhead and 0,2*L* from the A.P., *see* Notes 1, 2 and 3	The greater of the following: (a) $Z = C\,s\,k\,h_{T1}\,H^2 \times 10^{-3}$ (b) $Z = 9{,}1 s\,k\,D_1 \times 10^{-3}$	$I = \frac{3{,}2}{k} HZ$
(4) Main and 'tween deck frames elsewhere, *see* Notes 1, 2 and 3	As required in the midship region for the particular type of ship concerned	
(5) Panting stringers, *see* Note 4	Web depth, d_w, same depth as frames Web thickness, $t = t_w$ as in Ch 10,4.4 Face area, $A = k\,S_2\,(H + 1)$ cm^2	

Symbols

L, D, T, s, k as defined in 1.4.1

D_1 = D but need not exceed $T + H_b$, in metres, where H_b is the minimum bow height, in metres, obtained from Ch 3,6.1

D_2 = D_1 but is to be taken not greater than 16 m nor less than 6 m

H = H_{MF} or H_{TF} as applicable, *see* Note 3

H_{MF} = vertical framing depth, in metres, of main frames as shown in Fig. 6.4.1 but is not to be taken less than 3,5 m, *see* Note 5

H_{TF} = vertical framing depth, in metres, of 'tween deck frames as shown in Fig. 6.4.1, but is not to be taken less than 2,5 m

S_1 = vertical spacing of peak stringers or height of lower 'tween deck above the peak, in metres, as applicable

S_2 = vertical spacing of panting stringers, in metres

C = end connection factor
= 3,4 where two Rule standard brackets fitted
= 3,4 (1,8 – 0,8(l_a/l)) where one Rule standard bracket and one reduced bracket fitted
= 3,4 (2,15 – 1,15 (l_{amean}/l)) where two reduced brackets fitted
= 6,1 where one Rule standard bracket fitted
= 6,1 (1,2 – 0,2 (l_a/l)) where one reduced bracket fitted
= 7,3 where no brackets fitted
The requirements for frames where brackets larger than Rule standard are fitted will be specially considered

l = length, in mm, as derived from Pt 3, Ch 10,3.4.1

l_a = equivalent arm length, in mm, as derived from Pt 3, Ch 10,3.4.1

l_{amean} = mean equivalent arm length, in mm, for both brackets

T_1 = T but not to be taken less than 0,65D_1

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

$= f_w C_w \left(1 - \frac{h_6}{D_1 - T_1}\right) F_\lambda$, in metres for frames where the mid-length of frame is above the waterline, at draught T_1

$f_w \left(1 - \frac{h_6}{D_1 - T_1}\right)$ is not to be taken less than 0,7

$= \left[h_6 + f_w C_w \left(1 - \frac{h_6}{2T_1}\right)\right] F_\lambda$, in metres for frames where the mid-length of frame is below the waterline at draught T_1

where

f_w = 1,0 at 0,2*L* from A.P. and 1,32 at and aft of aft peak bulkhead Intermediate positions by interpolation.

h_6 = vertical distance in metres from the waterline at draught T_1 to the mid-length of H

F_λ = 1,0 for $L \le 200$ m
= [1,0 + 0,0023 (L – 200)] for $L > 200$ m

C_w = a wave head in metres
= $7{,}71 \times 10^{-2}\,L e^{-0{,}0044L}$
where e = base of natural logarithms 2,7183

NOTES
1. In fishing vessels the modulus of main and 'tween deck frames need not be greater than 80 per cent of that given in (2).
2. In offshore supply ships the moduli of main and 'tween deck frames are to be 25 per cent greater than those given in (2), (3) and (4).
3. Where frames are inclined at more than 15° to the vertical, H_{MF} or H_{TF} is to be measured along a chord between span points of the frame.
4. Panting stringers are not required in tugs less than 46 m in length, *see* Pt 4, Ch 3,4.
5. Where the frames are supported by fully effective horizontal stringers, these may be considered as decks for the purpose of determining H_{MF}.
6. Except for main frames the modulus for these members need not exceed that derived from (1) using H_{TF} in place of S_1.

4.3.2 The scantlings of main frames are normally to be based on Rule standard brackets at top and bottom, whilst the scantlings of 'tween deck frames are normally to be based on a Rule standard bracket at the top only.

4.3.3 End connections of transverse main and 'tween deck frames are to be in accordance with Ch 10,3. For bulk carriers (*see* 1.1.4), the end connections of main frames in cargo holds are to be in accordance with Pt 4, Ch 7,6.2.5 to 6.2.12.

4.4 Panting stringers in way of transverse framing

4.4.1 In deep 'tween decks above the after peak space, panting stringers having scantlings as given in Table 6.4.2 or increased shell plate thickness may be required, *see also* 3.4.2.

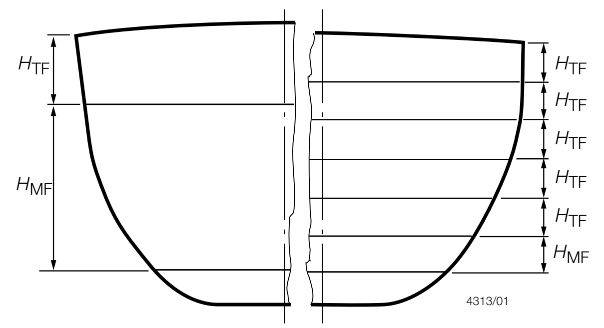


Fig. 6.4.1 Framing depths

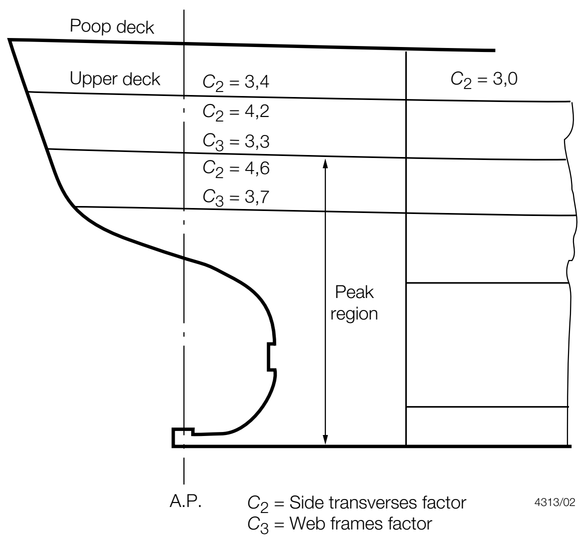


Fig. 6.4.2 Framing factors

4.5 Primary structure at sides

4.5.1 Where the 'tween decks above an after peak space are transversely framed, web frames are to be fitted. Their spacing is generally not to exceed the values given in Table 6.4.3, and their scantlings are to be determined from Table 6.4.4.

4.5.2 Where longitudinal framing is arranged, the spacing of transverses is generally not to exceed the values given in Table 6.4.3, and their scantlings are to be determined from Table 6.4.4.

4.5.3 Where the shape of the after sections is such that there are large sloped flat areas, particularly in the vicinity of the propellers, additional primary supports for the secondary stiffening may be required. Their extent and scantlings will be specially considered.

4.5.4 The web thickness, stiffening arrangements and connections of primary supporting members are to be in accordance with the requirements of Ch 10,4.

Table 6.4.3 Spacing of side transverses and web frames aft

Location	Maximum spacing	
	Web frames in association with transverse framing system	Side transverses in association with longitudinal framing system
(1) Aft of the after peak bulkhead	4 frame spaces	2,5 m where $L \leq 100$ m 3,5 m where $L \geq 300$ m Intermediate values by interpolation
(2) Elsewhere in way of dry cargo spaces or deep tanks, *see* Note	—	3,8 m where $L \leq 100$ m $(0{,}006L + 3{,}2)$ m where $L > 100$ m
(3) In way of cargo tanks of oil tankers, chemical tankers or ore or oil carriers	—	3,6 m where $L \leq 180$ m $0{,}02L$ where $L > 180$ m
NOTE For the maximum spacing of transverses in dredgers, *see* Pt 4, Ch 12,5.		

Table 6.4.4 Primary structure aft

Item and location	Modulus, in cm^3	Inertia, in cm^4
Longitudinal framing system		
(1) Side transverses in dry spaces aft of the after peak bulkhead, *see* Note 4: (a) Lower space (b) 'Tween deck	 $Z = 10\,k\,S\,h_{T1}\,l_e^2$ $Z = C_2\,k\,S\,T\,H_{TF}\sqrt{D}$	—
(2) Side transverses in tanks aft of the after peak bulkhead, *see* Note 4: (a) Lower space (b) 'Tween decks	 $Z = 11{,}7\rho\,k\,S\,h_4\,l_e^2$ $Z = 14{,}1\rho\,k\,S\,h_4\,l_e^2$ or as (1) above, whichever is the greater	$I = \dfrac{2{,}5}{k}\,l_e\,Z$
(3) Side transverses in dry spaces and deep tanks forward of the after peak bulkhead	As in Pt 4, Ch 1,6, *see* Notes 1 and 2	
Transverse framing system		
(4) Side stringers supported by webs in after peak dry space, *see* Note 3	$Z = 7{,}75\,k\,S\,h_{T1}\,l_e^2$	—
(5) Side stringers supported by webs in after peak tank, *see* Note 3	$Z = 11{,}7\,\rho\,k\,S\,h_4\,l_e^2$ or as (4) above, whichever is the greater	$I = \dfrac{2{,}5}{k}\,l_e\,Z$
(6) Web frames supporting side stringers in after peak, *see* Note 3	Z to be determined from the calculations based on following assumptions: (a) Fixed ends (b) Point loadings from stringers (c) Head h_4 or h_{T1} as applicable (d) Bending stress $\dfrac{93{,}2}{k}$ N/mm² $\left(\dfrac{9{,}5}{k}\text{ kgf/mm}^2\right)$ (e) Shear stress $\dfrac{83{,}4}{k}$ N/mm² $\left(\dfrac{8{,}5}{k}\text{ kgf/mm}^2\right)$	In deep tanks $I = \dfrac{2{,}5}{k}\,l_e\,Z$
(7) Web frames in 'tween decks aft of the after peak bulkhead not supporting side stringers	$Z = C_3\,k\,S\,T\,H_{TF}\sqrt{D}$	—
(8) Side stringers and web frames in dry spaces and deep tanks forward of the after peak bulkhead	As in Pt 4, Ch 1,6, *see* Notes 1 and 2	

Symbols

D, T, S, l_e, k, ρ as defined in 1.4.1

C_2, C_3 = factors obtained from Fig. 6.4.2

h_4 = tank head, in metres, as defined in Ch 3,5

h_{T1} = head, in metres, at mid-length of span

$= f_w C_w \left(1 - \dfrac{h_6}{D_1 - T_1}\right) F_\lambda$, in metres where the mid-length of span is above the waterline at draught T_1

where $f_w \left(1 - \dfrac{h_6}{D_1 - T_1}\right)$ is not to be taken less than 0,7

$= \left[h_6 + f_w C_w \left(1 - \dfrac{h_6}{2T_1}\right)\right] F_\lambda$, in metres where the mid-length of span is below the waterline at draught T_1

where

f_w = 1,0 at 0,2L from A.P. and 1,32 at and aft of aft peak bulkhead. Intermediate positions by interpolation

h_6 = vertical distance, in metres, from the waterline at draught T_1 to the mid-length of span

F_λ = 1,0 for $L \le 200$ m
= $[1{,}0 + 0{,}0023\,(L - 200)]$ for $L > 200$ m

C_w = a wave head, in metres
= $7{,}71 \times 10^{-2}\,L\,e^{-0{,}0044L}$
where e = base of natural logarithms 2,7183

D_1 = D but need not be taken greater than $T + H_b$, in metres, where H_b is the minimum bow height, in metres, obtained from Ch 3,6.1

T_1 = T but not to be taken less than $0{,}65D_1$

H_{TF} = vertical height of 'tween decks, in metres, as shown in Fig. 6.4.1

NOTES

1. In way of the cargo tanks or oil fuel tanks of oil tankers or ore carriers, the scantlings of primary structure are to comply with the requirements of Pt 4, Ch 9, Ch 10 or Ch 11, as appropriate.
2. For bulk carriers, *see* Pt 4, Ch 7,6.
3. For stringers and webs in after peaks, *see also* 6.2.
4. The web depth of side transverses aft of the after peak bulkhead is to be not less than 2,5 times the depth of the longitudinals supported. The web depth of stringers is to be not less than 2,2 times the depth of frames supported.

Section 5
Single and double bottom structure

5.1 General

5.1.1 For dry cargo ships exceeding 120 m in length, and for all ships which are strengthened for heavy cargoes, longitudinal framing is, in general, to be adopted, *see also* Pt 4, Ch 9,1.3.

5.1.2 For ships having the notation 'strengthened for heavy cargoes', the requirements of Pt 4, Ch 7,8 are also to be complied with, as applicable.

5.1.3 For ships intended to load or unload while aground, *see* Pt 3, Ch 9,13.

5.1.4 Provision is to be made for the free passage of water and/or air from all parts of single or double bottoms to the bilge or tank suctions, account being taken of the pumping rates required.

5.1.5 For passenger ships, *see* Pt 4, Ch 2,6.

5.2 Single bottoms – Transverse framing

5.2.1 In after peak spaces, floors are to be arranged at every frame. For details and scantlings, *see* 6.1.

5.2.2 In way of dry cargo spaces aft, the arrangement and scantlings of transversely framed single bottoms are to be generally as required in the midship region, as given in Pt 4, Ch 1,7, except that the thickness of the centreline girder may be tapered from the midship thickness at 0,3L from the A.P. to $t = (\sqrt{Lk} + 0{,}5)$ mm or 6 mm, whichever is the greater, at 0,075L from the A.P. In ships having considerable rise of floor towards the aft end, the depth of the floors may be required to be increased.

5.2.3 Where the shape of the after sections is such that there are large flat areas of shell plating, additional stiffening and/or increased shell plate thickness may be required, *see* 3.3. The extent of this stiffening will be specially considered.

5.3 Single bottoms – Longitudinal framing

5.3.1 The scantlings and arrangement of longitudinally framed single bottoms in way of dry cargo spaces will be specially considered.

5.4 Double bottoms

5.4.1 The minimum depth of centre girder aft is generally to be the same as that required in the midship region by Part 4 for the particular type of ship concerned, but in ships with considerable rise of floor a greater depth may be required at the aft end to provide adequate access throughout the double bottom tank.

5.4.2 Where the height of the double bottom varies, this variation is generally to be made gradual by sloping the inner bottom over an adequate longitudinal extent. Knuckles in the plating are to be arranged close to plate floors. Otherwise, suitable scarfing arrangements are to be made.

5.4.3 For dry cargo ships, the arrangement and scantlings of girders, floors, inner bottom plating and inner bottom stiffening in the aft end region are to be determined from Pt 4, Ch 1,8.

5.4.4 For double bottom construction in way of the cargo tanks of oil tankers or ore carriers, *see also* Pt 4, Ch 9, Ch 10 or Ch 11, as appropriate.

Section 6
After peak structure

6.1 Bottom structure

6.1.1 Floors are to be arranged at every frame space and are to be carried to a suitable height, and at least to above the sterntube, where fitted. They are to have a thickness as determined from Table 6.6.1 and are to be adequately stiffened. In way of a propeller post, rudder post or rudder horn, the floors are generally to be carried to the top of the space and are to be increased in thickness. The extent and amount of the increase will be specially considered, account being taken of the arrangements proposed.

6.2 Side structure – Transverse framing

6.2.1 Above the floors, transverse side framing is to be supported by one of the following arrangements:

(a) Side stringers spaced not more than 2,5 m apart and supported by web frames. The upper ends of the web frames are to be supported under the tank top by suitable deep beams to form a ring structure.

(b) Perforated flats spaced not more than 2,5 m apart. The area of perforations in each flat is to be not less than 10 per cent of the total area of the flat.

(c) A combination of the above arrangements.

6.2.2 The scantlings of side stringers supported by web frames, and also of the web frames are to be determined from 4.5.

6.2.3 The scantlings of perforated flats are to be determined from Table 6.6.1. Stiffeners are to be fitted at every frame.

6.3 Side structure – Longitudinal framing

6.3.1 The spacing and scantlings of side transverses supporting longitudinal framing are to be as required by 4.5.

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

Table 6.6.1 After peak structure

Item	Parameter	Requirement
(1) Floors	Thickness	$t = (7{,}5 + 0{,}025L_2)\sqrt{\dfrac{s_2}{800}}$ mm
(2) Perforated flats and wash bulkheads	Thickness, *see* Note	$t = (7{,}5 + 0{,}015L)\sqrt{\dfrac{s_2}{800}}$ mm
	Stiffener modulus	$z = \dfrac{0{,}0057\, s\, k\, h_6\, l_e^2}{b}$ cm^3
Symbols		
L, s, l_e, k as defined in 1.4.1 b = 1,4 for rolled or built sections = 1,6 for flat bars h_6 = vertical distance from middle of effective length of stiffener to top of tank, in metres	s_2 = spacing of stiffeners, in mm, but is to be taken not less than 800 mm L_2 = L but need not be taken greater than 215 m	
NOTE The thickness for perforated flats and wash bulkheads may be reduced by 1 mm for ships of 40 m and under with no reduction for ships of 90 m and above. Reduction for intermediate lengths to be by linear interpolation.		

6.4 Wash bulkheads

6.4.1 A centreline wash bulkhead is to be arranged in the upper part of the after peak space and counter or cruiser stern. Where the overhang is very large, or the breadth of the space at the widest point exceeds 20 m, additional wash bulkheads may be required port and starboard.

6.4.2 Wash bulkheads are to have an area of perforations not less than 5 per cent nor more than 10 per cent of the area of the bulkhead. The plating is to be suitably stiffened in way of openings, and the arrangement of openings is to be such as to maintain adequate shear rigidity.

6.4.3 The scantlings of wash bulkheads are to be determined from Table 6.6.1, and stiffeners are to be fitted at every frame and bracketed top and bottom. The plating thickness may be required to be increased locally in way of the upper part of the sternframe or the rudder horn.

6.5 After peak bulkhead

6.5.1 The position and height of the after peak bulkhead are to be in accordance with the requirements of Ch 3,4.

6.5.2 The scantlings of the after peak bulkhead and of the flat forming the top of the peak space are to be determined from Pt 4, Ch 1,9, but the plating thickness is to be increased locally in way of the sterntube gland.

■ *Section 7* Sternframes and appendages

7.1 General

7.1.1 Sternframes, rudder horns, boss end brackets and shaft brackets may be constructed of cast or forged steel, or may be fabricated from plate.

7.1.2 In castings, sudden changes of section or possible constrictions to the flow of metal during casting are to be avoided. All fillets are to have adequate radii, which should, in general, be not less than 50 to 75 mm, depending on the size of the casting.

7.1.3 Castings and forgings are to comply with the requirements of Chapter 4 and Chapter 5 of the Rules for Materials (Part 2) respectively.

7.1.4 Cast sternframes, rudder horns and solepieces are to be manufactured from special grade material. Cast bossings can be manufactured from normal grade material, *see* Ch 4,2 of the Rules for Materials (Part 2).

7.1.5 Sternframes, rudder horns, shaft brackets, etc., are to be effectively integrated into the ship's structure, and their design is to be such as to facilitate this.

7.2 Sternframes

7.2.1 The scantlings of sternframes are to be determined from Table 6.7.1. In the case of very large ships, the scantlings and arrangements may be required to be verified by direct calculations.

7.2.2 Fabricated and cast propeller posts and rudder posts of twin screw ships are to be strengthened at intervals by webs. In way of the upper part of the sternframe arch, these webs are to line up with the floors.

7.2.3 Rudder posts and propeller posts are to be connected to floors of increased thickness, see 6.1.

7.2.4 The sole piece is to be dimensioned such that the stresses do not exceed the permissible stresses given in Table 6.7.2.

Table 6.7.1 **Sternframes** (*see continuation)*

Item	Parameter	Requirement		
(1) Propeller posts *see* Notes 1 and 2		Cast steel, *see* Fig. 6.7.1(a)	Forged steel, *see* Fig. 6.7.1(b)	Fabricated mild steel, *see* Fig. 6.7.1(c)
	l	$165\sqrt{T}$ mm	—	$200\sqrt{T}$ mm
	r	$20\sqrt{T}$ mm	—	$18\sqrt{T}$ mm
	t_w	$8\sqrt{T}$ mm (need not exceed 38)	—	$6\sqrt{T}$ mm (need not exceed 30)
	t_1	$12\sqrt{T}$ mm (min. 19)	—	$12\sqrt{T}$ mm
	t_2	$16\sqrt{T}$ mm (min. 25)	—	—
	w	$115\sqrt{T}$ mm	$40\sqrt{T}$ mm	$140\sqrt{T}$ mm
	A	—	$(10 + 0{,}5L)T$ cm^2 where $L \leq 60$ m $40T$ cm^2 where $L > 60$ m	—
(2) Propeller boss, *see* Note 3 and Fig. 6.7.2	t_b	$(0{,}1\delta_{TS} + 56)$ mm, but need not exceed $0{,}3\,\delta_{TS}$		
(3) Rudder posts or axles		Single screw with integral solepiece, *see* Fig. 6.7.5(a)	Single screw with bolted rudder axle, *see* Fig. 6.7.3	Twin screw, integral with hull, *see* Fig. 6.7.4
	n	—	6 (*see* Note 4)	—
	r	—	—	$20\sqrt{T}$ mm
	r_b	—	δ_A mm	—
	t_F	—	δ_b mm	—
	t_1	—	—	$12\sqrt{T}$ mm
	t_2	—	—	$15\sqrt{T}$ mm
	t_3	—	—	$18\sqrt{T}$ mm
	w	—	—	$120\sqrt{T}$ mm
	z_{PB1}, z_{PB2}	—	$1{,}2\delta_{PL2}$ mm	—
	Z_T	$0{,}147\left(\dfrac{k_R}{0{,}248}\right)^3 A_R\, c_2\, b\, (V_o + 3)^2$ cm^3	—	—
	δ_A	—	$(25T + 76)$ mm but need not exceed $0{,}9\delta_{PL2}$ mm	—
	δ_b	—	$6{,}25T + 19$ mm or $0{,}225\delta_{PL2}$ mm whichever is the greater	—
	δ_{PL1}, δ_{PL2} bearing pressure and pintle clearance	—	As for rudder pintles (*see* Table 13.2.11 in Chapter 13)	—
(4) Solepieces, *see* Notes 5, 6 and 7	Z_T Z_V A_S	$0{,}0125M_b\,K_o$ $0{,}5Z_T$ $0{,}02B_1\,K_o$		

Table 6.7.1 Sternframes *(conclusion)*

Symbols	
L, *T* as defined in 1.4.1 *a*, *b*, *c* = distances, in metres, as shown in Fig. 6.7.5 B_1 = *see* Table 6.7.2 c_2 = rudder profile coefficient, as given by Table 13.2.1 in Chapter 13 *n* = number of bolts in palm coupling r_b = mean distance of bolt centres from centre of palm, in mm t_b = finished thickness of boss, in mm M_B = *see* Table 6.7.2 *A* = cross-sectional area of forged steel propeller post, in cm^2 A_R = rudder area, in m^2	k_R = rudder coefficient, as given by Table 6.7.4 *V* = maximum service speed, in knots, with the ship in the loaded condition Z_T = section modulus against transverse bending, in cm^3 Z_V = section modulus against vertical bending, in cm^3 δ_b = diameter of coupling bolts, in mm δ_{TS} = diameter of tail shaft, in mm K_o = as defined in 7.3.3 A_s = sectional area, in mm^2
NOTES 1. Where scantlings and proportions of the propeller post differ from those shown in Item (1), the section modulus about the longitudinal axis of the proposed section normal to the post is to be equivalent to that with Rule scantlings. *t* is to be not less than $8\sqrt{T}$ (minimum of 19 mm for cast steel sternframes) or as required by Ch 6,3.4.2, whichever is the greater. 2. On sternframes without solepieces, the modulus of the post below the propeller boss, about the longitudinal axis may be gradually reduced to not less than 85% of that required by Note 1, subject to the same thickness limitations. 3. In fabricated sternframes the connection of the propeller post to the boss is to be by full penetration welds. 4. If more than six bolts are fitted, the arrangements are to provide equivalent strength.	5. In fabricated solepieces, transverse webs are to be fitted spaced not more than 760 mm apart. Where the breadth of the solepiece exceeds 900 mm, a centreline vertical web is also to be fitted. 6. Solepieces supporting fixed or movable nozzles will be specially considered, *see* Ch 13,3.2. 7. For dredging and reclamation craft classed 'A1 protected waters service', the scantlings of an 'open' type solepiece are to be such that: (a) $Z_T = 0,625 Z_T$ (b) The cross-sectional area is not less than 18 cm^2 (c) The depth is not less than two-thirds of the width at any point.

Table 6.7.2 Permissible stresses for sole pieces

Mode	Permissible stress
(1) Equivalent stress	$115/K_0$ N/mm^2 ($11,7/K_0$ kgf/mm^2)
Symbols	
σ_e = equivalent stress $= \sqrt{\sigma_b^2 + 3\tau_T^2}$ N/mm^2 σ_b = bending stress $= \dfrac{M_B}{Z_T}$ N/mm^2 τ_T = shear stress $= \dfrac{B_1}{A_s}$ N/mm^2 K_o = as defined in 7.3.3 M_B = bending moment, in Nm, at the section considered $= B_1 x$ B_1 = supporting force, in N, in pintle bearing $= 0,5P_L$ P_L = rudder force, in N, as calculated in Ch 13,2 *x* = distance, in metres, from centre of rudder stock to section under consideration Z_T = *see* Table 6.7.1(4) A_s = sectional area, in mm^2, of solepiece	

7.3 Rudder horns

7.3.1 Rudder horns supporting semi-spade type rudders are to be efficiently integrated into the main hull structure, and additional web frames or side transverses may be required in the 'tween deck over.

7.3.2 The shell plating is to be increased in thickness in way of the horn. Where the horn plating is radiused into the shell plating, the radius at the shell connection is to be not less than:

$$r = (150 + 0,8L) \text{ mm}$$

7.3.3 The scantlings of the rudder horn are to be such that the section modulus against transverse bending at any section is not less than:

$$Z_T = 0,015 M_B K_o \text{ cm}^3$$

where

M_B = bending moment
$= B_{1L} z$ Nm
B_{1L} = as calculated in Table 13.2.11 in Ch 13,2
z = *see* Fig. 6.7.6
K_o = k_o *see* Table 13.2.4 in Ch 13,2 for cast steel
K_o = k = 1,0 for fabricated mild steels
= k = 0,78 for high tensile steels with yield stress σ_o = 315 N/mm^2
= k = 0,72 for high tensile steels with yield stress σ_o = 355 N/mm^2.

7.3.4 The rudder horn is to be dimensioned such that the stresses do not exceed the permissible stresses given in Table 6.7.3.

Table 6.7.3 Permissible stresses for rudder horns

Mode	Permissible stress	
(1) Shear stress	$48/K_o$ N/mm^2	($4,9/K_o$ kgf/mm^2)
(2) Equivalent stress	$120/K_o$ N/mm^2	($12/K_o$ kgf/mm^2)

Symbols

σ_e = equivalent stress
= $\sqrt{\sigma_b^2 + 3\left(\tau^2 + \tau_T^2\right)}$ N/mm^2 (kgf/mm^2)
σ_b = bending stress
= $\dfrac{M_B}{Z_T}$ N/mm^2
τ = shear stress
= $\dfrac{B_{1L}}{A_h}$ N/mm^2
τ_T = torsional stress
= $\dfrac{10^3 M_T}{2 A_T t_h}$ N/mm^2
A_h = effective shear area, in mm^2, of rudder horn in y-direction
A_T = area in the horizontal section enclosed by the rudder horn, in mm^2
B_{1L} = as calculated in Table 13.2.11 in Ch 13,2
K_o = as defined in 7.3.3
M_B = bending moment at the section considered, in Nm
= $B_{1L}\, z$
M_T = torsional moment at the section considered, in Nm
= $B_{1L}\, e$
t_h = plate thickness of rudder horn, in mm
e = *see* Fig. 6.7.6
z = *see* Fig. 6.7.6
Z_T = *see* 7.3.3

Table 6.7.4 Rudder coefficient k_R

Design criteria		k_R
Ahead condition	Rudder in propeller slipstream	0,248
	Rudder out of propeller slipstream	0,235
Astern condition		0,185
Bow rudder		0,226
Barge – non self-propelled		

7.4 Shaft bossing

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

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

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

Table 6.7.5 Recommended propeller/hull clearances

Number of blades	Hull clearances for single screw, in metres, *see* Fig. 6.7.7(a)				Hull clearances for twin screw, in metres, *see* Fig. 6.7.7(b)	
	a	*b*	*c*	*d*	*e*	*f*
3	$1,20K\delta$	$1,80K\delta$	$0,12\delta$	$0,03\delta$	$1,20K\delta$	$1,20K\delta$
4	$1,00K\delta$	$1,50K\delta$	$0,12\delta$	$0,03\delta$	$1,00K\delta$	$1,20K\delta$
5	$0,85K\delta$	$1,275K\delta$	$0,12\delta$	$0,03\delta$	$0,85K\delta$	$0,85K\delta$
6	$0,75K\delta$	$1,125K\delta$	$0,12\delta$	$0,03\delta$	$0,75K\delta$	$0,75K\delta$
Minimum value	$0,10\delta$	$0,15\delta$	t_R	—	3 and 4 blades, $0,20\delta$ 5 and 6 blades, $0,16\delta$	$0,15\delta$

Symbols

L as defined in 1.4.1
C_b = moulded block coefficient at load draught

$$K = \left(0,1 + \frac{L}{3050}\right)\left(\frac{3,48 C_b P}{L^2} + 0,3\right)$$

$$\left(K = \left(0,1 + \frac{L}{3050}\right)\left(\frac{2,56 C_b P}{L^2} + 0,3\right)\right)$$

t_R = thickness of rudder, in metres, measured at 0,7Rp above the shaft centreline
P = designed power on one shaft, in kW (shp)
R_P = propeller radius, in metres
δ = propeller diameter, in metres

NOTE
The above recommended minimum clearances also apply to semi-spade type rudders.

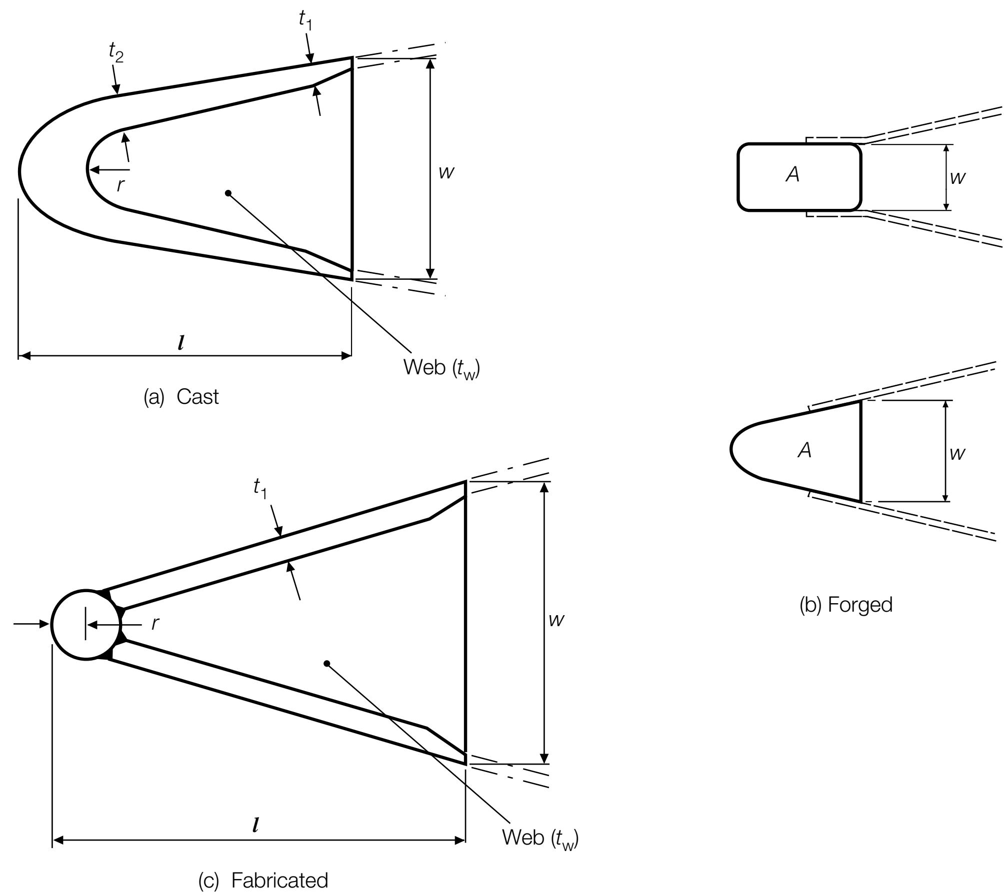


Fig. 6.7.1 Propeller posts

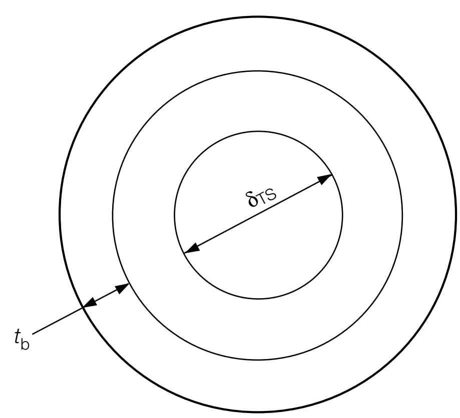


Fig. 6.7.2 Propeller boss

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

7.4.5 The scantlings of supports will be specially considered. In the case of certain high powered ships, direct calculations may be required.

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

7.5 Shaft brackets

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

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

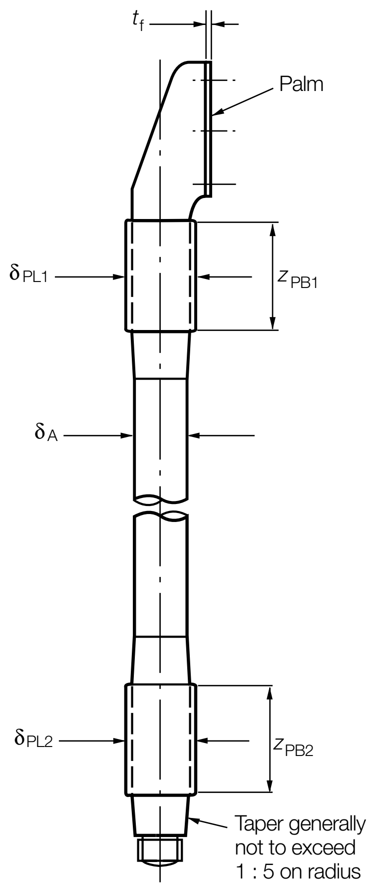


Fig. 6.7.3 Rudder axle

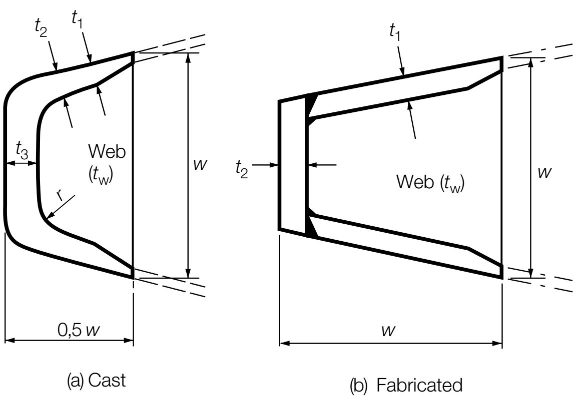


Fig. 6.7.4 Rudder post for twin screw ships

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

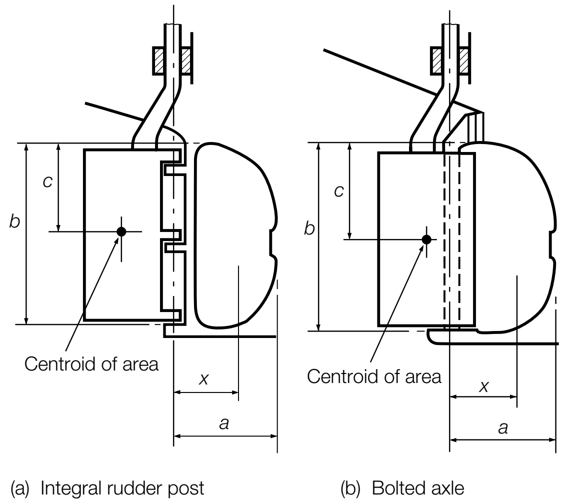


Fig. 6.7.5 Solepieces

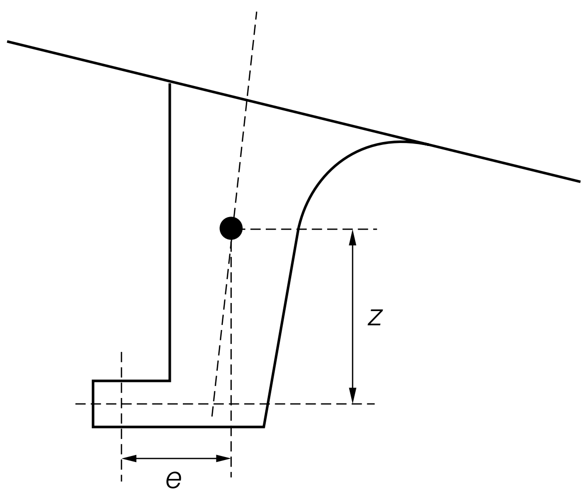


Fig. 6.7.6 Rudder horn

7.5.4 The scantlings of shaft brackets will be specially considered and, in the case of certain high powered ships, direct calculations may be required.

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

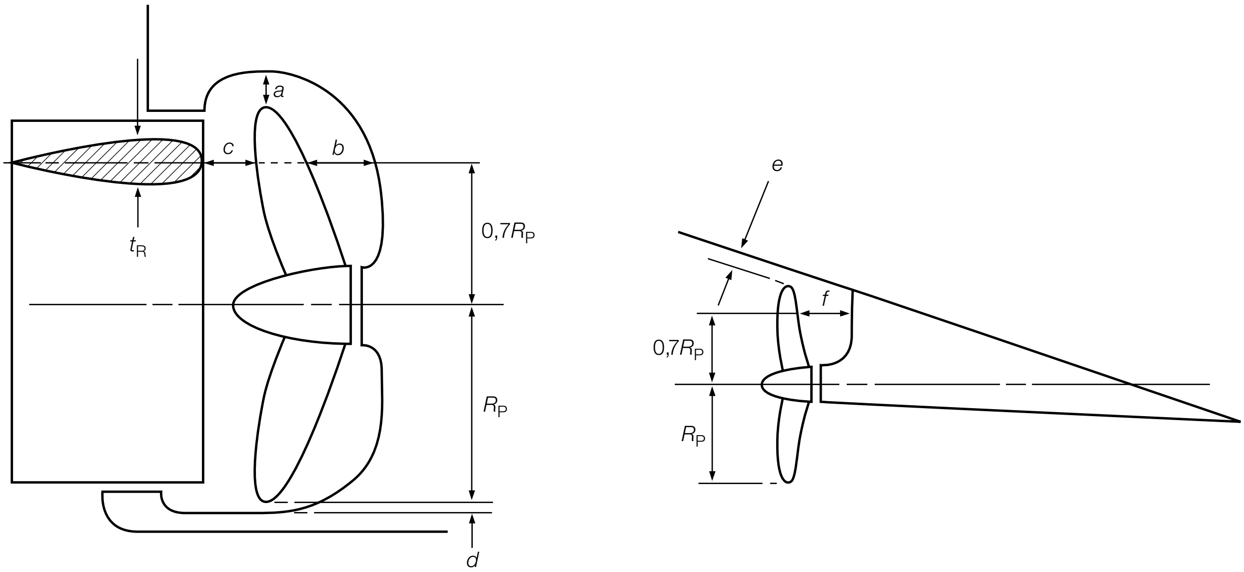


Fig. 6.7.7 Propeller clearances

7.6 Propeller hull clearances

7.6.1 Recommended minimum clearances between the propeller and the sternframe, rudder or hull are given in Table 6.7.3. These are the minimum distances considered desirable in order to expect reasonable levels of propeller excited vibration. Attention is drawn to the importance of the local hull form characteristics, shaft power, water flow characteristics into the propeller disc and cavitation when considering the recommended clearances.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all ship types detailed in Part 4. Only requirements particular to machinery spaces, including protected machinery casings and engine seatings, are given. For other scantlings and arrangement requirements, *see* the relevant Chapter in Part 4 for the particular ship type concerned.

1.1.2 Requirements are given for machinery spaces situated as follows:

(a) In the midship region.
(b) In the aft end region but with a cargo compartment between it and the after peak bulkhead.
(c) In the aft end region where the after peak bulkhead forms the aft end of the machinery space.

1.1.3 The requirements in this Chapter are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation. *See* Pt 1, Ch 2,2.3.

1.2 Structural configuration

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

1.2.2 For midship machinery spaces, where the shell and decks (outside line of openings) are longitudinally framed in way of adjacent cargo spaces, this system of framing is also to be adopted in the machinery space.

1.2.3 For machinery spaces situated aft, where the longitudinal framing terminates and is replaced by transverse framing, a suitable scarfing arrangement of the longitudinal framing is to be arranged, *see also* Ch 6,1.

1.2.4 The maximum spacing, S_{max}, of transverses in longitudinally framed machinery spaces is not to exceed the following:

(a) where $L \leq 100$ m, $S_{max} = 3{,}8$ m
(b) where $L > 100$ m, $S_{max} = (0{,}006L + 3{,}2)$ m

In addition, the spacing in way of a machinery space situated adjacent to the after peak is not to exceed five transverse frame spaces.

1.3 Structural continuity

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

1.3.2 In cargo ships, suitable taper brackets are, in general, to be arranged in way of deck ends.

1.3.3 In oil tankers and bulk carriers with machinery aft (*see* 1.1.3), continuity of the longitudinal bulkheads and topside tank structure is to be maintained as far as possible into the machinery space with suitable taper brackets at the end.

1.3.4 In container or similar ships having side tanks or double skin construction in way of the cargo spaces, the longitudinal bulkheads are generally to be carried through the machinery space where this is situated amidships or separated from the after peak by a cargo compartment. Where the machinery space is situated adjacent to the after peak, the longitudinal bulkheads are to be continued as far aft as possible and suitably tapered at their ends.

1.4 Symbols and definitions

1.4.1 For symbols not defined in this Chapter, *see* Pt 4, Ch 1. *L*, *B*, *D* and *T* are defined in Ch 1,6.1. Other symbols are defined in the appropriate Sections.

■ *Section 2* Deck structure

2.1 Strength deck – Plating

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

2.1.2 In the case of oil tankers (*see* 1.1.3), or other ships having small deck openings amidships and machinery aft, where the width of machinery openings exceeds $\frac{B}{2}$ and the opening extends forward beyond a point $\frac{B}{3}$ aft of the poop front, the thickness of deck plating may be required to be increased locally.

2.2 Strength deck – Primary structure

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

2.2.2 Where a longitudinal framing system is adopted, deck longitudinals are to be supported by transverses in association with pillars or pillar bulkheads. For the maximum spacing of transverses, *see* 1.2.4. Deck transverses are to be in line with side transverses or web frames.

2.2.3 Machinery casings are to be supported by a suitable arrangement of deep beams or transverses and longitudinal girders in association with pillars or pillar bulkheads. In way of particularly large machinery casing openings, cross ties may be required, and these are to be arranged in line with deep beams or transverses.

2.3 Lower decks

2.3.1 The scantlings of lower decks or flats are generally to be as detailed in Ch 5,2, Ch 6,2 or Pt 4, Ch 1,4 as appropriate. However, in way of concentrated loads such as those from boiler bearers or heavy auxiliary machinery, etc., the scantlings of deck structure will be specially considered, taking account of the actual loading.

2.3.2 In way of machinery openings, etc., particularly towards the aft end, decks or flats are to have sufficient strength where they are intended as effective supports for side framing, webs or transverses. Web frames and side transverses are to be supported by deep beams or deck transverses.

■ *Section 3* Side shell structure

3.1 Secondary stiffening

3.1.1 Transverse frames are generally to have scantlings determined as required by Pt 4, Ch 1,6 for cargo spaces, except that where, in a machinery space situated in the midship region, it is desired to omit web frames as permitted by 3.2.3, the section modulus of the ordinary main or 'tween deck frames is to be increased by 50 per cent, up to the level of the lowest deck above the load waterline. Where fully effective stringers supported by web frames are fitted, the stringers may be considered as decks for the purpose of calculating the modulus of the frames.

3.1.2 Longitudinal framing is generally to have scantlings determined as required by Pt 4, Ch 1,6 for machinery spaces in the midship region, and by Table 6.4.1 Location 2(b) in Chapter 6 for machinery spaces clear of and aft of the midship region.

3.2 Primary structure – Transverse framing

3.2.1 Where the space is situated in the aft end region, web frames are to be fitted, spaced in general not more than five frame spaces apart, extending from the tank top to the upper deck and having scantlings as required by Table 7.3.1. However, consideration will be given to a spacing of web frames at not more than seven transverse frame spaces apart, in association with substantially increased ordinary frames to satisfy the overall modulus and inertia requirements. The web frames are to be connected at top and bottom to members of adequate stiffness and supported at lower decks by deep beams. If the span of ordinary frames below the lowest deck or flat exceeds 6,5 m, one or more fully effective side stringers are to be fitted to support the frames. These are to have scantlings as required by Table 7.3.1. Stringers are to be efficiently bracketed to bulkheads, and their connection to the web frames is to be such as to provide adequate continuity of face material.

3.2.2 As an alternative to the fully effective stringers required by 3.2.1, an arrangement of light stringers spaced about 2,5 m apart may be accepted. These stringers are to have scantlings not less than those required in the panting region forward, *see* Ch 5,4.4.

3.2.3 Where the machinery space is situated in the midship region, it is recommended that web frames be fitted in the engine-room, spaced not more than five frame spaces apart and extending from the tank top to the level of the lowest deck above the load waterline. The scantlings of these webs are to be such that the combined section modulus of the web frame and the main or 'tween deck frames is 50 per cent greater than that required for normal transverse framing. These webs may be omitted if the section modulus of the transverse frames is increased as required by 3.1.1.

3.2.4 If an effective side stringer supporting the side frames is fitted, then its scantlings and those of the supporting web frames are to be determined from Table 7.3.1.

3.3 Primary structure – Longitudinal framing

3.3.1 Where the machinery space is longitudinally framed, side transverses are to be fitted having scantlings as required by Table 7.3.1. For the maximum spacing of transverses, *see* 1.2.4. Transverses are to be connected at top and bottom to members of adequate stiffness and supported at lower decks by transverses or deep beams.

Table 7.3.1 Primary structure in machinery spaces

Symbols	Item and position	Scantlings	
		Section modulus, in cm^3	Min. web depth d_w, in mm
L, *D* and *T* are as defined in Ch 1,6.1 *h* = load head, in metres, measured from mid-point of span to upper deck at side amidships *k* = higher tensile and steel factor, *see* Ch 2,1.2 l_e = effective length of stiffening member, in metres, *see* Ch 3,3.3 *s* = spacing of floors and longitudinals, in mm *C* = 2,2 for a lower 'tween deck or 2,0 for an upper 'tween deck *S* = spacing or mean spacing of primary supporting members, in metres	TRANSVERSE FRAMING SYSTEM Aft end region: Web frames below lowest deck and not supporting effective stringers	$Z = 5kShl_e^2$	2,5 x depth of adjacent main frames
	Web frames above lowest deck	$Z = 1{,}68CkTSl_e\sqrt{D}$	
	Any region: Fully effective stringers	$Z = 7{,}75kShl_e^2$	2,5 x depth of adjacent main frames
	Web frames below lowest deck supporting effective stringers	Determined from calculation based on following assumptions: (a) Fixed ends (b) Point loadings (c) Head to upper deck at side (d) Bending stress 93,2 N/mm^2 (9,5 kgf/mm^2) (e) Shear stress 83,4 N/mm^2 (8,5 kgf/mm^2)	
	LONGITUDINAL FRAMING SYSTEM Side transverses below lowest deck	$Z = 10kShl_e^2$	2,5 x depth of longitudinals
	Side transverses above lowest deck	$Z = 2{,}1CkTSl_e\sqrt{D}$	

Section 4
Double and single bottom structure

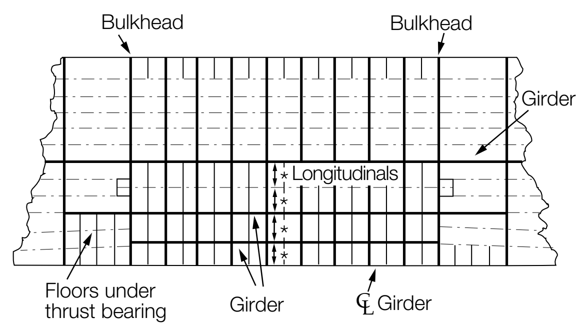
4.1 Double bottom structure

4.1.1 The minimum depth of the centre girder and its thickness are to be at least the same as required in way of cargo space amidships, *see* Pt 4, Ch 1,8. A greater depth is recommended in way of large engine-rooms when the variation in draught between light and load conditions is considerable. For passenger ships, *see* Pt 4, Ch 2,6.

4.1.2 In machinery spaces situated adjacent to the after peak, the double bottom is to be transversely framed. Elsewhere transverse or longitudinal framing may be adopted, but *see also* Pt 4, Ch 1,8.

4.1.3 Where the double bottom is transversely framed, plate floors are to be fitted at every frame in the engine-room. In way of boilers, plate floors are to be fitted under the boiler bearers, and elsewhere as required by Pt 4, Ch 1,8.

4.1.4 Where the double bottom is longitudinally framed, plate floors are to be fitted at every frame under the main engines and thrust bearing. Outboard of the engine seating, floors may be fitted at alternate frames, *see* Fig. 7.4.1.



*Maximum spacing = 1,5 x normal spacing of longitudinals

Fig. 7.4.1 Engine-room with longitudinal framing

4.1.5 The scantlings of floors clear of the main engine seatings, are generally to be as required in way of cargo spaces, *see* Pt 4, Ch 1,8. In way of engine seatings, the floors are to be increased in thickness, *see* 6.2.1.

4.1.6 Sufficient fore and aft girders are to be arranged in way of the main machinery to effectively distribute its weight and to ensure adequate rigidity of the structure. In midship machinery spaces these girders are to extend for the full length of the space and are to be carried aft to support the foremost shaft tunnel bearing. This extension beyond the after bulkhead of the engine-room is to be for at least three transverse frame spaces, aft of which the girders are to scarf into the structure. Forward of the engine-room bulkhead, the girders are to be tapered off over three frame spaces and effectively scarfed into the structure. In machinery spaces situated at the aft end the girders are to be carried as far aft as practicable and the ends effectively supported by web frames or transverses. For recommended scantlings of engine girders, *see* 6.2.1.

4.1.7 Outboard of the engines, side girders are to be arranged, where practicable, to line up with the side girders in adjacent cargo spaces. These are to have scantlings as required by Pt 4, Ch 1,8.

4.1.8 Where the double bottom is longitudinally framed and transverse floors are fitted in way of the engine seatings as required by 4.1.4, no additional longitudinal stiffening is required in way of the engines other than the main engine girders, provided that the spacing of girders does not exceed 1,5 times the normal spacing of longitudinals. Where this spacing of girders is exceeded, shell longitudinals are to be fitted. These are to scarf into the longitudinal framing clear of the machinery spaces. The scantlings of the longitudinals are to be determined as required by Pt 4, Ch 1,6 using a minimum span of 1,3 m, *see* Fig. 7.4.1.

4.1.9 The thickness, t, of inner bottom plating in engine-rooms, clear of the engine seatings, is to be not less than:

$$t = 0{,}0015 \sqrt[4]{L T k^2} \; (s + 660) \quad \text{mm}$$

and not less than 7,0 mm (symbols as defined in Table 7.3.1). This thickness will be required to be increased in way of engine seatings integral with the tank top, *see* 6.2.1.

4.1.10 Where the height of inner bottom in the machinery spaces differs from that in adjacent spaces, continuity of longitudinal material is to be maintained by sloping the inner bottom over an adequate longitudinal extent. The knuckles in the plating are to be arranged close to plate floors.

4.2 Single bottom structure

4.2.1 In way of machinery spaces situated amidships the minimum depth of floors is to be at least 10 per cent greater than that required elsewhere in general cargo ships, *see* Pt 4, Ch 1,7. If the top of the floors is recessed in way of the engines, the depth of the floors in way of the recess should generally be not less than that required by Pt 4, Ch 1,7, but this will be specially considered in each case in relation to the arrangements proposed.

4.2.2 In way of machinery spaces situated aft, or where there is considerable rise of floor, the depth of the floors will be specially considered.

4.2.3 Clear of the engine seatings the thickness and face plate area of the floor webs are to be 1,0 mm and 10 per cent greater, respectively, than the requirements for general cargo ships as given in Pt 4, Ch 1,7. The floors are not to be flanged.

4.2.4 Sufficient fore and aft girders are to be arranged in way of machinery to effectively distribute its weight and ensure adequate rigidity of the structure. In midship machinery spaces these girders are to extend for the full length of the space and are to be carried aft to support the foremost shaft tunnel bearing and forward to scarf into the structure. In machinery spaces situated at the aft end, the girders are to be carried as far aft as practicable and the ends effectively supported by web frames or transverses. For scantlings of engine girders, *see* 6.2.1.

4.2.5 Outboard of the engines, side girders are to be arranged having scantlings as required by Pt 4, Ch 1,7 and these are to be scarfed into the side girders in adjacent spaces.

■ *Section 5*
Machinery casings and oil fuel bunkers

5.1 Machinery casings

5.1.1 The scantlings and arrangements of exposed casings protecting machinery openings are to be in accordance with Ch 8,2.

5.1.2 The minimum scantlings of protected casings are to be in accordance with Table 7.5.1.

Table 7.5.1 Protected machinery casings

Item	Minimum scantlings
Plating: In way of cargo hold spaces	$t = 6{,}5 \sqrt{k}$ mm
In way of accommodation spaces	$t = 5{,}0 \sqrt{k}$ mm
Stiffeners	$Z = 0{,}008 l_e s k$ cm^3

Symbols

k = higher tensile steel factor, *see* Ch 2,1.2
l_e = effective length of stiffening member, in metres, *see* Ch 3,3.3
s = spacing of stiffeners, in mm
t = thickness, in mm
Z = section modulus of stiffening member, in cm^3, *see* Ch 3,3.2

NOTE
In no case is the depth of the stiffener to be less than 60 mm.

5.1.3 Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably increased, *see also* Pt 4, Ch 1,4.

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

5.2 Oil fuel bunkers

5.2.1 Oil fuel bunkers situated within the machinery space are generally to comply with the requirements given in Pt 4, Ch 1 or Ch 9, as appropriate.

■ *Section 6*
Engine seatings

6.1 General

6.1.1 Main engines and thrust bearings are to be effectively secured to the hull structure by seatings of adequate scantlings to resist the various gravitational, thrust, torque, dynamic and vibratory forces which may be imposed on them.

6.1.2 For initial guidance, recommended scantlings for oil engine seatings are given in 6.2.1.

6.1.3 In the case of higher power oil engines or turbine installations the seatings should generally be integral with the double bottom structure. The tank top plating in way of the engine foundation plate or the turbine gear case and the thrust bearing should be substantially increased in thickness, *see* Fig. 7.6.1, Type 1.

6.1.4 If the main machinery is supported on seatings of Type 2 as shown in Fig. 7.6.1, these are to be so designed that they distribute the forces from the engine as uniformly as possible into the supporting structure. Longitudinal members supporting the seating are to be arranged in line with girders in the double bottom, and adequate transverse stiffening is to be arranged in line with floors, *see* Fig. 7.6.1, Type 2.

6.1.5 In ships having open floors in the machinery space the seatings are generally to be arranged above the level of the top of floors and securely bracketed to them, *see* Fig. 7.6.1, Type 3.

6.2 Seats for oil engines

6.2.1 In determining the scantlings of seats for oil engines, consideration is to be given to the general rigidity of the engine itself and to its design characteristics in regard to out of balance forces. As a general guide to designers, recommended scantlings are given in Table 7.6.1.

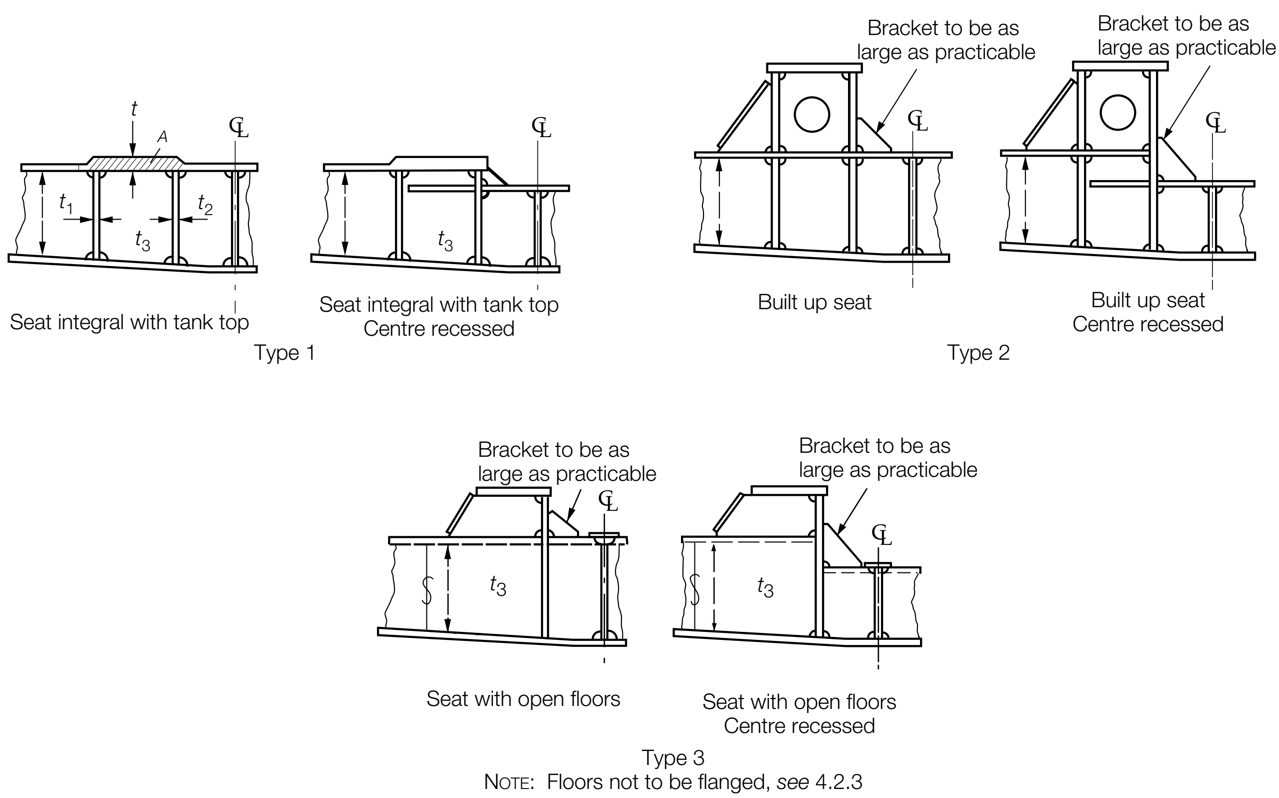


Fig. 7.6.1 Engine seatings

Table 7.6.1 Seats for oil engines – Recommended scantlings

Symbols	Item	Scantlings of one seat
L as defined in Ch 1,6.1 f = engine factor = $\frac{P}{Rl}$ t = minimum thickness of top plate, in mm t_1, t_2 = main engine girder thicknesses, in mm t_3 = floor plate thickness under seating, in mm, *see also* Fig. 7.6.1 A = area of top plate for one side of seat, in cm^2 where l = effective length of engine foundation plate, in metres, required for bolting the engine to the seating. The thrust and gearcase seating is to be considered as a separate item P = power of one engine at maximum service speed, in kW (bhp) R = rev/min of engine at maximum service speed	Top plate	A = $(120 + 44{,}2f + 4{,}07f^2)$ cm^2 (A = $(120 + 32{,}5f + 2{,}2f^2)$ cm^2) Minimum thickness: (a) Where two girders fitted t = $(19 + 3{,}4f)$ mm (t = $(19 + 2{,}5f)$ mm) (b) Where one girder fitted t = $(25 + 3{,}4f)$ mm (t = $(25 + 2{,}5f)$ mm)
	Girders (both inside and above double bottom where fitted)	Number: Generally two but a single girder can be accepted where all the following apply: (a) $f <$ 1,84 (2,5) (b) $P <$ 5900 kW (8000 bhp) (c) $L <$ 100 m Total thickness: (a) Where two girders are fitted $t_1 + t_2$ = $(28 + 4{,}08f)$ mm ($t_1 + t_2$ = $(28 + 3{,}0f)$ mm) (b) Where one girder is fitted t_1 = $(15 + 4{,}08f)$ mm (t_1 = $(15+ 3{,}0f)$ mm)
	Floors (between girders or under seat where a single girder is fitted)	Thickness: t_3 = $(10 + 1{,}5f)$ mm (t_3 = $(10 + 1{,}1f)$ mm

6.3 Seats for turbines

6.3.1 Seats are to be so designed as to provide effective support for the turbines and ensure their proper alignment with the gearing, and (where applicable) allow for thermal expansion of the casings. In general, the seats are not to be arranged in way of breaks or recesses in the double bottom.

6.4 Seats for boilers

6.4.1 Boiler bearers are to be of substantial construction and efficiently supported by transverse and horizontal brackets. These should generally be arranged in line with plate floors and girders in a double bottom or with suitable deep beams or transverses and girders at boiler flats. Suitable allowance is to be made in the design of the supporting structure for the variation in loading due to thermal expansion effects, *see also* Pt 5, Ch 14,2.

6.5 Seats for auxiliary machinery

6.5.1 Auxiliary machinery is to be secured on seatings, of adequate scantlings, so arranged as to distribute the loadings evenly into the supporting structure.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all types of ships detailed in Part 4, except for deckhouses situated on forecastles of offshore supply ships, which are dealt with separately in Pt 4, Ch 4.

1.1.2 The scantlings of exposed bulkheads and decks of superstructures and deckhouses are generally to comply with the following requirements, but increased scantlings may be required where the structure is subjected to loading additional to Rule. Where there is no access from inside the house to below the freeboard deck, or where a bulkhead is in a particularly sheltered location, the scantlings may be specially considered.

1.1.3 The term 'erection' is used in this Section to include both superstructures and deckhouses.

1.1.4 For requirements relating to companionways, doors, accesses and skylights, *see* Chapter 11.

1.1.5 The requirements in this Chapter are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation with the exception of Section 5 which is to be complied with. *See* Pt 1, Ch 2,2.3.

1.2 Symbols

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

L, B, T and C_b as defined in Ch 1,6.1

b = breadth of deckhouse, at the positions under consideration, in metres

k = higher tensile steel factor, *see* Ch 2,1.2

l_e = effective length, in metres, of the stiffening member, deck beam or longitudinal measured between span points, *see* Ch 3,3.3

l_s = span, in metres, of stiffeners, and is to be taken as the 'tween deck or house height but in no case as less than 2,0 m

s = spacing of stiffeners, beams or longitudinals, in mm

s_b = standard spacing, in mm, of stiffeners, beams or longitudinals, and is to be taken as:

(a) for 0,05L from the ends:
s_b = 610 mm or that required by (b), whichever is the lesser

(b) elsewhere:
$s_b = 470 + 1,67L_2$ mm
but forward of 0,2L from the forward perpendicular s_b is not to exceed 700 mm

B_1 = actual breadth of ship, at the section under consideration, measured at the weather deck, in metres

D = moulded depth of ship, in metres, to the uppermost continuous deck or the deck next above a height of 1,6T from the base line amidships, whichever is the lesser

L_2 = length of ship, in metres, but need not be taken greater than 250 m

L_3 = length of ship, in metres, but need not be taken greater than 300 m

X = distance, in metres, between the after perpendicular and the bulkhead under consideration. When determining the scantlings of deckhouse sides, the deckhouse is to be subdivided into parts of approximately equal length not exceeding 0,15L each, and X is to be measured to the mid-length of each part

α = a coefficient given in Table 8.1.1

$$\beta = 1{,}0 + \left(\frac{\left(\frac{X}{L} - 0{,}45\right)}{(C_b + 0{,}2)}\right)^2 \quad \text{for } \frac{X}{L} \leq 0{,}45$$

$$= 1{,}0 + 1{,}5\left(\frac{\left(\frac{X}{L} - 0{,}45\right)}{(C_b + 0{,}2)}\right)^2 \quad \text{for } \frac{X}{L} > 0{,}45$$

C_b is to be taken as not less than 0,6 nor greater than 0,8. Where the aft end of an erection is forward of amidships, the value of C_b used in determining β for the aft end bulkhead need be taken as not less than 0,8

γ = vertical distance, in metres, from the summer load waterline to the mid-point of span of the bulkhead stiffener, or the mid-point of the plate panel, as appropriate

δ = 1,0 for exposed machinery casings and houses protecting openings to pump-rooms

$\left(0{,}3 + 0{,}7\frac{b}{B_1}\right)$ elsewhere, but in no case to be taken less than 0,475

λ = a coefficient given in Table 8.1.2.

Table 8.1.1 Values of α

Position		α
Lowest tier	– unprotected front	$2{,}0 + 0{,}0083L_3$
Second tier	– unprotected front	$1{,}0 + 0{,}0083L_3$
Third tier and above All tiers All tiers	– unprotected front – protected fronts – sides	$0{,}5 + 0{,}0067L_3$
All tiers	– aft end where aft of amidships	$0{,}7 + 0{,}001L_3 - 0{,}8\frac{X}{L}$
All tiers	– aft end where forward of amidships	$0{,}5 + 0{,}001L_3 - 0{,}4\frac{X}{L}$

Table 8.1.2 Values of λ

Length L metres	λ	Expression for λ
20	0,89	$L \leq 150$ m $\lambda = \left(\frac{L}{10} e^{-\frac{L}{300}}\right) - \left(1 - \left(\frac{L}{150}\right)^2\right)$
30	1,76	
40	2,57	
50	3,34	
60	4,07	
70	4,76	
80	5,41	
90	6,03	
110	7,16	
130	8,18	
150	9,10	
150	9,10	$150 \text{ m} \leq L \leq 300$ m $\lambda = \frac{L}{10} e^{-\frac{L}{300}}$
170	9,65	
190	10,08	
210	10,43	
230	10,69	
250	10,86	
270	10,98	
290	11,03	
300	11,03	
300 and above	11,03	$L \geq 300$ m $\lambda = 11{,}03$

1.3 Definition of tiers

1.3.1 The lowest, or first tier, is normally that which is directly situated on the deck to which D is measured. The second tier is the next tier above the lowest tier and so on.

1.3.2 Where the freeboard corresponding to the required summer moulded draught for the ship can be obtained by considering the ship to have a virtual moulded depth at least one standard superstructure height less than the Rule depth, D, measured to the uppermost continuous deck, proposals to treat the first tier erection as a second tier, and so on, will be specially considered. The standard height of superstructure is the height defined in the *International Convention on Load Lines, 1966*.

1.4 Design pressure head

1.4.1 The design pressure head, h, to be used in the determination of erection scantlings is to be taken as:

$$h = \alpha\,\delta\,(\beta\,\lambda - \gamma) \text{ m}$$

1.4.2 In no case is the design pressure head to be taken as less than the following:

(a) Lowest tier of unprotected fronts:
minimum $h = 2{,}5 + 0{,}01L_2$ m

(b) All other locations:
minimum $h = 1{,}25 + 0{,}005L_2$ m.

■ *Section 2*
Scantlings of erections other than forecastles

2.1 Thickness of bulkhead and side plating

2.1.1 The thickness, t, of plating of the fronts, sides and aft ends of all erections, other than the sides of superstructures where these are an extension of the side shell, is to be not less than:

$$t = 0{,}003s\sqrt{kh} \text{ mm}$$

but in no case is the thickness to be less than:

(a) for the lowest tier:

$$t = (5{,}0 + 0{,}01L_3)\sqrt{k} \text{ mm}$$

(b) for the upper tiers:

$$t = 4{,}0 + 0{,}01L_3\sqrt{k} \text{ mm but not less than 5,0 mm.}$$

2.1.2 The thickness of sides of poops and bridges is to be as required by Ch 6,3 or Pt 4, Ch 1,5, as appropriate.

2.2 Stiffeners and their connections

2.2.1 The modulus of stiffeners, Z, on front, side and end bulkheads of all erections, other than sides of superstructures, is to be not less than:

$$Z = 0{,}0035h\,s\,l_s^2\,k \text{ cm}^3$$

2.2.2 The section modulus of side frames of poops and bridges is to comply with the requirements of Ch 6,4 or Pt 4, Ch 1,6, as appropriate.

2.2.3 The end connections of stiffeners are to be as given in Table 8.2.1.

2.3 Deck plating

2.3.1 The thickness of erection deck plating is to be not less than that required by Table 8.2.2.

Table 8.2.1 Stiffener end connections

Position	Attachment at top and bottom
1. Front stiffeners of lower tiers and of upper tiers when *L* is 160 m or greater	*See* Chapter 10
2. Front stiffeners of upper tiers when *L* is less than 160 m	May be unattached
3. Side stiffeners of lower tiers where two or more tiers are fitted	Bracketed, unless stiffener modulus is increased by 20 per cent and ends are welded to the deck all round
4. Side stiffeners if only one tier is fitted, and aft end stiffeners of after deck-houses on deck to which *D* is measured	*See* Chapter 10
5. Side stiffeners of upper tiers when *L* is 160 m or greater	*See* Chapter 10
6. Side stiffeners of upper tiers when *L* is less than 160 m	May be unattached
7. Aft end stiffeners except as covered by item 4	May be unattached
8. Exposed machinery and pump-room casings – Front stiffeners on amid-ship casings and all stiffeners on aft end casings which are situated on the deck to which *D* is measured	Bracketed
9. All other stiffeners on exposed machinery and pump-room casings	6,5 cm^2 of weld

Table 8.2.2 Thickness of deck plating

Position	Thickness of deck plating, in mm		
	$L \leq 100$ m		$L > 100$ m
Top of first tier erection	$(5,5 + 0,02L)\sqrt{\dfrac{ks}{s_b}}$	but not less than 5,0 mm	$7,5\sqrt{\dfrac{ks}{s_b}}$
Top of second tier erection	$(5,0 + 0,02L)\sqrt{\dfrac{ks}{s_b}}$	but not less than 5,0 mm	$7,0\sqrt{\dfrac{ks}{s_b}}$
Top of third tier and above	$(4,5 + 0,02L)\sqrt{\dfrac{ks}{s_b}}$	but not less than 5,0 mm	$6,5\sqrt{\dfrac{ks}{s_b}}$

2.3.2 When decks are fitted with approved sheathing, the thicknesses derived from Table 8.2.2 may be reduced by 10 per cent for a 50 mm sheathing thickness, or 5 per cent for 25,5 mm, with intermediate values in proportion. The steel deck is to be coated with a suitable material in order to prevent corrosive action, and the sheathing or composition is to be effectively secured to the deck, *see also* Pt 6, Ch 4. Inside deckhouses the thickness may be reduced by a further 10 per cent.

2.4 Deck longitudinals and beams

2.4.1 The section modulus of superstructure deck longitudinals and beams is to be in accordance with the requirements for location (2) in Table 1.4.4 and location (3) in Table 1.4.5 in Pt 4, Ch 1, using design heads not less than those specified in Table 3.5.1 in Chapter 3 for superstructure decks.

2.4.2 Transverse deck beams in deckhouses and deck longitudinals other than as in 2.7 are to have a section modulus, *Z*, not less than:

$Z = 0,0048 h_2 s\, l_e^2\, k$ cm^3, but in no case less than:

$Z = 0,025 s$ cm^3

and the value of h_2, the load head, is to be taken as not less than:

on first tier decks	0,9 m
on second tier decks	0,6 m
on third tier decks and above	0,45 m.

2.5 Deck girders and transverses

2.5.1 The section modulus of deck girders and transverses is to be in accordance with the requirements for location (1) in Table 1.4.6 in Pt 4, Ch 1, using design heads not less than those specified in Table 3.5.1 in Chapter 3 for superstructure decks.

2.6 Strengthening at ends and sides of erections

2.6.1 Web frames or partial bulkheads are to be fitted within poops and bridges that have large deckhouses or other erections above.

2.6.2 Web frames or equivalent strengthening are also to be arranged to support the sides and ends of large deck-houses.

2.6.3 These web frames should be spaced about 9 m apart and are to be arranged, where practicable, in line with watertight bulkheads below. Webs are also to be arranged in way of large openings, boats, davits and other points of high loading.

2.6.4 Arrangements are to be made to minimize the effect of discontinuities in erections. All openings cut in the sides are to be substantially framed and have well rounded corners. Continuous coamings or girders are to be fitted below and above doors and similar openings. House tops are to be strengthened in way of davits. Special care is to be taken to minimize the size and number of openings in the side bulkheads in the region of the ends of erections within 0,5*L* amidships. Account is to be taken of the high vertical shear loading which can occur in these areas.

2.6.5 Adequate support under the ends of erections is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams. At the corners of houses and in way of supporting structures, attention is to be given to the connection to the deck, and inserts or equivalent arrangements are generally to be fitted especially for erections that are effective in resisting vertical hull girder bending as defined in Pt 3, Ch 3,3.4.2.

2.6.6 The side plating of bridges having a length of 0,15*L* or greater is to be increased in thickness by 25 per cent at the ends of the structure, and is to be tapered into the upper deck sheerstrake. This plating is to be efficiently stiffened at the upper edge and supported by web plates not more than 1,5 m from the end bulkhead. Proposals for alternative arrangements, including the use of higher tensile steel, will be individually considered.

2.7 Erections contributing to hull strength

2.7.1 Where a long superstructure or deckhouse is fitted, extending within 0,5*L* amidships, the scantlings of the first tier deck plating and longitudinals may be required to be increased, *see also* Ch 3,3.4 and Ch 4,2.3.

2.8 Unusual designs

2.8.1 Where superstructures or deckhouses are of unusual design, the strength is to be not less than that required by this Chapter for a conventional design.

■ *Section 3* Aluminium erections

3.1 Scantlings

3.1.1 Where an aluminium alloy complying with Chapter 8 of the Rules for Materials (Part 2) is used in the construction of erections, the scantlings of these erections are to be increased (relative to those required for steel construction) by the percentages given in Table 8.3.1.

3.1.2 The thickness, *t*, of aluminium alloy members is to be not less than:

$t = 2{,}5 + 0{,}022 d_w$ mm but need not exceed 10 mm

where

d_w = depth of the section, in mm.

3.1.3 The minimum moment of inertia, I, of aluminium alloy stiffening members is to be not less than:

$I = 5{,}25 Z\, l_e$ cm^4

Where l_e is the effective length of the member in metres, as defined in 1.2.1, and *Z* is the section modulus of the stiffener and attached plating calculated using the formulae in 2.2.1 and 2.4.2 as applicable taking *k* as 1.

Table 8.3.1 Percentage increase of scantlings

Item	Percentage increase
Fronts, sides, aft ends, unsheathed deck plating	20
Decks sheathed in accordance with 2.3.2	10
Deck sheathed with wood, and on which the plating is fixed to the wood sheathing at the centre of each beam space	Nil
Stiffeners and beams	70
Scantlings of small isolated houses	Nil

3.2 Bimetallic joints

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

■ *Section 4* Forecastles

4.1 Construction

4.1.1 Side plating and framing of forecastles are to comply with the requirements of Ch 5,3 and Ch 5,4 respectively. The end plating and its stiffening are to comply with the requirements of 2.1.1 and 2.2.1 respectively.

4.1.2 The bow height and the extent of the forecastle are to comply with the requirements of Ch 3,6.

4.1.3 The thickness, *t*, of forecastle deck plating is to be not less than:

$$t = (6 + 0{,}017L)\sqrt{\frac{ks}{s_b}} \quad \text{mm}$$

4.1.4 Deck longitudinals and beams are to comply with Ch 5,2.3, using a head of 1,8 m forward of 0,075*L* and 1,5 m between 0,12*L* and 0,075*L.*

4.1.5 Girders, transverses and pillars are to be in accordance with Ch 5,2.4, and the depth of the girder or transverse is to be not less than twice that of the beam or longitudinal supported.

■ *Section 5* Bulwarks, guard rails and other means for the protection of crew

5.1 General requirements

5.1.1 Bulwarks or guard rails are to be provided around all exposed decks. Bulwarks or guard rails are to be not less than 1,0 m in height measured above sheathing, and are to be constructed as required by this Section. Consideration will be given to cases where this height would interfere with the normal operation of the ship.

5.1.2 The freeing arrangements in bulwarks are to be in accordance with 5.3.

5.1.3 Guard rails fitted on superstructure and freeboards decks are to have at least three courses. The opening below the lowest course of guard rails is not to exceed 230 mm. The other courses are to be spaced not more than 380 mm apart. In the case of ships with rounded gunwales, the guard rail supports are to be placed on the flat of the deck. In other locations, guard rails with at least two courses are to be fitted.

5.1.4 Guard rails are to be fitted with fixed, removable or hinged stanchions fitted no more than 1,5 m apart. Removable or hinged stanchions shall be capable of being locked in the upright position.

5.1.5 At least every third stanchion is to be supported by a stay.

5.1.6 Where necessary for the normal operation of the ship, steel wire ropes may be accepted in lieu of guard rails. Wires are to be made taut by means of turnbuckles. Chains are only permitted in short lengths in way of access openings.

5.1.7 Satisfactory means, in the form of guard rails, life-lines, handrails, gangways, underdeck passageways or other equivalent arrangements, are to be provided for the protection of the crew in getting to and from their quarters, the machinery space and all other parts used in the necessary work of the ship in accordance with Table 8.5.1.

5.1.8 Where gangways on a trunk are provided by means of a stringer plate fitted outboard of the trunk side bulkheads (port and starboard), each gangway is to be a solid plate, effectively stayed and supported, with a clear walkway at least 450 mm wide, at or near the top of the coaming, with guard rails complying with 5.1.3 and hatch cover securing appliances accessible from the gangway.

5.1.9 Where permitted by the National Authority, gangways or walkways may be omitted on ships engaged on protected or extended protected water service. However, life-lines are to be provided on tankers and flush deck ships, or where the cargo hatch coamings are less than 600 mm high.

5.1.10 For a Type ‘A’ ship with freeboards assigned greater than, or equal to, Type ‘B’, a life-line may be provided in lieu of a walkway.

5.2 Bulwark construction

5.2.1 Plate bulwarks are to be stiffened by a strong rail section and supported by stays from the deck. The spacing of these stays forward of 0,07*L* from the forward perpendicular is to be not more than 1,2 m on Type ‘A’, Type ‘B-60’ and Type ‘B-100’ ships (as defined in Ch 11,1.1), and not more than 1,83 m on other Types. Elsewhere, bulwark stays are to be not more then 1,83 m apart. Where bulwarks are cut to form a gangway or other opening, stays of increased strength are to be fitted at the ends of the openings. Bulwarks are to be adequately strengthened in way of eyeplates for cargo gear, and in way of mooring pipes the plating is to be doubled or increased in thickness and adequately stiffened.

5.2.2 Bulwarks should not be cut for gangway or other openings near the breaks of superstructures, and are also to be arranged to ensure their freedom from main structural stresses. *See* shell plating in appropriate Chapters.

5.2.3 The section modulus, Z, at the bottom of the bulwark stay is to be not less than:

$$Z = (33{,}0 + 0{,}44L)\, h^2 s \quad \text{cm}^3$$

where

h = height of bulwark from the top of the deck plating to the top of the rail, in metres

s = spacing of the stays, in metres, in accordance with 5.2.1

L = length of ship, in metres (as defined in Ch 1,6.1), but to be not greater than 100 m.

5.2.4 In the calculation of the section modulus, only the material connected to the deck is to be included. The bulb or flange of the stay may be taken into account where connected to the deck, and where, at the ends of the ship, the bulwark plating is connected to the sheerstrake, a width of plating not exceeding 600 mm may also be included. The free edge of the stay is to be stiffened.

5.2.5 Bulwark stays are to be supported by, or to be in line with, suitable underdeck stiffening, which is to be connected by double continuous fillet welds in way of the bulwark stay connection.

5.2.6 It should be noted that the above requirements do not allow for any loading from deck cargoes.

5.3 Freeing arrangements

5.3.1 The requirements of 5.3.2 to 5.3.11 apply to ships of Type ‘B’. Additional requirements applicable to ships of Type ‘A’, Type ‘B-100’ and Type ‘B-60’ are indicated in 5.3.18 and 5.3.20. The ship Types are as defined in Ch 11,1.1.

5.3.2 Where bulwarks on the weather portions of free-board or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of large quantities of water by means of freeing ports, and also for draining them.

Table 8.5.1 Protection of crew (*see continuation*)

Ship type	Location in ship	Assigned Summer Freeboard, in mm	Acceptable arrangements according to type of freeboard assigned			
			Type A	Type (B-100)	Type (B-60)	Type (B & B+)
Oil tankers, chemical tankers and gas carriers (*see* 1.1.5)	1.1 Access to bow 1.1.1 Between poop and bow or 1.1.2 Between a deckhouse containing living accommodation or navigation equipment, or both, and bow, or 1.1.3 In the case of a flush deck vessel, between crew accommodation and the forward ends of ship	≤ ($A_f + H_s$)	a e f(1) f(5)	a e f(1) f(5)	a e f(1) f(5)	a e f(1) f(5)
		>($A_f + H_s$)	a e f(1) f(2)			
	1.2 Access to after end In the case of a flush deck vessel, between crew accommodation and the after end of ship	As required in item 2.2.4 in Table 8.5.1 for other types of ships				

Symbols

A_f = the minimum summer freeboard calculated as Type A ship regardless of type freeboard actually assigned
H_s = the standard height of superstructure as defined in International Convention on Load Lines, Regulation 33

Acceptable arrangements:

Acceptable arrangements referred to in the Table are defined as follows:

a A well lighted and ventilated under-deck passageway (clear opening 0,8 m wide, 2 m high) as close as practicable to the freeboard deck, connecting and providing access to the locations in question.

b A permanent and efficiently constructed gangway fitted at or above the level of the superstructure deck on or as near as practicable to the centreline of the ship, providing a continuous platform at least 0,6 m in width and a non-slip surface, with guard rails extending on each side throughout its length. Guard rails shall be at least 1 m high with courses as required in 5.1, and supported by stanchions spaced not more than 1,5 m; a foot-stop shall be provided.

c A permanent walkway at least 0,6 m in width fitted at freeboard deck level consisting of two rows of guard rails with stanchions spaced not more than 3 m. The number of courses of rails and their spacing are to be as required by 5.1. On Type B ships, hatchway coamings not less than 0,6 m in height may be regarded as forming one side of the walkway, provided that between the hatchways two rows of guard rails are fitted.

d A 10 mm minimum thickness diameter wire rope life-line supported by stanchions about 10 m apart, or a single hand rail or wire rope attached to hatch coamings, continued and adequately supported between hatchways.

e A permanent and efficiently constructed gangway fitted at or above the level of the superstructure deck on or as near as practicable to the centreline of the ship:
- located so as not to hinder easy access across the working areas of the deck;
- providing a continuous platform at least 1,0 m in width;
- constructed of fire resistant and non-slip material;
- fitted with guard rails extending on each side throughout its length; guard rails should be at least 1,0 m high with courses as required by Regulation 25(3) and supported by stanchions spaced not more than 1,5 m;
- provided with a foot stop on each side;
- having openings, with ladders where appropriate, to and from the deck. Openings should not be more than 40 m apart;
- having shelters of substantial construction set in way of the gangway at intervals not exceeding 45 m if the length of the exposed deck to be traversed exceeds 70 m. Every such shelter should be capable of accommodating at least one person and be so constructed as to afford weather protection on the forward port and starboard sides.

f A permanent and efficiently constructed walkway fitted at freeboard deck level on or as near as practicable to the centre line of the ship having the same specifications as those for a permanent gangway listed in (e) except for foot-stops. On Type B ships (certified for the carriage of liquids in bulk), with a combined height of hatch coaming and fitted hatch cover of together not less than 1 m in height the hatchway coamings may be regarded as forming one side of the walkway, provided that between the hatchways two rows of guard rails are fitted.

Alternative transverse locations for (c), (d) and (f):

(1) At or near centreline of ship; or
fitted on hatchways at or near centreline of ship.
(2) Fitted on each side of the ship.
(3) Fitted on one side of the ship, provision being made for fitting on either side.
(4) Fitted on one side of the ship only.
(5) Fitted on each side of hatchways as near to the centreline as practicable.

Table 8.5.1 Protection of crew (*conclusion*)

Ship type	Location in ship	Assigned Summer Freeboard, in mm	Acceptable arrangements according to type of freeboard assigned			
			Type A	Type (B-100)	Type (B-60)	Type (B & B+)
Other ship type	2.1 Access to midship quarters 2.1.1 Between poop and bridge, or	≤ 3000 mm	a b e	a b e	a b c(1) e f(1)	a b c(1) c(2) c(4) d(1) d(2) d(3) e f(1) f(2) f(4)
	2.1.2 Between poop and deckhouse containing living accommodation or navigation equipment, or both	> 3000 mm	a b e	a b e	a b c(1) c(2) e f(1) f(2)	
	2.2 Access to ends 2.2.1 Between poop and bow (if there is no bridge), 2.2.2 Between bridge and bow, or	≤ 3000 mm	a b c(1) e f(1)	a b c(1) c(2) e f(1) f(2)	a b c(1) c(2) e f(1) f(2)	
	2.2.3 Between a deckhouse containing living accommodation or navigation equipment, or both, and bow, or 2.2.4 In the case of a flush deck vessel, between crew accommodation and the forward and after ends of ship	> 3000 mm	a b c(1) d(1) e f(1)	a b c(1) c(2) d(1) d(2) e f(1) f(2)	a b c(1) c(2) c(4) d(1) d(2) d(3) e f(1) f(2) f(4)	

NOTES
1. In all cases where wire ropes are fitted, adequate devices are to be provided to ensure their tautness.
2. Wire ropes may only be accepted in lieu of guard rails in special circumstances and then only in limited lengths.
3. Lengths of chain may only be accepted in lieu of guard rails if fitted between two fixed stanchions.
4. Where stanchions are fitted, every third stanchion is to be supported by a bracket or stay.
5. Removable or hinged stanchions shall be capable of being locked in the upright position.
6. A means of passage over obstructions, if any, such as pipes or other fittings of a permanent nature, should be provided.
7. Generally, the width of the gangway or deck-level walkway should not exceed 1,5 m.

5.3.3 The minimum freeing area on each side of the ship, for each well on the freeboard deck or raised quarterdeck, where the sheer in the well is not less than the standard sheer required by the *International Convention on Load Lines,1966*, is to be derived from the following formulae:

(a) where the length, l, of the bulwark in the well is 20 m or less:
area required = $0,7 + 0,035l$ m^2

(b) where the length, l, exceeds 20 m:
area required = $0,07l$ m^2

l need not be taken greater than $0,7L_L$, where L_L is the length of the ship as defined in Ch 1,6.1.

5.3.4 If the average height of the bulwark exceeds 1,2 m or is less than 0,9 m, the freeing area is to be increased or decreased, respectively, by 0,004 m^2 per metre of length of well for each 0,1 m increase or decrease in height respectively.

5.3.5 The minimum freeing area for each well on a first tier superstructure is to be half the area calculated from 5.3.3.

5.3.6 Two-thirds of the freeing port area required is to be provided in the half of the well nearest to the lowest point of the sheer curve.

5.3.7 When the deck has little or no sheer, the freeing area is to be spread along the length of the well.

5.3.8 In ships with no sheer the freeing area as calculated from 5.3.3 is to be increased by 50 per cent. Where the sheer is less than the standard, the percentage is to be obtained by linear interpolation.

5.3.9 Where the length of the well is less than 10 m, or where a deckhouse occupies most of the length, the freeing port area will be specially considered but in general need not exceed 10 per cent of the bulwark area.

5.3.10 Where it is not practical to provide sufficient freeing port area in the bulwark, particularly in small ships, credit can be given for bollard and fairlead openings where these extend to the deck.

5.3.11 Where a ship fitted with bulwarks has a continuous trunk, or hatch side coamings that are continuous, or substantially continuous, the minimum freeing area is to be not less than 20 per cent of the total bulwark area where the width of trunk or hatchway is 0,4*B* or less, and not less than 10 per cent of the total bulwark area when the width of the trunk or hatch is 0,75*B* or greater. The freeing area required for an intermediate width of trunk or hatch is to be obtained by linear interpolation.

5.3.12 Where the trunk referred to in 5.3.11 or its equivalent is included in the calculation of freeboard, open rails are to be fitted for at least 50 per cent of the length of the exposed part of the weather deck. Alternatively, if a continuous bulwark is fitted, the minimum freeing area is to be at least 33 per cent of the bulwark area. The freeing area is to be placed in the lower part of the bulwark.

5.3.13 Where a deckhouse has a breadth less than 80 per cent of the beam of the ship, or the width of the side passageways exceeds 1,5 m, the arrangement is considered as one well. Where a deckhouse has a breadth equal to or more than 80 per cent of the beam of the ship, or the width of the side passageways does not exceed 1,5 m, or when a screen bulkhead is fitted across the full breadth of the ship, this arrangement is considered as two wells, before and abaft the deckhouse.

5.3.14 Suitable provision is also to be made for the rapid freeing of water from recesses formed by superstructures, deckhouses and deck cargo arrangements, etc., in which water may be shipped and trapped. Deck gear, particularly on fishing vessels, is not to be stowed in such a manner as to obstruct unduly the flow of water to freeing ports.

5.3.15 The lower edges of freeing ports are to be as near to the deck as practicable, and should not be more than 100 mm above the deck.

5.3.16 Where freeing ports are more than 230 mm high, vertical bars spaced 230 mm apart may be accepted as an alternative to a horizontal rail to limit the height of the freeing port.

5.3.17 Where shutters are fitted, the pins or bearings are to be of a non-corrodible material, with ample clearance to prevent jamming. The hinges are to be within the upper third of the port. Shutters are not to be fitted with securing appliances.

5.3.18 Ships of Type 'A' and Type 'B-100' are to have open rails for at least half the length of the exposed part of the weather deck. Alternatively, if a continuous bulwark is fitted, the minimum freeing area is to be at least 33 per cent of the total area of the bulwark. The freeing area is to be placed in the lower part of the bulwark.

5.3.19 Where superstructures are connected by trunks, open rails are to be fitted for the whole length of the exposed part of the freeboard deck.

5.3.20 Ships of Type 'B-60' are to have a minimum freeing area of at least 25 per cent of the total area of the bulwark. The freeing area is to be placed in the lower part of the bulwark.

5.3.21 Gutter bars greater than 300 mm in height fitted on the weather decks of tankers are to be treated as bulwarks and freeing ports arranged as required by this Section. Closures for use during loading and discharge operations are to be arranged in such a way that jamming cannot occur while at sea.

5.3.22 In ships having superstructures which are open at either or both ends to wells formed by bulwarks on the open deck, adequate provision for freeing the open spaces are to be provided as follows:
The freeing port area, A_w for the open well:

$$A_w = (0,07l_w + A_c)(S_c)\left(\frac{0,5h_s}{h_w}\right)$$

The freeing port area, A_s for the open superstructure:

$$A_s = (0,07l_t)(S_c)\left(\frac{b_o}{l_t}\left(1-\left(\frac{l_w}{l_t}\right)^2\right)\left(\frac{0,5h_s}{h_w}\right)\right)$$

where
l_w = the length of the open deck enclosed by bulwarks, in metres
l_s = the length of the common space within the open superstructure, in metres
l_t = $l_w + l_s$ but if 20 m or less then the freeing area is to be calculated in accordance with 5.3.3(a)
S_c = sheer correction factor, maximum 1,5 as defined in 5.3.8
b_o = breadth of openings in the end bulkhead of the enclosed superstructure, in metres
h_w = distance of the well deck above the freeboard deck, in metres
h_s = one standard superstructure height
h_b = actual height of the bulwark, in metres.
A_c = bulwark height correction factor taken as;
= 0 for bulwarks between 0,9 and 1,2 m in height
= $l_w\left(\frac{(h_b - 1,2)}{1,0}\right)(0,004)$ m^2 for bulwarks of height greater than 1,2 m, and
= $l_w\left(\frac{(h_b - 0,9)}{1,0}\right)(0,004)$ m^2 for bulwarks of height less than 0,9 m

5.4 Free flow area

5.4.1 The effectiveness of the freeing port area in bulwarks of vessels not fitted with a continuous deck obstruction, depends on the free flow across the deck.

5.4.2 The free flow area is the net total longitudinal area of the transverse passageways or gaps between hatchways and superstructures or deckhouses, due account being made for any obstructions such as equipment or other fittings. The height of passageways or gaps used in the calculation of the area is the height of the bulwark.

5.4.3 The provision of freeing area in bulwarks should be related to the net free flow area as follows:

(a) If the free flow area is equal to, or greater than the freeing port area calculated from 5.3.11 when the hatchway coamings are continuous, then the minimum freeing area calculated from 5.3.3 is sufficient.

(b) If the free flow area is less than the freeing port area calculated from 5.3.3, then the minimum freeing area is to be that calculated from 5.3.11.

(c) If the free flow area is less than the freeing port area derived from (a) but greater than that derived from (b), the minimum freeing area, F, in the bulwark is to be obtained from the following formula:

$$F = F_1 + F_2 - f_p \quad m^2$$

where

f_p = total net area of passages and gaps between hatchways, superstructures and deckhouses (the free flow area)

F_1 = minimum area from 5.3.3

F_2 = minimum area from 5.3.11.

5.5 Special requirements for tugs and offshore supply ships

5.5.1 In tugs and offshore supply ships where there is a recess at the after end of the forecastle for the towing winch, the freeing port area in way of the recess is to be calculated as follows:

B = breadth of ship

b = breadth of recess

L = length of well

l = mean length of recess

a = freeing area for well length L

Freeing port area in way of recess:

$$A = a \frac{l}{L}$$

Reduction due to breadth of recess:

$$A_1 = A \frac{b}{B}$$

Reduce A_1 by 25 per cent for winch area:

A_2 = 0,75 A_1

= required freeing port area each side in way of the recess

Where the winch is enclosed in a non-weathertight compartment freeing ports are not required but adequate drainage by means of scuppers is to be provided.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are to be taken in conjunction with the Chapters of Parts 3 and 4 applicable to the particular ship type.

1.2 Symbols

1.2.1 The following symbols and definitions are applicable to this Chapter:

k = higher tensile steel factor, *see* Ch 2,1.2
l = overall length, of the stiffening member, in metres
l_e = effective length, in metres, of the stiffening member, measured between span points, *see* Ch 3,3.3
s = spacing, of stiffeners, in mm
B = moulded breadth of ship, in metres, *see* Ch 1,6.1
L = length of ship, in metres, *see* Ch 1,6.1
Z = section modulus of the stiffening member, in cm^3, *see* Ch 3,3.2.

1.2.2 Other symbols are defined in the appropriate Section.

■ *Section 2* Timber deck cargoes

2.1 Application

2.1.1 Where timber load lines are to be assigned, the full requirements of this Section are to be complied with, and the ship will be eligible to be assigned the notation 'timber deck cargoes'.

2.1.2 In other cases, proposals to carry timber deck cargoes which will impose on the weather deck a mean cargo loading in excess of 8,5 kN/m^2 (0,865 tonne-f/m^2) will be considered on the basis of these requirements. In particular, the requirements of 2.5 to 2.8 are to be complied with.

2.2 Symbols and definitions

2.2.1 The term 'timber deck cargo' means a cargo of timber carried on an uncovered part of the freeboard or superstructure deck. The term does not include wood pulp or similar cargo.

2.2.2 The symbols used in this Section are defined as follows:

C = mean stowage rate, in m^3/tonne, of the timber deck cargo, making allowance for normal battens, etc.
h = the height, in metres, to which the timber deck cargo is to be stowed, measured vertically from the deck or hatch cover as applicable.

2.2.3 Other symbols are defined in 1.2.

2.3 Statutory Requirements

2.3.1 Attention is drawn to the requirements of the *International Load Line Convention, 1966*, concerning timber deck cargoes, and also to National Regulations.

2.3.2 A timber deck cargo loading and lashing plan, showing the stowage and securing of the timber cargo and the walkway/life-line arrangements, is to be submitted for approval, and a copy placed on board the ship for the information of the Master.

2.3.3 Timber freeboards cannot be used where wood pulp is being carried as the deck cargo. Packaged timber (timber which has been prelashed) may be carried on deck with the ship at its timber freeboards.

2.3.4 Type 'B–60' ships may have timber freeboards assigned based on ordinary Type 'B' freeboards.

2.3.5 Timber freeboards are not appropriate for ships which are assigned freeboards from a second deck. However, where the maximum geometric upper deck draught is restricted, a restricted timber draught may be assigned.

2.3.6 It is the Owner's/Master's responsibility to supply loose gear (e.g. uprights, wire lashings and life-lines) in accordance with the approved timber deck cargo loading and lashing plan when the ship is carrying timber deck cargoes at timber freeboards. However, it is not a requirement that loose gear remains permanently on board a ship assigned timber freeboards.

2.4 Arrangements

2.4.1 Double bottom tanks within the midship half-length are to have adequate longitudinal subdivision.

2.4.2 A forecastle of at least standard height and of length at least 0,07*L* is to be fitted. In addition, in ships of less than 100 m in length, a poop of at least standard height, or a raised quarterdeck with a deckhouse or strong steel hood of at least the same total height, is to be fitted.

2.4.3 Uprights are to be of adequate strength. Where timber uprights are used, it is the responsibility of the Master to use timber which is of a type and grade which has proved satisfactory for the purpose.

2.4.4 Where only packaged timber is to be carried, uprights may be omitted.

2.4.5 The spacing of the uprights is to be suitable for the length and character of the timber to be carried but should not exceed 3 m.

2.4.6 Each upright is to extend above the top of the cargo and be fitted with a strap or bracket support at the top of the bulwark to hold it upright whilst loading.

2.4.7 Strong permanent bulwarks, or efficient rails of specially strong construction, are to be fitted. Steel bulwarks, along with guard rails and stanchions, are acceptable as supports for uprights, provided substantial sockets are built for each upright.

2.4.8 Deck sockets are to be of a size to suit the dimensions of the uprights and are to be not less than 100 mm in depth with drainage provided. They are to be efficiently connected to the hull structure. A locking pin or wedge is to be provided to prevent the upright lifting out of the socket.

2.4.9 The timber deck cargo is to be secured along its length by independent overall lashings.

2.4.10 The spacing of lashings is to be determined by the height of the cargo above the deck:

(a) For a height not exceeding 4 m, the spacing should not be more than 3 m.
(b) For a height of 6 m and above, the spacing should not be more than 1,5 m where the timber uprights are used.
(c) At intermediate heights, the average spacing is to be obtained by linear interpolation.

2.4.11 Lashings are to be provided 0,6 m and 1,5 m from the ends of timber deck cargoes where there is no end bulkhead.

2.4.12 Where only packaged timber is to be carried, and uprights are omitted, lashings are to be spaced 1,5 m apart.

2.4.13 Lashings are to be not less than 19 mm close link chain, or flexible wire rope of equivalent strength, fitted with slip hooks and turnbuckles which are accessible at all times. Wire rope lashings are to have a short length of long link chain to permit the length of the lashings to be regulated.

2.4.14 Lashings and fittings are to have a minimum SWL of 2700 kg and 2800 kg respectively. Each component is to be proof loaded to twice the SWL, and should not show any sign of damage or deformation afterwards.

2.4.15 Where timber is in lengths less than 3,6 m, the spacing of lashings is to be reduced, or other suitable provisions made to suit the length of the timber.

2.4.16 Eye plates are to be of substantial construction, effectively connected to the hull structure, and placed at intervals determined from 2.4.10, 2.4.11 or 2.4.12. The distance from a superstructure end bulkhead to the first eye plate is to be not more than 2 m.

2.4.17 A walkway is to be provided over the timber deck cargo. This walkway is either to be:

(a) At, or near, the centreline of the ship, consisting of two sets of guard wires, spaced 1 m apart, each with three courses of wires, the lower spaced at 230 mm and the remainder at 380 mm. Stanchions are to be not more than 3 m apart, and these are to be secured to the timber cargo by spikes, or other equivalent means. A polypropylene net, with a mesh not greater than 230 mm x 230 mm, in conjunction with stanchions and top and bottom wires, may also be accepted, or
(b) where the timber uprights are taken up 1 m above the top of the timber cargo, three courses of guard wires spaced not more than 350 mm apart, secured to the uprights from forward to aft, port and starboard, with a single wire life-line fitted at the centreline of the ship adequately supported by stanchions spaced not more than 10 m apart.

2.4.18 Safe access is to be provided from the top of the timber deck cargo to poop and forecastle decks.

2.4.19 All openings in the weather deck are to be capable of being properly closed and secured tight. Ventilators, air pipes and other fittings enclosing openings are to be efficiently protected against damage.

2.4.20 Access hatches, vents, air pipes, fire hydrants, hoses, valve operating positions, sounding pipes and other essential equipment are to be clearly marked and left accessible.

2.4.21 The timber deck cargo is to extend athwartships as close as possible to the ship's side, due allowance being made for obstructions provided any gap thus created at the side of the ship does not exceed a mean of four per cent of the breadth.

2.4.22 The timber is to be stowed as solidly as possible to at least the standard height of a superstructure other than a raised quarter deck.

2.5 Longitudinal strength

2.5.1 The proposed timber deck loading conditions are to be taken into account in the longitudinal strength calculations, *see* Chapter 4, and details are to be included in the ship's Loading Manual.

2.6 Deck loading and scantlings

2.6.1 In general, the stowage rate, *C*, of timber deck cargoes is to be taken as:

(a) for round timber and logs:
  $C = 2{,}1$ m^3/tonne

(b) for packaged sawn timber:
  $C = 1{,}45$ m^3/tonne.

These values are based on the total volume occupied by the cargo, including normal battens, etc., measured from bulwark to bulwark, and deck, or hatch cover, to top of cargo.

2.6.2 Where it is proposed to store timber more densely than that corresponding to the above values, the appropriate value of *C* is to be used.

2.6.3 The load height, *h*, of the cargo at any position is to be determined from the overall heights of cargo stowage as supplied by the Shipbuilder. Where the height of cargo varies, a mean effective load height is to be adopted. Attention is drawn to the limitation on height of cargo contained in the Load Lines Conventions where these apply.

2.6.4 A scantling correction factor, *K*, is to be determined from $K = \dfrac{h}{1{,}08C}$, and the hull scantlings are to be increased as follows:

(a) **Deck longitudinals.** The section modulus is to be multiplied by the factor 0,5 (1 + *K*).

(b) **Deck beams.** The load head contained in the expression for section modulus is to be multiplied by *K*, and the section modulus determined using the increased value.

(c) **Deck girders and transverses.** The section modulus is to be multiplied by the factor *K*.

(d) **Pillars and deck supporting structure.** The design load is to be multiplied by the factor *K*, and scantlings determined using the increased value.

(e) **Side structure.** The arrangement and scantlings of side structure are to be considered, and increased scantlings of framing may be required.

2.7 Scantlings of hatch covers

2.7.1 The section modulus and moment of inertia of hatch cover webs and stiffeners determined from Pt 3, Ch 11 are to be multiplied by the factor $\dfrac{1{,}39h}{h_H\, C}$ where h_H is defined in Ch 3,5.1.

2.7.2 The hatch cover securing and support arrangements, stoppers, etc., and coamings are to be suitably reinforced to take account of increased loading from timber deck cargoes, *see* Ch 11,4.2.

2.8 Direct calculations

2.8.1 As an alternative to the above, the scantlings of the deck and side structure, and of hatch covers, may be assessed using direct calculations based on the proposed loading of the ship.

2.8.2 In the case of hatch covers, the stress and deflection criteria given in Table 11.2.3 in Chapter 11 corresponding to a uniformly distributed weather load are not to be exceeded.

■ *Section 3*
Decks loaded by wheeled vehicles

3.1 General

3.1.1 Where it is proposed either to stow wheeled vehicles on the deck or to use wheeled vehicles for cargo handling, the deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, the hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required as a weather or cargo deck or hatch cover, as applicable.

3.1.2 The vehicles, types and axle loads, for which the vehicle carrying decks including, where applicable, hatch covers have been approved, are to be stated in the Loading Manual and be contained in a notice displayed on each deck.

3.2 Symbols

3.2.1 The symbols used in this Section are defined in 1.2 and in the appropriate sub-Section.

3.3 Loading

3.3.1 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Shipbuilder. These details are to include the wheel load, axle and wheel spacing, tyre print dimensions and type of tyre for the vehicles.

3.3.2 For design purposes, where wheeled vehicles are to be used for cargo handling, the deck is to be taken as loaded with a normal head cargo, except in way of the vehicle.

Table 9.3.1 Deck plate thickness calculation

Symbols	Expression
a, s, u, and *v* as defined in Fig. 9.3.1 n = tyre correction factor, *see* Table 9.3.3 P_w = load, in tonnes, on the tyre print. For closely spaced wheels the shaded area shown in Fig. 9.3.1 may be taken as the combined print P_1 = corrected patch load, in tonnes λ = dynamic magnification factor ϕ_1 = patch aspect ratio correction factor ϕ_2 = panel aspect ratio correction factor ϕ_3 = wide patch load factor	$P_1 = \phi_1 \phi_2 \phi_3 \lambda P_w$
	$\phi_1 = \dfrac{2v_1 + 1{,}1s}{u_1 + 1{,}1s}$ $v_1 = v$, but $\not> s$ $u_1 = u$, but $\not> a$
	$\phi_2 = 1{,}0$ for $u \leq (a - s)$ $= \dfrac{1}{1{,}3 - \dfrac{0{,}3}{s}(a - u)}$ for $a \geq u > (a - s)$ $= 0{,}77 \dfrac{a}{u}$ for $u > a$
	$\phi_3 = 1{,}0$ for $v < s$ $= 0{,}6 \dfrac{s}{v} + 0{,}4$ for $1{,}5 > \dfrac{v}{s} \geq 1{,}0$ $= 1{,}2 \dfrac{s}{v}$ for $\dfrac{v}{s} \geq 1{,}5$
	λ = 1,25 for harbour conditions = $(1 + 0{,}7n)$ for sea-going conditions

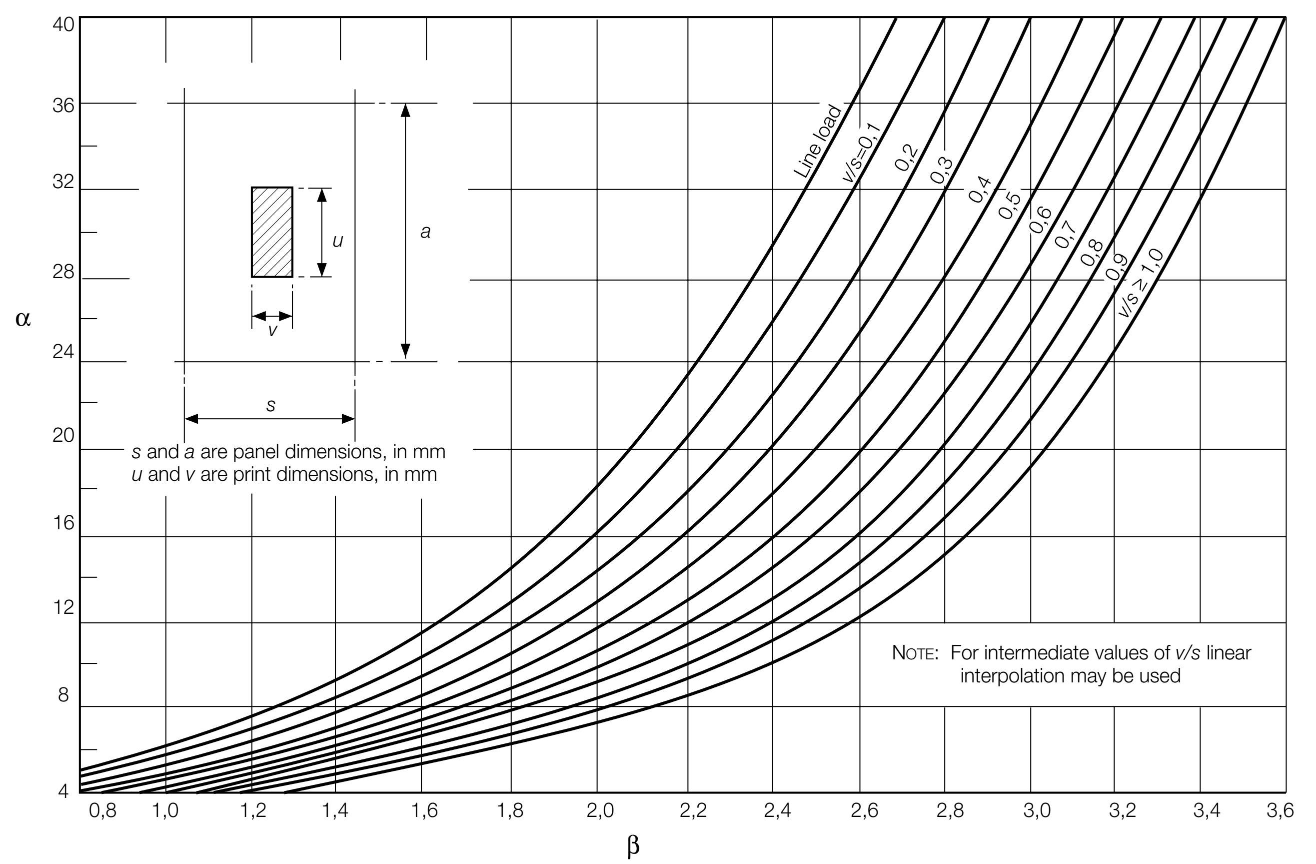


Fig. 9.3.1 Tyre print chart

3.4 Deck plating

3.4.1 The deck plate thickness, t, is to be not less than:

$t = t_1 + t_c$ mm

where

t_c = wear and wastage allowance determined from Table 9.3.2

$t_1 = \dfrac{\alpha s}{1000\sqrt{k}}$ mm

P_1 = corrected patch load obtained from Table 9.3.1

α = thickness coefficient obtained from Fig. 9.3.1

β = tyre print coefficient used in Fig. 9.3.1

$= \log_{10}\left(\dfrac{P_1\,k^2}{s^2} \times 10^7\right)$

Table 9.3.2 Wear and wastage allowance

Location	t_c, in mm
Strength deck, weather decks, decks forming crown of tank, inner bottom	1,5
Internal decks elsewhere	0,75

Table 9.3.3 Tyre correction factor, n

Number of wheels in idealized patch	Pneumatic tyres	Solid rubber tyres	Steel or solid tyres
1	0,6	0,8	1,0
2 or more	0,75	0,9	1,0

3.4.2 Where transversely framed decks contribute to the hull girder strength, or where secondary stiffening is fitted perpendicular to the direction of vehicle lanes, the thickness, t, derived from 3.4.1 is to be increased by 1,0 mm.

3.4.3 Where decks are designed for the exclusive carriage of unladen wheeled vehicles, the deck plate thickness, t, may be reduced as follows:

$t = (t_1 - 0{,}75) + t_c$ mm

3.4.4 Where it is proposed to carry tracked vehicles, the patch dimensions may be taken as the track print dimensions and P_w is to be taken as half the total weight of the vehicle. The wear and wastage allowance from Table 9.3.2 is to be increased by 0,5 mm. Deck fittings in way of vehicle lanes are to be recessed.

3.4.5 If wheeled vehicles are to be used on insulated decks or tank tops, consideration will be given to the permissible loading in association with the insulation arrangements and the plating thickness.

3.5 Deck longitudinals and beams

3.5.1 The section modulus, Z, of deck longitudinals or beams is to be not less than that required for a weather or cargo deck as appropriate, nor less than the following:

(a) For general purpose cargo decks where fork lift trucks are to be used:

$Z = (0{,}375K_1\,P\,l_e + 0{,}001\,25\,K_2\,h\,s\,l_e^2)\,k$ cm^3

(b) For permanent vehicle decks in association with a value of h which need not exceed 2,5 m:

h = normal load height on the deck, in metres

P = total weight, in tonnes, of the vehicle divided by the number of axles. Where distribution of weight is not uniform, P is to be taken as the maximum axle load. For fork lift trucks the total weight is to be applied to one axle

$Z = (0{,}536K_1 P l_e + 0{,}00125\,K_2\,h\,s\,l_e^2)\,k$ cm^3

where the values of K_1 and K_2 are given in Table 9.3.4

(c) For decks designed for the carriage of wheeled vehicles only that required to satisfy the most severe arrangement of print wheel loads on the stiffener in association with a bending stress of $\dfrac{100}{k}$ N/mm^2 $\left(\dfrac{10{,}2}{k}\right.$ kgf/mm$^2\left.\right)$ assuming 100 per cent end fixity.

Table 9.3.4 Values of K_1 and K_2

Wheel spacing* / Beam span	K_1	K_2
0,1	15,4	1,89
0,2	14,6	1,845
0,3	13,35	1,730
0,4	11,8	1,55
0,5 and greater	10,1	1,30
* Outer wheel to outer wheel on axles with multiple wheel arrangements		

3.6 Deck girders and transverses

3.6.1 Where the load on deck girders and transverses is uniformly distributed, the section modulus is to be not less than:

$Z = 4{,}75b\,h\,l_e^2\,k$ cm^3

where

h is defined in 3.5.1

b = mean width of plating supported by a deck girder or transverse, in metres.

3.6.2 Where the member supports point loads, with or without the addition of uniformly distributed load, the section modulus is to be based on a stress of $\dfrac{123{,}6}{k}$ N/mm^2 $\left(\dfrac{12{,}6}{k}\right.$ kgf/mm$^2\left.\right)$, assuming 100 per cent end fixity.

3.6.3 Where it is proposed to carry tracked vehicles, the total weight of the vehicle is to be taken when determining the section modulus of the transverse at the top of a ramp or at other changes of gradient.

3.7 Direct calculations

3.7.1 As an alternative to the above, permissible deck loads may be determined by direct calculation. The assumed loadings in these calculations are to include suitable allowance for weather, generally 2,16 kN/m^2 (0,22 tonne-f/m^2), where applicable.

3.8 Hatch covers

3.8.1 Where wheeled vehicles are to be used, the hatch cover plating is to be not less in thickness than that required by 3.4, and the modulus of the stiffeners is to be not less than:

$$Z = (K_3 P\, l_e + 0{,}00167 K_4\, h\, s\, l_e^2)\, k$$

where the values of K_3 and K_4 are given in Table 9.3.5 and P and h are defined in 3.5.1.
In no case, however, are the scantlings of plating and stiffeners to be less than would be required as a weather or cargo deck hatch cover, as applicable.

Table 9.3.5 Values of K_3 and K_4

Wheel spacing* / Stiffener span	K_3	K_4
0,1	11,96	2,32
0,2	10,69	1,89
0,3	9,58	1,55
0,4	8,46	1,28
0,5	7,46	1,07
0,6	6,51	0,91
0,7	5,55	0,73
0,8	4,23	0,36
0,9	2,38	0,11

* Outer wheel to outer wheel on axles with multiple wheel arrangements

3.8.2 Where unusual arrangements of hatch cover stiffening are proposed, the scantlings may be determined by direct calculations using a two-dimensional grillage idealization, and the parameters given in Table 11.2.3 in Chapter 11.

3.9 Train decks

3.9.1 Decks for the transport of railway rolling stock on fixed rails will be specially considered.

3.10 Heavy and special loads

3.10.1 Where heavy or special loads, such as machinery transporters, are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered.

3.11 Securing arrangements

3.11.1 Details of the connections to the hull of vehicle securing arrangements are to be submitted for approval.

■ *Section 4* **Movable decks**

4.1 Classification

4.1.1 Movable decks other than those described in 4.1.2 are not a classification item, although consideration must be given to associated supporting structure. Where movable decks are fitted, it is recommended that they be based on the requirements of this Section.

4.1.2 At the Owner's or Builder's request, however, movable decks will be included as a classification item, and the class notation 'movable decks' will be entered in the *Register Book*. In such cases, all movable decks on board the ship are to comply with the requirements of this Section.

4.2 Symbols

4.2.1 The symbols used in this Section are defined in 1.2 and in the appropriate sub-Section.

4.3 Arrangements and design

4.3.1 Movable decks are generally to be constructed as pontoons comprising a web structure with top decking. Other forms of construction will be individually considered.

4.3.2 These requirements assume that the pontoons are to be constructed of steel. Other materials will be considered on the basis of equivalent strength.

4.3.3 Positive means of control are to be provided to secure decks in the lowered position.

4.3.4 The decks are to be efficiently supported, and hinges, pillars, chains or other means (or a combination of these) are to be designed on the basis of the imposed loads. Where supporting chains and fittings are required, they are to have a factor of safety of at least two on the proof load.

4.3.5 Plans showing the proposed scantlings and arrangements of the system are to be submitted.

4.3.6 Where it is proposed to stow the pontoons on deck, when not in use, details of the proposals for racks, fittings, etc., are to be submitted for consideration.

4.4 Loading

4.4.1 Details of the deck loading resulting from the proposed stowage arrangements of vehicles are to be supplied by the Shipbuilder. These details are to include the axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. For design purposes the axle loading is to be taken as not less than 5,9 kN (0,6 tonne-f).

4.4.2 Where it is proposed also to use the decks for general cargo, the design loadings are to be submitted for consideration.

4.5 Pontoon deck plating

4.5.1 Where the pontoon is constructed of steel decking with stiffening webs, the deck plate thickness, t, is to be not less than that required by 3.4.

4.5.2 The plate thickness, t, for aluminium pontoons is to be not less than:

$$t = (1,4t_1 + 0,75) \text{ mm}$$

where

t_1 is the mild steel thickness as determined from 3.4. For aluminium pontoons designed for the exclusive carriage of unladen wheeled vehicles:

$$t = 1,4t_1 \text{ mm}$$

4.5.3 Where it is proposed to use plywood decking, the arrangement and thickness will be considered. Plywood alone, is not, generally, to be used for axle loads in excess of 7,8 kN (0,8 tonne-f).

4.5.4 Attention is drawn to National fire regulations which in certain cases may ban the use of plywood and certain other materials in ‘special category spaces’ on passenger ships.

4.6 Pontoon webs and stiffeners

4.6.1 The section modulus of webs and stiffening of steel pontoons is to be not less than:

(a) For general purpose cargo decks where fork lift trucks may be used:

$$Z = (0,375K_1\, P\, l_e + 0,00125K_2\, h\, s\, l_e^2)\, k \quad \text{cm}^3$$

(b) For decks designed for the carriage of vehicles only:

$$Z = 1,39K_1 P\, l_e\, k \quad \text{cm}^3$$

where the values of K_1 and K_2 are given in Table 9.4.1, and

h = load height of cargo on the deck, where this is proposed to be carried, in metres

P = total weight, in tonnes, of the vehicle divided by the number of axles. Where the distribution of weight is not uniform, P is to be taken as the greatest axle load. For fork lift trucks the total weight is to be applied to one axle.

4.6.2 The section modulus of webs and stiffening of aluminium pontoons is to be not less than that defined in 4.6.1 replacing k by k_a where k_a is defined in Ch 2,1.

Table 9.4.1 Values of K_1 and K_2

Wheel spacing* / Beam span	K_1	K_2
0,1	15,4	1,89
0,2	14,6	1,845
0,3	13,35	1,730
0,4	11,8	1,55
0,5 and greater	10,1	1,30

* Outer wheel to outer wheel on axles with multiple wheel arrangements

4.6.3 Where plywood decking is proposed, or in other arrangements where the decking is not integral with the stiffening webs, the arrangement of the grillage of webs is to be such as to provide the required strength.

4.7 Deflection

4.7.1 Where wheeled vehicles are to be used, the supporting arrangements are to be such that the movement at the edge of one pontoon relative to the next does not exceed 50 mm during loading or unloading operations.

4.8 Direct calculations

4.8.1 As an alternative to 4.3 to 4.7, the structure may be designed on the basis of a direct calculation using a grillage idealization. The method adopted and the stress levels proposed for the material of construction are to be submitted for consideration.

■ *Section 5* Helicopter landing areas

5.1 General

5.1.1 Where it is proposed to provide a helicopter landing area on the ship, the structure is to be designed to suit the largest helicopter type which it is intended to use.

5.1.2 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the ship.

5.1.3 Plans are to be submitted showing the proposed scantlings and arrangements of the structure. The type, size and weight of helicopters to be used are also to be indicated. Details of the helicopter types to be used are to be included in the Loading Manual (*see* Ch 4,8.2) and be contained in a notice displayed on the helicopter landing deck.

5.1.4 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

5.2 Symbols

5.2.1 The symbols in this Section are defined in 1.2 and in the appropriate sub-Section.

5.3 Arrangements

5.3.1 The landing area is to be sufficiently large to allow for the landing and manoeuvring of the helicopter, and is to be approached by a clear landing and take-off sector complying in extent with the applicable Regulations.

5.3.2 The landing area is to be free of any projections above the level of the deck. Projections in the zone surrounding the landing area are to be kept below the heights permitted by the Regulations.

5.3.3 Suitable arrangements are to be made to minimize the risk of personnel or machinery sliding off the landing area. A non-slip surface and anchoring devices are to be provided.

5.3.4 Arrangements are to be made for drainage of the platform, including drainage of spilt fuel. These arrangements are to be constructed of steel and lead directly overboard, independent of any other system, and shall be designed so that drainage does not fall onto any other part of the ship.

5.3.5 If the helideck is constructed from aluminium alloy, the following provisions apply:

(a) the deckhouse top and bulkheads under the platform shall have no openings;

(b) windows under the platform are to be provided with steel shutters.

5.3.6 Engine uptake arrangements are to be sited such that exhaust gases cannot be drawn into helicopter engine intakes during helicopter take off or landing operations.

5.4 Landing area plating

5.4.1 The deck plate thickness, t, within the landing area is to be not less than:

$t = t_1 + 1,5$ mm

where

$$t_1 = \frac{\alpha s}{1000\sqrt{k}} \text{ mm}$$

α = thickness coefficient obtained from Fig. 9.3.1

β = tyre print coefficient used in Fig. 9.3.1

$$= \log_{10}\left(\frac{P_1 k^2}{s^2} \times 10^7\right)$$

The plating is to be designed for the emergency landing case taking:

$P_1 = 2,5\, \phi_1\, \phi_2\, \phi_3\, f \gamma P_w$ tonnes

in which ϕ_1, ϕ_2, ϕ_3 are to be determined from Table 9.3.1

f = 1,15 for landing decks over manned spaces, e.g., deckhouses, bridges, control rooms, etc.

= 1,0 elsewhere

P = the maximum all-up weight of the helicopter, in tonnes

P_w = landing load, on the tyre print in tonnes; for helicopters with a single main rotor, P_w is to be taken as P divided equally between the two main undercarriages, for helicopters with tandem main rotors, P_w is to be taken as P distributed between all main undercarriages in proportion to the static loads they carry

γ = a location factor given in Table 9.5.1.

The tyre print dimensions specified by the manufacturer are to be used for the calculation. Where these are unknown, it may be assumed that the print area is 300 x 300 mm and this assumption is to be indicated on the submitted plan.

Table 9.5.1 Location factor

Location	γ	
On decks forming part of the hull girder (a) within 0,4L amidships	0,71	Values for intermediate locations are to be determined by interpolation
(b) at the F.P. or A.P.	0,6	
Elsewhere	0,6	

5.4.2 The plate thickness for aluminium decks is to be not less than:

$t = 1,4t_1 + 1,5$ mm

where t_1 is the mild steel thickness as determined from 5.4.1.

5.4.3 For helicopters fitted with landing gear consisting of skids, the print dimensions specified by the manufacturer are to be used. Where these are unknown, it may be assumed that the print consists of a 300 mm line load at each end of each skid, when applying Fig. 9.3.1.

5.5 Deck stiffening and supporting structure

5.5.1 The helicopter deck stiffening and the supporting structure for helicopter platforms is to be designed for the load cases given in Table 9.5.2 in association with the permissible stresses given in Table 9.5.3.

5.5.2 The minimum moment of inertia, I, of aluminium secondary structure stiffening is to be not less than:

$$I = \frac{5,25}{k_a} Z\, l_e \text{ cm}^4$$

where Z is the required section modulus of the aluminium stiffener and attached plating and k_a as defined in 4.6.2.

5.5.3 Where a grillage arrangement is adopted for the platform stiffening, it is recommended that direct calculation procedures be used.

Table 9.5.2 Design load cases for deck stiffening and supporting structure

Loadcase	Loads			
	Landing area		Supporting structure (*See* Note 1)	
	UDL	Helicopter (*See* Note 2)	Self weight	Horizontal load (*See* Note 2)
(1) Overall distributed loading	2 (0,2)	–	—	–
(2) Helicopter emergency landing	0,2 (0,02)	2,5*Pf*	*W*	0,5*P*
(3) Normal usage	0,5 (0,05)	1,5*P*	*W*	0,5*P* + 0,5*W*

Symbols

P and *f* as defined in 5.4.1
UDL = Uniformly distributed vertical load over entire landing area, kN/m^2 (tonne-f/m^2)
W = structural weight of helicopter platform

NOTES
1. For the design of the supporting structure for helicopter platforms, applicable self weight and horizontal loads are to be added to the landing area loads.
2. The helicopter is to be so positioned as to produce the most severe loading condition for each structural member under consideration.

Table 9.5.3 Permissible stresses for deck stiffening and supporting structure

Loadcase (*See* Table 9.5.2)	Permissible stresses, in N/mm^2 (kgf/mm^2)			
	Deck secondary structure (beams, longitudinals) (*See* Notes 1 and 2)	Primary structure (transverses, girders, pillars, trusses)		All structure
	Bending		Combined bending and axial	Shear
(1) Overall distributed loading	$\frac{147}{k}$ $\left(\frac{15}{k}\right)$	$\frac{147}{k}$ $\left(\frac{15}{k}\right)$	0,6σ_C	$\frac{\text{Bending}}{\sqrt{3}}$
(2) Helicopter emergency landing	$\frac{245}{k}$ $\left(\frac{25}{k}\right)$	$\frac{220,5}{k}$ $\left(\frac{22,5}{k}\right)$	0,9σ_C	
(3) Normal usage	$\frac{176}{k}$ $\left(\frac{18}{k}\right)$	$\frac{147}{k}$ $\left(\frac{15}{k}\right)$	0,6σ_C	

Symbols

k = a material factor:
= as defined in 1.2 for steel members
= k_a as defined in 4.6.2 for aluminium alloy members
σ_C = yield stress, 0,2% proof stress or compressive buckling stress, in N/mm^2 (kgf/mm^2), whichever is the lesser

NOTES
1. For strength deck longitudinals and girders, the permissible bending stresses are to be reduced as follows:
   (a) within 0,4*L* of amidships – by 30%
   (b) at the F.P. or A.P. – by 0%
   Values at intermediate locations are to be determined by interpolation between (a) and (b).
2. When determining bending stresses in secondary structure, for compliance with the above permissible stresses, 100% end fixity may be assumed.

5.6 Bimetallic connections

5.6.1 Where aluminium alloy platforms are connected to steel structures, details of the arrangements in way of the bimetallic connections are to be submitted.

Section 6 Strengthening requirements for navigation in ice – Application of requirements

6.1 Additional strengthening

6.1.1 Where additional strengthening is fitted in accordance with the requirements given in Sections 7 and 8, an appropriate special features notation will be assigned. It is the responsibility of the Owner to determine which notation is most suitable for his requirements. For material requirements, *see* Ch 2,2. For machinery requirements, *see* Pt 5, Ch 9.

6.1.2 Where a special features notation is desired, the ship is to comply with the requirements of the applicable Sections, in addition to those for sea-going service, so far as they are applicable.

6.1.3 Ships that comply with the requirements of the Finnish Swedish Ice Class Rules in force at the time of contract and Section 7, for Ice Class **IA Super, IA, IB** and **IC** may be assigned the corresponding notations Ice Class **1AS FS,** Ice Class **1A FS,** Ice Class **1B FS** or Ice Class **1C FS.** The Finnish Swedish Ice Class Rules may be obtained from the following website:
www.fma.fi

6.1.4 The requirements for **Ice Class 1D** are for ships intended to navigate in light first year ice conditions. The requirements for strengthening the forward region, the rudder and steering arrangements for **Ice Class 1C FS** are applicable.

6.1.5 The requirements for Ice Class **IE** are for offshore supply ships, as defined in Pt 4, Ch 4, and are intended to navigate in very light first-year ice conditions, such as in brash ice and small ice pieces. The requirements of Section 9 are to be complied with.

6.1.6 For ships where the ice class notation Ice Class **1AS FS(+),** Ice Class **1A FS(+),** Ice Class **1B FS(+)** or Ice Class **1C FS(+)** is requested, the requirements of the Finnish Swedish Ice Class Rules in force at the time of contract, and Section 7, and Pt 5, Ch 9,4 are to be complied with.

6.1.7 The requirements for strengthening for navigation in ice, as given in Section 8, are intended for ships operating in multi-year ice in Arctic or Antarctic ice conditions under their own power.

6.2 Geographical zones

6.2.1 Ships intending to navigate in the Canadian Arctic must comply with the *Canadian Arctic Shipping Pollution Prevention Regulations* established by the Consolidated Regulations of Canada, 1978, Chapter 353, in respect of which Lloyd's Register (hereinafter referred to as 'LR') is authorized to issue Arctic Pollution Prevention Certificates.

6.2.2 The Canadian Arctic areas have been divided into zones relative to the severity of the ice conditions experienced and, in addition to geographic boundaries, each zone has seasonal limits affecting the necessary ice class notation required to permit operations at a particular time of year. It is the responsibility of the Owner to determine which notation is most suitable for his requirements.

6.2.3 The Canadian Authorities recognize that in the period November 6 to July 31 and any extension to that period declared by the Canadian Coast Guard, oil and bulk chemical tankers which qualify for Canadian Type A, B, C and D as indicated in Table 9.6.1 are suitable for operating in designated ice control zones within Canadian waters, off the east coast of Canada south of 60° north latitude. For all Type E tankers operating in this zone during the specified period, the Canadian Authorities will require either additional hull strength in way of the forward wing cargo tanks port and starboard, or the level of oil or chemical in these tanks to be not higher than one metre below the waterline of the ship in her condition of transit. Where the latter arrangement is adopted, the effect on longitudinal strength is to be considered.

Table 9.6.1 Canadian Types

Canadian Type	Lloyd's Register Ice Class Notation	
Type A	100A1	Ice Class 1AS FS
Type B	100A1	Ice Class 1A FS
Type C	100A1	Ice Class 1B FS
Type D	100A1	Ice Class 1C FS and 1D
Type E	100A1	

6.3 Icebreakers

6.3.1 Sea-going ships specially designed for icebreaking duties will be assigned the ship type notation 'Icebreaker' in addition to the special features notation appropriate to the degree of ice strengthening provided.

Section 7 Strengthening requirements for navigation in first-year ice conditions

7.1 General

7.1.1 In addition to the requirements of the Finnish Swedish Ice Class Rules,the following sections are to be complied with for **Ice Class 1AS FS**, **Ice Class 1A FS**, **Ice Class 1B FS**, **Ice Class 1C FS** and **Ice Class 1D** where applicable. Alternative arrangements to attain similar performance will be specially considered.

7.1.2 The ballast capacity of the ship is to be sufficient to give adequate propeller immersion in all ice navigating conditions without trimming the ship in such a manner that the actual waterline at the bow is below the ice light waterline. Ballast tanks situated above the ice light waterline and adjacent to the shell, which are intended to be used in ice navigating conditions, are to be provided with heating pipes.

7.1.3 These Rules are formulated for both transverse and longitudinal framing systems but it is recommended that, whenever practicable, transverse framing is selected.

7.1.4 These Rules assume that when approaching ice infested waters, the ship's speed will be reduced appropriately. The vertical extent of ice strengthening for ships intended to operate at speeds exceeding 15 knots in areas containing isolated ice floes will be specially considered.

7.1.5 An icebreaking ship is to have a hull form at the fore end adapted to break ice effectively. It is recommended that bulbous bows are not fitted to Ice Class 1AS ships.

7.1.6 The stern of an icebreaking ship is to have a form such that broken ice is effectively displaced.

7.1.7 Where it is desired to make provision for short tow operations, the bow area is to be suitably reinforced. Similarly, icebreakers may require local reinforcement in way of the stern fork.

7.1.8 The vertical extent of the ice strengthening is related to the ice light and ice load waterlines, which are defined in 7.3. The maximum and minimum Ice Class draughts at both the fore and aft ends will be stated on the Class Certificate. In addition, the minimum engine output, *see* Pt 5, Ch 9, will be stated on the Class Certificate.

7.2 Definitions

7.2.1 The Ice Load Waterline corresponds to the Fresh Water Summer Loadline. Where specially requested and where permitted by the appropriate National Administration, an Ice Load Waterline may be specified which differs from the foregoing, but corresponds to the deepest condition in which the ship is expected to navigate in ice.

7.2.2 The Ice Light Waterline is that corresponding to the lightest condition in which the ship is expected to navigate ice.

7.2.3 The Ice Load Waterline and the Ice Light Waterline are to be indicated on the plans. For navigation in certain geographical areas, the relevant National Authority may require the maximum Ice Class draught to be marked on the ship in a specified manner.

7.2.4 **Displacement** Δ is the displacement, in tonnes, at the Ice Load Waterline when floating in water having a relative density of 1,0.

7.2.5 **Shaft power**, P_0 (H_0), is the maximum propulsion shaft power, in kW (shp), for which the machinery is to be classed.

7.3 Framing – General requirements

7.3.1 Where a frame intersects a boundary between two of the hull regions the scantling requirements applicable will be those for the forward region if the forward midship boundary is intersected or for the midship region if the aft midship boundary is intersected.

7.3.2 The effective weld area attaching ice frames to primary members is not to be less than the shear area for the frames.

7.4 Primary longitudinal members supporting transverse ice framing

7.4.1 The webs of primary longitudinal members supporting transverse ice frames are to be stiffened and connected to the main or intermediate frames so that the distance, *r*, between such stiffening is not to be greater than given according to the following formula:

$$r = \sqrt{\frac{291 t^3}{\alpha_o \gamma^2}} \text{ mm}$$

where

t = thickness, in mm, of the primary longitudinal member adjacent to the shell plating

α_o = longitudinal distribution factor as given in Table 9.7.1

(a) Forward region

$\gamma = 0{,}653 + 3{,}217 \sqrt{P_0 \Delta} \times 10^{-5}$

$(\gamma = 0{,}653 + 2{,}76 \sqrt{H_0 \Delta} \times 10^{-5})$, or

$\gamma = 0{,}876 + 9{,}908 \sqrt{P_0 \Delta} \times 10^{-6}$

$(\gamma = 0{,}876 + 8{,}5 \sqrt{H_0 \Delta} \times 10^{-6})$

or γ = 1,0 whichever is the least

where P_0 (H_0) and Δ are as defined in 7.2.

(b) Midship and aft regions

$\gamma = 0{,}653 + 9{,}908 \sqrt{P_0 \Delta} \times 10^{-6}$

$(\gamma = 0{,}653 + 8{,}5 \sqrt{H_0 \Delta} \times 10^{-6})$

or γ = 0,79, whichever is the lesser.

Table 9.7.1 Longitudinal distribution factor α_o

Ice Class	α_o		
	Forward	Midship	Aft
1AS FS	1,00	0,98	0,89
1A FS	0,87	0,75	0,64
1B FS	0,78	0,64	0,51
1C FS	0,68	0,53	0,37
1D	0,68	—	—

7.4.2 The minimum thickness of the web plating of longitudinal primary members is to comply with the requirements of Ch 10,4.

7.5 Stem

7.5.1 The stem is to be made of rolled, cast or forged steel or of shaped steel plates. A sharp edged stem, as shown in Fig. 9.7.1 improves the manoeuvrability of the ship in ice.

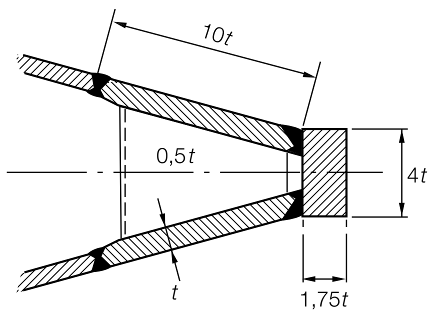


Fig. 9.7.1 A sharp edged stem

7.5.2 The section modulus of the stem in the fore and aft direction is not to be less than determined in accordance with the following formula:

$Z = 1500 (\alpha_o \gamma^2)^{3/2}$ cm^3

where

α_o = longitudinal distribution factor for the forward region as given in Table 9.7.1

γ is defined in 7.5.2.

7.5.3 The dimensions of a welded stem constructed as shown in Fig. 9.7.1 are to be determined in accordance with the following formula:

$t = 31 \sqrt{\alpha_o \gamma^2}$ mm

where

t = thickness of the side plates, in mm.

7.5.4 In bulbous bow constructions, the extent of plating below the Ice Light Waterline should be such as to cover that part of the bulb forward of the vertical line originating at the intersection of the Ice Light Waterline and the stem contour at the centreline. A suitably tapered transition piece should be arranged between the reinforced stem plating and keel. However, in no case should the reinforced stem plating extend vertically below the Ice Light Waterline for less than 750 mm. The adjacent strake to the reinforced shaped stem plating of the bulb should be in accordance with the requirements for shell plating.

7.5.5 Where in the ice belt region the radius of the stem or bulb front plating is large, one or more vertical stiffeners are to be fitted in order to meet the section modulus requirement of 7.7.2. In addition, vertical ring stiffening will be required for the bulb.

7.5.6 The dimensions of the stem may be tapered to the requirements of Ch 5,3.3 at the upper deck. The connections of the shell plating to the stem are to be flush.

7.6 Stern

7.6.1 Where the screwshaft diameter exceeds the Rule diameter, the propeller post is to be correspondingly strengthened, *see* Ch 6,7.

7.7 Rudder and steering arrangements

7.7.1 Rudder scantlings, posts, rudder horns, solepieces, rudder stocks, steering engine and pintles are to be dimensioned in accordance with Chapters 6 and 13 as appropriate. The speed used in the calculations is to be the maximum service speed or that given in Table 9.7.3, whichever is the greater. When used in association with the speed given in Table 9.7.3, the hull form factor and the rudder profile coefficients are to be taken as 1,0.

Table 9.7.2 Longitudinal distribution factor α_p

Ice Class	α_p		
	Forward	Midship	Aft
1AS FS	1,00	0,95	0,85
1A FS	0,98	0,86	0,73
1B FS	0,93	0,71	0,57
1C FS	0,86	0,53	0,38
1D	0,86	—	—

Table 9.7.3 Minimum speed

Ice Class	Minimum speed, in knots
1AS FS	20
1A FS	18
1B FS	16
1C FS	14
1D	14

7.7.2 For double plate rudders, the minimum thickness of plating and horizontal and vertical webs in the main ice belt zone is to be determined as for shell plating in the aft region. For the horizontal and vertical webs the corrosion-abrasion increment, *c*, need not be added. For Ice Class 1D, the minimum thickness of plating and webs, of double plate rudders and the extent of application are to be determined as for those in Ice Class 1C FS.

7.7.3 Where an ice class notation is included in the class of a ship, the nozzle construction requirements, as defined in Table 13.3.1 in Chapter 13, are to be upgraded to include abrasion allowance as follows:

Ice Class	Thickness increment
1AS FS	5 mm
1A FS	4 mm
1B FS	3 mm
1C FS	2 mm
1D	2 mm

However, the thickness of the shroud plating is not to be less than the shell plating for the aft region taking frame spacing *s* in the formula as 500 mm.

7.7.4 The scantlings of the stock, pintles, gudgeon and solepiece associated with the nozzle are to be increased on the basis given in 7.7.1. However, the diameter of the nozzle stock is to be not less than that calculated in the astern condition taking the astern speed as half the speed given in Table 9.7.3 or the actual astern speed, whichever is the greater.

7.7.5 Nozzles with articulated flaps will be subject to special consideration.

7.7.6 For the ice classes **1AS FS** and **1A FS** the rudder stock and the upper edge of the rudder shall be protected against ice pressure by an ice knife or equivalent means. The ice knife is to extend down to the ice light waterline; this requirement may be waived where this would lead to impracticable ice knifes, e.g. for ships with large draught variations.

7.7.7 For the ice classes **1AS FS** and **1A FS** due regard is to be paid to the excessive load caused by the rudder being forced out of the midship position when backing into an ice ridge. When vessels are intended to operate with significant time in astern operation, then the hull strength is to be based on the method used in the forward region, however due consideration may be given to the anticipated power in this mode of operation.

7.7.8 Relief valves for hydraulic pressure are to be effective, *see* Pt 5, Ch 19,3.3. The components of the rudder steering gear are to be able to withstand the yield torque of the rudder stock, *see* Pt 5, Ch 19,3.2.2. Rudder stoppers working on the rudder blade or rudder head are to be fitted.

■ *Section 8*
Strengthening requirements for navigation in multi-year ice conditions

8.1 Ice Class notations

8.1.1 Where the requirements of this Section are complied with, the ship will be eligible for the addition of the term 'Icebreaking' to the ship type notation, e.g. 'Icebreaking Bulk Carrier', 'Icebreaking Tanker', etc. In addition, one of the following special features notations will be assigned:

(a) **Ice Class AC1**: The requirements for the assignment of this class are intended for ships designed to navigate in Arctic or Antarctic ice conditions equivalent to unbroken ice with a thickness of 1,0 m.

(b) **Ice Class AC1,5**: The requirements for the assignment of this class are intended for ships designed to navigate in Arctic or Antarctic ice conditions equivalent to unbroken ice with a thickness of 1,5 m.

(c) **Ice Class AC2**: The requirements for the assignment of this class are intended for ships designed to navigate in Arctic or Antarctic ice conditions equivalent to unbroken ice with a thickness of 2,0 m.

(d) **Ice Class AC3**: The requirements for the assignment of this class are intended for ships designed to navigate in Arctic or Antarctic ice conditions equivalent to unbroken ice with a thickness of 3,0 m.

8.2 Application

8.2.1 The requirements of this Section are formulated on the assumption that ships having Ice Class AC notations will be longitudinally framed at the uppermost continuous deck and at the bottom. Alternative proposals will be specially considered.

8.2.2 The vertical extent of ice strengthening is related to the Ice Load Waterline or Deepest Ice Operating Waterline and the Ice Light Waterline as defined in 8.3. The maximum and minimum ice class draughts at both the fore and aft ends will be stated on the Class Certificate.

8.3 Definitions, *see* Fig. 9.8.1

8.3.1 The Ice Load Waterline corresponds to the Freshwater Load Line in summer as defined by the *1966 International Load Line Convention.*

8.3.2 A Deepest Ice Operating Waterline which differs from the Ice Load Waterline may be specified, where specially requested, and would correspond to the deepest condition in which the ship is expected to navigate in ice.

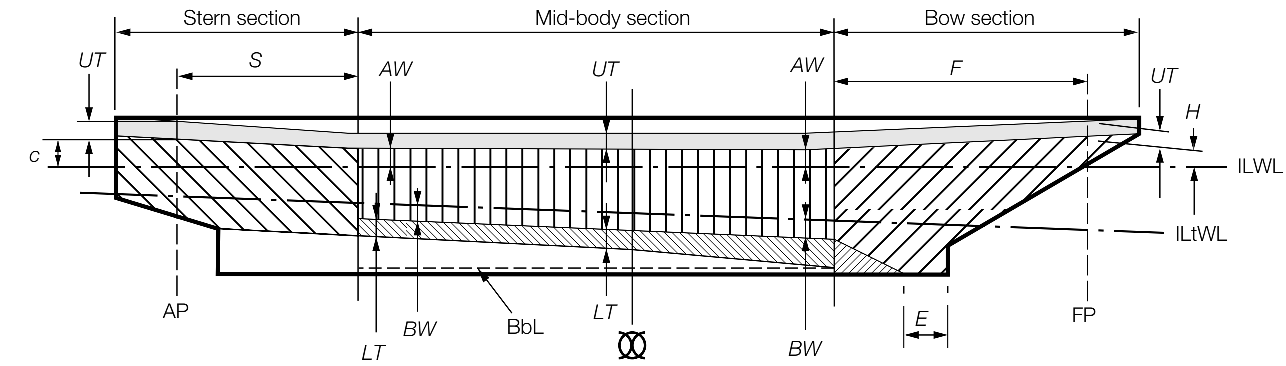
8.3.3 The Ice Light Waterline is that corresponding to the lightest condition in which the ship is expected to navigate in ice.

8.3.4 The Ice Load Waterline, the Deepest Ice Operating Waterline and the Ice Light Waterline should be indicated on the plans. For navigation in certain geographic areas, the relevant National Authority may require the maximum Ice Class draught to be marked on the ship in a specified manner.

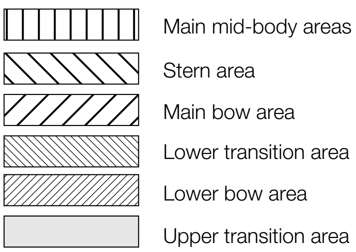
8.3.5 For the purpose of defining the standard of ice strengthening required, which is dependent upon longitudinal and vertical position, the hull is divided longitudinally into three regions designated bow section, mid-body section and stern section. Each section is further subdivided in its depth so that the bow section contains the lower bow area, main bow area and that part of the upper transition area in way, the mid-body section contains the lower transition area, main mid-body area and that part of the upper transition area in way and the stern section contains the stern area and that part of the upper transition area in way. These divisions are shown in Fig. 9.8.1 and further defined in 8.3.6 and 8.3.21.

8.3.6 The bow section is that region between the forward boundary of the mid-body section and the stem, *see also* 8.3.9.

8.3.7 The mid-body section has its aft boundary a distance *S* forward of the A.P. and its forward boundary, except as provided by 8.3.9, a distance *F* aft of the F.P. The distances *F* and *S* are given in Fig. 9.8.1.



ILWL = Ice Load Water Line or
Deepest Ice Operating Waterline
ILtWL = Ice Light Waterline
BbL = Bilge Boundary Line



	H cm	*AW* cm	*BW* cm	*UT* cm	*LT* cm	*C* cm	*E* %L	*F* %L	*S* %L
Ice Class AC1	200	180	250	50	70	180	2,5	30	20
Ice Class AC1,5	300	240	375	75	110	240	2,5	30	20
Ice Class AC2	400	300	500	100	150	300	2,5	30	20
Ice Class AC3	600	515	850	170	260	515	2,5	30	25

Fig. 9.8.1 Regions and zones (multi-year ice conditions)

8.3.8 The stern section is that region between the stern and the aft boundary of the mid-body section.

8.3.9 Where the shoulder of the ship consists of a pronounced hard chine, this may be taken as the basis of the boundary between the bow and mid-body sections of the hull. This chine may be in the form of a reamer or of a knuckle line. In the latter case, an overlap of the bow section beyond this line by the lesser of 0,04*L* or 5 m may be necessary.

8.3.10 The main bow area is part of the bow section and extends vertically above the keel to a line a distance, *H*, above the Ice Load Waterline or Deepest Ice Operating Waterline, if applicable, at the F.P., and a distance *AW* above these waterlines at the main mid-body area, but need not include the area defined as lower bow area.

8.3.11 The main mid-body area is part of the mid-body section and extends vertically from a line a distance *BW* below the Ice Light Waterline to a line a distance *AW* above the Ice Load Waterline or Deepest Ice Operating Waterline, if applicable. The distances *BW* and *AW* are given in Fig. 9.8.1.

8.3.12 The stern area is part of the stern section. It has its upper edge a distance *AW* above the Ice Load Waterline or Deepest Ice Operating Waterline at its fore end and a distance *C* above these waterlines at the A.P. The lower edge of the stern region is a distance (*BW* + *LT*), below the Ice Light Waterline. The distances *AW*, *C* and *LT* are given in Fig. 9.8.1.

8.3.13 The main ice belt zone comprises the main bow area, main mid-body area and stern area.

8.3.14 The upper transition area extends a distance, *UT*, above the main ice belt zone.

8.3.15 The lower transition area is part of the mid-body section. Aft of amidships, it extends below the main mid-body area by a distance *LT*. Forward of amidships, its lower edge is a line drawn from a point a distance *LT* below the main mid-body area at amidships to the junction of the bilge boundary line with the aft end of the main bow area.

8.3.16 The lower bow area is that part of the bow section below the main bow area. Its upper edge is a line drawn from a point at the aft end of the bow section set a distance *BW* below the Ice Light Waterline to a point on the keel line set a distance *E* aft of the bow line's departure from the level keel line.

8.3.17 The lower transition area need not extend below the bilge boundary line by more than the value of *LT* (*see* Fig. 9.8.1) measured around the circumference of the bilge.

8.3.18 The Ice Belt comprises the main Ice Belt Zone together with the lower bow area and the upper and lower transition areas.

8.3.19 Displacement, Δ, is the displacement in tonnes at the Ice Load Waterline, or Deepest Ice Operating Waterline, if applicable, when floating in water having a relative density of 1,0.

8.3.20 Shaft power, P_0 (H_0) is the maximum propulsion shaft power in kW (horsepower) for which the machinery is classed, *see* Pt 5, Ch 1,3 and Pt 5, Ch 9,1.3.

8.3.21 Bilge boundary line is that line which in elevation is parallel to the keel and at amidships is coincident with the upper turn of bilge.

8.4 Arrangement

8.4.1 The ballast capacity of the ship should be sufficient to give adequate propeller immersion in all ice navigating conditions. It is anticipated that the propeller tips at their highest point will not be closer to the Ice Light Waterline than the distance given in Table 9.8.1.

Table 9.8.1 Propeller tip minimum distance

Class	Ice Light Waterline Propeller tip minimum distance, in metres
Ice Class AC1	3,0
Ice Class AC1,5	3,75
Ice Class AC2	4,5
Ice Class AC3	6,0

8.4.2 It is recommended that the minimum draught at the fore-end should be not less than:

$$T_f = \left(1,5 + 0,1\sqrt[3]{\Delta}\right) h \quad \text{m}$$

where

h = the nominal ice thickness, in metres, associated with the desired Ice Class notation, *see* 8.1.

Δ = displacement as defined in 8.3.

8.4.3 All wing ballast tanks adjacent to the shell are to be supplied with heating pipes. All deck machinery such as mooring winches, windlass and essential parts of ice management systems, etc., should be equipped with an efficient de-icing system.

8.4.4 The bow should be such as to break ice effectively. The rake of stem should, in general, be less than 30° relative to the horizontal for Ice Classes AC1,5, AC2 and AC3. Apart from spoon shaped bow forms, the entry angle of the portion of the fore-body below the deepest ice waterline should not exceed 30°. Bulbous bows are not to be fitted to ships having Ice Class AC notations.

8.4.5 Where flare of the side shell amidships is proposed, it is recommended the slope of the side should be at least 8°.

8.4.6 For ships provided with a heel inducing system, it is recommended that the depth of the ship is such that immersion of the deck edge does not occur when the ship, whilst floating at the Ice Load Waterline or Deepest Ice Operating Waterline as applicable, is heeled to an angle of 5° greater than the nominal capacity of the system or 15° whichever is the greater.

8.4.7 It is recommended that the upper deck bulwark is sloped inboard and efficiently supported by transverse stays spaced at no more than 1,5 m, *see also* Ch 8,5.

8.4.8 The aft body of icebreaking ships should have a form such that broken ice is effectively displaced.

8.4.9 Where it is desired to make provision for close tow-push operations, the bow area should be suitably reinforced. Similarly, it is recommended that suitable reinforcements are arranged in way of the stern fork.

8.5 Longitudinal strength

8.5.1 The section modulus at deck and keel of vessels having Ice Class AC notations is to be increased above that required in Pt 3, Ch 4,5 to take account of beaching and dynamic impact loads during ice-breaking operations. Relevant calculations are to be submitted. For initial structural design guidance, the minimum required section modulus of ice-breaking ships would normally be expected to be greater than:

$$Z_{act} = K\,Z_{min}$$

where K is a modulus amplification factor depending on L as follows:

L (m)	K
50	1,80
75	1,58
100	1,45
150	1,30
200 and over	1,20

The midship scantlings of the main longitudinal members are to be maintained between 0,2L aft of amidships and 0,3L forward of amidships. However, these scantlings are to extend to at least B/3 forward of the position of the maximum bending moment obtained from the simulated beaching calculations carried out in the structural design of these ships. The position of this maximum bending moment is to be indicated on the submitted plan. The corrosion-abrasion increment required for the shell plating given in Table 9.8.5 is not to be included in the calculation of the actual modulus.

8.5.2 The maximum permissible still water bending moment $|\overline{M}_S|$ which can be assigned to ships having Ice Class AC notations is as follows:

(a) Non-Ice-transiting voyages:
$|\overline{M}_S|$ is to be calculated from Ch 4,5.4.

(b) Ice-transiting or partially Ice-transiting voyages:
$|\overline{M}_S|$ is to be taken as 95 per cent of the value calculated from Ch 4,5.4, taking F_B = 1,0 and F_D as calculated from Ch 4,5.6.

8.6 Bulkheads

8.6.1 Bulkheads are to be arranged in accordance with the requirements given in Table 9.8.2, *see also* Ch 3,4.

8.6.2 It is recommended that vertically stiffened transverse bulkheads are fitted with additional horizontal stiffening to resist buckling.

Table 9.8.2 Bulkhead arrangements

Class	Longitudinal bulkheads minimum requirements	Transverse bulkheads(1) (2) maximum spacing
Ice Class AC1	1 – fwd. 0,4*L*(1) (4)	Lesser of 0,14*L* or 40 m
Ice Class AC1,5	Double skin for full length of ship(3)	
Ice Class AC2	Double skin for full length of ship(3) plus 1 – fwd. 0,4*L*(1)	
Ice Class AC3	Double skin for full length of ship(3) plus 3 – fwd. 0,4*L*(1) 1 – aft 0,6*L*(1)	

NOTES
1. May be watertight or non-watertight.
2. In the case of ships intended to navigate in Canadian Arctic waters attention is drawn to the requirements of the Arctic Shipping Pollution Prevention Regulation C353 in respect to subdivision standards.
3. The minimum width of the side tanks formed by the double skin should not be less than 1,2 m and the vertical extent of these tanks should be at least up to the bulkhead deck.
4. It is recommended that double skin is also adopted for this Class.

8.7 Bottom structure

8.7.1 The maximum spacing of floors should not exceed 2(550 + 1,667*L*) or 1700 mm whichever is the lesser. The maximum spacing of side girders in the double bottom should not exceed 1,6 m. Special consideration will be given to ships having deep draughts.

8.7.2 Ships designed to operate in ice conditions at shallow draught, i.e. at a draught less than indicated by 8.4.2, will require additional strengthening of bottom shell structure forward. Spacing of floors forward for such ships should not exceed 1,0 m. Bottom shell and bottom shell longitudinals will be specially considered. The spacing of side girders forward should not exceed 1,4 m.

8.8 Powering of ships intended to operate in multi-year ice conditions

8.8.1 The total shaft power installed in icebreaking ships intended to operate in Canadian Arctic regions should be not less than that required by the Canadian Arctic Shipping Pollution Prevention Regulations. For other regions, the minimum power is to be not less than that obtained by 8.8.3 taking the ship's speed as 1 knot.

8.8.2 Ships intended to operate in multi-year ice conditions should, in general, be able to develop sufficient thrust to permit continuous mode ice-breaking at a speed of five knots assuming the ice thickness related to the required Ice Class AC notation as given in 8.1. Snow cover should be assumed to be at least 0,3 m.

8.8.3 The requirements of 8.8 to 8.18 are formulated on the basis that the power necessary to provide the independent icebreaking capability described in 8.7.2 can be determined by the equation:

$$P_1\,(H_1) = C_0\,C_1\,C_2\,C_3\,\left(240B\,h\,(1 + h + 0{,}035v^2) + 70S_c\sqrt{L}\right)\ \text{kW (shp)}$$

where
- h = ice thickness for desired Ice Class AC notation, *see* 8.1
- v = ship speed (knots) when breaking ice of thickness h
- C_0 = 0,736 (1,0)
- $C_1 = \dfrac{1{,}2B}{\sqrt[3]{\Delta}}$ but to be taken as not less than 1,0
- C_2 = 0,9 if ship fitted with controllable pitch propeller, otherwise 1,0
- C_3 = 0,9 if the rake of stem is 45° or less, otherwise 1,0. The product $C_2\,C_3$ is not to be taken as less than 0,85
- S_c = depth of snow cover, in metres
- Δ = displacement as defined in 8.3.19.

8.8.4 The ice strengthening requirements set out in 8.9 to 8.15 include a power-displacement correction factor which is to be determined as follows:

(a) Bow section

$$\gamma = (0{,}88 + 0{,}0103f - 2{,}232f^2 \times 10^{-4})\,(1 + A\,(F - 1))$$

(b) Stern and mid-body sections

$$\gamma = 0{,}7 + 0{,}00924f - 2{,}134f^2 \times 10^{-4}$$

where
- $f = \sqrt{P_0\,\Delta} \times 10^{-3}\ \left(= 0{,}858\sqrt{H_0\,\Delta} \times 10^{-3}\right)$ but is not to be taken greater than 22
- A = 0,1 for shell plating
  = 0 for frames, stringers and web-frames
- F = ratio of installed power P_0 (H_0) to the power P_1(H_1) calculated in accordance with 8.8.2 and 8.8.3 but is not to be taken as less than 1,0

and P_0, H_0, Δ are defined in 8.3.19 and 8.3.20.

8.9 Shell plating

8.9.1 In way of the Ice Belt, the thickness of the shell plating is not to be less than:

$$t = 0{,}5s\,\alpha_p\,\beta\,\gamma\sqrt{\frac{p}{\sigma_o}} + c\ \text{mm}$$

in association with transverse or longitudinal framing,
where
- c = corrosion-abrasion increment as given in Table 9.8.5
- p = design ice pressure for each Ice Class as given in Table 9.8.4
- s = frame spacing between adjacent frames, in mm
- α_p = longitudinal distribution factor dependent upon Ice Class AC notation and longitudinal position as given in Table 9.8.3
- β = vertical distribution factor dependent on vertical position as given in Table 9.8.6
- γ = power-displacement factor as defined in 8.8.4
- σ_o = specified minimum yield stress of steel in N/mm^2 (kgf/mm^2). For mild steel, the value of 235 N/mm^2 (24 kgf/mm^2) is to be used.

Table 9.8.3 Longitudinal distribution factor α_p

Class	α_p		
	Bow	Mid-body	Stern
Ice Class AC1	1,0	0,8	0,9
Ice Class AC1,5	1,31	1,05	1,16
Ice Class AC2	1,6	1,28	1,45
Ice Class AC3	2,1	1,7	1,9

Table 9.8.4 Design ice pressure *p*

Class	Design ice pressure, p N/mm^2 (kgf/mm^2)
Ice Class AC1	5,89 (0,60)
Ice Class AC1,5	5,40 (0,55)
Ice Class AC2	4,91 (0,50)
Ice Class AC3	3,92 (0,40)

Table 9.8.5 Corrosion-abrasion increment *c*

Class	Corrosion-abrasion increment, c (mm)
Ice Class AC1	5
Ice Class AC1,5	6
Ice Class AC2	7
Ice Class AC3	9

Table 9.8.6 Vertical distribution factor β

Vertical position	β
Main ice belt zone	1,0
Upper transition area:	
Above main bow area	0,8
Above main mid-body area	0,5
Above main stern area	0,5
Lower transition area	0,5
Lower bow area	0,5

8.10 Transverse framing

8.10.1 The section modulus of main and intermediate transverse frames in way of the ice belt (including a width of attached plating equal to s) is to be not less than that determined in accordance with the following:

$$Z = 40\,\alpha_t\,\beta\,\gamma\,\frac{p\,s\,h_o}{l\,\sigma_o}\left(3l^2 - h_o^2\right)\ \text{cm}^3$$

where

h = as defined in 8.7.3

h_o = ice bearing height, dependent upon the span l, as given in Table 9.8.7 but is to be taken as not greater than the design ice thickness h or the span l, whichever is the least

l = span, in metres, measured along a chord at the side between the span points. For definition of span points, *see* Ch 3,3.3. Where adjacent main and intermediate frames have different end connections, resulting in different spans, a mean value is to be used

p = the ice pressure dependent upon ice bearing height, h_o, as given in Table 9.8.10

s, σ_o = as defined in 8.9.1

α_t = longitudinal distribution factor dependent on ice bearing height, h_o, and longitudinal position as given in Table 9.8.8

β = vertical distribution factor on vertical position and given in Table 9.8.9

γ = as defined in 8.8.4.

Table 9.8.7 Ice bearing height h_o

Span l m	Ice bearing height, h_o m
Less than 1,5	1,0
$1,5 \leq l < 2,2$	1,5
$2,2 \leq l < 4$	2
4 or greater	3
NOTE h_o is not to be taken greater than the value of ice thickness, h, implied by the Ice Class AC notation.	

Table 9.8.8 Longitudinal distribution factor α_t

Ice bearing height, h_o m	α_t		
	Bow	Mid-body	Stern
1 or less	1,0	0,8	0,9
1,5	0,95	0,76	0,86
2	0,91	0,73	0,82
3 or greater	0,86	0,69	0,78

Table 9.8.9 Vertical distribution factor β

Vertical position	β
Main ice belt zone	1,0
Upper transition area	0,5
Lower transition area	0,7
Lower bow area	0,5

Table 9.8.10 Ice bearing height h_o

Ice bearing height, h_o m	p N/mm^2 (kgf/mm^2)
1,0 or less	5,89 (0,6)
1,5	5,40 (0,55)
2,0	4,91 (0,50)
3 or greater	3,92 (0,40)

8.10.2 The cross-sectional shear area of transverse main and intermediate frames is to be not less than determined in accordance with the following formula:

$$A = 13\alpha_t \beta \gamma h_o \frac{ps}{\sigma_o} \text{ cm}^2$$

where

h_o = ice bearing height to be taken as equal to the span, l, but is not to be taken as greater than the design ice thickness for the desired Ice Class as given in 8.1

p = design ice pressure dependent upon ice bearing height, h_o, as given in Table 9.8.10. Linear interpolation is to be used for intermediate values of h_o

α_t = longitudinal distribution factor dependent on ice bearing height, h_o, and longitudinal position as given in Table 9.8.8. Linear interpolation is to be used for intermediate values of h_o

l, β as defined in 8.10.1

s, σ_o as defined in 8.9.1

γ as defined in 8.8.4.

8.10.3 The main and intermediate frames of the main ice belt zone, having scantlings as required by 8.10.1 and 8.10.2, should be extended to the first primary longitudinal member above or below this zone. The end connections of these frames to the primary longitudinal members are to be bracketed. Where the side frames are flat bar sections, they may be extended through the primary longitudinal member, suitably tapered and butt welded to the flat bar side frames required for the upper and lower transition areas.

8.10.4 The main and intermediate frames of the upper transition and lower transition areas, having scantlings as required by 8.10.1 and 8.10.2, should be extended, in the case of the upper transition area, to the first primary member above this area and for the lower transition area continued to the double bottom and/or margin plate as applicable. These frames should be effectively bracketed to the primary longitudinal member.

8.10.5 In the context of 8.10.3 and 8.10.4, a primary longitudinal member is defined as either a deck, deep tank top, or ice stringer complying with 8.13.

8.10.6 The intermediate frames need not extend beyond the limits defined in 8.10.4 provided that, in the case where the primary longitudinal member is an ice stringer, a suitable extension bracket is fitted.

8.11 Longitudinal framing

8.11.1 The section modulus of longitudinal frames (including a width of attached plating s) is to be not less than that determined in accordance with the following:

$$Z = 56\alpha_l \beta \gamma s l^2 \frac{p}{\sigma_o} \text{ cm}^3$$

l = span of longitudinal, in metres, determined in accordance with Ch 3,3.3

p = 5,89 (0,60)

s = longitudinal frame spacing, in mm

α_l = longitudinal distribution factor as given in Table 9.8.11

Table 9.8.11 Longitudinal distribution factor α_l

Class	α_l		
	Bow	Mid-body	Stern
All ice classes	1,0	0,8	0,9

Table 9.8.12 Vertical distribution factor β

Vertical position	β
Main ice belt zone	1,0
Upper transition area:	
Above main bow area	1,0
Above main mid-body area	0,7
Above main stern area	1,0
Lower transition area	0,7
Lower bow area	0,8

β = vertical distribution factor as given in Table 9.8.12

γ, σ_o = is as defined in 8.8.4 and 8.9.1.

8.11.2 The cross-section shear resisting area of longitudinal frames is to be not less than that determined in accordance with the following:

$$A = 13\alpha_l \beta \gamma s l \frac{p}{\sigma_o} \text{ cm}^2$$

where

α_l, β, l, p, s are defined in 8.11.1

σ_o is defined in 8.9.1

γ is defined in 8.8.4.

8.12 Framing – General requirements

8.12.1 In general, the web thickness of frames within the ice belt is to be not less than half that of the attached shell plating and the depth to thickness ratio for flat bar frames and longitudinals not greater than 15.

8.12.2 Where a frame intersects a boundary between two hull sections, the scantling requirements applicable will be those for the bow section, if the boundary between the bow and mid-body sections is intersected, or those for the stern section, if the boundary between the stern and mid-body sections is intersected.

8.12.3 Main and intermediate frames within the ice belt are to be efficiently supported to prevent tripping as shown in Fig. 9.7.6. The distance between anti-tripping supports is not to exceed 1,0 m.

8.12.4 Frames within the ice belt are to be attached to the shell plating by double continuous welding and are not to be scalloped except in way of shell butts.

8.12.5 The effective weld area attaching frames to primary members is to be not less than the shear area for the frames as required by 8.10.2 or 8.11.2 as appropriate.

8.12.6 For bulkheads or decks within the ice belt, the thickness of the plating adjacent to the shell is to be not less than that of the web of the adjacent frame. This increased thickness should extend for a width sufficient to give an area equal to that required for such frames.

8.13 Primary longitudinal members supporting transverse ice framing

8.13.1 The section modulus of ice stringers or of decks adjacent to hatchways, including a width of attached plating determined in accordance with Ch 3,3.2, and taken about an axis perpendicular to the web, is to be not less than that given by:

$$Z = 16\,700\,\alpha_o\,\beta\,\gamma^2\,S\,l^2\,\frac{p}{\sigma_o}\ \text{cm}^3$$

where

l = span of member, in metres, measured between span points but is to be taken as not less than 1,6 m

p = design ice pressure for desired Ice class as given in Table 9.8.4

S = spacing of primary longitudinal members, in metres, but need not be taken as greater than h, the nominal ice thickness for desired Ice Class as given in 8.1

α_o = longitudinal distribution factor as given in Table 9.8.13

β = vertical distribution factor as given in Table 9.8.14.

and γ, σ_o as given in 8.8.4 and 8.9.1.

Table 9.8.13 Longitudinal distribution factor α_o

Class	α_o		
	Bow	Mid-body	Stern
Ice Class AC1	1	0,9	0,95
Ice Class AC1,5	1,13	1,02	1,07
Ice Class AC2	1,8	1,6	1,7
Ice Class AC3	2,5	2,25	2,4

Table 9.8.14 Vertical distribution factor β

Vertical position	β
Main ice belt zone	1,0
Upper transition area:	
In way of bow section	0,9
In way of mid-body section	0,7
In way of stern section	0,8
Lower transition area	0,7
Lower bow area	0,9

8.13.2 The cross-sectional shear resisting area of ice stringers or of decks adjacent to hatchways is to be not less than that determined in accordance with the following:

$$A = 3000\,\alpha_o\,\beta\,\gamma^2\,S\,l^2\,\frac{p}{\sigma_o}\ \text{cm}^3$$

where

α_o, β, l, p and S are defined in 8.13.1

γ, σ_o are defined in 8.8.4 and 8.9.1.

8.13.3 Primary longitudinal members supporting tranverse frames should normally be arranged so that the maximum deviation of their webs from the perpendicular to the shell plating does not exceed ±20 degrees. Arrangements based on horizontal side stringers will be acceptable only if the section modulus is related to the axis parallel to the shell plating and brackets extending the full depth of the web are arranged at every transverse frame.

8.13.4 In all cases, the transverse frames are to be attached to the ice stringers by flat bars extending the full depth of the web of the primary longitudinal member. These flat bars should be fitted to both sides of the primary longitudinal member in vessels having designations Ice Class AC2 and AC3.

8.13.5 The minimum thickness of the web plating of longitudinal primary members is to comply with the requirements of Ch 10,4.

8.14 Web frames

8.14.1 The section modulus of web frames supporting ice stringers or longitudinal ice frames, including a width of attached plating determined in accordance with Ch 3,3.2 and taken about an axis perpendicular to the web, is to be not less than that given by:

$$Z = 8300\,\alpha_o\,\beta\,\gamma^2\,\frac{Sp}{l\,\sigma_o}\,h_o\left(3l^2 - h_o^2\right)\ \text{cm}^3$$

where

h = nominal ice thickness for desired Ice Class as given in 8.1

h_o = ice bearing height, in metres, to be taken as equal to the ice thickness h but is not to exceed the span l

l = web frame span, in metres, measured along a chord at side between span points but is to be taken as not less than 2 m. For definition of span points, *see* Ch 3,3.3

p = design ice pressure as given in Table 9.8.10

S = web frame spacing, in metres

α_o = longitudinal distribution factor as given by Table 9.8.13

β = vertical distribution factor as given by Table 9.8.14

γ, σ_o are defined in 8.8.4 and 8.9.1.

8.14.2 The cross-sectional shear resisting area of web frames supporting ice stringers or longitudinal ice frames is to be not less than that determined in accordance with the following:

$$A = 3000\, \alpha_o\, \beta\, \gamma^2\, S\, h_o\, \frac{p}{\sigma_o} \quad \text{cm}^2$$

where

α_o, β, S, p and h_o are defined in 8.14.1
γ, σ_o are defined in 8.8.4 and 8.9.1.

8.14.3 The thickness of the web plating of web frames below the upper deck level is to be not less than one per cent of the web depth or the thickness given in Table 9.8.15 whichever is the greater, *see also* 8.14.6.

Table 9.8.15 Web frame thickness

Class	Minimum web thickness of web frames mm
Ice Class AC1	12
Ice Class AC1,5	15
Ice Class AC2	18
Ice Class AC3	20

8.14.4 The minimum thickness of the face flat attached to the web frame is to be not less than 10 mm greater than the minimum web thickness as given by 8.14.3 and the minimum width of the face plate should be not less than 15 per cent of the web depth.

8.14.5 The spacing of tripping brackets supporting web frames should not exceed 2 m in the main ice-belt zone and 2,5 m elsewhere.

8.14.6 Where longitudinal frames pass through web frames, watertight or non-watertight bulkheads, the thickness of these members, adjacent to the shell plating, is to be not less than 60 per cent of the thickness of the longitudinals.

8.14.7 The longitudinal frames should be connected to the web frames by a flat bar extending the full depth of the web frame. In the case of Ice Class AC1,5, Ice Class AC2 and Ice Class AC3, this connection should be effected by double brackets.

8.15 Stem

8.15.1 The stem is to be made from rolled, cast or forged steel or of shaped steel plates.

8.15.2 The plate thickness of a plate stem is to be not less than:

$$t = 0{,}5s\, \alpha_p\, \beta\, \gamma \sqrt{\frac{p}{\sigma_o}} + c \quad \text{mm}$$

where

α_p, β, γ, σ_o, p, c are defined in 8.9.1

and

s = distance, in mm, between horizontal webs and diaphragm plates having a thickness of at least 0,5t.

8.15.3 The thickness of the stem plate is to be not less than 1,1 times the thickness of the adjacent plating in the bow section as determined by 8.9.1.

8.15.4 Where a forged or cast steel stem profile is incorporated, the extent of the ice reinforced profile is to extend to at least the upper edge of the upper transition zone. The connection of the shell plating to the stem is to be flush. Similar requirements apply to welded stem constructions.

8.15.5 The stem should extend to the forefoot ice arrester structure. Ice arresters are recommended for all ships having Arctic Ice Class AC notations to prevent riding up of the bow and submergence of the aftermost deck edge.

8.16 Stern

8.16.1 Where the screwshaft diameter exceeds the Rule diameter, the propeller post is to be correspondingly strengthened, *see* Ch 6,7.

8.16.2 A transom stern should not normally extend below the Ice Load Waterline. Where this cannot be avoided, the transom should be kept as narrow as possible and the scantlings of plating and stiffeners are to be as required for the stern section.

8.16.3 Where special provision is made in the stern area of the vessel for close tow-push operations, the fork structure should be of sufficient strength to transmit the applied forces.

8.17 Bossings and shaft struts

8.17.1 Shaftings and sterntubes of ships with two or more propellers are to be enclosed within plated bossings.

8.18 Rudder, steering arrangements and nozzles

8.18.1 In general, spade rudders are not to be fitted on ships employed in Arctic or Antarctic operations.

8.18.2 Rudder posts, rudder horns, solepieces, rudder stocks and pintles are to be dimensioned in accordance with Chapter 6 or Chapter 13 as appropriate. The speed used in the calculations is to be the maximum service speed or that given in Table 9.8.16, whichever is the greater. However, the section modulus of the solepiece calculated in accordance with the above need not be greater than three times the section modulus of solepiece calculated in accordance with Ch 6,7 using the maximum service speed.

8.18.3 For double plate rudders, the minimum thickness of plates and horizontal and vertical webs in the main ice-belt zones is to be determined as for the shell plating in the stern area, as required by 8.9.1. Horizontal and vertical webs, however, need not include the corrosion abrasion increment of Table 9.8.5.

Table 9.8.16 Minimum speed

Class	Minimum speed knots
Ice Class AC1	22
Ice Class AC1,5	23
Ice Class AC2	24
Ice Class AC3	26

8.18.4 The rudder head and upper edge of the rudder are to be efficiently protected against ice impact, when the ship is backing into ice, by a robust ice knife. The thickness of the boundaries of this ice knife structure is to be not less than that of the rudder side plating. The width of the ice knife should exceed the maximum width of the rudder by five per cent.

8.18.5 Fixed nozzles are to be effectively integrated into the aft end structure. Where a twin screw nozzle arrangement is fitted, a heavy skeg is to be arranged in front of each nozzle. For such an arrangement it is considered advisable to keep the distance between the nozzles to a minimum in order to restrict ice flow between the nozzles. The head box structure should contain a dense grillage of longitudinal and transverse plate girders. Particular attention is to be paid to all structural details and especially the connections between the nozzle and the solepiece. Freely suspended nozzles are not considered suitable for icebreaking duties.

8.18.6 The nozzle construction requirements of Table 13.3.1 in Ch 13,3 should be upgraded for ships having Ice Class AC notations to include the abrasion allowance given in Table 9.8.17. However, the thickness of the shroud plating is to be not less than the shell plating in the stern area as determined by 8.9.1 taking the frame spacing, *s*, as 350 mm, but need not exceed 45 mm.

Table 9.8.17 Abrasion allowance

Class	Abrasion increment
Ice Class AC1	8
Ice Class AC1,5	10
Ice Class AC2	12
Ice Class AC3	15

8.18.7 The scantling, of nozzle stock, gudgeon, pintles, solepiece, etc., determined in accordance with Ch 13,3, should be increased on the basis of 8.17.2. However the diameter of the nozzle stock is to be not less than that calculated in the astern condition taking the astern speed as half the speed given in Table 9.8.16 or the actual stern speed, whichever is the greater. The allowable stresses to be used in the calculation of nozzle stock diameter are to be taken as:

combined stress at lower bearings ≤ 85 N/mm^2 (8,7 kgf/mm^2)

torsional stress in upper stock ≤ 55 N/mm^2 (5,6 kgf/mm^2)

8.18.8 The section modulus of the solepiece obtained from 8.18.7 is to be not less than that determined in accordance with the following:

$Z = C\,Z_s$ cm^3

where

Z_s = modulus of the solepiece calculated using the Rule stress given in Ch 13,3

C = *see* Table 9.8.18

For the ahead condition, the maximum service speed is to be used and for the astern condition, the greater of half the maximum service speed or the astern speed.

Table 9.8.18 Values of *C*

Class	*C*
Ice Class AC1	1,5
Ice Class AC1,5	2
Ice Class AC2	2,5
Ice Class AC3	3,0

8.18.9 Nozzles with articulated flaps will be subject to special consideration.

8.18.10 Where the nozzle numeral as per Table 13.3.1, in Chapter 13, exceeds 400 an analysis of the nozzle structure should be carried out including appropriate simulation of ice impact loading.

8.18.11 It is advisable to verify that the natural frequency of the nozzle arrangement immersed in water is well removed from the excitation frequencies.

8.18.12 Due regard is to be paid to the method of securing the rudder in the centreline position when backing into ice. Where possible, rudder stoppers working on the blade or rudder head should be fitted.

8.18.13 Ships having Ice Class AC notations are, in addition to the main steering gear, to be fitted with auxiliary steering gear capable of being readily connected to the tiller, *see also* Pt 5, Ch 19. In the case of twin rudders operated by a single steering gear, there is to be provision for each rudder to be readily disconnected and secured.

8.18.14 The main steering gear of ships having Ice Class AC notations shall be fitted with a shock absorbing device and be capable of moving the rudder from 35° on one side to 30° on the other side in $\sqrt{6{,}56L}$ seconds or 28 seconds, whichever, is the lesser when the ship is fully loaded and travelling at her maximum service speed.

8.19 Direct calculations

8.19.1 If, as an alternative to the requirements of 8.12 and 8.13, the scantlings of primary longitudinal members and web frames are determined by direct calculation as permitted by Ch 1,2.1, the following procedure is to be adopted:

(a) The extent of the structural model should be at least equal to the largest cargo hold length between two transverse bulkheads. The upper boundary should be the upper deck and the lower boundary the inner bottom.

(b) The structural members represented should include stringers, web frames, side frames and all relevant decks.

(c) The rate of applied ice loading q, for the mid-body section, should be taken as:
$q = p\, h\, 10^3$ kN/m (tonne-f/m)
where p is given in Table 9.8.4
h is defined in 8.4

(d) The scantlings should be suitable for the centre of load depth to be located at any height between the Ice Load Waterline and Ice Light Waterline.

(e) The maximum von Mises-Hencky combined stress is not to exceed 80 per cent of the yield stress of the steel.

■ *Section 9* Strengthening requirements for navigation in very light first-year ice conditions

9.1 General

9.1.1 These requirements apply to offshore supply ships, as defined in Pt 4, Ch 4, and which are intended to operate in very light first-year ice conditions. Where additional strengthening is fitted in accordance with the requirements of this sub-Section, the notation Ice Class **1E** will be assigned.

9.1.2 For longitudinally framed ships, the scantlings of shell plating and framing are to comply with the requirements of Ice Class **1C FS** using 0,9 times the ice pressure. The requirements for shell plating need only be applied in the region shown in Fig. 9.1.1. The requirements for framing need only be applied forward of the flat of side.

9.1.3 For transversely framed ships, the requirements of 9.3 to 9.8 are to be applied.

9.1.4 Where the structural requirements of Ice Class **1C FS** give lesser scantlings than the requirements of this sub-Section, the lesser scantlings may be applied.

9.2 Shell plating

9.2.1 The shell plating thickness within the region shown in Fig. 9.1.1 is not to be less than:

$$t = 21{,}75s\sqrt{k\left(\frac{BL^2}{110000} + 1\right)\left(1{,}3 - \frac{4{,}2}{(0{,}26s + 1{,}8)^2}\right)} + 2 \text{ mm}$$

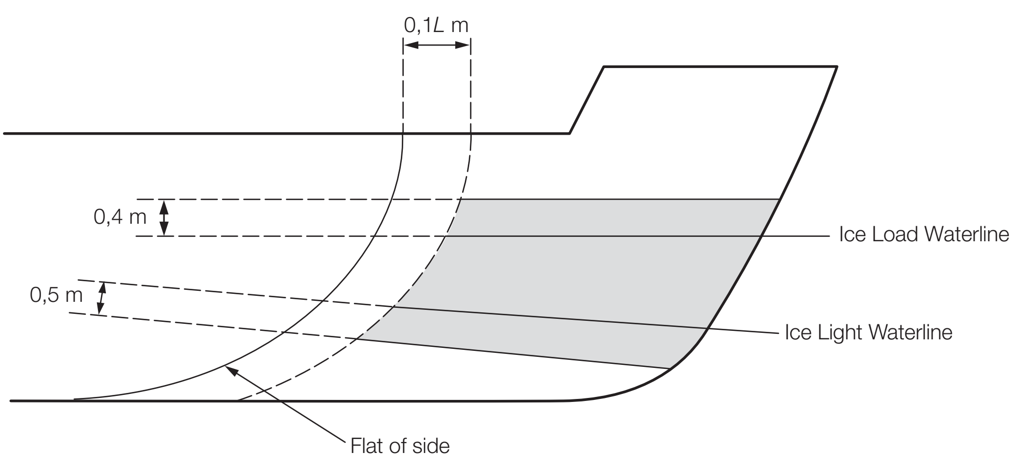
where
s = spacing of main frames, in metres
L and B are defined in Ch 1,6.1
k is defined in Ch 2,1.2.

9.3 Transverse framing

9.3.1 The section modulus of main frames forward of the flat of side is not to be less than:

$$z = 6{,}08 s\, l\, k\left(\frac{BL^2}{140000} + 1{,}23\right)\left(7 - \frac{1}{21}\right) \text{ cm}^3$$

but need not be taken as greater than:
$z = sLT$
where
s = spacing of main frames, in metres
l = span, in metres



Ice Load Waterline and Ice Light Waterline are defined in 7.2
L, as defined in Ch 1,6.1

Fig. 9.1.1 Extent of application of plating requirements

L and *B* are defined in Ch 1,6.1
k is defined in Ch 2,1.2.

9.3.2 Intermediate ice frames are to be fitted in the region forward of the flat of side and are to extend from 0,62 m above the Ice Load Waterline to 1 m below the Ice Light Waterline.

9.3.3 Intermediate ice frames aft of the collision bulkhead are to have a section modulus not less than 65 per cent of that given in 9.3.1.

9.3.4 Intermediate ice frames forward of the collision bulkhead are to have a section modulus not less than 40 per cent of that given in 9.3.1.

9.4 Primary longitudinal members supporting ice frames

9.4.1 Forward of the collision bulkhead, in single deck ships, an ice stringer is to be fitted approximately 0,25 m below the Ice Load Waterline and is to have scantlings in accordance with Table 5.4.4 in Chapter 5.

9.4.2 Aft of the collision bulkhead a series of tripping brackets are to be fitted at each main and intermediate frame at the same level as the ice stringer to a distance 0,1*L* aft of the flat of side.

9.5 Sternframe and rudder

9.6.1 The rudder and sternframe scantlings are to be in accordance with 7.7. However, the ship's speed need not be taken as greater than 14 knots. The hull form factor and the rudder profile coefficients are to be taken as 1,0.

9.6 Weld connections

9.6.1 Weld connections to the shell plating forward of the collision bulkhead are to be double continuous.

■ *Section 10* Lifting appliances and support arrangements

10.1 General

10.1.1 Masts, derrick posts, crane pedestals and similar supporting structures are classification items, and the scantlings and arrangements are to comply with LR's requirements whether or not LR is also requested to issue the Register of Ships' Cargo Gear and Lifting Appliances.

10.1.2 Where the lifting appliance is considered to be an essential feature of a classed ship, the special feature class notation **LA** will, in general, be mandatory.

10.1.3 Elsewhere, classification of lifting appliances is optional and may be assigned at the request of the Owner on compliance with the appropriate requirements.

10.1.4 Certain movable support structures and lifting appliances on special purpose vessels which are considered an essential feature of the vessel are to be included in the classification of the vessel.

10.1.5 Proposals to class lifting appliances on unclassed ships will be specially considered.

10.2 Masts, derrick posts and crane pedestals

10.2.1 The scantlings of masts and derrick posts, intended to support derrick booms, conveyor arms and similar loads, and of crane pedestals, are to comply with the requirements of LR's Code for *Lifting Appliances in a Marine Environment* (hereinafter referred to as LAME).

10.2.2 In addition to the information and plans requested in LR's LAME the following details are to be submitted:

(a) Details of masthouses or other supports for the masts, derrick posts or crane pedestals, together with details of the attachments to the hull structure.
(b) Details of any reinforcement or additional supporting material fitted to the hull structure in way of the mast, derrick post or crane pedestal.

10.3 Support structure for masts, derrick posts and crane pedestals

10.3.1 The requirements of 10.2.3 and 10.2.4 are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation (*see* Pt 1, Ch 2,2.3)

10.3.2 Masts, derrick posts and crane pedestals are to be efficiently supported and, in general, are to be carried through the deck and satisfactorily scarfed into a transverse hold or 'tween deck bulkhead. Alternatively, the masts, derrick posts or crane pedestals may be carried into a mast house, in which case the mast house is to be of substantial construction. Proposals for other support arrangements will be specially considered.

10.3.3 Deck plating and underdeck structure are to be reinforced under masts, derrick posts or crane pedestals and, where the deck is penetrated, the deck plating is to be suitably increased locally.

10.4 Lifting appliances

10.4.1 Ships or offshore units fitted with lifting appliances built in accordance with LR's LAME in respect of structural and machinery requirements will be eligible to be assigned Special Features class notations as listed in Table 9.10.1. This notation will be retained so long as the appliances are found upon examination at the prescribed surveys to be maintained in accordance with LR's requirements.

Table 9.10.1 Special features class notations associated with lifting appliances

Lifting appliance	Special features class notation	Remarks
Derricks, derrick cranes or cranes on ships	CG	Optional notation. Indicates that the ship's cargo gear is included in class.
Cranes on offshore installations	PC	Optional notation. Indicates that the installation's platform cranes are included in class.
Lifts and ramps on ships	CL PL CR	Optional notations. Indicate that the ship's cargo lifts (CL), passenger lifts (PL) or cargo ramps (CR) are included in class.
Lifting appliances forming an essential feature of the vessel, e.g. cranes on crane barges or pontoons, lifting arrangements for diving on diving support ships, etc.	LA	Mandatory notation. Indicates that the lifting appliance is included in class.

■ *Section 11* Freight container securing arrangements

11.1 Classification

11.1.1 Where freight container securing arrangements are fitted and the design and construction of the system are in accordance with the requirements of Chapter 14, the ship will be eligible to be assigned the special features notation **Certified Container Securing Arrangements**.

■ *Section 12* Bottom strengthening for loading and unloading aground

12.1 Application

12.1.1 Where a ship of length, *L*, less than 90 m has the bottom structure additionally strengthened for loading and unloading aground in accordance with Table 9.12.1, it will be eligible for the special features notation 'bottom strengthened for loading and unloading aground'. Ships of length, *L*, 90 m or more intended for this service will receive individual consideration.

12.1.2 For dredgers intended to operate aground, the requirements of Pt 4, Ch 12 are to be applied.

Table 9.12.1 Bottom strengthening for loading and unloading aground

Item	Requirement	
The following requirements are to be applied to the bottom structure upon which the ship is likely to be supported whilst aground		
(1) Bottom shell and keel plating	Thickness to be increased by 20% over the minimum requirements given in Part 4 for the particular type of ship with a minimum of 8 mm	
(2) Bottom longitudinals in way of single bottoms	For dry cargo ships, as required in way of double bottoms, *see* item (3) For oil tankers, scantlings as required by Table 9.5.1 in Pt 4, Ch 9 in taking c_1 = 1,0	
(3) Bottom longitudinals in way of double bottoms, *see* Note 1	For dry cargo ships, scantlings as required by Table 1.6.1 in Pt 4, Ch 1 in taking c_1 = 1,0	
(4) Bilge longitudinals (where fitted)	Scantlings to be the same as bottom longitudinals	
	Transverse framing	Longitudinal framing
(5) Primary stiffening in way of single bottoms, *see* Notes 2 and 3	(a) Floors to be fitted at every frame with vertical stiffeners spaced, in general, not more than 1,25 m apart (b) One side girder is to be fitted on each side of the centreline in addition to the requirements of Pt 4, Ch 1,7 and intermediate 150 x 10 bulb plate longitudinals or equivalent fitted	(a) The arrangements and scantlings will receive individual consideration depending on the structural arrangements of the particular ship type (b) The spacing of transverse or floors is, in general, not to exceed 1,85 m
(6) Primary stiffening in way of double bottoms, *see* Notes 1, 2 and 3	(a) Plate floors are to be fitted at every frame and vertical stiffening arranged to give panel widths, in general, not exceeding 1,25 m (b) One side girder is to be fitted on each side of the centreline in addition to the requirements of Pt 4, Ch 1,8 and intermediate 150 x 10 bulb plate longitudinals or equivalent fitted	(a) The spacing of floors is, in general, not to exceed 1,85 m (b) One side girder is to be fitted on each side of the centreline in addition to the requirements of Pt 4, Ch 1,8

NOTES
1. For oil tankers, to be specially considered.
2. The scantlings of floors, girders and transverses are to be determined from Part 4, for the particular ship type.
3. The number and sizes of holes in floors, girders and transverses are to be kept to a minimum; *see* Pt 4, Ch 1,8 and Pt 4, Ch 9,6.

■ *Section 13*
Strengthening for regular discharge by heavy grabs

13.1 Application

13.1.1 For bulk carriers where cargoes are regularly discharged by heavy grabs and the thickness of the plating of the hold inner bottom, hopper and transverse bulkhead bottom stool is increased in accordance with the requirements of this Section, the ship will, at the Owner's option, be assigned the notation 'strengthened for regular discharge by heavy grabs'.

13.1.2 It should be noted that damage to the plating cannot be excluded even when complying with these requirements and can result from the mishandling of the grabs during the discharge of cargo.

13.1.3 The grab weight given in 13.2.1 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.

13.1.4 The maximum unladen weight of the grab is to be recorded in the Loading Manual, *see also* Ch 4,8.2.4(e).

13.1.5 The requirements in this Section are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation. *See* Pt 1, Ch 2,2.3.

13.2 Inner bottom plating

13.2.1 The thickness of the inner bottom plating in the holds is to be not less than required by the greater of the following:

(a) $$t = \frac{\left(\log_{10}\left(1{,}775P\left(\frac{k}{s}\right)^2\right) + 5{,}7633\right)s - 344{,}5}{40{,}875\sqrt{k}} + 1{,}5 \text{ mm}$$

(b) t = the Rule required thickness, in mm in accordance with Pt 4, Ch 7,8 for the intended class notation.

where

P = specified unladen grab weight for the hold, in tonnes, and is not to be taken as less than 25 tonnes

s = spacing of inner bottom longitudinals, in mm

k = higher tensile steel factor as defined in Ch 2,1.2.

13.3 Hopper side tank sloped bulkhead plating

13.3.1 The thickness of the sloped bulkhead plating adjacent to the inner bottom knuckle is to be as required by 13.2.1 but based on the actual spacing of stiffeners. The plating of increased thickness is to extend for a minimum distance corresponding to a vertical height of 1,5 m above the line of the inner bottom. Outboard of the plating of increased thickness, the thickness of the adjacent strakes is to be tapered to the Rule thickness for plating, as required by Pt 4, Ch 1,8.4.1, at the top corner of the tank, *see also* Pt 4, Ch 7,9.2.3 where, in addition, the 'strengthened for heavy cargo' notation is desired.

13.4 Transverse bulkhead plating

13.4.1 The thickness of the bulkhead or stool plating adjacent to the inner bottom is to be as required by 13.2.1 but based on the actual spacing of the bulkhead or stool stiffeners. The plating of increased thickness is to extend for a minimum distance corresponding to a vertical height of 1,5 m above the line of the inner bottom.

Section

■ *Section 1*
General

1.1 Application

1.1.1 This Chapter is applicable to all ship types and components.

1.1.2 Requirements are given in this Chapter for the following:
(a) Welding-connection details, defined practices and sequence, consumables and equipment, procedures, workmanship and inspection.
(b) End connection scantlings and constructional details for longitudinals, beams, frames and bulkhead stiffeners.
(c) Primary member proportions, stiffening and construction details.
Additional requirements for primary structure of tankers and similar ships are given in Pt 4, Ch 9,6.

1.1.3 The requirements in this Chapter are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation (*see* Pt 1, Ch 2,2.3) with the exception of 2.9 to 2.13 which are to be complied with

1.2 Symbols

1.2.1 Symbols are defined as necessary in each Section.

■ *Section 2*
Welding

2.1 General

2.1.1 The plans to be submitted for approval are to indicate clearly details of the welded connections of main structural members, including the type and size of welds. This requirement includes welded connections to steel castings.

The information to be submitted should include the following:
(a) Whether weld sizes given are throat thicknesses or leg lengths.
(b) Grades and thicknesses of materials to be welded.
(c) Location, types of joints and angles of abutting members.
(d) Reference to welding procedures to be used.
(e) Sequence of welding of assemblies and joining up of assemblies.

2.2 Butt welds

2.2.1 Abrupt change of section is to be avoided where plates of different thicknesses are to be butt welded. Where the difference in thickness exceeds 3 mm, the thicker plate to be welded is to be prepared with a taper not exceeding 1 in 3 or with a bevelled edge to form a welded joint proportioned correspondingly. Where the difference in thickness is less than 3 mm the transition may be achieved within the width of the weld. Difference in thickness greater than 3 mm may be accepted provided it can be proven by the Builder, through procedure tests, that the Rule transition shape can be achieved and that the weld profile is such that structural continuity is maintained to the Surveyor's satisfaction.

2.2.2 Where stiffening members are attached by continuous fillet welds and cross completely finished butt or seam welds, these welds are to be made flush in way of the faying surface. Similarly, for butt welds in webs of stiffening members, the butt weld is to be completed and generally made flush with the stiffening member before the fillet weld is made. The ends of the flush portion are to run out smoothly without notches or sudden change of section. Where these conditions cannot be complied with, a scallop is to be arranged in the web of the stiffening member. Scallops are to be of such size, and in such a position, that a satisfactory weld can be made.

2.3 Lap connections

2.3.1 Overlaps are generally not to be used to connect plates which may be subjected to high tensile or compressive loading and alternative arrangements are to be considered. Where, however, plate overlaps are adopted, the width of the overlap is not to exceed four times nor be less than three times the thickness of the thinner plate and the joints are to be positioned as to allow adequate access for completion of sound welds. The faying surfaces of lap joints are to be in close contact and both edges of the overlap are to have continuous fillet welds.

2.4 Closing plates

2.4.1 For the connection of plating to internal webs, where access for welding is not practicable, the closing plating is to be attached by continuous full penetration welds or by slot fillet welds to face plates fitted to the webs. Slots are to have a minimum length of 90 mm and a minimum width of twice the plating thickness, with well rounded ends. Slots cut in plating are to have smooth, clean and square edges and should be spaced not more than 230 mm apart centre to centre. Slots are not to be filled with welding. For rudder closing plates, *see* Ch 13,2.5.6.

2.5 Stud welding

2.5.1 Where permanent or temporary studs are to be attached by welding to main structural parts in areas subject to high stress, the proposed location of the studs and the welding procedures adopted are to be to the satisfaction of the Surveyors.

2.6 Fillet welds

2.6.1 T-connections are generally to be made by fillet welds on both sides of the abutting plate, the dimensions and spacing of which are shown in Fig. 10.2.1. Where the connection is highly stressed, deep penetration or full penetration welding may be required. Where full penetration welding is required, the abutting plate may be required to be bevelled.

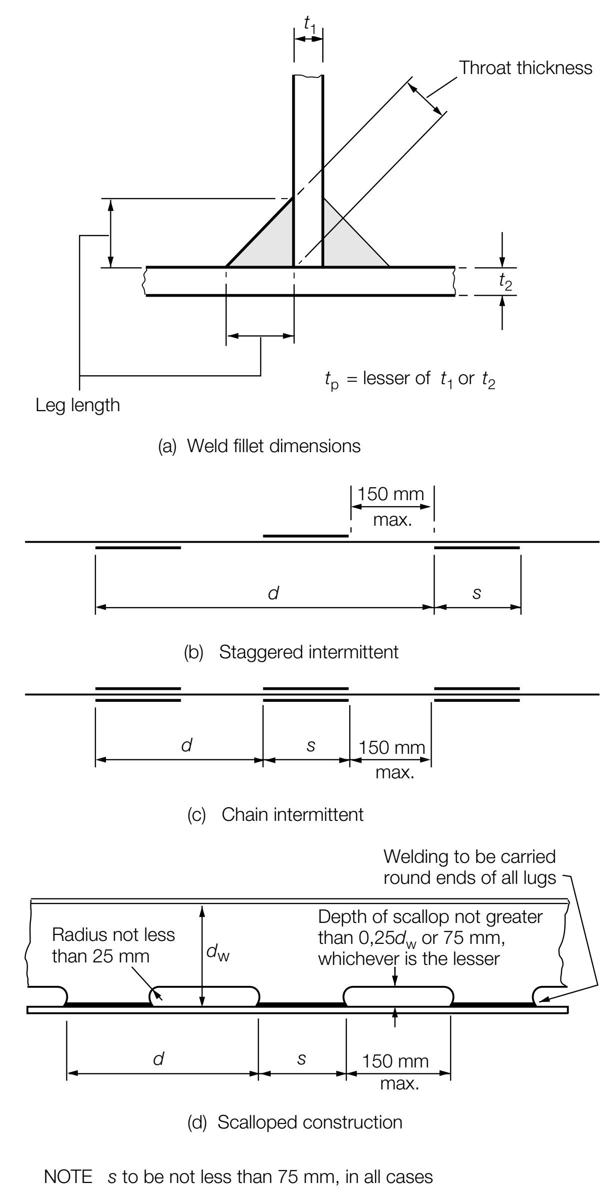


Fig. 10.2.1 Weld types

2.6.2 The throat thickness of fillet welds is to be determined from:

$$\text{Throat thickness} = t_p \times \text{weld factor} \times \frac{d}{s}$$

where

d = the distance between start positions of successive weld fillet, in mm

s = the length, in mm, of correctly proportioned weld fillet, clear of end craters, and is to be not less than 75 mm

t_p = plate thickness, on which weld fillet size is based, in mm

see also Fig. 10.2.1

Weld factors are given in Tables 10.2.1, 10.2.3 and 10.2.4.

2.6.3 Where an approved deep penetration procedure is used, the fillet leg length calculated from the weld factors given in the Tables may be reduced by 15 per cent provided that the Shipyard is able to meet the following requirements:

(a) Use of a welding consumable approved for deep penetration welding in accordance with Pt 2, Ch 11 for either the 'p' or 'T' techniques.

(b) Demonstrations by way of production weld testing that the minimum required penetration depths (i.e. throat thicknesses) are maintained. This is to be documented on a monthly basis by the Shipyard, and made available to the Surveyor on request.

A reduction of 20 per cent may be given provided that in addition to the requirements of (a) and (b) the Shipyard is able to consistently meet the following additional requirements:

(c) The documentation required in (b) is to be completed and made available to the Surveyor upon request on a weekly basis.

(d) Suitable process selection confirmed by satisfactory welding procedure tests covering both minimum and maximum root gaps.

2.6.4 Where double continuous fillet welding is proposed, the throat thickness is to be determined taking $\frac{d}{s}$ equal to 1,0.

2.6.5 The leg length of the weld is to be not less than $\sqrt{2}$ x the specified throat thickness.

2.6.6 The plate thickness, t_p, to be used in the above calculation is generally to be that of the thinner of the two parts being joined. Where the difference in thickness is considerable, the size of fillet will be considered.

2.6.7 Where the thickness of the abutting member of the connection (e.g. the web of a stiffener) is greater than 15 mm and exceeds the thickness of the table member (e.g. plating), the welding is to be double continuous and the throat thickness of the weld is to be not less than the greatest of the following:

(a) 0,21 x thickness of the table member. The table member thickness used need not exceed 25 mm.

(b) 0,21 (0,27 in tanks) x half the thickness of the abutting member.

(c) As required by Table 10.2.2.

2.6.8 Except as permitted by 2.6.7, the throat thickness of the weld is not to be outside the limits specified in Table 10.2.2.

Table 10.2.1 Weld factors (*see continuation*)

Item	Weld factor	Remarks
(1) General application:		except as required below
Watertight plate boundaries	0,34	
Non-tight plate boundaries	0,13	
Longitudinals, frames, beams, and other secondary members to shell, deck or bulkhead plating	0,10 0,13 0,21	 in tanks in way of end connections
Panel stiffeners, etc.	0,10	
Overlap welds generally	0,27	
Longitudinals of the flat-bar type to plating		*see* Note 5
(2) Bottom construction in way of holds or tanks:		
Non-tight centre girder: to keel to inner bottom	0,27 0,21	 no scallops
Non-tight boundaries of floors, girders and brackets	0,21 0,27	in way of 0,2 x span at ends in way of brackets at lower end of main frame
Inner bottom longitudinals or reverse frames	0,13	under holds strengthened for heavy cargoes
Connection of floors to inner bottom in way of plane bulkheads, bulkhead stools, or corrugated and double plate bulkheads supported on inner bottom. The supporting floors are to be continuously welded to the inner bottom	0,44	Weld size based on floor thickness Weld material compatible with floor material *See* Note 4
(3) Hull framing:		
Webs of web frames and stringers: to shell to face plate	 0,16 0,13	
Tank side brackets to shell and inner bottom	0,34	
(4) Decks and supporting structure:		
Strength deck plating to shell		as shown in Table 10.2.5 but alternative proposals will be considered
Other decks to shell and bulkheads (except where forming tank boundaries)	0,21	generally continuous
Webs of cantilevers to deck and to shell in way of root bracket	0,44	
Webs of cantilevers to face plate	0,21	
Pillars: fabricated end connections end connections (tubular)	0,10 0,34 full penetration	 *see* Note 1
Girder web connections and brackets in way of pillar heads and heels	0,21	continuous

2.6.9 Continuous welding is to be adopted in the following locations, and may be used elsewhere if desired:

(a) Boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings.

(b) Boundaries of tanks and watertight compartments.

(c) All structure in the after peak and the after peak bulkhead stiffeners.

(d) All welding inside tanks intended for chemicals or edible liquid cargoes.

(e) All lap welds in tanks.

(f) Primary and secondary members to bottom shell in the 0,3L forward.

(g) Primary and secondary members to plating in way of end connections, and end brackets to plating in the case of lap connections.

(h) Where 2.6.7 applies.

(j) Other connections or attachments, where considered necessary, and in particular the attachment of minor fittings to higher tensile steel plating.

(k) Fillet welds where higher tensile steel is used.

2.6.10 Where intermittent welding is used, the welding is to be made continuous in way of brackets, lugs and scallops and at the orthogonal connections with other members.

Table 10.2.1 Weld factors (*continued*)

Item	Weld factor	Remarks
(5) Bulkheads and tank construction, *see also* Pt 4, Ch 7,10:		
Plane, double plate and corrugated watertight bulkhead boundary at bottom, bilge, inner bottom, deck and connection to shelf plate, where fitted	0,44	weld size to be based on thickness of bulkhead plating weld material to be compatible with bulkhead plating material
Shelf plate connection to stool	0,44	weld size to be based on thickness of stool at junction with shelf plate. Weld material to be compatible with stool material
Plane, double plate and corrugated bulkhead boundaries in way of deep tanks, holds in bulk carriers (*see* 1.1.3) which are floodable for the sea going ballast condition or for the carriage of oil cargoes (Holds in bulk carriers (*see* 1.1.3) which are partially flooded for harbour conditions will be specially considered):		
– Boundary at bottom, bilge, inner bottom and deck	0,44	
– Connection of stool and bulkhead to lower stool shelf plating	full penetration	
– Connection of stool and bulkhead plating to upper stool shelf plate	0,44	
– Connection of bulkhead plating to hopper and topside tanks	0,44	
– Connection of bulkhead plating to side shell	0,34	
Secondary members where acting as pillars	0,13	
Non-watertight pillar bulkhead boundaries	0,13	
Perforated flats and wash bulkhead boundaries	0,10	
(6) Structure in cargo oil tanks of tankers (*see* 1.1.3):		
Bottom longitudinals to shell	0,21	for forward of 0,3*L*
Longitudinal of flat-bar type to plating		*see* 2.6.7
Connections between primary structural members	0,44 0,34	at bottom at deck
Oiltight bulkhead boundaries:		
longitudinal bulkhead	0,44	*see* Note 2
transverse bulkhead	0,44 0,34	at bottom, *see* Note 3 at deck, sides and longitudinal bulkhead
Vertical corrugations to an inner bottom	full penetration	
Non-tight bulkhead boundaries to plating	0,21	
(7) Structure in cargo tanks of chemical tankers:		
Tank boundary bulkheads:		
Type 1 ship	full penetration	
Type 2 ship		
longitudinal bulkheads	0,44	*see* Note 2
transverse bulkheads	0,44	
Type 3 ship		
longitudinal bulkheads	0,44	*see* Note 2
transverse bulkheads	0,44	at bottom *see* Note 3
transverse bulkheads at deck, sides and longitudinal bulkhead	0,34	
(8) Structure in hoppers of hopper dredgers, etc.:		
Bulkhead boundary connections	0,44 0,34	at bottom and bilge at deck and coamings
Cross members to bulkheads and keel	0,44	
Pillar end connections	0,34	
Hopper door hinges	full penetration	generally

Table 10.2.1 Weld factors *(continued)*

Item	Weld factor	Remarks
(9) Structure in machinery space:		
Centre girder to keel and inner bottom	0,27	
Floors to centre girder in way of engine, thrust and boiler bearers	0,27	
Floors and girders to shell and inner bottom	0,21	
Main engine foundation girders: to top plate; to hull structure	deep penetration to depend on design	edge to be prepared with maximum root $0{,}33t_p$ deep penetration generally
Floors to main engine foundation girders	0,27	
Brackets, etc., to main engine foundation girders	0,21	
Transverse and longitudinal framing to shell	0,13	
(10) Construction in 0,25*L* forward:		
Floors and girders to shell and inner bottom	0,21	
Bottom longitudinals to shell	0,13	
Transverse and longitudinal side framing to shell	0,13	
Tank side brackets to frame and inner bottom	0,34	
Panting stringers to shell and frames	0,34	
Fore peak construction: all internal structure	0,13	unless a greater weld factor is required
(11) After peak construction:		
All internal structure and stiffeners on after peak bulkhead	0,21	unless a greater weld factor is required
(12) Superstructure and deckhouses:		
Connection of external bulkheads to deck	0,34 0,21	1st and 2nd tier erections elsewhere
Internal bulkheads	0,13	
(13) Hatchways and closing arrangements:		
Hatchways coamings to deck	0,34	0,44 at corners
Hatch cover rest bar	0,16	
Hatch coaming stays to coaming	0,13	
Hatch coaming stays to deck	0,21	
Cleats and fittings	0,44	full penetration welding may be required
Primary and secondary stiffening of hatch covers	0,10	0,13 for tank covers and where covers strengthened for loads over
(14) Steering control systems:		
Rudder:		
Fabricated mainpiece and mainpiece to side plates and webs	0,44	
Slot welds inside plates	0,44	
Remaining construction	0,21	
Fixed and steering nozzles: Main structure	0,44	
Elsewhere	0,21	
Fabricated housing and structure of thruster units, stabilizers, etc.: Main structure	0,44	
Elsewhere	0,21	

Table 10.2.1 Weld factors (*conclusion*)

Item	Weld factor	Remarks
(15) Miscellaneous fittings and equipment:		
Rings for manhole type covers, to deck or bulkhead	0,34	
Frames of shell and weathertight bulkhead doors	0,34	
Stiffening of doors	0,21	
Ventilator, air pipe, etc., coamings to deck	0,34 0,21	Load Line Positions 1 and 2 elsewhere
Ventilator, etc., fittings	0,21	
Scuppers and discharges, to deck	0,44	
Masts, derrick posts, crane pedestals, etc., to deck	0,44	full penetration welding may be required
Deck machinery seats to deck	0,21	generally
Mooring equipment seats	0,21	generally, but increased or full penetration welding may be required
Bulwark stays to deck	0,21	
Bulwark attachment to deck	0,34	
Guard rails, stanchions, etc., to deck	0,34	
Bilge keel ground bars to shell	0,34	Continuous fillet weld, minimum throat thickness 4 mm
Bilge keels to ground bars	0,21	Light continuous fillet weld, minimum throat thickness 3 mm
Fabricated anchors	full penetration	

NOTES
1. Where pillars are fitted inside tanks or under watertight flats, the end connection is to be such that the tensile stress in the weld does not exceed 108 N/mm^2 (11 kgf/mm^2).
2. t_p need not be taken greater than the thickness determined from item 1(a) or 1(b) and Notes, as appropriate, of Table 9.6.1 in Pt 4, Ch 9, but in no case is the weld throat thickness to be less than 0,34 x actual plate thickness.
3. t_p need not be taken greater than the Rule thickness determined from Table 9.7.1 of Pt 4, Ch 9 for stiffener spacing of 760 mm, but in no case is the weld throat thickness to be less than 0,34 x actual plate thickness.
4. In way of bulkhead stools in ballast holds of bulk carriers or in tanks at longitudinal girder/transverse floor intersection, cut-outs are to be omitted and full penetration welding is to be applied to both floor and girder for a distance of 150 mm on either side of intersection.
5. The throat thickness of the weld is to be determined by 2.6.7. For longitudinals within *D*/4 of the strength deck and with a thickness less than 100 mm, the throat thickness need not exceed 5,5 mm.

2.6.11 Where structural members pass through the boundary of a tank, and leakage into the adjacent space could be hazardous or undesirable, full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively a small scallop of suitable shape may be cut in the member close to the boundary outside the compartment, and carefully welded all round.

2.7 Welding of primary structure

2.7.1 Weld factors for the connections of primary structure are given in Table 10.2.3.

2.7.2 The weld connection to shell, deck or bulkhead is to take account of the material lost in the notch where longitudinals or stiffeners pass through the member. Where the width of notch exceeds 15 per cent of the stiffener spacing, the weld factor is to be multiplied by:

$$\frac{0{,}85 \times \text{stiffener spacing}}{\text{length of web plating between notches}}$$

2.7.3 Where direct calculation procedures have been adopted, the weld factors for the 0,2 x overall length at the ends of the members will be considered in relation to the calculated loads.

2.7.4 The throat thickness limits given in Table 10.2.2 are to be complied with.

2.8 Welding of primary and secondary member end connections

2.8.1 Welding of end connections of primary members is to be such that the area of welding is not less than the cross-sectional area of the member, and the weld factor is to be not less than 0,34 in tanks or 0,27 elsewhere.

2.8.2 The welding of secondary member end connections is to be not less than as required by Table 10.2.4. Where two requirements are given the greater is to be complied with.

Table 10.2.2 Throat thickness limits

Item	Throat thickness, in mm Minimum	Throat thickness, in mm Maximum
(1) Double continuous welding	$0{,}21t_p$	$0{,}44t_p$
(2) Intermittent welding	$0{,}27t_p$	$0{,}44t_p$ or 4,5
(3) All welds, overriding minimum:		
(a) Plate thickness $t_p \leq 7{,}5$ mm		
Hand or automatic welding	3,0	—
Automatic deep penetration welding	3,0	—
(b) Plate thickness $t_p > 7{,}5$ mm		
Hand or automatic welding	3,25	—
Automatic deep penetration welding	3,0	—

NOTES
1. In all cases, the limiting value is to be taken as the greatest of the applicable values given above.
2. Where t_p exceeds 25 mm, the limiting values may be calculated using a notional thickness equal to $0{,}4\,(t_p + 25)$ mm.
3. The maximum throat thicknesses shown are intended only as a design limit for the approval of fillet welded joints. Any welding in excess of these limits is to be to the Surveyor's satisfaction.

2.8.3 The area of weld, A_w, is to be applied to each arm of the bracket or lapped connection.

2.8.4 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the area of weld is to be not less than the cross-sectional area of the member.

2.8.5 Where the secondary member passes through, and is supported by, the web of a primary member, the weld connection is to be in accordance with the following:

(a) In strengthening of bottom forward region: Comply with the requirements of Ch 5,1.5.

(b) Elsewhere: Comply with the requirements of 5.2.

2.8.6 The throat thickness limits given in Table 10.2.2 are to be complied with.

2.9 Welding equipment

2.9.1 Welding plant and appliances are to be suitable for the purpose intended and properly maintained taking due cognizance of relevant safety precautions.

2.9.2 Satisfactory storage and handling equipment for consumables are to be provided close to working areas.

2.9.3 The fabricator is to provide suitable means at the welding area to enable accurate measurement of current and voltage.

Table 10.2.3 Connections of primary structure

Primary member face area, in cm^2		Position(1)	Weld factor			
			In tanks		In dry spaces	
Exceeding	Not exceeding		To face plate	To plating	To face plate	To plating
	30,0	At ends	0,21	0,27	0,21	0,21
		Remainder	0,10	0,16	0,10	0,13
30,0	65,0	At ends	0,21	0,34	0,21	0,21
		Remainder	0,13	0,27	0,13	0,16
65,0	95,0	At ends	0,34	0,44(3)	0,21	0,27
		Remainder	0,27(2)	0,34	0,16	0,21
95,0	130,0	At ends	0,34	0,44(3)	0,27	0,34
		Remainder	0,27(2)	0,34	0,21	0,27
130,0		At ends	0,44	0,44(3)	0,34	0,44(3)
		Remainder	0,34	0,34	0,27	0,34

NOTES
1. The weld factors 'at ends' are to be applied for 0,2 x the overall length of the member from each end, but at least beyond the toes of the member end brackets. On vertical webs the increased welding may be omitted at the top, but is to extend at least 0,3 x overall length from the bottom.
2. Weld factor 0,34 in cargo oil tanks.
3. Where the web plate thickness is increased locally, the weld size may be based on the thickness clear of the increase, but is to be not less than 0,34 x the increased thickness.
4. In tankers over 122 m in length, the weld factor of the connection of bottom transverses to shell, and of side transverses to shell and vertical webs to longitudinal and transverse bulkheads all in the lower half depth, is to be not less than 0,34.
5. The final throat thickness of the weld fillet to be not less than $0{,}34t_p$ in cargo oil tanks.

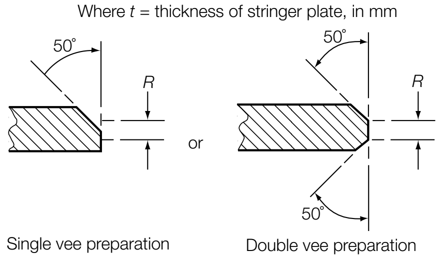
Table 10.2.4 Secondary member end connection welds

Connection	Weld area, A_W, in cm^2	Weld factor
(1) Stiffener welded direct to plating	$0,25A_S$ or 6,5 cm^2 whichever is the greater	0,34
(2) Bracketless connection of stiffeners or stiffener lapped to bracket or bracket lapped to stiffener:		
(a) in dry space	$1,2\sqrt{Z}$	0,27
(b) in tank	$1,4\sqrt{Z}$	0,34
(c) main frame to tank side bracket in 0,15*L* forward	as (a) or (b)	0,34
(3) Bracket welded to face of stiffener and bracket connection to plating	—	0,34
(4) Stiffener to plating for 0,1 x span at ends, or in way of end bracket if that be greater	—	0,34
Symbols		
A_S = cross sectional area of the stiffener, in cm^2 A_W = the area of the weld, in cm^2, and is calculated as total length of weld, in cm, x throat thickness, in cm Z = the section modulus, in cm^2, of the stiffener on which the scantlings of the bracket are based, *see* Section 3		
NOTE For maximum and minimum weld fillet sizes, *see* Table 10.2.2.		

Table 10.2.5 Weld connection of strength deck plating to sheerstrake

Item	Stringer plate thickness, mm	Weld type
1	$t \leq 15$	Double continuous fillet weld with a weld factor of 0,44
2	$15 < t \leq 20$	Single vee preparation to provide included angle of 50° with root $R \leq 1/3\,t$ in conjunction with a continuous fillet weld having a weld factor of 0,39 or Double vee preparation to provide included angles of 50° with root $R \leq 1/3\,t$
3	$t > 20$	Double vee preparation to provide included angles of 50° with root $R \leq 1/3\,t$ but not to exceed 10 mm

Where *t* = thickness of stringer plate, in mm



NOTES
1 Welding procedure, including joint preparation, is to be specified. Procedure is to be qualified and approved for individual Builders.
2. *See also* 2.6.11.
3. For thickness *t* in excess of 20 mm the stringer plate may be bevelled to achieve a reduced thickness at the weld connection. The length of the bevel is in general to be based on a taper not exceeding 1 in 3 and the reduced thickness is in general to be not less than 0,65 times the thickness of stringer plate or 20 mm, whichever is the greater.
4. Alternative connections will be considered.

2.10 Welding consumables and equipment

2.10.1 All welding consumables are to be approved by Lloyd's Register (hereinafter referred to as 'LR') and are to be suitable for the type of joint and grade of material, *see* Chapter 11 of the Rules for Materials (Part 2).

2.10.2 Special care is to be taken in the distribution, storage and handling of all welding consumables. Prior to use they are to be kept in a heated dry storage area with a relatively uniform temperature. Condensation on the metal surface during storage and use is to be avoided. Flux-coated electrodes and submerged arc fluxes are to be stored under controlled conditions. Other welding consumables, such as bare wire and welding studs, are to be stored under dry conditions to prevent rusting. Prior to use, the welding consumables are to be baked as per the manufacturers' recommendations.

2.10.3 Steel welding consumables approved by LR, up to and including Grade Y40, are considered acceptable for marine construction in line with the following:

(a) Consumables are acceptable for welding steels up to three strength levels below that for which the approval applies (e.g. 3Y is acceptable for welding 36, 32 and 27S higher tensile ship steels and normal strength ship steel).
(b) Consumables with an approved impact toughness grading are acceptable for welding steels with lower specified impact properties subject to (a) (e.g. 3Y is acceptable for EH, DH and AH materials).
(c) For joints between steels of different grades or different strength levels, the welding consumables may be of a type suitable for the lesser grade or strength being connected, provided that due consideration is given to the total load carrying requirement of the joint. The use of a higher grade of welding consumable may be required where attachments are made to main structural members of a higher grade or strength.

2.10.4 Where the carbon equivalent, calculated from the ladle analysis and using the formula given below, is in excess of 0,45 per cent, approved low hydrogen welding consumables and preheating are to be used. Where the carbon equivalent is above 0,41 per cent but is not more than 0,45 per cent, approved low hydrogen welding consumables are to be used, but preheating will not generally be required except under conditions of high restraint or low ambient temperature. Where the carbon equivalent is not more than 0,41 per cent, welding consumables that have no hydrogen grading may be used and preheating will not generally be required except as above.

$$\text{Carbon equivalent} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

The type of consumable and preheat proposed for low alloy steels will be subject to special consideration.

2.10.5 All aluminium alloy welding consumables are to be approved by LR. The following consumables and material grades apply:

Consumable alloy grade	Base material alloy grade
RA/WA	5754
RB/WB	5086, 5754
RC/WC	5083,5086,5754
RD/WD	6005A, 6061, 6082

2.11 Welding procedures and welder qualifications

2.11.1 Welding procedures, giving details of the welding process, type of consumables, joint preparation and welding position, are to be established for the welding of all joints.

2.11.2 Welding procedures are to be tested and qualified in accordance with a recognized National or International Standard. For this purpose, the sample joints are to be prepared under conditions similar to those that will occur during construction of the ship.

2.11.3 The proposed welding procedures are to be approved by the Surveyor prior to construction.

2.11.4 Weld repairs, when required, are to be carried out in accordance with the approved procedures.

2.11.5 Welders and welding operators are to be proficient in the type of work on which they are engaged.

2.11.6 The responsibility for selection, training and testing of welding operators rests with the Builders. The Builders are to test welding operators to a suitable National or International Standard. Records of tests and qualifications are to be kept by the Builders and made available to the Surveyors so that they can be satisfied that the personnel employed during the construction of the ship can achieve the required standard of workmanship.

2.12 Workmanship and shipyard practice

2.12.1 A sufficient number of skilled supervisors is to be provided to ensure an effective and systematic control at all stages of welding operations.

2.12.2 Where structural components are to be assembled and welded in works sub-contracted by Builders, the Surveyors are to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter can be achieved.

2.12.3 Structural arrangements are to be such as will allow adequate ventilation and access for preheating, where required, and for the satisfactory completion of all welding operations.

2.12.4 The location of welding connections and sequences of welding are to be arranged to minimize restraint. Welded joints are to be so arranged as to facilitate the use of downhand welding wherever possible.

2.12.5 All welding is to be carried out in accordance with the approved welding procedure, *see* 2.11. The welding arrangements and sequence are to be in accordance with the approved plans and agreed with the Surveyor prior to construction.

2.12.6 Careful consideration is to be given to assembly sequence and overall shrinkage of plate panels, assemblies, etc., resulting from welding processes employed. Welding is to proceed systematically with each welded joint being completed in correct sequence without undue interruption. Where practicable, welding is to commence at the centre of a joint and proceed outwards or at the centre of an assembly and progress outwards towards the perimeter so that each part has freedom to move in one or more directions. Generally, the welding of stiffener members, including transverses, frames, girders, etc., to welded plate panels by automatic processes is to be carried out in such a way as to minimize angular distortion of the stiffener.

2.12.7 The surfaces of all parts to be welded are to be clean, dry and free from rust, scale and grease. Where manual metal arc welding is used, each run of deposit is to be clean and free from slag before the next run is applied. Before a sealing run, or the first run, is applied to the second side of a full penetration butt weld or T-joint, the root is to be back-chipped, ground or air-arc gouged to sound metal. With other multi-run welding processes, back-gouging may not be necessary, before the first run is applied to the second side. When air-arc gouging is used for this operation, special care is to be taken to ensure that the ensuing groove is slag free and has a profile suitable for the completion of welding.

2.12.8 Where prefabrication primers are applied over areas which will be subsequently welded, they are to be of a quality acceptable to LR as having no significant deleterious effect on the finished weld, *see* Ch 2,3.

2.12.9 All joints are to be properly aligned and closed or adjusted before welding. Excessive force is not to be used in fairing and closing the work. Where excessive gaps exist between surfaces or edges to be joined, the corrective measures adopted are to be to the satisfaction of the Surveyor. Provision is to be made for retaining correct adjustment during welding operations. Clamps with wedges or strong-backs used for this purpose are to be suitably arranged to allow freedom of lateral movement between adjacent elements. All such temporary fitting aids are to be made from the same type of material as that of the weld joint, e.g. stainless steel with stainless steel.

2.12.10 Tack welds are to be kept to the minimum and are to be made in accordance with the approved welding procedure. Tack welds that are to be retained as part of the finished weld are to be clean and free from defects. Care is to be taken when removing tack welds used for assembly to ensure that the material of the structure is not damaged.

2.12.11 Generally, tack welds are not to be applied in lengths of less than 30 mm for mild steel grades and aluminium alloys, and 50 mm for higher tensile steel grades.

2.12.12 Special attention is to be given to the examination of plating in way of all lifting eye plate positions to ensure freedom from cracks. This examination is not restricted to the positions where eye plates have been removed but includes the positions where lifting eye plates are permanent fixtures.

2.12.13 Welded temporary attachments used to aid construction are to be removed carefully by grinding, cutting or chipping. The surface of the material is to be finished smooth by grinding followed by crack detection.

2.12.14 Where complete removal of lifting lug attachments is required, it is recommended they be burned off at the top of the fillet weld connections and the remainder chipped and ground smooth. However, alternative methods of removing these attachments will be considered.

2.12.15 Any defects in the structure resulting from the removal of temporary attachments are to be repaired.

2.12.16 When modifications or repairs have been made which result in openings having to be closed by welded inserts, particular care is to be given to the fit of the insert and the welding sequence. The welding is also to be subject to non-destructive examination.

2.12.17 Fairing, by linear or spot heating, to correct distortions due to welding, is to be carried out using approved procedures in order to ensure that the properties of the material are not adversely affected. Visual examination of all heat affected areas and welds in the vicinity is to be carried out to ensure freedom from cracking. The use of spot or line heating to correct distortion is not permitted for aluminium alloys.

2.12.18 All major welding operations that would adversely affect finished machined tolerances are to be complete before the final machining operations on, for example, rudders, sterntubes, propeller brackets and jet units.

2.12.19 Preheating is to be applied in accordance with the approved procedure. When the ambient temperature is below 0°C or where moisture resides on the surfaces to be welded, due care is to be taken to prewarm and dry the joint preparation.

2.12.20 Adequate protection is to be provided where welding is required to be carried out in exposed positions in wet, windy or cold weather.

2.12.21 Special attention is to be paid to preheating when low hydrogen electrodes are used for higher tensile steels on thick materials under high restraint or when applying small weld beads.

2.12.22 Repairs to defective welding are to be carried out using approved welding consumables and procedures. The repair is to be re-examined, *see also* 2.13.19.

2.12.23 Major repairs are not to be carried out without prior approval of the Surveyor.

2.12.24 Repairs to defects found in the base materials during construction are not to be carried out without prior approval of the Surveyor. If repairs are agreed, these are to be carried out in accordance with the requirements of the relevant Section of Part 2, using qualified welding procedures.

2.12.25 When misalignment of structural members either side of bulkheads, decks etc., exceeds the agreed tolerance, the misaligned item is to be released, realigned and rewelded in accordance with an approved weld procedure.

2.12.26 Where welding of aluminium alloy is employed, the following additional requirements are to be complied with, if applicable:

(a) The aluminium alloys are to be welded by the metal inert gas or tungsten inert gas processes. Where it is proposed to use other welding processes, details are to be submitted for approval.

(b) The edges of the material to be welded are to be clean and free from grease by chemical or solvent cleaning. The joint edges are to be scratch-brushed, preferably immediately before welding, in order to remove oxide or adhering films of dirt, fillings, etc.

2.13 Inspection of welds

2.13.1 Effective arrangements are to be provided by the Shipbuilder for the visual inspection of finished welds to ensure that all welding has been satisfactorily completed.

2.13.2 All finished welds are to be sound and free from cracks and lack of fusion and substantially free from incomplete penetration, porosity and slag. The surfaces of welds are to be reasonably smooth and substantially free from undercut and overlap. Care is to be taken to ensure that the specified dimensions of welds have been achieved and that both excessive reinforcement and under-fill of welds are avoided.

2.13.3 Welds are to be clean and free from paint at the time of visual inspection.

2.13.4 Welds may be coated with a thin layer of protective primer prior to inspection provided it does not interfere with inspection and is removed, if required by the Surveyor, for closer interpretation of possible defective areas.

2.13.5 Visual inspection of all welds may be supplemented by other non-destructive examination techniques in cases of unclear interpretation, as considered necessary by the Surveyor.

2.13.6 In addition to visual inspection, welded joints are to be examined using any one or a combination of ultrasonic, radiographic, magnetic particle, eddy current, dye penetrant or other acceptable methods appropriate to the configuration of the weld.

2.13.7 The method to be used for the volumetric examinations of welds is the responsibility of the Shipbuilder. Radiography using x-rays is generally preferred for the examination of butt welds of 10 mm thickness or less. Ultrasonic examination is acceptable for welds of 10 mm thickness or greater and is to be used for the examination of full penetration, tee butt or cruciform welds or joints of similar configuration. Where ultrasonic inspection of welds below 10 mm in thickness is proposed, this will be specially considered by LR NDE.

2.13.8 Non-destructive examinations are to be made in accordance with definitive written procedures prepared in accordance with a nationally or internationally recognised standard and authorised by Level III qualified personnel. As a minimum, procedures are to identify personnel qualification levels required, NDE datum and identification system, the extent of testing, NDE methods to be applied with technique sheets, acceptance criteria to be applied and the reporting requirements. All NDE procedures are to be approved by a surveyor prior to beginning examination.

2.13.9 Non-destructive examinations are to be undertaken by personnel qualified to an appropriate level of a certification scheme recognized by LR, such as those based on the requirements of ISO 9712, EN 473 or SNT-TC-1A. Generally, inspection personnel subject to direct supervision are to be qualified to Level I; where personnel are unsupervised, they are required to be qualified to Level II or Level III as appropriate. Qualification schemes for Level I and II personnel are to include assessment of practical ability where examinations are to be made on representative test pieces containing relevant defects. The results of qualification tests are to be made available upon request.

2.13.10 Checkpoints examined at the pre-fabrication stage are to include ultrasonic testing on examples of the stop/start points of automatic welding and magnetic particle inspections of weld ends.

2.13.11 Checkpoints examined at the construction stage are generally to be selected from those welds intended to be examined as part of the agreed quality control programme to be applied by the Shipbuilder. The locations and numbers of checkpoints are to be agreed between the Shipbuilder and the Surveyor.

2.13.12 Where components of the structure are sub-contracted for fabrication, the same inspection regime is to be applied as if the item had been constructed within the shipyard. In these cases, particular attention is to be given to highly loaded fabrications (such as stabilizer fin boxes) forming an integral part of the hull envelope.

2.13.13 Particular attention is to be paid to highly stressed items. Magnetic particle inspection is to be used at ends of fillet welds, T-joints, joints or crossings in main structural members and at sternframe connections.

2.13.14 Checkpoints for volumetric examination are to be selected so that a representative sample of welding is examined.

2.13.15 Typical locations for volumetric examination and number of checkpoints to be taken are shown in Table 10.2.6. Critical locations as identified by ShipRight FDA Procedure (*see* Chapter 16) will also be considered. A list of the proposed items to be examined is to be submitted for approval.

2.13.16 In addition, the following non-destructive examination is to be carried out on ships to be assigned the class notation 'Chemical tanker':

(a) All crossings of butts and seams of cargo tank bulkhead plating joint welded in assembly areas or on the berth.
(b) Where cargo tank boundary welding is completed in assembly areas or on the berth, a minimum of 10 per cent of the total weld length is to be crack detected.
(c) Where side and bottom longitudinal framing and longitudinal stiffeners terminate at transverse bulkheads, a minimum of 10 per cent of the bulkhead boundary connections is to be crack detected in addition to the requirement given in (b).
(d) Where longitudinal framing and longitudinal bulkhead stiffeners are continuous through transverse bulkheads, 30 per cent each of the bottom and shipside boundaries and 20 per cent of the longitudinal bulkhead boundaries are to be crack detected in addition to the requirement given in (b).
(e) Where transverse framing members are continuous through the cargo tank boundary, a minimum of 10 per cent of boundary connections is to be crack detected.

2.13.17 For the hull structure of refrigerated spaces, and of ships designed to operate in low air temperatures, the extent of non-destructive examination will be specially considered. For non-destructive examination of gas ships *see* the *Rules for Liquefied Gases.*

2.13.18 For all ship types, the Shipbuilder is to carry out random non-destructive examination at the request of the Surveyor.

2.13.19 The full extent of any weld defect is to be ascertained by applying additional non-destructive examinations where required. Unacceptable defects are to be completely removed and where necessary, re-welded. The repair is to be examined after re-welding.

Table 10.2.6 Non-destructive examination of welds

Volumetric non-destructive examinations – Recommended extent of testing, *see* 2.13.15		
Item	Location	Checkpoints, *see* Note 1
Intersections of butts and seams of fabrication and section welds	Throughout: (a) hull envelope, shell envelope and deck structure plating: • at highly stressed areas, *see* Note 3 • remainder (b) longitudinal and transverse bulkheads (c) inner bottom and hopper plating	 all 1 in 2 (*see* Note 4) 1 in 2 1 in 2
SDA/FDA	At critical locations identified by SDA or FDA, see Note 2	all
Butt welds in plating	Throughout	1 m in 25 m (*see* Notes 5 and 6)
Seam welds in plating	Throughout	1 m in 100 m
Butts in longitudinals	Hull envelope within 0,4*L* amidships Hull envelope outside 0,4*L* amidships	1 in 10 welds (*see* Note 7) 1 in 20 welds
Bilge keel butts	Within 0,4*L* amidships Remainder	all 1 in 3
Structural items when made with full penetration welding as follows: • connection of stool and bulkhead to lower stool shelf plating • vertical corrugations to an inner bottom • hopper knuckles • sheerstrake to deck stringer • hatchways coaming to deck	Throughout Hatchway ends within 0,4*L* amidships Hatchway ends outside 0,4*L* amidships Remainder	 1 m in 20 m 1 m in 20 m 1 m in 20 m 1 m in 40 m All 1 in 2 1 in 40 m

NOTES
1. The length of each checkpoint is to be between 0,3 m and 0,5 m.
2. SDA signifies the ShipRight Structural Design Assessment Procedure, FDA signifies the ShipRight Fatigue Design Assessment Procedure.
3. Typically those at sheerstrake, deck stringer, keel strake and turn of bilge.
4. The extent of testing in those areas shown by SDA to be lightly stressed in service may be reduced to 1 in 4 with the agreement of the Surveyor.
5. Checkpoints in butt welds and seam welds are in addition to those at intersections.
6. Welds at inserts used to close openings in hull envelope plating are to be checked by non-destructive examination.
7. Particular attention is to be given to repair rates in longitudinal butts. Additional welds are to be tested if defects such as lack of fusion or incomplete penetration are observed in more than 10 per cent of the welds examined.
8. Agreed locations are not to be indicated on the blocks prior to the welding taking place, nor is special treatment to be given at these locations.

2.13.20 Results of non-destructive examinations made during construction are to be recorded and evaluated by the Shipbuilder on a continual basis in order that the quality of welding can be monitored. These records are to be made available to the Surveyors.

2.13.21 The extent of applied non-destructive examinations is to be increased when warranted by the analysis of previous results.

■ *Section 3* Secondary member end connections

3.1 General

3.1.1 Secondary members, that is longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are generally to be connected at their ends in accordance with the requirements of this Section. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered.

3.1.2 Where end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

3.1.3 Where the section modulus of the secondary member on which the bracket is based (*see* 3.3.2) exceeds 2000 cm^3, the scantlings of the connection will be considered.

3.2 Symbols

3.2.1 The symbols used in this Section are defined as follows:

a, b = the actual lengths of the two arms of the bracket, in mm, measured from the plating to the toe of the bracket

b_f = the breadth of the flange, in mm

t = the thickness of the bracket, in mm

Z = the section modulus of the secondary member, in cm^3.

3.3 Basis for calculation

3.3.1 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the scantlings of the brackets are to be such that their section modulus and effective cross-sectional area are not less than those of the member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member.

3.3.2 In other cases the scantlings of the bracket are to be based on the modulus as follows:

(a) Bracket connecting stiffener to primary member: modulus of the stiffener.

(b) Bracket at the head of a main transverse frame where frame terminates:
modulus of the frame.

(c) Brackets connecting lower deck beams or longitudinals to the main frame in the forward 0,15L:
modulus of the frame.

(d) Elsewhere:
the lesser modulus of the members being connected by the bracket.

3.3.3 Typical arrangements of stiffener end brackets are shown diagrammatically in Fig. 10.3.1.

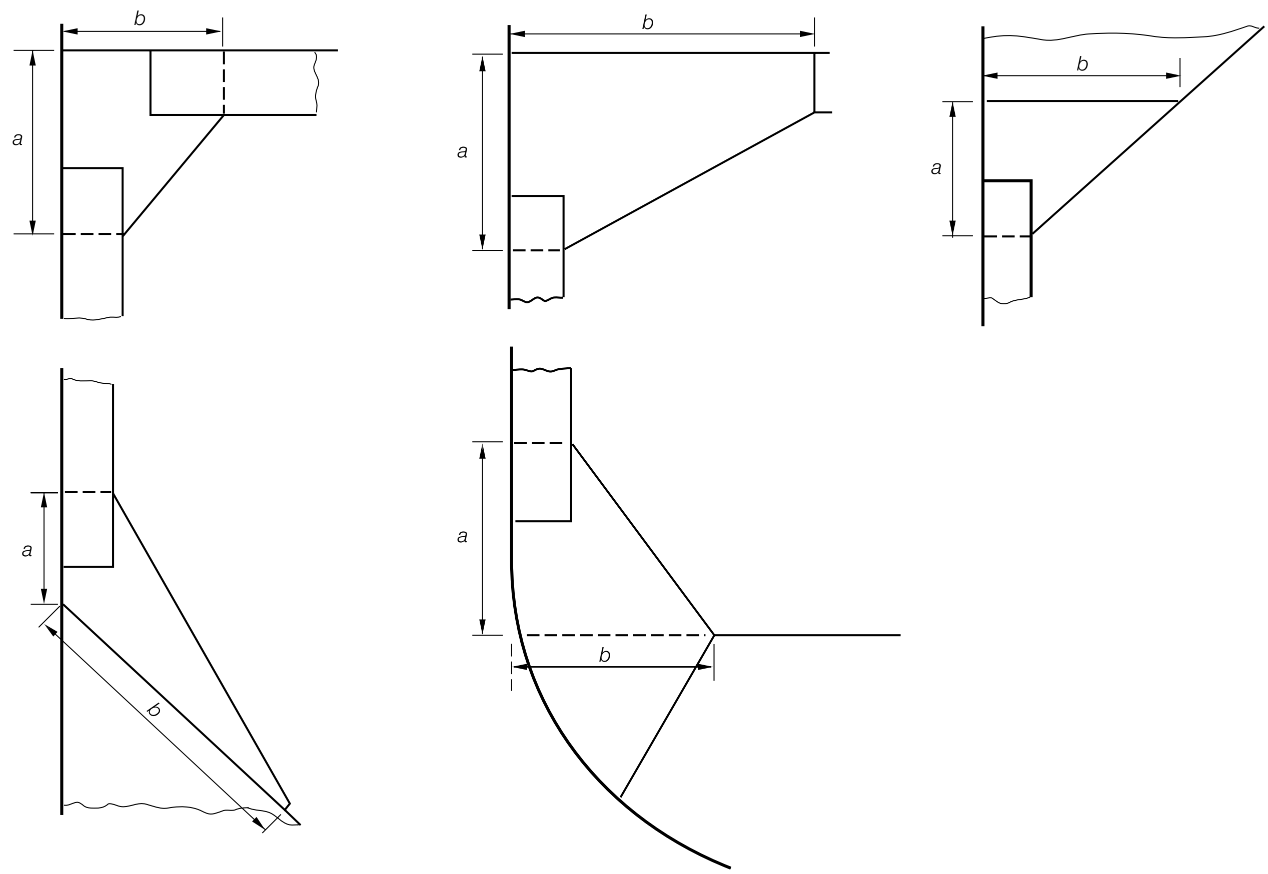


Fig. 10.3.1 Diagrammatic arrangements of stiffener end brackets

3.4 Scantlings of end brackets

3.4.1 The lengths, *a* and *b*, of the arms are to be measured from the plating to the toe of the bracket and are to be such that:

(a) $a + b \geq 2{,}0l$

(b) $a \geq 0{,}8l$

(c) $b \geq 0{,}8l$

where

$$l = 90\left(2\sqrt{\frac{Z}{14 + \sqrt{Z}}} - 1\right) \text{ mm}$$

but in no case is l to be taken as less than twice the web depth of the stiffener on which the bracket scantlings are to be based.

The scantlings of main frames are normally to be based on these standard brackets at top and bottom, while the scantlings of 'tween deck frames are normally to be based on a standard bracket at the top only. Where the actual arm lengths fitted, a_1 and b_1 (in mm) are smaller than Rule size, or bracket is omitted, an equivalent arm length, l_a, for the calculation of end connection factor, *see* Table 1.6.2 in Pt 4, Ch 1, is to be derived from:

(d) $l_a = \dfrac{(a_1 + b_1)}{2}$

(e) $a_1 \geq 0{,}8l_a$

(f) $b_1 \geq 0{,}8l_a$

(g) $l_a = 0$, where:

- (i) bracket is omitted from the upper or lower ends of the frame, or
- (ii) lower frame bracket at bilge is at same level as the inner bottom, or
- (iii) lower frame is welded directly to the inner bottom.

3.4.2 The length of arm of tank side and hopper side brackets is to be not less than 20 per cent greater than that required above.

3.4.3 The thickness of the bracket is to be not less than as required by Table 10.3.1.

3.4.4 The free edge of the bracket is to be stiffened where any of the following apply:

(a) The section modulus, *Z*, exceeds 2000 cm^3.

(b) The length of free edge exceeds 50*t* mm.

(c) The bracket is fitted at the lower end of main transverse side framing.

3.4.5 Where a flange is fitted, its breadth is to be not less than:

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

but not less than 50 mm

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

(a) $0{,}009 b_f t$ cm^2 for offset edge stiffening.

(b) $0{,}014 b_f t$ cm^2 for symmetrically placed stiffening.

3.4.7 Where the stiffening member is lapped on to the bracket, the length of overlap is to be adequate to provide for the required area of welding. In general, the length of overlap should be not less than $10\sqrt{Z}$ mm, or the depth of stiffener, whichever is the greater.

3.4.8 Where the free edge of the bracket is hollowed out, it is to be stiffened or increased in size to ensure that the modulus of the bracket through the throat is not less than that of the required straight edged bracket.

3.5 Arrangements and details

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

3.5.2 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.

Table 10.3.1 Thickness of brackets

Bracket	Thickness, in mm	Limits	
		Minimum	Maximum
With edge stiffened:			
(a) in dry spaces	$3{,}5 + 0{,}25\sqrt{Z}$	6,5	12,5
(b) in tanks	$4{,}5 + 0{,}25\sqrt{Z}$	7,5 (*see* Note)	13,5
Unstiffened brackets:			
(a) in dry spaces	$5{,}5 + \frac{Z}{55} - \left(\frac{Z}{168}\right)^{1{,}3}$	7,5	—
(b) in tanks	$6{,}5 + \frac{Z}{55} - \left(\frac{Z}{168}\right)^{1{,}3}$	8,5 (*see* Note)	—

NOTE
In the cargo tank region of tankers, the minimum thickness is to be not less than the compartment minimum thickness, *see* Pt 4, Ch 9,10.

3.5.3 For arrangements where end brackets are not perpendicular to the adjacent plating the strength of the brackets, in term of lateral stability, may need to be specially considered.

Section 4 Construction details for primary members

4.1 General

4.1.1 The requirements for section modulus and inertia (if applicable) of primary members are given in the appropriate Chapter. This Section includes the requirements for proportions, stiffening and construction details for primary members in dry spaces and in tanks of all ship types other than tankers.

4.1.2 The requirements for construction details for the primary structure of tankers are given in Pt 4, Ch 9,10.

4.1.3 The requirements of this Section may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

4.2 Symbols

4.2.1 The symbols used in this Section are defined as follows:

d_w = depth of member web, in mm
k_L, k = higher tensile steel factor, *see* Ch 2,1.2
t_w = thickness of member web, in mm
A_f = area of member face plate or flange, in cm^2
F_D = local scantlings reduction factor as defined in Pt 3, Ch 4,5.6
S_w = spacing of stiffeners on member web, or depth of unstiffened web, in mm.

4.3 Arrangements

4.3.1 Primary members are to be so arranged as to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring system.

4.3.2 The members are to have adequate lateral stability and web stiffening and the structure is to be arranged to minimize hard spots and other sources of stress concentration. Openings are to have well rounded corners and smooth edges and are to be located having regard to the stress distribution and buckling strength of the panel.

4.3.3 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

4.3.4 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended for at least two frame spaces, or equivalent, beyond the point of support before being tapered.

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

4.4 Geometric properties and proportions

4.4.1 The geometric properties of the members are to be calculated in association with an effective width of attached plating determined in accordance with Ch 3,3.2.

4.4.2 The minimum thickness or area of material in each component part of the primary member is given in Table 10.4.1.

Table 10.4.1 Minimum thickness of primary members

Item	Requirement
(1) Member web plate (*see* Note)	$t_w = 0{,}01 S_w$ but not less than 7 mm in dry spaces and not less than 8 mm in tanks
(2) Member face plate	A_f not to exceed $\dfrac{d_w\, t_w}{150}$ cm^2
(3) Deck plating forming the upper flange of underdeck girders	Plate thickness not less than $\sqrt{\dfrac{A_f}{1{,}8k}}$ mm, and 10 per cent greater for hatch side girders Width of plate not less than 700 mm
(4) Primary members in cargo oil tanks in tankers	As required by Pt 4, Ch 9,10

NOTE
For primary members having a web depth exceeding 1500 mm, the arrangement of stiffeners will be individually considered, and stiffening parallel to the member face plate may be required.

4.4.3 Primary members constructed of higher tensile steel are to comply with Table 10.4.1.

4.5 Web stability

4.5.1 Primary members of asymmetrical section are to be supported by tripping brackets at alternate secondary members. If the section is symmetrical, the tripping brackets may be four spaces apart.

4.5.2 Tripping brackets are also to be fitted at the toes of end brackets and in way of heavy or concentrated loads such as the heels of pillars.

4.5.3 Where the ratio of unsupported width of face plate (or flange) to its thickness exceeds 16:1, the tripping brackets are to be connected to the face plate and on members of symmetrical section, the brackets are to be fitted on both sides of the web.

4.5.4 Intermediate secondary members may be welded directly to the web or connected by lugs.

4.5.5 Where the depth of web of a longitudinal girder at the strength deck within 0,4L amidships exceeds:

(a) $55t_w$ for mild steel members

(b) $55t_w \sqrt{\frac{k_L}{F_D}}$ for higher tensile steel members

additional longitudinal web stiffeners are to be fitted at a spacing not exceeding the value given in (a) or (b) as appropriate, with a maximum of $65t_w \sqrt{k_L}$ for higher tensile steel members. In cases where this spacing is exceeded, the web thickness is, in general, to be suitably increased.

4.5.6 The arm length of unstiffened end brackets is not to exceed $100t_w$. Stiffeners parallel to the bracket face plate are to be fitted where necessary to ensure that this limit is not exceeded.

4.5.7 Web stiffeners may be flat bars of thickness t_w and depth $0,1d_w$, or 50 mm, whichever is the greater. Alternative sections of equivalent moment of inertia may be adopted.

4.6 Openings in the web

4.6.1 Where openings are cut in the web, the depth of opening is not to exceed 25 per cent of the web depth, and the opening is to be so located that the edges are not less than 40 per cent of the web depth from the face plate. The length of opening is not to exceed the web depth or 60 per cent of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be considered.

4.6.2 Openings are to have smooth edges and well rounded corners.

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

4.7 End connections

4.7.1 End connections of primary members are generally to comply with the requirements of Section 3, taking Z as the section modulus of the primary member.

4.7.2 The thickness of the bracket is to be not less than that of the primary member web. The free edge of the bracket is to be stiffened.

4.7.3 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

4.7.4 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support. Proposals to fit brackets of reduced scantlings, or alternative arrangements, will be considered.

4.7.5 Connections between primary members forming a ring system are to minimize stress concentrations at the junctions. Integral brackets are generally to be radiused or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

■ *Section 5* Structural details

5.1 Continuity and alignment

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

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

5.1.3 Pillars and pillar bulkheads are to be fitted in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

5.1.4 Continuity is to be maintained where primary members intersect and where the members are of the same depth, a suitable gusset plate is to be fitted.

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

5.1.6 The toes of brackets, etc., should not land on unstiffened panels of plating. Special care should be taken to avoid notch effects at the toes of brackets, by making the toe concave or otherwise tapering it off.

5.1.7 Where primary and/or secondary members are constructed of higher tensile steel, particular attention is to be paid to the design of the end bracket toes in order to minimize stress concentrations. Sniped face plates which are welded onto the edge of primary member brackets are to be carried well around the radiused bracket toe and are to incorporate a taper not exceeding 1 in 3. Where sniped face plates are welded adjacent to the edge of primary member brackets, adequate cross sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area measured perpendicular to the face plate, is to be not less than 60 per cent of the full cross-sectional area of the face plate, *see* Fig. 10.5.1. *See also* Pt 4, Ch 1,4.3, Pt 4, Ch 1,6.1, Pt 4, Ch 9,5.7 and Pt 4, Ch 9,10.13.

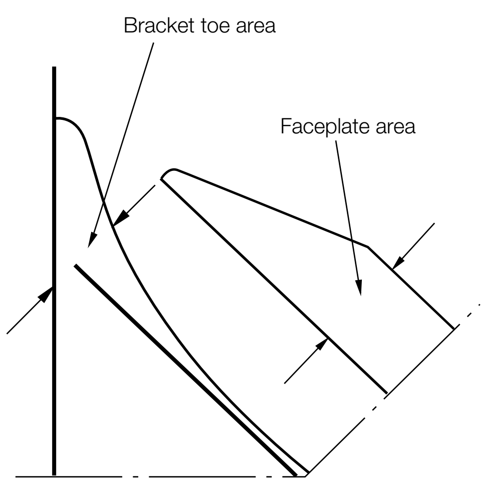


Fig. 10.5.1 Bracket toe construction

5.2 Arrangements at intersections of continuous secondary and primary members

5.2.1 Cut-outs for the passage of secondary members through the web of primary members, and the related collaring arrangements, are to be designed to minimize stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating. The critical shear buckling stress of the panel in which the cut-out is made is to be investigated. Cut-outs for longitudinals will be required to have double lugs in areas of high stress, e.g. in way of cross tie ends and floors under bulkhead stools in ore and ballast holds.

5.2.2 Cut-outs are to have smooth edges, and the corner radii are to be as large as practicable, with a minimum of 20 per cent of the breadth of the cut-out or 25 mm, whichever is the greater. It is recommended that the web plate connection to the hull envelope or bulkhead should end in a smooth tapered ‘soft toe’. Recommended shapes of cut-out are shown in Fig. 10.5.3, but consideration will be given to other shapes on the basis of maintaining equivalent strength and minimizing stress concentration. Consideration is to be given to the provision of adequate drainage and unimpeded flow of air and water when designing the cut-outs and connection details.

5.2.3 Asymmetrical secondary members are to be connected on the heel side to the primary member web plate. Additional connection by lugs on the opposite side may be required.

5.2.4 Symmetrical secondary members are to be connected by lugs on one or both sides, as necessary.

5.2.5 The cross-sectional areas of the connections are to be determined from the proportion of load transmitted through each component in association with its appropriate permissible stress.

5.2.6 The total load, P, transmitted to the primary member is to be derived in accordance with Table 10.5.1.

5.2.7 This load is to be apportioned between the connections as follows:

(a) Transmitted through the collar arrangement:

$$P_1 = P\left(\frac{s_1}{S_w} + \frac{A_1}{4C_f A_f + A_1}\right)$$

where A_1 is derived in accordance with 5.2.8 and $\frac{s_1}{S_w}$ is not to be taken as greater than 0,25

The collar load factor, C_f, is to be derived as follows:

Symmetrical secondary members

$C_f = 1,85$ for $A_f \le 18$

$C_f = 1,85 - 0,0341\,(A_f - 18)$ for $18 < A_f \le 40$

$C_f = 1,1 - 0,01\,(A_f - 40)$ for $A_f > 40$

Asymmetrical secondary members

$$C_f = 0,68 + 0,0224\,\frac{b_l}{A_f}$$

where

A_f = the area, in cm^2, of the primary member web stiffener in way of the connection including backing bracket, where fitted, *see* 5.2.10

b_l = the length of lug or direct connection, in mm, as shown in Fig. 10.5.3. Where the lug or direct connections differ in length, a mean value of b_l is to be used.

(b) Transmitted through the primary member web stiffener:

$P_2 = P - P_1$ kN (tonne-f)

(c) Where the web stiffener is not connected to the secondary member, P_1 is to be taken equal to P.

Table 10.5.1 Total load transmitted to connection of secondary members *(see continuation)*

Ship type	Head, h_1, in metres	Total load, P, transmitted to connection
(1) Oil tankers, bulk chemical tankers and combination carriers (*see* 1.1.3)	h_1 = load height, in metres, derived in accordance with the following provisions, but to be taken as not less than $\frac{L_1}{56}$ or $(0{,}01L_1 + 0{,}7)$ m whichever is the greater For shell framing members: (a) With mid-point of span at base line, $h_1 = 0{,}8D_2$ (b) With mid-point of span at a distance $0{,}6D_2$ above base line, $h_1 = f\,D_2\,B_f$ (c) With mid-point of span intermediate between (a) and (b). The value of h_1 is to be obtained by linear interpolation between values from (a) and (b). (d) With mid-point of span higher than $0{,}6D_2$ above base line. The value of h_1 is to be obtained by linear interpolation between the values from (b) and the values at the following points: (i) For framing members located at and abaft $0{,}2L$ from the forward perpendicular (*see* Fig. 10.5.2(a)) — Zero value at the level of the deck edge amidships (ii) For framing members forward of cargo tank region (*see* Fig. 10.5.2(b)) — Value of $f\,D_2\,(B_f - 1)$ at the level 3 m above the minimum bow height determined from the Load Lines Conventions (iii) Intermediate values between locations (i) and (ii) are to be determined by linear interpolation For secondary stiffening members of transverse and longitudinal bulkheads, and inner hull and inner bottom of double hull tankers (*see* 1.1.3): h_1 = distance from mid-point of span to top of tank but need not exceed $0{,}8D_2$	(a) In general $P = 10{,}06\,(S_w - s_1/2)\,s_1\,h_1$ kN ($P = 1{,}025\,(S_w - s_1/2)\,s_1\,h_1$ tonne-f) (b) For wash bulkheads $P = 11{,}77\,(S_w - s_1/2)\,s_1\,h_1$ kN ($P = 1{,}2\,(S_w - s_1/2)\,s_1\,h_1$ tonne-f)
(2) Other ship types for which oil tanker (*see* 1.1.3) requirements are not applicable	Side and bottom shell longitudinals As for (1) except as follows: (a) h_1 to be derived in accordance with (1) above but to be taken as not less than $\frac{L_1}{56}$ m for type 'B – 60' and the greater of $\frac{L_1}{70}$, or 1,20 m for Type 'B' ships (b) h_1 for item (1)(d)(ii) above to extend forward of $0{,}15L$ from the forward perpendicular	$P = 10{,}06\,(S_w - s_1/2)\,s_1\,h_1$ kN ($P = 1{,}025\,(S_w - s_1/2)\,s_1\,h_1$ tonne-f)

Table 10.5.1 Total load transmitted to connection of secondary members *(conclusion)*

Ship type	Head, h_1, in metres	Total load, P, transmitted to connection
(3) Other ship types for which oil tanker (*see* 1.1.3) requirements are not applicable (continued)	Internal tank boundaries (a) Topside tank longitudinals h_1 = distance from the longitudinal under consideration to the highest point of the tank with the ship inclined 30° either way, or = the greater of the distance from the longitudinal under consideration to the top of the tank, or half the distance to the top of the overflow, or = 1,5 m whichever is the greatest	$P = 10{,}06\ (S_w - s_1/2)\ s_1\ h_1$ kN ($P = 1{,}025\ (S_w - s_1/2)\ s_1\ h_1$ tonne-f)
	(b) Inner bottom and hopper longitudinals (i) For cargo ships and bulk carriers (*see* 1.1.3) without the notation 'strengthened for heavy cargoes' $h_1 = 1{,}39T$ (ii) For cargo ships and bulk carriers (*see* 1.1.3) with the notation 'strengthened for heavy cargoes' $h_1 = H$	$P = 9{,}81\ (S_w - s_1/2)\ s_1\ h_1/C$ kN $P = (S_w - s_1/2)\ s_1\ h_1/C$ tonne-f but not to be taken less than the load derived from (b)(iii), (b)(iv), (b)(v) or (c) where applicable
	(iii) For bulk carriers (*see* 1.1.3) where the topside wing tank is interconnected with hopper side and double bottom tanks h_1 = the distance from the longitudinal under consideration to the top of the topside tank with the ship inclined 25° either way	$P = 10{,}06\ (S_w - s_1/2)\ s_1\ h_1$ kN ($P = 1{,}025\ (S_w - s_1/2)\ s_1\ h_1$ tonne-f)
	(iv) For bulk carriers (*see* 1.1.3) in way of ballast hold h_1 = the distance from the longitudinal under consideration to the top of the hatchway coaming	$P = 10{,}06\ (S_w - s_1/2)\ s_1\ h_1$ kN ($P = 1{,}025\ (S_w - s_1/2)\ s_1\ h_1$ tonne-f)
	(v) For cargo ships and bulk carriers (*see* 1.1.3) with double hull where tank at side interconnected with double bottom $h_1 = H$	$P = 10{,}06\ (S_w - s_1/2)\ s_1\ h_1$ kN ($P = 1{,}025\ (S_w - s_1/2)\ s_1\ h_1$ tonne-f)
	(c) Longitudinals of inner hull of double hull cargo ships and bulk carriers (*see* 1.1.3) h_1 = the distance from the longitudinal under consideration to the top of the tank, or half the distance to the top of the overflow, whichever is the greater	$P = 10{,}06\ (S_w - s_1/2)\ s_1\ h_1$ kN ($P = 1{,}025\ (S_w - s_1/2)\ s_1\ h_1$ tonne-f)

B_f = bow fullness factor determined from Ch 5, Fig. 5.4.3 to be considered. To be taken as 1 for framing members located at and abaft 0,2L from the forward perpendicular
f = load height factor at level 0,6D above base line, *see* Table 10.5.2
h_1 = load height, in metres, *see also* Fig. 10.5.2
C = stowage rate, in m^3/tonne, as defined in Ch 3,5.2. For cargo ships without the notation 'strengthened for heavy cargoes', the value to be used is 1,39 m^3/tonne. For cargo ships and bulk carriers (*see* 1.1.3) 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 = height from inner bottom at position under consideration, to deck at side amidships, in metres, for inner bottom longitudinals
= height from the longitudinal under consideration to the underside of the topside tank sloped bulkhead, in metres, for hopper longitudinals
S_w = spacing of primary members, in metres
s_1 = spacing of secondary members, in metres
T = the summer draught, in metres, measured from top of keel
D_2 = D in metres, but need not be taken greater than 1,6T
L_1 = L but need not be taken as greater than 190 m

Table 10.5.2 Load height factor, *f*

	Ship depth, *D* metres					
	≤17,5	20	22,5	25	27,5	30
(1) (a) For oil tankers, bulk chemical tankers and combination carriers (*see* 1.1.3), tank boundaries wholly within parallel mid-body (b) For other ship types, at and abaft 0,2*L* from the forward perpendicular	0,6	0,6	0,582	0,556	0,535	0,517
(2) (a) For oil tankers, bulk chemical tankers and combination carriers (*see* 1.1.3), tank boundaries wholly or partially outside parallel mid-body (b) For other ship types, forward of 0,15*L* from the forward perpendicular	0,7	0,685	0,685	0,628	0,6	0,577

NOTE
Intermediate values to be obtained by linear interpolation.

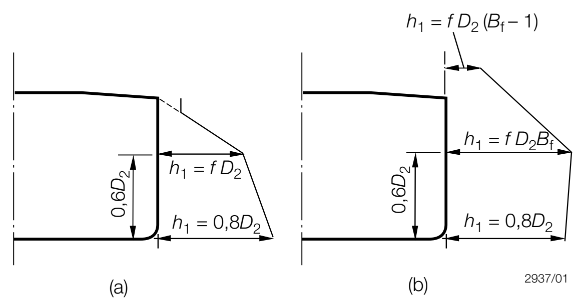


Fig. 10.5.2
Load height diagrams for framing members (a) at and abaft 0,2*L* from the forward perpendicular and (b) forward of cargo tank region for oil tankers, bulk chemical tankers and combination carriers (*see* 1.1.3) and forward of 0,15*L* from the forward perpendicular for other ship types

5.2.8 The effective cross-sectional area A_1 of the collar arrangements is to be taken as the sum of cross-sectional areas of the components of the connection as follows:

(a) Direct connection:

$A_1 = 0,01 b_1 t_w$ cm^2

(b) Lug connection:

$A_1 = 0,01 f_1 b_1 t_1$ cm^2

where

f_1 = 1,0 for symmetrical secondary member connections

$\frac{140}{W_1}$ but not greater than 1,0, for asymmetrical secondary member connections

t_w = thickness of primary member web, in mm

t_2 = thickness, in mm, of lug connection, and is to be taken not greater than the thickness of the adjacent primary member web plate

W = overall width of the cut-out, in mm

W_2 = width for cut-out asymmetrical to secondary member web, in mm

(*see* Fig. 10.5.3)

5.2.9 The values of A_f and A_1 are to be such that the stresses given in Table 10.5.3 are not exceeded.

5.2.10 Where a bracket is fitted to the primary member web plate in addition to a connected stiffener it is to be arranged on the opposite side to, and in alignment with the stiffener. The arm length of the bracket is to be not less than the depth of the stiffener, and its cross-sectional area through the throat of the bracket is to be included in the calculation of A_f.

5.2.11 In general where the primary member stiffener is connected to the secondary member it is to be aligned with the web of the secondary member, except where the face plate of the latter is offset and abutted to the web, in which case the stiffener connection is to be lapped. Lapped connections of primary member stiffeners to mild steel bulb plate or rolled angle secondary members may also be permitted. Where such lapped connections are fitted, particular care is to be taken to ensure that the primary member stiffener wrap around weld connection is free from undercut and notches, *see also* 2.13.

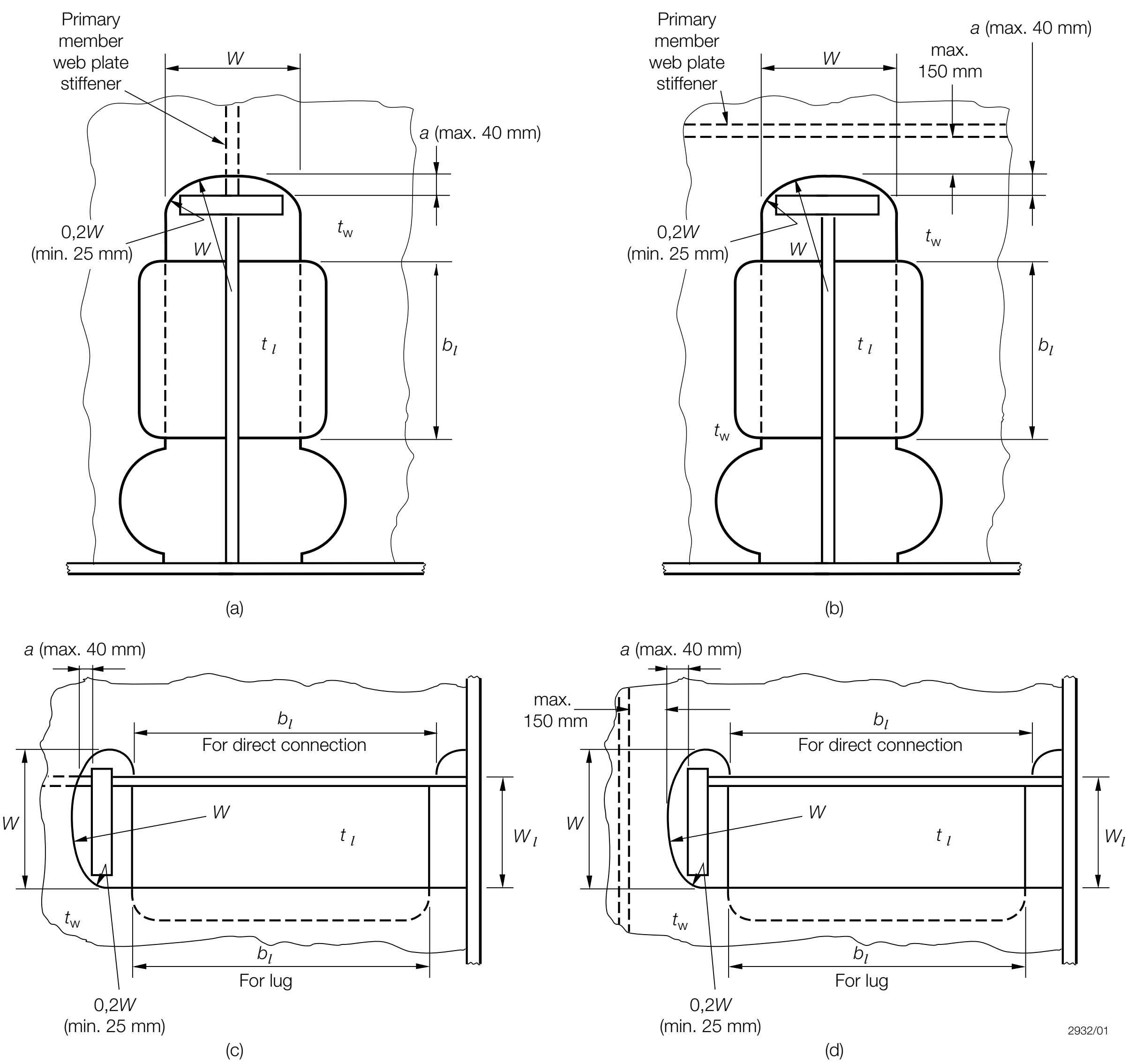


Fig. 10.5.3 Cut-outs and connections

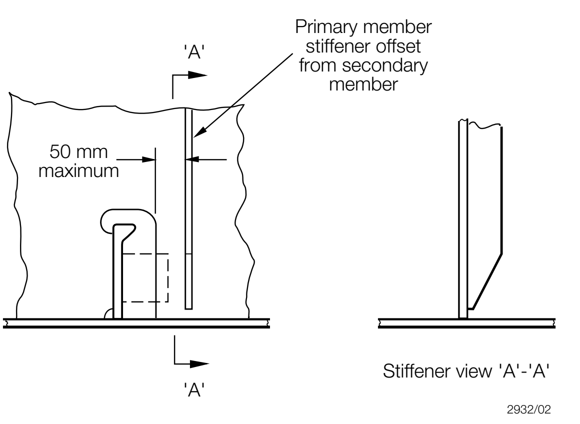


Fig. 10.5.4
Arrangement with offset stiffener

5.2.12 Fabricated longitudinals having the face plate welded to the underside of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where it is proposed to fit such sections, a symmetrical arrangement of connection to transverse members is to be incorporated. This can be achieved by fitting backing brackets on the opposite side of the transverse web or bulkhead. The primary member stiffener and backing brackets are to be lapped to the longitudinal web, *see* 5.2.11.

Table 10.5.3 Permissible stresses

Item		Direct stress, in N/mm^2 (kgf/mm^2) (*see* Notes 1 and 2)		Shear stress, in N/mm^2 (kgf/mm^2) (*see* Note 1)	
		Oil tankers	Other ship types for which oil tanker requirements are not applicable	Oil tankers and ship types where primary member stiffener unconnected	Other ship types for which oil tanker requirements are not applicable
Primary member web plate stiffener within distance *a* of end, *see* Fig. 10.5.3		147,2 (15,0)	157 (16,0)	—	—
Welding of primary member web plate stiffener to secondary member	Butted	98,1 (10,0) (double continuous fillet)	117,7 (12,0) (double continuous fillet)	—	—
		147,2 (15,0) (automatic deep penetration)	157 (16,0) (automatic deep penetration)	—	—
	Lapped	—	—	83,4 (8,5) (*See* Note 2)	98,1 (10,0) (*See* Note 2)
Lug or collar plate and weld	Single	—	—	68,6 (7,0)	98,1 (10,0)
	Double	—	—	83,4 (8,5)	

NOTES
1. The welding requirements of Section 2 and, where applicable 5.2.13 are also to be complied with (*see* 1.1.3).
2. Where longitudinals are of higher tensile steel having a yield stress of 32 kg/mm^2 or more, these stresses are to be divided by the factor 1,2 for application to side longitudinals above 0,3D_2 from the base-line. For definition of D_2 *see* Table 10.5.1.

5.2.13 For ship types for which oil tanker (*see* 1.1.3) requirements are not applicable, the collar arrangement is to satisfy the requirements of 5.2.1 to 5.2.12 inclusive. In addition the weld area of the connections is to be not less than the following:

(a) Connection of primary member stiffener to the secondary member:

A_w = 0,25A_f or 6,5 cm^2, whichever is the greater, corresponding to a weld factor of 0,34 for the throat thickness

(b) Connection of secondary member to the web of the primary member:

A_w = 0,5 $\sqrt{Z}$ corresponding to a weld factor of 0,34 in tanks or 0,27 in dry spaces for the throat thickness

where

A_w = weld area, in cm^2, and is calculated as total length of weld, in cm, multiplied by throat thickness, in cm

A_f = cross-sectional area of the primary member web stiffener, in cm^2, in way of connection

Z = the section modulus, in cm^3, of the secondary member.

5.2.14 Where the stiffeners of the double bottom floors, and the hopper primary members are unconnected to the secondary members and offset from them (*see* Fig. 10.5.4) the collar arrangement is to satisfy the requirements of 5.2.1 to 5.2.13 inclusive. In addition, the fillet welds attaching the lugs to the secondary members are to be based on a weld factor of 0,44 for the throat thickness. To facilitate access for welding the offset, stiffeners are to be located 50 mm from the slot edge furthest from the web of the secondary member. The ends of the offset stiffeners are to be suitably tapered and softened.

5.2.15 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

5.3 Openings

5.3.1 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or double plate bulkheads within one-third of their length from either end, nor in floors or double bottom girders close to their span ends, or below the heels of pillars, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

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

5.3.3 Air and drain holes, notches and scallops are to be kept at least 200 mm clear of the toes of end brackets and other areas of high stress. Openings are to be well rounded with smooth edges. Details of scalloped construction are shown in Fig. 10.2.1. Closely spaced scallops are not permitted in higher tensile steel members. Widely spaced air or drain holes may be accepted, provided that they are of elliptical shape, or equivalent, to minimize stress concentration and are, in general, cut clear of the weld connection.

5.4 Sheerstrake and bulwarks

5.4.1 Where an angled gunwale is fitted, the top edge of the sheerstrake is to be kept free of all notches and isolated welded fittings. Bulwarks are not to be welded to the top of the sheerstrake within the 0,5*L* amidships.

5.4.2 Where a rounded gunwale is adopted, the welding of fairlead stools and other fittings to this plate is to be kept to the minimum, and the design of the fittings is to be such as to minimize stress concentration.

5.4.3 Arrangements are to ensure a smooth transition from rounded gunwale to angled gunwale towards the ends of the ship.

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

5.5 Fittings and attachments, general

5.5.1 The quality of welding and general workmanship of fittings and attachments as given in 5.6 and 5.7 are to be equivalent to that of the main hull structure. Visual examination of all welds is to be supplemented by non-destructive testing as considered necessary by the Surveyor.

5.6 Bilge keels and ground bars

5.6.1 It is recommended that bilge keels should not be fitted in the forward 0,3*L* region on ships intended to navigate in severe ice conditions.

5.6.2 Bilge keels are to be attached to a continuous ground bar as shown in Fig. 10.5.5. Butt welds in shell plating, ground bar and bilge keels are to be staggered.

5.6.3 The minimum thickness of the ground bar is to be equal to the thickness of the bilge strake or 14 mm, whichever is the lesser.

5.6.4 The material class, grade and quality of the ground bar are to be in accordance with Table 2.2.1, Note 11 in Chapter 2.

5.6.5 The ground bar is to be connected to the shell with a continuous fillet weld and the bilge keel to the ground bar with a light continuous fillet weld.

5.6.6 Direct connection between ground bar butt welds and shell plating, and between bilge keel butt welds and ground bar is to be avoided.

5.6.7 The design of single web bilge keels is to ensure that failure to the web occurs before failure of the ground bar. In general, this may be achieved by ensuring the web thickness of bilge keels does not exceed that of the ground bar.

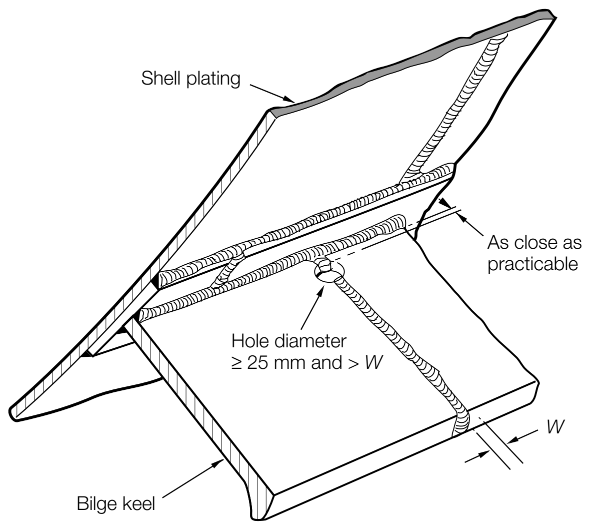


Fig. 10.5.5 Bilge keel construction

5.6.8 The end details of bilge keels and intermittent bilge keels, where adopted, are to be as shown in Fig. 10.5.6.

5.6.9 The ground bar and bilge keel ends are to be tapered or rounded. Where the ends are tapered, the tapers are to be gradual with ratios of at least 3:1, *see* Figs. 10.5.6(a) and (b). Where the ends are rounded, details are to be as shown in Fig. 10.5.6(c). Cut-outs on the bilge keel web within zone 'A' (see Fig. 10.5.6(b)) are not permitted.

5.6.10 The end of the bilge keel web is to be between 50 mm and 100 mm from the end of the ground bar, *see* Fig. 10.5.6(a).

5.6.11 An internal transverse support is to be positioned as close as possible to halfway between the end of the bilge keel web and the end of the ground bar, *see* Fig. 10.5.6(b).

5.6.12 Where an internal longitudinal stiffener is fitted in line with the bilge keel web, the longitudinal stiffener is to extend to at least the nearest transverse member outside zone 'A', *see* Fig. 10.5.6(b). In this case, the requirement of 5.6.10 does not apply.

5.6.13 For ships over 65 m in length, holes are to be drilled in the bilge keel butt welds. The size and position of these holes are to be as illustrated in Fig. 10.5.5. Where the butt weld has been subject to non-destructive examination the stop hole may be omitted.

5.6.14 Bilge keels of a different design from that shown in Fig.10.5.5 and Fig. 10.5.6 will be specially considered.

5.6.15 Within zone 'B' (*see* Fig. 10.5.6(a)) welds at the end of the ground bar and bilge plating, and at the end of the bilge keel web and ground bar, are to have weld factors of 0,44 and 0,34 respectively. These welds are to be ground and to blend smoothly with the base materials.

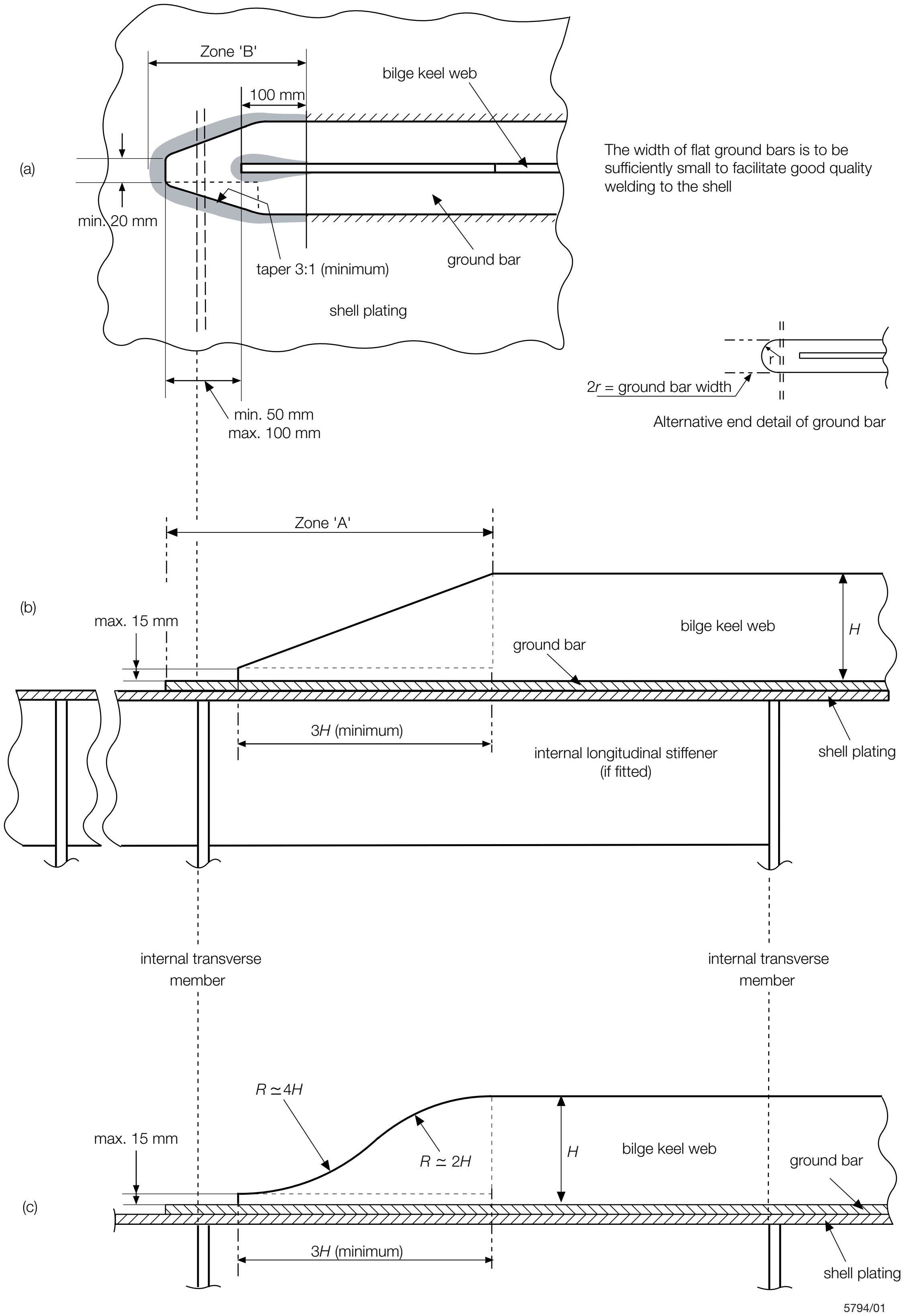


Fig. 10.5.6 Bilge keel end design

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

5.7 Other fittings and attachments

5.7.1 Gutterway bars at the upper deck are to be so arranged that the effect of main hull stresses on them is minimized.

5.7.2 Minor attachments, such as pipe clips, staging lugs and supports, are generally to be kept clear of toes of end brackets, corners of openings and similar areas of high stress. Where connected to asymmetrical stiffeners, the attachments may be in line with the web providing the fillet weld leg length is clear of the offset face plate or flange edge. Where this cannot be achieved the attachments are to be connected to the web, and in the case of flanged stiffeners they are to be kept at least 25 mm clear of the flange edge. On symmetrical stiffeners, they may be connected to the web or to the centreline of the face plate in line with the web.

5.7.3 Where necessary in the construction of the ship, lifting lugs may be welded to the hull plating but they are not to be slotted through. Where they are subsequently removed, this is to be done by flame or mechanical cutting close to the plate surface, and the remaining material and welding ground off. After removal the area is to be carefully examined to ensure freedom from cracks or other defects in the plate surface.

■ *Section 6*
Access arrangements for oil tankers and bulk carriers

6.1 Application

6.1.1 Access arrangements are to be provided as required by SOLAS.

6.2 Information for approval

6.2.1 Details of the attachment of the access arrangements to the ship's structure are to be submitted for approval and suitable designs are to take into account proper location, strength, detail and reinforcement of all attachments to hull structural members.

Closing Arrangements for Shell, Deck and Bulkheads

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all ship types detailed in Part 4 with the exception of Sections 1 to 5 which are not applicable to Bulk Carriers with a **CSR** notation (*see* Pt 1, Ch 2,2.3). Additional provisions regarding access arrangements for oil tankers and chemical carriers are contained in Pt 4, Ch 9, Ch 10 and the *Rules for Liquid Chemicals in Bulk*, respectively.

1.1.2 Requirements are given for steel and wooden hatch covers, securing arrangements, tarpaulins, coamings and side shell doors for main openings, also closing arrangements for other miscellaneous openings.

1.1.3 Where relevant, the contents of this Chapter conform with the requirements of the *International Convention on Load Lines, 1966*. Attention should, however, be given to any additional Statutory Requirements of the National Authority of the country in which the ship is to be registered and to the relevant regulations of the *International Convention for the Safety of Life at Sea, 1974* and applicable amendments.

1.1.4 For the purpose of this Chapter the basic types of ships are those defined in the *International Convention on Load Lines, 1966,* namely:

Type 'A' Ships designed solely for the carriage of liquid cargoes.

Type 'B' Cargo ships, other than Type 'A', with steel weathertight hatch covers.

Type 'B-100' }
Type 'B-60' } Cargo ships of type 'B' with reduced freeboards on account of their ability to survive a stipulated damage.

Type 'B +' Cargo ships with increased freeboard on account of hatch cover arrangements.

1.1.5 The type of hatch covers on the weather decks of the basic ship types defined in 1.1.4 are detailed below and may be used in the types of ships as indicated in Table 11.1.1:

(a) Steel plated cargo hatch covers stiffened by webs or stiffeners and secured by clamping devices. Weathertightness to be achieved by means of gaskets. Hatch covers used for holds containing liquid cargoes are included in this category.

(b) Steel plated cargo hatch pontoon covers having interior webs and stiffeners extending for the full width of the hatchway. Weathertightness to be obtained by tarpaulins.

(c) Hatch covers of wood or steel used in conjunction with portable beams. Weathertightness to be obtained by tarpaulins.

(d) Access hatch covers for cargo oil tanks and adjacent spaces. The hatch covers are to be of steel and gasketed.

(e) Access hatch covers other than (d). For Type 'A', Type 'B-100' and Type 'B-60' ships, the covers are to be of steel, and weathertightness is to be achieved by means of gaskets.

Table 11.1.1 Covers associated with ship types

Type of cover	Type of ship				
	'A'	'B-100'	'B-60'	'B'	'B +'
(a)	–	X	X	X	X
(b)	–	–	–	X	X
(c)	–	–	–	–	X
(d)	X	X	X	Not applicable	
(e)	X	X	X	X	X

1.1.6 The positions of hatches on weather decks are defined in Ch 1,6.5.

1.1.7 'Tween deck hatch covers may be any of the types defined in 1.1.5, but need not be weathertight unless fitted to deep tanks or water ballast holds or compartments, in which case the covers are to be of type (a) and oiltight or watertight as appropriate.

1.1.8 The scantlings specified in the following Sections are applicable to covers of mild steel or higher tensile steel. Where other materials are used, equivalent scantlings are to be provided. The scantlings apply basically to rectangular covers, with the stiffening members arranged primarily in one direction and carrying a uniformly distributed load. The covers are assumed to be simply supported. Where covers are stiffened by a grillage formation, and also where point loads are applied to any type of cover, the scantlings are to be determined from direct calculations, *see* 2.2.4.

1.1.9 In the case of flush hatch covers or of covers on coamings of lesser height than required by 5.1.1, their scantlings, the securing and sealing arrangements and the drainage of gutterways will be specially considered.

1.1.10 The scantlings of hatch covers need to be increased only if the maximum loading exceeds 17,17 kN/m^2. The scantlings of the surrounding deck structure are to be sufficient to support this loading. Heavier loading may be permitted only if the scantlings of the cover are increased in direct proportion to the load. The deck structure is to be capable of withstanding this increased loading.

1.1.11 Where timber cargo is to be carried on the hatch covers the requirements of Ch 9,2.7 are to be satisfied.

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

1.1.13 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 11.1.2.

Table 11.1.2 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 (ii) for the internal structures	 2,0 1,5
For coaming and coaming stays	1,5

1.1.14 For ships with cargo environments giving permanently reduced corrosion characteristics and with increased protection of hatch covers from excessive freeboard height above the freeboard, or virtual freeboard deck, the corrosion margin may be specially considered.

1.2 Symbols

1.2.1 The minimum design 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 at the freeboard deck, p is to be the greater of 34,3 or the following:

$$p = 34{,}3 + \frac{p_{FP} - 34{,}3}{0{,}25}\left(0{,}25 - \frac{x}{L_L}\right) \text{ kN/m}^2$$

Where a hatchway is located in the forward quarter of the Load Line length and at least one standard superstructure height higher than the freeboard deck, the pressure p may be 34,3 kN/m^2. Position 2 hatch covers are to be designed with p taken as 25,5 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 $0{,}195L_L + 14{,}9$ or the following:

$$p = 15{,}8 + \frac{L_L}{3}\left(1 - \frac{5}{3}\,\frac{x}{L}\right) - 3{,}6\,\frac{x}{L_L} \quad \text{kN/m}^2$$

Where two or more panels are connected by hinges, each individual panel is to be considered separately. Position 2 hatch covers are to be designed with p taken as 14,7 kN/m^2 where L_L is 24 m and p taken as 25,5 kN/m^2 where L_L is 100 m; intermediate values are to be obtained by linear interpolation.

Where

p_{FP} = pressure at the forward perpendicular.
= $49{,}1 + (L_L - 100)\,a$

a = 0,0726 for type B freeboard ships
= 0,356 for ships with reduced freeboard

L_L = freeboard length, in metres, as defined in the Load Lines Conventions, 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_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 for the internal load is to be taken as that corresponding to the ship heeled to 25° with the liquid level in the hold intersecting the hatch cover top line at the centreline of the ship.

The pressure p, in kN/m^2 for the member and position under consideration is not to be less than $4{,}14Y_s$ where

Y_s = is to be taken as the distance from ship centreline to the edge, stiffener, or primary member under consideration, in metres.

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.

The above pressures are to be applied in conjunction with a stowage rate of 0,975 m^3/tonne.

However, where the rolling angle has been determined by direct calculations, the load may be derived accordingly, but is not to be less than that required in (a).

(d) In 'tween decks:

p = is to be taken as the 'tween deck height, in metres, measured vertically on the centreline of the ship from 'tween deck to underside of hatch cover stiffeners on deck above, multiplied by a factor of 7,06

For specified rates of loading in excess of 1,39 m^3/tonne, an equivalent p is to be used.

In accommodation spaces, p is to be taken as 12,7 kN/m^2.

1.2.2 The following symbols and definitions, in addition to those given in 1.2.1, are applicable to this Chapter, unless otherwise stated:

(a) L, L_L as defined in Ch 1,6.1.

(b) The following definitions apply to webs or stiffeners with attached plating, or portable beams:

b = length of panel (longer panel dimension), in mm, in transverse direction, *see* Fig. 11.1.1

d_w = overall depth at the supports, measured as shown in Fig. 11.1.2, but is to be not less than 150 mm, *see also* definition of l_1

k = higher tensile steel factor, *see* Ch 2,1.2

l_0 = unsupported span, in metres, measured as shown in Fig. 11.1.2

l_1 = proportion of the span, in metres, measured as shown in Fig. 11.1.2. The depth and face area over the remainder of the span is assumed to be constant

s = spacing of webs and stiffeners (shorter panel dimension), in mm

t = thickness of plating, in mm

H_c = height of hatch coaming, in mm

σ_{ac} = corrected critical buckling stress, in N/mm^2 (kgf/mm^2)

σ_b = the compressive bending stress, in N/mm^2 (kgf/mm^2), in the steel cover plating, calculated by taking the cover as a loaded beam simply supported at its ends

σ_c = critical buckling stress of panel, in N/mm^2 (kgf/mm^2)

σ_o = yield stress of cover plating material, in N/mm^2 (kgf/mm^2)

σ_u = minimum ultimate tensile strength, in N/mm^2 (kgf/mm^2).

h_H = head, as defined in Ch 3,5.1.

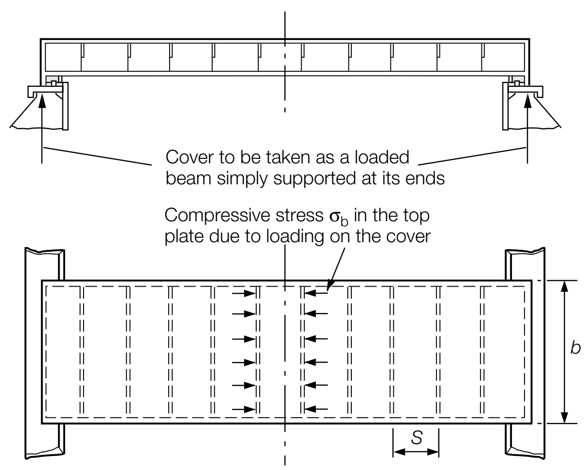


Fig. 11.1.1
Cover with stiffening fitted normal to the axis of primary bending

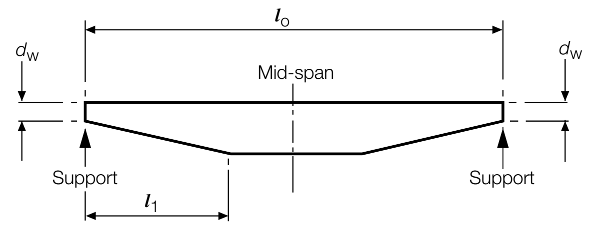


Fig. 11.1.2
Diagrammatic profile of web or stiffener or portable beam

■ *Section 2*
Steel hatch covers

2.1 Plating

2.1.1 The thickness of the plating of steel hatch covers is to be not less than required by Table 11.2.1.

2.2 Webs and stiffeners

2.2.1 The scantlings of steel cover primary and secondary webs or stiffeners are to be not less than would be required to satisfy the requirements of Table 11.2.2.

2.2.2 As an alternative to 2.2.1, scantlings may be determined by direct calculations, which are to be submitted for approval. In no case are the stresses and deflections given in Table 11.2.3 to be exceeded.

2.2.3 Where hatch covers are subjected to point loads, such as from containers, the requirements of Pt 4, Ch 8,11 are also to be complied with.

2.2.4 Covers having primary stiffeners in two directions will be considered using direct calculations in conjunction with the requirements of Table 11.2.3. 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 loading is to be as required by 1.2.1(b) but is not to be less than 1.2.1(a).

2.2.5 On ships of length L_L greater than 100 m, hatch covers fitted on top of a second, or virtual second, tier superstructure (as defined in Ch 8,1.3) or above, may be permitted a reduction in design pressure. The following minimum scantlings are to be complied with:

(a) Abaft $0{,}25L_L$ the cover plate thickness may be $0{,}0091s$ but not less than 6 mm.

(b) The value of h_H used in 1.2.1 may be 25,5 kN/m^2 forward of $0{,}25L_L$, and 20,6 kN/m^2 abaft of $0{,}25L_L$.

2.2.6 For the omission of gaskets or hatch covers in ships carrying container cargoes, *see* Pt 4, Ch 8,11.

Table 11.2.1 Steel hatch cover plating

Symbols	Position of cover	Thickness of cover
k, s, b and t as defined in 1.2 For $h_H \leq 3{,}5$ m, $K_c = 1$ $p \leq 34{,}3$ kN/m^2, $K_c = 1{,}116$ For $h_H > 3{,}5$ m, $K_c = \sqrt[3]{0{,}286 h_H}$ $p > 34{,}3$ kN/m^2, $K_c = \sqrt[3]{0{,}0405p}$ Y = distance from ship centreline to the outboard edge of the plate under consideration, in metres	Steel covers to dry cargo holds	The greater of: (a) $t = 0{,}01 s K_c \sqrt{k}$ mm (b) $t = 6{,}0$ mm
	OBO, ore or oil or similar types of ships and weather deck openings to holds which may be flooded and used as ballast tanks	The greatest of: (a) $t = (0{,}01s + 0{,}5)\sqrt{k}$ mm (b) $t = (0{,}0025s\sqrt{Y} + 2{,}5)\sqrt{k}$ mm (c) $t = 7{,}5$ mm
	'Tween deck covers to deep tanks	Pt 4, Ch 1,9 for plating forming boundaries of tanks
	Covers on decks where wheeled vehicles are used	Ch 9,3 for deck plating where wheeled vehicles are used
	Portable covers	The greater of: (a) $t = 0{,}01s$ mm (b) $t = 3{,}5$ mm
	Reduced thicknesses for covers in certain positions	*See* 2.2.5
Buckling requirements for hatch cover plating		

σ_b, σ_c, σ_{ac} and σ_o are defined in 1.2

$$\sigma_c = 18{,}6 R_c \left(\frac{t}{b}\right)^2 \times 10^4 \text{ N/mm}^2$$

$$\left(\sigma_c = 1{,}9 R_c \left(\frac{t}{b}\right)^2 \times 10^4 \text{ kgf/mm}^2\right)$$

$$\sigma_{ac} = \sigma_o \left(1 - \frac{\sigma_o}{4\sigma_c}\right) \text{ N/mm}^2 \quad (\text{kgf/mm}^2)$$

(a) Where primary bending stress acts on longer panel edge b, *see* Fig. 11.1.1:

$$\frac{\sigma_c}{\sigma_b} \left(\text{or } \frac{\sigma_{ac}}{\sigma_b}\right) \geq 1{,}3 \qquad \text{where } R_c = \left(\frac{s}{b} + \frac{b}{s}\right)^2$$

Where primary bending stress acts on shorter panel edge s:

$$\frac{\sigma_c}{\sigma_b} \left(\text{or } \frac{\sigma_{ac}}{\sigma_b}\right) \geq 1{,}2 \qquad \text{where } R_c = 4\left(\frac{b^2}{s^2}\right)$$

If $\sigma_c > 0{,}5\ \sigma_o$ then corrected value σ_{ac} is used

It is recommended that $\left(\frac{b}{s}\right) < 5{,}0$

(b) Where covers are stiffened in two directions by a grillage formation, buckling checks are to be carried out as per (a) above for bending stresses acting on both the longer and shorter edges of the panel.
For the derivation of the section modulus for primary members an effective width of plating to achieve a balanced section is to be adopted. However a greater width of plating in accordance with Ch 3,3.2 may be adopted where this is suitably stiffened in the directions being considered from the buckling aspect.

Table 11.2.2 Steel hatch cover webs and stiffeners

<table>
<tr><th>Symbols</th><th>Position of cover</th><th>Type of cover</th><th colspan="4">Requirement (primary stiffening)</th></tr>
<tr><td rowspan="9">I_0 and I_1 are moments of inertia, in cm^4, at mid-span and supports, where $I_1 > 0{,}05 I_0$
l_0, l_1 and h_H are defined in 1.2, except that for covers to deep tanks in ’tween decks $h_H = 1{,}67H$, where H is half the vertical height from top of the overflow
$C_H = 1 + \dfrac{8\alpha_H^3 (1 - \beta_H)}{0{,}2 + 3\sqrt{\beta_H}}$
$K_H = 1 + \dfrac{3{,}2\alpha_H - \gamma_H - 0{,}8}{7{,}0\gamma_H + 0{,}4}$
but not less than 1,0. To be specially considered when discontinuities in area of face material occur
K_1 and C_1 are given opposite
Z_0 and Z_1 are section moduli, in cm^3, at mid-span and supports
$\alpha_H = \dfrac{l_1}{l_0}$ $\beta_H = \dfrac{I_1}{I_0}$ $\gamma_H = \dfrac{Z_1}{Z_0}$
For weather decks:
$F = \dfrac{400\ N/mm^2\ (41\ kgf/mm^2)}{\text{Minimum ultimate tensile strength for higher tensile steel used in manufacture}}$
For ’tween decks
$F = k$
k as defined in 1.2.2</td>
<td rowspan="3">Weather decks – Positions 1 and 2</td><td>(1)
(a) Covers secured by clamping devices
(b) Portable covers</td><td colspan="4">$Z_0 = \dfrac{p\, s\, l_0^2\, K_H\, F}{K_1}\ cm^3$
$I_0 = \dfrac{p\, s\, l_0^3\, C_H}{C_1}\ cm^4$</td></tr>
<tr><td>(2) Covers for holds in OBO, ore or oil or similar types of ships and covers to holds which may be flooded and used as ballast tanks</td><td colspan="4">As for (1)
Thickness of webs or stiffeners >7,5 mm</td></tr>
<tr><td>(3) Pontoon covers</td><td colspan="4">As for (1)</td></tr>
<tr><td>Cargo ’tween decks</td><td>(4) Covers including pontoon covers</td><td colspan="4">As for (1)
Covers carrying wheeled vehicles are also to comply with Ch 9,3</td></tr>
<tr><td colspan="6">Secondary panel stiffening</td></tr>
<tr><td colspan="6">The section modulus and moment of inertia are to be derived as for longitudinal primary stiffening, using appropriate span and spacing. Where the ends of the panel stiffeners are effectively bracketed or continuous, these values of modulus and inertia may be reduced respectively by 33 per cent and 80 per cent</td></tr>
<tr><td>Type of cover</td><td>1</td><td>2</td><td>3</td><td>4</td><td></td></tr>
<tr><td>K_1</td><td>1507</td><td>1507</td><td>1281</td><td>1865</td><td></td></tr>
<tr><td>C_1</td><td>886</td><td>633</td><td>696</td><td>1108</td><td></td></tr>
</table>

Table 11.2.3 Parameters for direct calculations

Location	Item	Loading	Permissible bending stress N/mm^2 (kgf/mm^2)	Permissible shear stress N/mm^2 (kgf/mm^2)	Permissible deflection, metres
Weather deck – Positions 1 and 2, *see* Note	Steel weather-tight covers	Uniformly distributed (weather load)	$0{,}8\sigma_0$	$0{,}46\sigma_0$	$0{,}0056 l_0$
	Steel weather deck covers for holds which may be flooded and used as ballast tanks, and holds in OBO, ore or oil or similar types of ships	Internal loading *See* 1.2.1(b)	$\dfrac{117{,}7}{k} \left(\dfrac{12{,}0}{k}\right)$	$\dfrac{68{,}7}{k} \left(\dfrac{7{,}0}{k}\right)$	$0{,}0020 l_0$
	Pontoon covers	Uniformly distributed (weather load) *See* Ch 3,5	$0{,}68\sigma_0$		$0{,}0044 l_0$
Cargo ’tween deck, *see* Note	Steel covers	Uniformly distributed container or other specified loading	$\dfrac{117{,}7}{k} \left(\dfrac{12{,}0}{k}\right)$		$0{,}0035 l_0$

NOTE
For buckling requirements for hatch cover plating, *see* Table 11.2.1. Alternatively, the criteria in Pt 4, Ch 7,12 may be applied.

■ *Section 3*
Hatch beams and wood covers

3.1 Portable hatch beams

3.1.1 The section modulus and moment of inertia of portable web plate beams stiffened at their upper and lower edges by continuous flat bars are to satisfy the requirements of 2.2.1 for pontoon covers. Alternatively, direct calculations may be used, provided the requirements of 2.2.2 for pontoon covers are complied with.

3.1.2 The ends of web plates are to be doubled, or inserts fitted for at least 180 mm along length of web.

3.1.3 At beams which carry the ends of wood or steel hatch covers, a vertical 50 mm flat is to be arranged on the upper face plate. The width of bearing surface for hatch covers is to be not less than 65 mm.

3.1.4 Carriers or sockets, or other suitable arrangements, of suitable construction are to provide means for the efficient fitting and securing of portable hatch beams. The width of bearing surface is to be not less than 75 mm.

3.1.5 Sliding hatch beams are to be provided with an efficient device for locking them in their correct fore and aft positions when the hatchway is closed.

3.2 Wood covers

3.2.1 Wood covers are to have a finished thickness of not less than 60 mm in association with an unsupported span of not more than 1,5 m. Where the 'tween deck height as specified in 1.2.1, exceeds 2,6 m, the thickness of the wood covers is to be increased at the rate of 16,5 per cent per metre excess in 'tween deck height.

3.2.2 The ends of all wood hatch covers are to be protected by encircling galvanized steel bands, about 65 mm wide and 33 mm thick, efficiently secured.

■ *Section 4*
Hatch cover securing arrangements and tarpaulins

4.1 Cargo oil tank and adjacent spaces

4.1.1 For access hatchways to cargo oil tanks and adjacent spaces, *see* Section 7.

4.2 Steel covers – Clamped and gasketed

4.2.1 These requirements, unless stated otherwise, apply to steel hatch covers in Positions 1 and 2 fitted with gaskets and securing devices and situated above dry cargo holds.

4.2.2 Where steel hatch covers are fitted to hatch openings on weather decks, the arrangements are to be such that weathertightness can be maintained.

4.2.3 The weight of the covers and weather loading may be transmitted to the ship's structure by means of continuous steel to steel contact of the cover skirt plate with the ship's structure in association with a maximum bearing pressure of 200 kgf/cm^2. Alternatively the weight may be transmitted by means of defined bearing pads. For covers loaded by containers or other cargo, the total load together with inertial forces generated by the ship's motion, are to be transmitted by means of defined bearing pads only. The maximum pressure on steel to steel bearing areas is not to exceed 600 kgf/cm^2. In cases where the pads are constructed of materials other than steel, the maximum bearing pressure should be based on the manufacturer's recommendation.

For hatch cover roll/pitching stoppers intended to prevent horizontal movement of the cover panels, the force components parallel to the cover are to be taken as given in Table 14.8.2 of Ch 14,8:

and the permissible stresses are as follows:

Shear stress	$0,4\sigma_o$
Bending stress plus axial stress	$0,67\sigma_o$
Combined stress	$0,86\sigma_o$

where σ_o is the yield stress of the material.

In addition, the hatch side coamings and stays are to be of sufficient strength to accommodate the transverse inertial forces, *see* 5.2.12.

4.2.4 The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness. Similar sealing is to be arranged between cross-joint elements. Where fitted, compression flat bars or angles are to be well rounded where in contact with the gasket and are to be made of a corrosion-restraint material or suitably protected against corrosion.

4.2.5 Special consideration is to be given to the gasket and securing arrangements in ships with large relative movements between cover and ship structure or between cover elements. The relative horizontal and vertical deflections are to be calculated and submitted with the hatch cover plans. Where applicable, deflections due to thermal effects and internal pressure loads are also to be included.

4.2.6 The suitability of the gasket material and the securing adhesive is the responsibility of the Builder and Owner. When selecting such material, consideration is to be given to its suitability for the environmental conditions likely to be experienced by the ship and its compatibility with the cargo carried. The material and form of gasket selected are to be considered in conjunction with the type of cover, the securing arrangement and the expected relative movement between cover and ship structure. The gasket is to be effectively secured to the cover.

4.2.7 Drainage is to be arranged inside the line of gasket by means of a gutter bar or vertical extension of the hatch side and end coaming. This requirement need not be complied with for special ships carrying container cargoes when the requirements of 2.2.6 are satisfied.

4.2.8 Where the arrangement includes continuous steel to steel contact between hatch cover and coaming or at cross-joints, drainage on both sides of the gasket is to be provided.

4.2.9 Drain openings are to be arranged at the ends of drain channels and are to be provided with effective means for preventing ingress of water from outside.
The following requirements are to be complied with:

(a) If manufactured from steel, the minimum drain pipe wall thickness is to be not less than 5,5 mm.
(b) If not manufactured from steel, details of the drain, including the material specification, method of manufacture and details of any tests carried out, are to be submitted for consideration.
(c) Where the drains are not provided with an approved automatic means of preventing water entering the hold, the drains are to be capable of being closed by a screw plug or cap which is to be attached by a strong keep chain to the drain.
(d) The drains are to be securely attached to the hatch coaming and adequately protected if in an exposed position.
(e) When the drain is fitted to a hold also designed to carry liquids, a shut-off valve is to be incorporated into the assembly.

4.2.10 Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced alongside the coamings. The securing devices are not to have a vertical clearance but are to be pre-tensioned when the cover is in the closed position. The devices are also to be arranged in close proximity horizontally to the gasket. Arrangement and spacing are to be determined with due attention to the effectiveness for weathertightness, 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. A minimum of two securing devices for each side of a panel are to be fitted. The securing devices should be arranged as close to the panel corners as is practicable.

4.2.11 Between cover and coaming and at cross-joints, a gasket pressure sufficient to obtain weathertightness is to be maintained by the securing devices. This pressure is to be specified. Securing devices of a design other than rod or bolts will be specially considered, *see* 4.2.26.

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

$$A = \frac{1,4 S_1 W_1}{50 f} \text{ cm}^2 \quad \left(\frac{1,4 S_1 W_1}{5,1 f} \text{ cm}^2 \right)$$

where

$$f = \left(\frac{\sigma_c}{235} \right)^e$$

S_1 = spacing or securing devices, in metres, not to exceed 6 m

W_1 = the gasket loading per unit length, in N/cm (kgf/cm), but not less than 50 N/cm (5,1 kgf/cm)

σ_c = specified minimum upper yield stress in N/mm^2 (kgf/mm^2) of the steel used for cleats or securing devices, to be taken not greater than 70 per cent of the ultimate tensile strength

e = 0,75 for $\sigma_c \geq 235$ (24)
= 1,0 for $\sigma_c < 235$ (24)

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

4.2.14 In order to ensure compression between gasket and compression bar along the full length, the cover edge stiffness is to be examined. The inertia of the cover edge is to be not less than:

I_E = $0,6 W_1 S_1^4$ cm^4
(I_E = $5,89 W_1 S_1^4$ cm^4)

where W_1 and S_1 are as defined in 4.2.12.

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

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

4.2.17 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.

4.2.18 The cross-joints of multi-panel covers are to be arranged with wedges, or locators (male and female) to retain the hatch covers in the correct sealing position, the number and spacing are to be arranged to suit the size and type of cover, gasket arrangements and stiffness of cover edges at cross-joints. Means are also to be provided to prevent excessive relative vertical deflections between loaded and unloaded panels. The arrangement of the gasket retaining angle and the compression bar at the cross-joints is to be such that the gasket compression is maintained between loaded and unloaded panels.

4.2.19 In addition to the requirements given above, all hatch covers, especially those carrying deck cargo are to be effectively secured against horizontal shifting due to the horizontal forces arising from the ship motions.

4.2.20 To prevent damage to hatch covers and ship structure, the location of stoppers is to be compatible with the relative movements between hatch covers and ship structure. The number should be as small as practically possible.

4.2.21 Towards the ends of the ship, vertical acceleration forces may exceed gravity forces. The resulting lifting forces must therefore be also considered when dimensioning the securing devices. Also lifting forces from cargo secured on the hatch cover during rolling are to be taken into account.

4.2.22 Hatch coamings and supporting structure are to be adequately stiffened to accommodate the loading from hatch covers and cargo carried thereon.

4.2.23 Upon completion of installation of hatch covers, a hose test with a pressure of water as specified in Table 1.8.1 in Chapter 1 is to be carried out. Alternative methods of tightness testing will be considered. This does not apply to covers with reduced securing arrangements as specified in 2.2.6.

4.2.24 All hatch covers are to be tested to prove satisfactory operation.

4.2.25 It is recommended that ships with steel hatch covers are supplied with an operation and maintenance manual including:
(a) opening and closing instructions;
(b) maintenance requirements and specifications for packings, securing devices and operating items;
(c) cleaning instructions for the drainage system;
(d) corrosion prevention instructions;
(e) list of spare parts.

4.2.26 The spacing and size of securing devices in hatch covers for holds which may be flooded and used for ballast tanks and holds in OBO, ore or oil and similar types of ship are to correspond to the reaction forces at the cover edges found by calculation, *see* 2.2.4.

The permissible stresses are not to exceed the following values:
(a) For rod and bolt type; a tensile stress of 120f N/mm^2 (12,2f kgf/mm^2) in way of the thread or in way of the minimum section clear of the thread whichever is the smaller section.
(b) For devices other than rod and bolt type:

σ = 120f N/mm^2 (12,2f kgf/mm^2)
σ_e = 150f N/mm^2 (15,3f kgf/mm^2)
τ = 80f N/mm^2 (8,2f kgf/mm^2)

where
f = material factor as defined in 4.2.12
σ = bending stress in N/mm^2 (kgf/mm^2)
σ_e = equivalent stress, in N/mm^2 (kgf/mm^2)
= $\sqrt{(\sigma^2 + 3\tau^2)}$
τ = shear stress in N/mm^2.

4.2.27 On tank hatch covers in 'tween decks the maximum spacing of cleats is to be 600 mm, but cleats are to be arranged as close to the corners as practicable.

4.2.28 Steel hatch covers with special sealing arrangements, insulated covers, flush hatch covers, and covers having coamings less than required by 5.1, will be specially considered.

4.2.29 For reduced securing arrangements, *see* 2.2.6.

4.3 Portable covers – Tarpaulins and battening devices

4.3.1 At least two layers of tarpaulin in good condition are to be provided for each hatchway in Positions 1 and 2.

4.3.2 Tarpaulins are to be free from jute, waterproof and of ample strength. The minimum mass of the material before treatment is to be 0,65 kg/m^2 if the material is to be tarred, 0,60 kg/m^2 if to be chemically dressed, or 0,55 kg/m^2 if to be dressed with black oil. A certificate to this effect is to be supplied by the makers of the tarpaulins. Special consideration will be given to the use of synthetic materials for tarpaulins.

4.3.3 Cleats are to be of an approved pattern, at least 65 mm wide, with edges so rounded as to minimize damage to the wedges, and are to be spaced not more than 600 mm from centre to centre: the first and last cleats along each side or end are to be not more than 150 mm from the hatch corners. Cleats should be so set as to fit the taper of the wedges.

4.3.4 Battens and wedges shall be efficient and in good condition. Wedges are to be of tough wood, generally not more than 200 mm in length and 50 mm in width. They should have a taper of not more than 1 in 6 and should not be less than 13 mm at the point.

4.3.5 For all hatchways in Positions 1 and 2, steel bars or other equivalent means are to be provided in order to secure each section of hatch covers efficiently and independently after the tarpaulins are battened down. Hatch covers of more than 1,5 m in length are to be secured by at least two such securing appliances. Where hatchway covers extend over intermediate supports, steel bars or their equivalent are to be fitted at each end of each section of covers. At all other hatchways in exposed positions on weather decks, ring bolts or other fittings suitable for lashings are to be provided.

■ *Section 5* Hatch coamings

5.1 General

5.1.1 The height of coamings above the upper surface of the deck, measured above sheathing if fitted, for hatchways closed by portable covers secured weathertight by tarpaulins and battening devices, is to be not less than:
600 mm at Position 1,
450 mm at Position 2.

5.1.2 The height of coamings of hatchways situated in Positions 1 and 2 closed by steel covers fitted with gaskets and clamping devices is to be as specified in 5.1.1, but may be reduced, or the coamings may be omitted entirely, if the safety of the ship is not thereby impaired in any sea condition. Special attention will be given in such cases to the scantlings of the covers, to their gasketing and securing arrangements and to the drainage of recesses in the deck. The agreement of the National Authority concerned will also be required.

5.1.3 The height of coamings may be required to be increased on ships of Type 'B-100' or Type 'B-60' where this is shown to be necessary by the floatability calculations required by the *International Convention on Load Lines, 1966.*

5.2 Construction

5.2.1 Vertical coamings are to have a thickness, t, in mm not less than the greater of the following:

(a) $t = 0{,}008H_C\sqrt{k} + 1{,}0$ mm

(b) t = 12,0 mm where $L \geq 60$ m, and not less than 9 mm where $L \leq 30$ m

Intermediate values are to be obtained by interpolation.

In addition, for ships without a forecastle or breakwater the scantlings of the coamings for No. 1 cargo hatchway are not to be less than that required by Ch 8,2 for front bulkhead of deckhouse at that position.

5.2.2 Vertical cargo hatch coamings 600 mm or more in height are to be stiffened on their upper edges by a horizontal bulb flat or equivalent which is to be not less than 180 mm in width for ships where L is greater than 75 m. Additional support is to be afforded by fitting brackets or stays from the bulb flat to the deck at intervals of not more than 3 m. Each bracket or stay is to be aligned with suitable underdeckstiffeners and is to have a softened nose.

5.2.3 Vertical coamings less than 600 mm in height are to be stiffened at their upper edge by a substantial rolled or fabricated section. Additional support is to be arranged as required by 5.2.2.

5.2.4 Cargo hatchways on other decks, in positions not specified in Ch 1,6.5, are to be suitably framed.

5.2.5 The scantlings and arrangements of vertical cargo hatch coamings more than 900 mm in height and of cargo hatch coamings acting as girders will be specially considered. The coamings are to be arranged with intermediate continuous horizontal stiffeners supported by the bracket stays. In such cases the coamings are to have a thickness as required by 5.2.1 taking H_C, in mm, as the vertical distance between the continuous longitudinal stiffeners.

5.2.6 Sloped cargo hatch coamings will be specially considered. In general, the sloped coaming arrangement is to be restricted to the hatch side coamings with vertical coamings at the ends. The sloped coaming is not to have a knuckle and the angle to the vertical is not to exceed 30°. The scantlings are to be in accordance with 5.2.1 to 5.2.3 inclusive except that the end coamings are to be increased by 20 per cent for a distance of 0,15b from the side coamings where b is the width of the hatchway at the deck. Particular care is to be taken where the proposed loadings exceed the loadings given in 1.2.1(a) and Ch 3,5, and where the coamings are not in alignment with the topside tank vertical strake in bulk carriers.

5.2.7 A radiused coaming plate at the corner junction of the longitudinal and transverse cargo hatch coamings is acceptable for ships where $L \leq 90$ m and the heights of coamings are not in excess of that specified in 5.1.1. Where $L > 90$ m the corner junctions are to be rectangular and arranged with continuation brackets as required by 5.2.8.

5.2.8 The deck plating is to extend inside the coamings and the side coamings are to be extended in the form of tapered brackets. A recommended arrangement is shown in Fig. 11.5.1. Continuation brackets are also to be arranged athwartships in line with the hatch end coamings and the under deck transverse. In bulk carriers the athwartship brackets, in conjunction with the hatch end beams should be arranged to achieve a satisfactory overlap with the top side tank transverses. In cases where the hatch end beam is formed by the transverse bulkhead top stool the horizontal knuckle of the stool should be arranged well clear of the topside tank knuckle line.

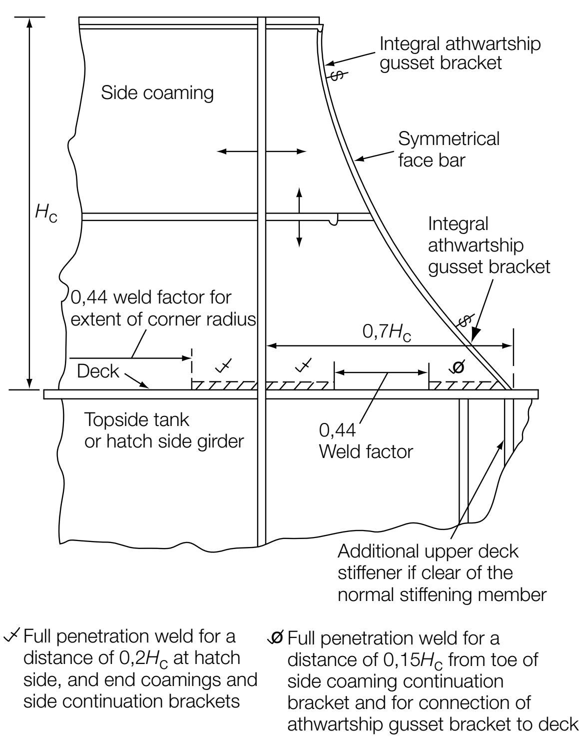


Fig. 11.5.1
Coaming continuation bracket –Recommended arrangement

5.2.9 In bulk carriers where the hatch side coaming does not align with the topside tank vertical strake the arrangement and scantlings will be specially considered. In general, suitable underdeck girders and cantilever brackets are to be arranged taking into consideration the hatch cover loading. The under-deck girders are to continue beyond the hatch end for a distance of 2H_C mm. Alternative arrangements incorporating bulkhead top stool structure or cross-deck structure will be considered.

5.2.10 Extension brackets or rails arranged approximately in line with the cargo hatch side coamings and intended for the stowage of steel covers are not to be welded to a deck-house, masthouse or to each other unless they form part of the longitudinal strength members.

5.2.11 The arrangement and scantlings of continuous hatchway coamings on the strength deck will be specially considered. The material of the coamings is to comply with Tables 2.2.1 and 2.2.2 in Chapter 2 and is to be of the same strength level as the deck plating. Discontinuous coamings of length greater than 0,09*L* are also to satisfy this requirement.

5.2.12 Where containers are carried on multi-panel hatch covers, the hatch coaming in way of the loaded panel will be required to be reinforced to resist the lateral loads imposed on the coaming due to rolling of the ship. Thrust blocks are to be fitted on the coaming rest bar to prevent the covers from moving. Where one-piece hatch covers are fitted with locating devices, the coamings are to be reinforced in way of the locators.

5.2.13 Cut outs in the top of hatch coamings are to be avoided. Where these are necessary for the securing devices they are to be circular or elliptical in shape. Also any local reinforcements should be given a tapered transition in the longitudinal direction with a taper the rate of which should not exceed 1 in 3. Cut-outs and drain holes are to be avoided in the hatch side coaming continuation brackets. Where these are necessary the size, shape and position will be specially considered.

5.3 Rest bars in hatchways

5.3.1 Rest bars are to provide at least 65 mm bearing surface and are to be aligned if required to suit the slope of the hatches.

5.4 Loading in excess of Rule requirements

5.4.1 For weather deck hatch side coamings forming part of a hatch side girder subjected to loading exceeding that defined in 1.2.1, *see* Pt 4, Ch 1,4.

■ *Section 6*
Miscellaneous openings

6.1 Small hatchways on exposed decks

6.1.1 Hatches which:

- are designed for access to spaces below the deck;
- are capable of being closed weathertight or watertight, as applicable;
- have an opening 2,5 m^2 or less;
- are located on the exposed deck over the forward 0,25*L* of the ship's rule length;
- are on a ship of sea-going service of length 80 m or more, where the height of the exposed deck in way of the hatch is less than 0,1*L* or 22 m above the summer load waterline, whichever is the lesser;

are to comply with the requirements of 6.6. All other small hatchways or access openings in the positions defined in 1.1.6 are to comply with the following requirements.

6.1.2 The number and size of hatchways and other access openings are to be kept to the minimum consistent with the satisfactory operation of the ship.

6.1.3 The height of coamings is to be in accordance with 5.1.1. Lower heights may be considered in relation to operational requirements and the nature of the spaces to which access is given.

6.1.4 Rope hatches may be accepted with reduced coamings, but generally not less than 380 mm, provided they are well secured and closed before the ship leaves port. A suitable notice is to be displayed at the hatch stating that it is to be closed whilst the ship is at sea.

6.1.5 The thickness of the coamings is to be not less than the Rule minimum thickness for the deck inside line of openings for that position, or 11 mm, whichever is the lesser. Stiffening of the coaming is to be appropriate to its length and height.

6.1.6 Hatch covers are to be of steel, weathertight and generally hinged. The means of securing are to be such that weathertightness can be maintained in any sea condition. Where toggles are fitted, their diameter and spacing are to be in accordance with ISO standard or equivalent.

6.1.7 Hinges are not to be used as securing devices unless specially considered.

6.1.8 The thickness of covers is to be not less than the Rule minimum thickness inside the line of openings for the deck at that point, or 8 mm, whichever is the lesser.

6.1.9 The covers are to be adequately stiffened.

6.1.10 Escape hatches are to be capable of being opened from either side.

6.1.11 Small hatches, including escape hatches, are to be situated clear of cargo containment areas, particularly in the case of offshore supply ships.

6.1.12 Where portable plates are required in decks for unshipping machinery, or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced deck and are secured by gaskets and closely spaced bolts at a pitch not exceeding five diameters.

6.1.13 Satisfactory means are to be provided to prevent inadvertent flooding of chain lockers. *See* Ch 13,7.8.5 and 7.8.7.

6.1.14 Where permitted by the National Authority, access hatch coaming heights may be reduced on ships engaged on protected or extended protected water service. Coaming heights are to be as high as practicable with a minimum height of 230 mm.

6.2 Manholes and flush scuttles

6.2.1 Manholes and flush scuttles fitted in Positions 1 and 2, or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

6.3 Hatchways within enclosed superstructures or ’tween decks

6.3.1 The requirements of 6.1 are to be complied with where applicable.

6.3.2 Access hatches within a superstructure or deckhouse in Positions 1 or 2 need not be provided with means for closing if all openings in the surrounding bulkheads have weathertight closing appliances.

6.4 Companionways, doors and accesses on weather decks

6.4.1 Companionways on exposed decks are to be of equivalent construction, weathertightness and strength to a deckhouse in the same position and effectively secured to the deck.

6.4.2 Access openings in:

(a) bulkheads at ends of enclosed superstructures;

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

(c) deckhouse on a deckhouse protecting an opening leading to a space below the freeboard deck;

are to be fitted with doors of steel or other equivalent material, permanently and strongly attached to the bulkhead and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead, and weathertight when closed. The doors are to be gasketed and secured weathertight by means of clamping devices or equivalent arrangements, permanently attached to the bulkhead or to the door. Doors are generally to open outwards and are to be capable of being operated and secured from both sides. The sill heights are to be as required by 6.4.5. *See also* Section 7 and Pt 4, Ch 9,13 and Ch 11,1 and the *Rules for Liquid Chemicals in Bulk*, Chapter 3 concerning access openings in tankers, chemical tankers and ore or oil ships. Double doors are to be equivalent in strength to the unpierced bulkhead, and in Position 1, a centre pillar is to be provided which may be portable.

6.4.3 Elsewhere doors may be of hardwood not less than 50 mm in thickness or of equivalent material and strength.

6.4.4 Fixed lights in doors in Positions 1 and 2 are to comply with the requirements for side scuttles as given in 6.5.1 and 6.5.2. Hinged steel deadlights may be external.

6.4.5 The height of doorway sills above deck sheathing, if fitted, is to be not less than 600 mm in Position 1, and not less than 380 mm in Position 2.

6.4.6 Where access is provided from the deck above as an alternative to access from the freeboard deck, the height of sill into a bridge or a poop is to be not less than 380 mm. The same requirement applies to deckhouses on the freeboard deck. The sill height for doorways in a forecastle, if protecting a companionway, is to be 600 mm regardless of whether or not access is provided from above. If not protecting a companionway, the sill height may be 380 mm.

6.4.7 When the closing appliances of openings in superstructures and deckhouses do not comply with 6.4.2, interior deck openings are to be treated as if exposed on the weather deck.

6.4.8 Where an access opening, in the top of a deckhouse situated on a raised quarterdeck, gives access below the freeboard deck or to an enclosed superstructure, the closing appliances in the surrounding bulkheads are not required to be gasketed, provided the raised quarterdeck is at least standard height, and the deckhouse is at least standard superstructure height.

6.4.9 The height of door sills may be required to be increased on ships of Type ‘A’, Type ‘B-100’ or Type ‘B-60’ where this is shown to be necessary by the floatability calculations required by the *International Convention on Load Lines, 1966.*

6.4.10 Direct access from the freeboard deck to the machinery space through exposed casings is not permitted on ships of Type ‘A’, Type ‘B-100’ or Type ‘B-60’. A door complying with 6.4.2 may, however, be fitted in an exposed machinery casing on these ships, provided that it leads to a space or passageway which is of equivalent strength to the casing and is separated from the machinery space by a second weathertight door complying with 6.4.2. The outer and inner weathertight doors are to have sill heights of not less than 600 mm and 230 mm, respectively and the space between is to be adequately drained by means of a screw plug or equivalent.

6.4.11 For a Type ‘A’ ship with freeboards assigned greater than, or equal to, Type ‘B’, inner doors are not required for direct access to the engine-room.

6.4.12 If internal access is provided from a wheelhouse in Position 2, or below, to spaces below the weather deck either directly or through other spaces, the opening should be protected by a hinged weathertight cover adequately secured, fitted on a coaming appropriate to its position, or by an equivalent arrangement, and the space adequately drained.

6.4.13 In way of a moonpool, where a working or platform deck is provided below the weather deck, openings in the surrounding bulkheads are to be kept to a minimum. Access or companionway openings are to be provided with weathertight closing appliances as for an exposed superstructure bulkhead, with 600 mm high coamings.

6.4.14 Where portable plates are required in casings for unshipping machinery, or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced bulkhead and are secured by gaskets and close spaced bolts at a pitch not exceeding five diameters.

6.4.15 The sill heights of accesses closed by covers which are secured by closely spaced bolts or otherwise kept permanently closed at sea will be specially considered.

6.4.16 Where permitted by the National Authority, companionway coaming heights may be reduced on ships engaged on protected or extended protected water service. Coaming heights are to be as high as practicable with a minimum height of 230 mm. Where the wheelhouse is on the freeboard deck, or located in the forward quarter of the ship's length, with internal access below, a weathertight cover, fitted to a coaming not less than 230 mm high, is to be provided for the access. Alternatively, storm covers are to be provided for windows in exposed positions. The wheelhouse is to be adequately drained.

6.5 Side scuttles, windows and skylights

6.5.1 Side scuttles are defined as being round or oval openings with an area not exceeding 0,16 m^2.

6.5.2 Windows are defined as being rectangular openings generally, and round or oval openings with an area exceeding 0,16 m^2.

6.5.3 A plan showing the location of side scuttles and windows is to be submitted. Attention is to be given to any relevant Statutory Requirements of the National Authority of the country in which the ship is to be registered.

6.5.4 Side scuttles and windows together with their glasses and deadlights if fitted, are to be of an approved design or in accordance with a recognized National or International Standard, *see also* Pt 4, Ch 4,6.3 for offshore supply ships.

6.5.5 Side scuttles to spaces below the freeboard deck, or to spaces within the first tier of enclosed superstructures, or to first tier deckhouses on the freeboard deck protecting openings leading below or considered buoyant in stability calculations, are to be fitted with efficient, hinged, inside deadlights and capable of being effectively closed and secured watertight.

6.5.6 Deadlights are to be capable of being closed and secured watertight if fitted below the freeboard deck or weathertight if fitted above.

6.5.7 No side scuttle is to be fitted in such a position that its sill is below a line drawn parallel to the freeboard deck at side and having its lowest point 2,5 per cent of the breadth *B* above the load waterline corresponding to the summer freeboard (or timber summer freeboard if assigned), or 500 mm, whichever is the greater distance, *see* Fig. 11.6.1.

6.5.8 If the required damage stability or floatability calculations indicate that the side scuttles would become immersed at any intermediate stages of flooding or the final equilibrium waterline, these are to be of the non-opening type. Windows are not to be fitted in such locations.

6.5.9 Windows are not to be fitted in machinery space boundaries. However this does not preclude the use of glass in control rooms within the machinery space.

6.5.10 If fitted in a deckhouse in Position 1, windows are to be provided with strong, hinged, steel, weathertight storm covers. However, if there is an opening leading below deck in this deckhouse, this opening is to be treated as being on an exposed deck and is to be protected as required by 6.5.5.

6.5.11 Windows are not to be fitted below the freeboard deck, in first tier end bulkheads or sides of enclosed superstructures, or in first tier deckhouses that are considered buoyant in stability calculations.

6.5.12 Side scuttles and windows at the shell in Position 2, protecting direct access below, are to be provided with strong permanently attached deadlights.

6.5.13 Side scuttles and windows at the shell in Position 2, not protecting direct access below, are to be provided with strong portable steel covers for 50 per cent of each size, with means for securing at each side scuttle and window.

6.5.14 Side scuttles and windows set inboard from the shell in Position 2, protecting direct access below, are either to be provided with strong permanently attached deadlights or, where they are accessible, strong permanently attached external steel storm covers instead of internal deadlights.

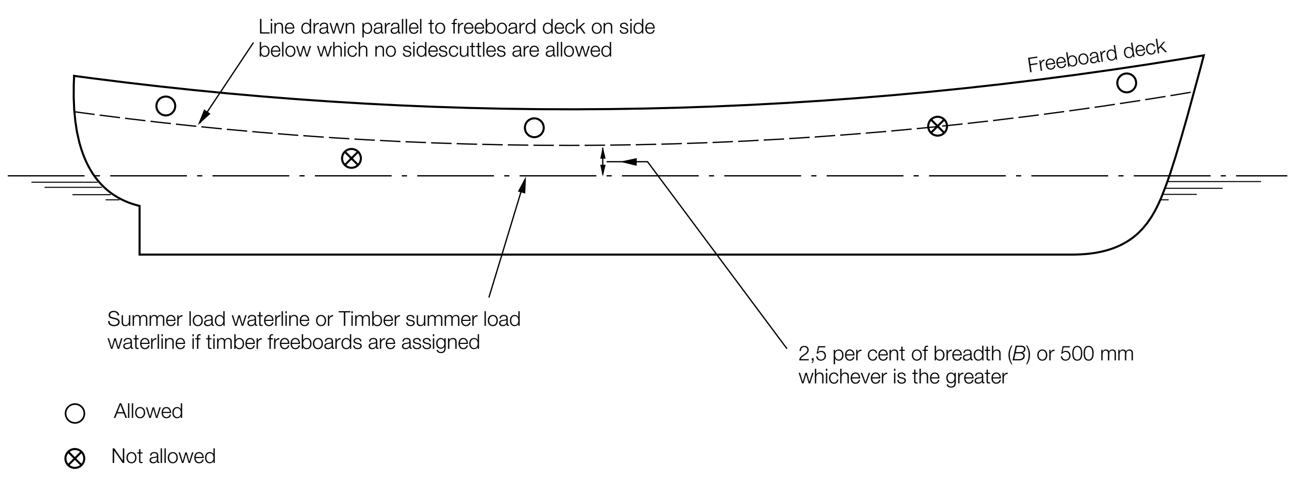


Fig. 11.6.1 Side scuttle positioning

6.5.15 Side scuttles and windows set inboard from the shell in Position 2, not protecting direct access below, do not require deadlights or storm covers.

6.5.16 In Position 2, cabin bulkheads and doors are considered effective between side scuttles or windows and access below.

6.5.17 Windows in the shell above Position 2 are to be provided with strong portable internal storm covers for 25 per cent of each size of window, with means of securing being provided at each window.

6.5.18 Where windows are permitted in an exposed bulkhead on the weather deck in the forward 0,25L_L, strong external storm covers which may be portable and stored adjacent are to be provided.

6.5.19 Where the wheelhouse is in Position 2, in lieu of storm covers being provided for the wheelhouse windows, a weathertight cover, fitted to a coaming of not less than 230 mm in height around the internal stairway opening within the wheelhouse, may be accepted. If this arrangement is accepted, adequate means of draining the wheelhouse are to be provided.

6.5.20 If necessary, for practical considerations, the storm covers may be in two parts.

6.5.21 Deckhouses situated on a raised quarter deck may be treated as being in Position 2 as far as the provision of deadlights is concerned, provided the height of the raised quarter deck is equal to, or greater than, the standard height.

6.5.22 Skylights, where fitted, are to be of substantial construction and securely attached to their coamings. The height of the lower edge of opening is to be as required by 5.1.1. The scantlings of the coaming are to be as required by this Section or Section 5, as appropriate. The thickness of glasses in fixed or opening skylights is to be appropriate to their size and position as required for side scuttles or windows. Glasses in any position are to be protected from mechanical damage, and where fitted in Positions 1 or 2 are to be provided with robust deadlights or storm covers permanently attached. Cargo pump room and machinery space skylights are not to contain glass.

6.5.23 Skylights to cargo pump rooms are to be capable of being closed from outside the pump room.

6.5.24 Laminated toughened safety glass may also be used for windows but the total thickness will need to be greater than that required for the equivalent sized window using toughened safety glass. The equivalent thickness of laminated toughened safety glass is to be determined from the following formula:

$$T_{L1}^2 + T_{L2}^2 + ...T_{Ln}^2 = T_S^2$$

where:

n = number of laminates
T_L = thickness of glass laminate
T_S = thickness of toughened safety glass

6.5.25 Rubber frames are not acceptable for windows in Positions 1 and 2, and are not generally acceptable in any other position in external casings. Any proposals to fit rubber frames are to be submitted for consideration, and are to be acceptable to the administration. The proposed locations, frame dimensions, glass thicknesses and the results of any tests carried out, are to be forwarded.

6.6 Small hatchways on exposed fore decks

6.6.1 For the application of the following requirements, *see* 6.1.1.

6.6.2 The number and size of hatchways and other access openings are to be kept to the minimum consistent with the satisfactory operation of the ship.

6.6.3 The height of coamings is to be in accordance with 5.1.1. Lower heights may be considered in relation to operational requirements and the nature of the spaces to which access is given.

6.6.4 Rope hatches may be accepted with reduced coamings, but generally not less than 380 mm, provided they are well secured and closed before the ship leaves port. A suitable notice is to be displayed at the hatch stating that it is to be closed whilst the ship is at sea.

6.6.5 Where permitted by the National Authority, access hatch coaming heights may be reduced on ships engaged on protected or extended protected water service. Coaming heights are to be as high as practicable with a minimum height of 230 mm.

6.6.6 The thickness of the coamings is to be not less than the Rule minimum thickness for the deck inside line of openings for that position, or 11 mm, whichever is the lesser.

6.6.7 The upper edge of the hatchway coamings is to be suitably reinforced by a horizontal section, normally not more than 170 to 190 mm from the upper edge of the coamings.

6.6.8 Hatches are to be fitted with primary securing devices such that their hatch covers can be secured in place and weather-tight by means of a mechanism employing any one of the following methods:

(a) Butterfly nuts tightening onto forks (clamps),
(b) Quick acting cleats, or
(c) Central locking device.

Emergency escape hatches are excluded from options (a) and (b).

6.6.9 Dogs (twist tightening handles) with wedges are not acceptable as primary securing devices.

6.6.10 Escape hatches are to be capable of being opened from either side.

6.6.11 For a primary securing method using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed to minimize the risk of butterfly nuts being dislodged while in use; by means of curving the forks upward, a raised surface on the free end, or a similar method. The plate thickness of unstiffened steel forks is not to be less than 16 mm. An example arrangement is shown in Fig. 11.6.3.

6.6.12 The hatch cover is to be fitted with a gasket of elastic material. This is to be designed to allow a metal to metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged. The metal-to-metal contacts are to be arranged close to each securing device in accordance with Fig. 11.6.2, and of sufficient capacity to withstand the bearing force.

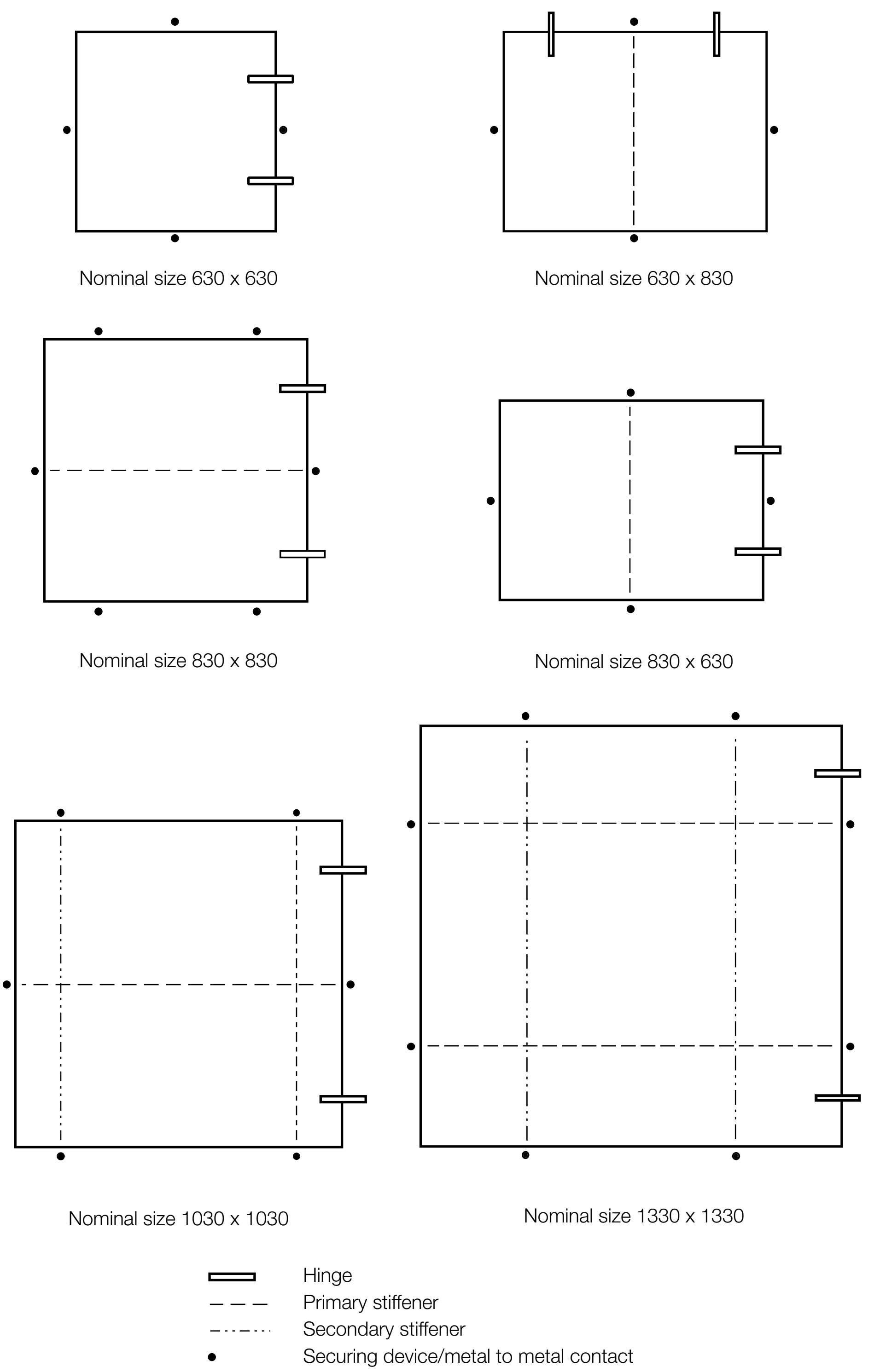
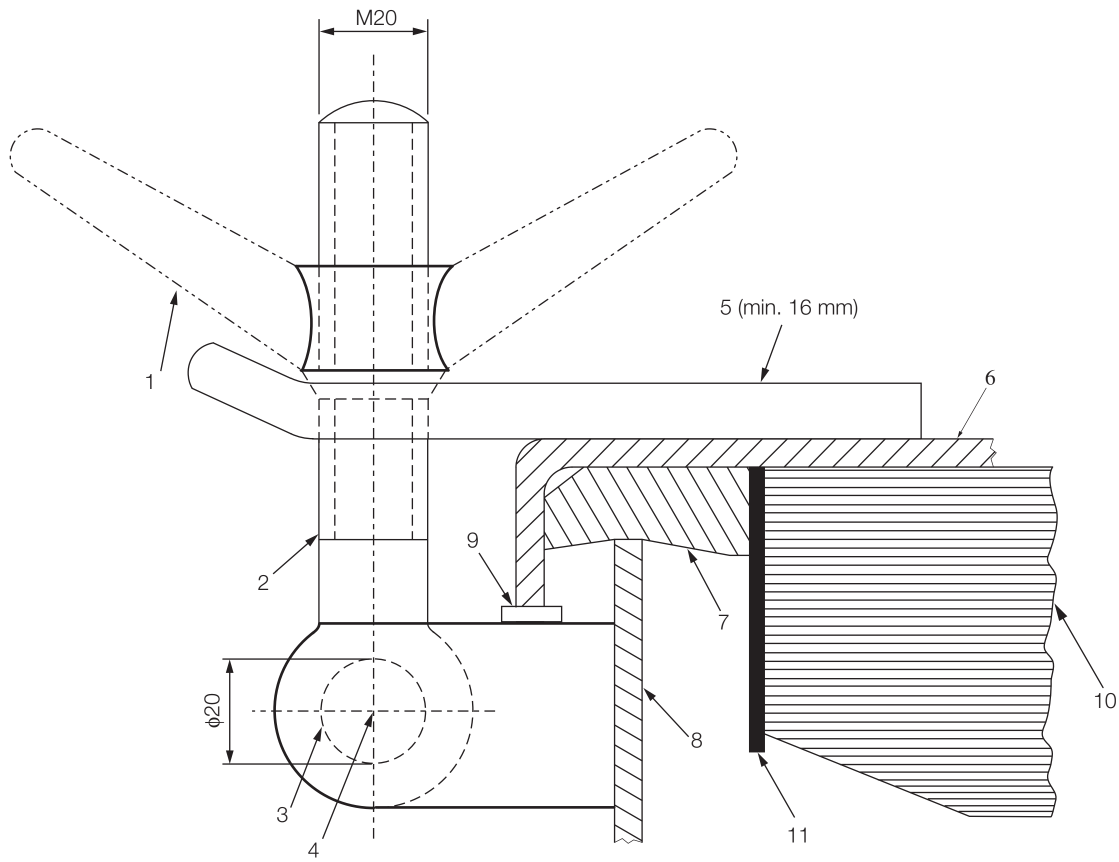


Fig. 11.6.2 Arrangement of stiffeners



1. butterfly nut
2. bolt
3. pin
4. centre of pin
5. fork (clamp) plate
6. hatch cover
7. gasket
8. hatch coaming
9. bearing pad welded on the bracket of a toggle bolt for metal to metal contact
10. stiffener
11. inner edge stiffener

(Note: Dimensions in millimeters)

Fig. 11.6.3 Example of a primary securing method

6.6.13 The primary securing method is to be designed and manufactured such that the designed compression pressure can be achieved by one person without the need of any tools.

6.6.14 For small rectangular steel hatch covers, the plate thickness, stiffener arrangement and scantlings are to be in accordance with Table 11.6.1 and Fig. 11.6.2. Stiffeners, where fitted, are to be aligned with the metal-to-metal contact points required in 6.6.11, *see* Fig. 11.6.2. Primary stiffeners are to be continuous. All stiffeners are to be welded to the inner edge stiffener, *see* Fig. 11.6.3.

6.6.15 For hatch covers constructed of materials other than steel, the required scantlings are to provide equivalent strength.

Table 11.6.1 Scantlings for small steel hatch covers on exposed deck

Nominal size (mm x mm)	Cover plate thickness (mm)	Primary stiffeners	Secondary stiffeners
		Flat bar (mm x mm); number	
630 x 630	8	–	–
630 x 830	8	100 x 8;1	–
830 x 630	8	100 x 8;1	–
830 x 830	8	100 x 10;1	–
1030 x 1030	8	120 x 12;1	80 x 8;2
1330 x 1330	8	150 x 12;2	100 x 10;2

6.6.16 For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement are to be of equivalent strength to that of the small rectangular steel hatch covers described in 2.2.1.

6.6.17 For hatch covers located on the deck forward of the fore-most cargo hatch, the hinges are to be fitted such that the predominant direction of green sea will cause the cover to close. The hinges are normally to be located on the fore edge.

6.6.18 On small hatches located between the main hatches, for example between Nos. 1 and 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green water in beam sea and bow quartering conditions.

6.6.19 Hatches, excluding emergency escape hatches, are to be fitted with an independent secondary securing device, e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

6.6.20 Small hatches, including escape hatches, are to be situated clear of cargo containment areas, particularly in the case of offshore supply ships.

6.6.21 Where portable plates are required in decks for unshipping machinery, or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced deck and are secured by gaskets and closely spaced bolts at a pitch not exceeding five diameters.

6.6.22 Satisfactory means are to be provided to prevent inadvertent flooding of chain lockers, *see* Ch 13,7.8.5 and 7.8.7.

■ *Section 7*
Tanker access arrangements and closing appliances

7.1 Materials

7.1.1 Covers for access hatches, tank cleaning and other openings to cargo tanks and adjacent spaces are to be manufactured from mild steel complying with the Rules for Materials (Part 2).

7.1.2 Consideration will be given to the use of bronze, brass or other materials; however, aluminium alloy is not to be used for the covers of any openings to tanks.

7.1.3 Synthetic materials will be considered, taking into account their fire resistance and physical and chemical properties in relation to the intended operating conditions. Details of the properties of the material, the design of the cover and the method of manufacture are to be submitted for approval.

7.1.4 The hatch cover packing material is to be compatible with the cargoes to be carried and is to be efficiently held in place.

7.2 Cargo tank access hatchways

7.2.1 Attention is drawn to IMO Resolutions concerning safe access to, and working in, large tanks.

7.2.2 Oiltight hatchways are to be kept to the minimum size required to provide reasonable access and ventilation. Where tanks are large or subdivided by wash bulkheads, additional hatchways may be required. In determining the size and location of hatchways, consideration should be given to the handling of materials and staging for maintenance in the tank.

7.2.3 The size and location of hatchways should also take into account access for personnel wearing breathing apparatus, and removal of injured personnel (possibly on a stretcher) from the bottom of the tank.

7.2.4 The height of hatch coaming is to be not less than 600 mm, measured above the upper surface of the freeboard deck, unless a lower height is permitted by the Administration of the country in which the ship is to be registered.

7.2.5 Taking account of sheer and camber, the height of any cargo tank hatch coaming is to be such as to ensure that the top of the hatch coaming is above the highest point of the tank over which it is fitted.

7.2.6 The height of the coaming may be required to be increased if this is shown to be necessary by the floatability calculations required by the *International Convention on Load Lines, 1966.*

7.2.7 The thickness of the coaming plate is to be not less than 10 mm, but may be required to be increased, and edge stiffening fitted, where the coaming height exceeds 600 mm.

7.2.8 Unstiffened plate covers are to be not less than 12,5 mm in thickness, but if the area of the cover exceeds 1,2 m^2 this thickness may be required to be increased or stiffening fitted.

7.2.9 Unstiffened covers are to be secured by fastenings spaced not more than 600 mm apart on circular hatchways. On rectangular hatchways the spacing of fastenings is generally not to exceed 450 mm, and the distance between hatch corners and adjacent fastenings is to be not more than 230 mm.

7.2.10 The arrangement of fastenings on stiffened hatchway covers and covers of special design will be specially considered.

7.2.11 Where the cover is hinged, adequate stiffening of the coaming and cover in way of the hinge is to be provided. In general, hinges are not to be used as securing devices for the cover.

7.3 Enlarged cargo tank access openings

7.3.1 Proposals to fit enlarged cargo tank accesses closed by bolted plate covers will be considered. Such openings may be of extended dimensions for ease of access and evacuation of personnel, *see* 7.2.3, and may incorporate a smaller access hatch for normal use constructed as required by 7.2.

7.3.2 The plate cover is to be not less than 15 mm in thickness and is to be secured by closely spaced studs to a ring of suitable dimensions, welded to the deck. The studs are not to penetrate the deck plating.

7.4 Miscellaneous openings

7.4.1 Small openings for tank cleaning, ullage and similar purposes may be closed by flush covers which are to be not less than 12,5 mm in thickness and secured by studs not more than 100 mm apart. Studs are to be arranged in a ring of suitable width and thickness attached to the deck, and are not to penetrate the deck plating.

7.4.2 Small diameter holes provided for staging wires are to be closed by plugs of an approved pattern. The plugs are to be provided with a thick washer of suitable material which is also compatible with the intended cargoes. Spare plugs equal to at least 10 per cent of the number of holes are to be provided and maintained on board, *see also* Pt 4, Ch 9,4. If these openings are threaded they are to be protected while in use with a protective sleeve of suitable material.

7.5 Access to spaces other than cargo tanks

7.5.1 Access to clean ballast or dry tanks and to cofferdams may be either by access hatch or by manhole generally complying with the preceding requirements.

7.6 Equivalents

7.6.1 Alternative access cover designs and securing arrangements will be considered on the basis of equivalence to the above requirements and taking into account any relevant National Requirements.

7.7 Other openings

7.7.1 For access to structure within cargo tanks, *see* Pt 4, Ch 9,13.

■ *Section 8* Side and stern doors and other shell openings

8.1 Symbols

8.1.1 The symbols used in this Section are defined as follows:

d = distance between closing devices, in metres

k = material factor, *see* Ch 2,1.2, but is not to be taken less than 0,72 unless demonstrated otherwise by a direct strength analysis with regard to relevant modes of failure

I = moment of inertia, in cm^4, of the stiffener or girder, in association with an effective width of attached plating determined in accordance with Ch 3,3

σ = bending stress, in N/mm^2 (kgf/mm^2)

σ_e = equivalent stress, in N/mm^2 (kgf/mm^2)

$= \sqrt{(\sigma^2 + 3\tau^2)}$

σ_o = minimum yield stress of the bearing material, in N/mm^2 (kgf/mm^2)

τ = shear stress, in N/mm^2 (kgf/mm^2).

8.2 General

8.2.1 These requirements cover cargo and service doors in the ship side (abaft the collision bulkhead) and stern area, below the freeboard deck and in enclosed superstructures.

8.2.2 For the requirements of bow doors, *see* Pt 4, Ch 2,8.

8.2.3 Side and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure, *see also* Ch 1,6.3.2 and 6.4.2.

8.2.4 In general, and for passenger ships in particular, the lower edge of door openings is not to be below a line drawn parallel to the freeboard deck at side, which has at its lowest point at least 230 mm above the upper edge of the uppermost Load Line.

8.2.5 When the lower edge is below the line specified in 8.2.4, the arrangement will be specially considered. Special consideration is to be given to preventing the spread of leakage water over the deck. The reference to the uppermost Load Line is to be taken as the tropical fresh waterline or, if timber freeboards are assigned, the timber tropical fresh waterline.

8.2.6 Doors are generally to be arranged to open outwards, however inward opening doors will be considered provided these satisfy the requirements of 8.2.7.

8.2.7 Inward opening doors situated in the first two 'tween decks above the summer load waterline are to be fitted with a second independent securing device, such as a strongback or equivalent arrangement, capable of providing weathertight integrity. Where the consequences of water ingress due to failure of the door are minimal, such as a small pilot door giving access to a watertight trunk leading to the bulkhead deck, the required enhancements will be specially considered.

8.2.8 For passenger ships the following are also applicable:

(a) Gangway, cargo and service ports fitted below the margin line, *see* Ch 3,4.3, are to satisfy the strength requirements given for side doors in this Section. They are to be effectively closed and secured watertight before the ship leaves port, and are to be kept closed during navigation. Such ports are not to have their lowest point below the deepest subdivision Load Line.

(b) Where the inboard end of a rubbish chute is below the margin line in a passenger ship, the inboard end cover is to be watertight and, in addition to the discharge flap interlock, a screwdown automatic non-return valve is to be fitted in an easily accessible position above the deepest subdivision. The valve is to be controlled from a position above the bulkhead deck and provided with an open/shut indicator, and kept closed when not in use. A suitable notice is to be displayed at the valve position.

8.2.9 For ships complying with the requirements of this Section, the securing, supporting and locking devices are defined as follows:

(a) A securing device is used to keep the door closed by preventing it from rotating about its hinges or other pivoted attachments to the ship.

(b) A supporting device is used to transmit external and internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the ship's structure.

(c) A locking device locks a securing device in the closed position.

8.2.10 Ro-ro cargo spaces are spaces not normally subdivided in any way and extending to either a substantial length or the entire length of the ship, in which motor vehicles with fuel in their tanks for their own propulsion and/or goods (packaged or in bulk, in or on rail or road cars, vehicles (including road or rail tankers), trailers, containers, pallets, demountable tanks in or on similar stowage units or other receptacles) can be loaded and unloaded normally in a horizontal direction.

8.2.11 Special category spaces are those enclosed spaces above and below the bulkhead deck, into and from which vehicles can be driven and to which passengers have access, and which may be accommodated on more than one deck where total overall clear height for vehicles does not exceed 10 m.

8.3 Scantlings

8.3.1 In general the strength of side and stern doors is to be equivalent to the strength of the surrounding structure.

8.3.2 Door openings in the side shell are to have well rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below, *see* Pt 4, Ch 1,5.

8.3.3 Doors are to be adequately stiffened, and means are to be provided to prevent movement of the doors when closed. Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the ship structure.

8.3.4 The thickness of the door plating is to be not less than the shell plating calculated with the door stiffener spacing, and in no case to be less than the minimum adjacent shell thickness.

8.3.5 Where stern doors are protected against direct wave impact by a permanent external ramp, the thickness of the stern door plating may be reduced by 20 per cent relative to the requirements of 8.3.4. Those parts of the stern door which are not protected by the ramp are to have the thickness of plating in full compliance with 8.3.4.

8.3.6 Where higher tensile steel is proposed, the plating thickness required in 8.3.4 and 8.3.5 may be reduced by $\sqrt{k}$.

8.3.7 The section modulus of horizontal or vertical stiffeners is to be not less than required for the adjacent shell framing using the actual stiffener spacing. Consideration is to be given, where necessary, to differences in fixity between ship's frames and door stiffeners.

8.3.8 Where necessary, door secondary stiffeners are to be supported by primary members constituting the main stiffening elements of the door.

8.3.9 The scantlings of such primary members are to be based on direct strength calculations. Normally, formulae for simple beam theory may be applied to determine the bending stress. Members are to be considered to have simply supported end connections. The design load is the uniformly distributed external sea pressure, p_e, as defined in 8.8.1. For minimum scantlings, p_e, is to be taken as 25 kN/m^2 (2,55 tonne-f/m^2) and the permissible stresses as follows:

$$\tau = \frac{80}{k} \text{ N/mm}^2 \quad \left(\frac{8,2}{k} \text{ kgf/mm}^2\right)$$

$$\sigma = \frac{120}{k} \text{ N/mm}^2 \quad \left(\frac{12,2}{k} \text{ kgf/mm}^2\right)$$

$$\sigma_e = \frac{150}{k} \text{ N/mm}^2 \quad \left(\frac{15,3}{k} \text{ kgf/mm}^2\right)$$

8.3.10 The webs of primary members are to be adequately stiffened, preferably in a direction perpendicular to the shell plating.

8.3.11 The stiffness of the edges of the doors and the hull structure in way are to be sufficient to ensure weathertight integrity. Edge stiffeners/girders are to be adequately stiffened against rotation and are to have a moment of inertia not less than:

$$I = 0,8 p_I d^4 \text{ cm}^4$$

$$(I = 8 p_I d^4 \text{ cm}^4)$$

where

p_I = packing line pressure along edges, not to be taken less than 50 N/cm (5,1 kgf/cm).

For edge girders supporting main door girders between securing devices, the moment of inertia is to be increased in relation to the additional force.

8.3.12 The buckling strength of primary members is to be specially considered.

8.3.13 All load transmitting elements in the design load path from door through securing and supporting devices into the ship structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices. These elements include pins, supporting brackets and back-up brackets. Where cut-outs are made in the supporting structure, the strength and stiffness will be specially considered.

8.4 Doors serving as ramps

8.4.1 Where doors also serve as vehicle ramps, the plating and stiffeners are to be not less than required for vehicle decks, *see* Ch 9,3.

8.4.2 The design of the hinges for these doors should take into account the ship angle of trim or heel which may result in uneven loading of the hinges.

8.5 Arrangements for the closing, securing and supporting of doors

8.5.1 Doors are to be fitted with adequate means of closing, securing and support so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

8.5.2 Devices are to be simple to operate and easily accessible. They are to be of a design approved by Lloyd's Register (hereinafter referred to as 'LR') for the intended purpose.

8.5.3 Securing devices are to be equipped with positive locking arrangements. Arrangements are to be such that the securing devices are retained in the closed position within design limits of inclination, vibration and other motion-induced loads and in the event of loss of any actuating power supply.

8.5.4 Systems for door opening/closing and securing/locking are to be interlocked in such a way that they can only operate in a proper sequence. Hydraulic systems are to comply with Pt 5, Ch 14,9.

8.5.5 Means are to be provided to enable the doors to be mechanically fixed in the open position taking into account the self weight of the door and a minimum wind pressure of 1,5 kN/m^2 (0,153 tonne-f/m^2) acting on the maximum projected area in the open position.

8.5.6 The spacing for cleats or closing devices should not exceed 2,5 m and there should be cleats or closing devices positioned as close to the corners as practicable. Alternative arrangements for ensuring weathertight sealing will be specially considered.

8.5.7 Control and monitoring arrangements are to comply with the applicable requirements of Pt 6, Ch 2,18.

8.6 Design loads

8.6.1 The design force considered for the scantlings of primary members, securing and supporting devices of side shell doors and stern doors are to be taken not less than:

(a) Design forces for securing or supporting devices of doors opening inwards:
External force:
$P_e = Ap_e + P_p$ kN (tonne-f)
Internal force:
$P_i = P_o + 10W$ kN
($P_i = P_o + 1{,}02W$ tonne-f)

(b) Design forces for securing or supporting devices of doors opening outwards:
External force:
$P_e = Ap_e$ kN (tonne-f)
Internal force:
$P_i = P_o + 10W + P_p$ kN
($P_i = P_o + 1{,}02W + P_p$ tonne-f)

(c) Design forces for primary members:
External force:
$P_e = Ap_e$ kN (tonne-f)
Internal force:
$P_i = P_o + 10W$ kN
($P_i = P_o + 1{,}02W$ tonne-f)

whichever is the greater.

The symbols used are defined as follows:

p_e = external sea pressure, in kN/m^2 (tonne-f/m^2), determined at the centre of gravity of the door opening and is not to be taken less than:
for $Z_G < T$ — $10\,(T - Z_G) + 25$ kN/m^2 ($1{,}02\,(T - Z_G) + 2{,}55$ tonne-f/m^2)
for $Z_G \geq T$ — 25 kN/m^2 (2,55 tonne-f/m^2)
For stern doors of ships fitted with bow doors, p_e is not to be taken less than:

$p_{emin} = 0{,}6\lambda C_H (0{,}8 + 0{,}6L^{0,5})^2$ kN/m^2
($p_{emin} = 0{,}061\lambda C_H (0{,}8 + 0{,}6L^{0,5})^2$ tonne-f/m^2)

T = summer draught, in metres
Z_G = height of the centre of area of the door, in m, above the base line
L = length of ship, but need not be taken greater than 200 m
λ = coefficient depending on the area where the ship is intended to be operated:
= 1 for sea-going ships
= 0,8 for ships operated in coastal waters
= 0,5 for ships operated in sheltered waters
C_H = $0{,}0125L$ for $L < 80$ m
= 1 for $L \geq 80$ m
A = area, in m^2, of the door opening
W = weight of the door, in tonnes
P_p = total packing force, kN (tonne-f). When packing is fitted, the packing line force per unit length is to be specified, normally not to be taken less than: 5 kN/m (0,51 tonne-f/m)

P_o = the greater of P_c and 5A kN (0,5A tonne-f)

P_c = accidental force, in kN (tonne-f), due to loose cargo, etc., to be uniformly distributed over the area A and not to be taken less than 300 kN (30,6 tonne-f). For small doors such as bunker doors and pilot doors, the value of P_c may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental force due to loose cargoes.

8.7 Design of securing and supporting devices

8.7.1 Securing devices and supporting devices are to be designed to withstand the forces given above using the following permissible stresses:

$$\tau = \frac{80}{k} \text{ N/mm}^2 \quad \left(\frac{8,2}{k} \text{ kgf/mm}^2\right)$$

$$\sigma = \frac{120}{k} \text{ N/mm}^2 \quad \left(\frac{12,2}{k} \text{ kgf/mm}^2\right)$$

$$\sigma_e = \frac{150}{k} \text{ N/mm}^2 \quad \left(\frac{15,3}{k} \text{ kgf/mm}^2\right)$$

The terms 'securing device' and 'supporting device' are defined in Pt 4, Ch 2,8.2.8.

8.7.2 The arrangement of securing and supporting devices is to be such that threaded bolts are not to carry support forces. The maximum tensile stress in way of threads of bolts, not carrying support forces, is not to exceed:

$$\frac{125}{k} \text{ N/mm}^2 \quad \left(\frac{12,7}{k} \text{ kgf/mm}^2\right)$$

8.7.3 For steel to steel bearings in securing and supporting devices, the normal bearing pressure is not to exceed 0,8σ_o, *see* 8.1.1. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification. The normal bearing pressure is to be calculated by dividing the design force by the projected bearing area.

8.7.4 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports. Small and/or flexible devices, such as cleats, intended to provide load compression of the packing material are not generally to be included in these calculations.

8.7.5 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be considered in the calculation of the reaction forces acting on the devices.

8.7.6 The number of securing and supporting devices is generally to be the minimum practicable whilst complying with 8.5.3 and taking account of the available space in the hull for adequate support.

8.7.7 The arrangement of securing devices and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces, without exceeding, by more than 20 per cent, the permissible stresses as defined in 8.7.1.

8.8 Operating and Maintenance Manual

8.8.1 An Operating and Maintenance Manual for the doors is to be provided on board and is to contain necessary information on:

(a) main particulars and design drawings,
(b) service conditions, e.g. service area restrictions, acceptable clearances for supports,
(c) maintenance and function testing,
(d) register of inspections, repairs and renewals.

8.8.2 For passenger/vehicle ferries and roll on-roll off cargo ships, *see* Pt 4, Ch 2,1.1.1, an Operating and Maintenance Manual for the doors, as defined in Pt 4, Ch 2,8.7.1, is to be provided on board instead of that required by 8.8.1.

8.8.3 The Manual is to be submitted for approval, and is to contain a note recommending that recorded inspections of the door supporting and securing devices be carried out by the ship's staff at monthly intervals or following incidents that could result in damage, including heavy weather or contact in the region of the doors. Any damages recorded during such inspections are to be reported to LR.

8.8.4 Documented operating procedures for closing and securing the doors are to be kept on board and posted at an appropriate place.

■ *Section 9*
Watertight doors in bulkheads below the freeboard deck

9.1 Openings in bulkheads

9.1.1 Certain openings below the freeboard deck are permitted, but these must be kept to a minimum and provided with means of closing to watertight standards. All such openings are to be to the satisfaction of the Surveyor.

9.2 Watertight doors

9.2.1 Watertight doors are to be of equivalent strength to the unpierced bulkhead, efficiently constructed and fitted, and are to be capable of being closed watertight when the ship is listed up to 15° either way. They are to be operated under working conditions and hose tested in place, *see* Ch 1,8.3.

9.2.2 The scantlings of the watertight doors are to comply with Pt 4, Ch 1,9 using the actual stiffener spacing of the door.

9.2.3 The scantlings of the frames of the watertight doors are to satisfy the requirements of watertight bulkheads given in Table 1.9.1(5) in Pt 4, Ch 1,9 taking into account the arrangement of door stiffeners and securing arrangements.

9.2.4 Watertight doors of the sliding type are to be capable of being operated by efficient hand operated gear, both at the door itself and from an accessible position above the bulkhead deck. Means are to be provided at the remote operating position to indicate whether the door is open or closed. The lead of shafting is to be as direct as possible and the screw is to work in a gunmetal nut, *see also* Ch 3,4.8.

9.2.5 Hinged watertight doors of approved pattern may be fitted in 'tween decks in approved positions. The hinges of these doors are to be fitted with gunmetal pins or gunmetal bushes.

9.2.6 Means are to be provided on the navigating bridge to indicate whether the watertight doors are open or closed.

9.2.7 In passenger ships the number and construction of the watertight doors in bulkheads will be specially considered. Each watertight door is to be tested, *see* Table 1.8.1 in Chapter 1. The test may be carried out either before or after the door is fitted. The relevant regulations regarding openings in watertight bulkheads in passenger ships, contained in the *International Convention for the Safety of Life at Sea, 1974* and applicable amendments, are also to be complied with.

■ *Section 10*
External openings and openings in watertight bulkheads and internal decks in cargo ships

10.1 Shell and watertight subdivision openings

10.1.1 In addition to the requirements of Sections 8 and 9, for cargo ships of 80 m in length and above, the relevant regulations concerning shell and watertight subdivision openings contained in the *International Convention for the Safety of Life at Sea*, 1974, and amendments thereto are also to be complied with.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all ship types detailed in Part 4, and provides requirements for ventilators, air and sounding pipes and overboard discharges.

1.1.2 The requirements conform, where relevant, with those of the *International Convention on Load Lines, 1966*. Reference should also be made to any additional requirements of the National Authority of the country in which the ship is to be registered and to the relevant regulations of the *International Convention for the Safety of Life at Sea, 1974* and applicable amendments.

1.2 Protection

1.2.1 In all cargo spaces and other areas where mechanical damage is likely, all air and sounding pipes, scuppers and discharges, including their valves, controls and indicators, are to be well protected. This protection is to be of steel or other equivalent material.

■ *Section 2* Ventilators

2.1 General

2.1.1 Ventilators located on the exposed deck over the forward 0,25*L* of the rule length, of ships of sea-going service of length 80 m or more, where the height of the exposed deck in way of the item is less than 0,1*L* or 22 m above the summer load waterline, whichever is the lesser, are to comply with the requirements of Section 5. All other ventilators are to comply with the following requirements.

2.1.2 Special care is to be taken in the design and positioning of ventilator openings and coamings, particularly in the region of the forward end of superstructures and other points of high stress. The deck plating in way of the coamings is to be efficiently stiffened.

2.1.3 Ventilators from deep tanks and tunnels passing through 'tween decks are to have scantlings suitable for withstanding the pressures to which they may be subjected, and are to be made watertight.

2.1.4 For height and location of cargo tank vent outlets, *see* Pt 5, Ch 15,4 and *see also* Ch 8,8.2.9 and 8.2.10 of the *Rules for Ships for Liquefied Gases*, or Ch 8,8.2.2, of the *Rules for Ships for Liquid Chemicals*, where applicable.

2.2 Coamings

2.2.1 The scantlings and height of ventilator coamings exposed to the weather are to be not less than required by Table 12.2.1 but the thickness need not exceed that of the adjacent deck or bulkhead plating. In particularly exposed positions, the height of coamings and scantlings may be required to be increased.

Table 12.2.1 Ventilator coaming requirements

Feature	Requirements
Height (measured above sheathing if fitted)	(1) z_C = 900 mm at Position 1 (*see* Ch 1,6.5) z_C = 760 mm at Position 2 (*see* Ch 1,6.5)
Thickness	(2) $t_C = 5{,}5 + 0{,}01\delta_V$ mm where 7,5 mm $\le t_C \le$ 10,0 mm
Support	(3) If z_C > 900 mm the coaming is to be specially supported
Symbols	
t_C = thickness of coaming, in mm z_C = height of coaming, in mm δ_V = internal diameter of coaming, in mm	
NOTE Where the height of the ventilator exceeds that given in Item (1), the thickness given by (2) may be gradually reduced, above that height, to a minimum of 6,5 mm. The ventilator is to be adequately stayed.	

2.2.2 The height of ventilator coamings may be required to be increased on ships of Type 'A', Type 'B-100' and Type 'B-60' where this is shown to be necessary by the floatability calculations required by the *International Convention on Load Lines, 1966.*

2.2.3 For gooseneck ventilators, the coaming height is to be measured to the underside of the bend, this being the lowest point through which water on deck could pass freely to spaces below.

2.2.4 Where wall vents are fitted with an internal baffle which rises above the lower edge of the exterior opening, the coaming height is measured to the top of the baffle.

2.2.5 Where permitted by the National Authority, ventilator coaming heights may be reduced on ships engaged on protected or extended protected water service. Coaming heights are to be as high as practicable, with a minimum height of 450 mm in Position 1 and 300 mm in Position 2.

2.3 Closing appliances

2.3.1 All ventilator openings are to be provided with efficient weathertight closing appliances of steel or other equivalent material unless:
(a) the height of the coaming is greater than 4,5 m where Table 12.2.1 requires a minimum height of 900 mm; or
(b) the height of the coaming is greater than 2,3 m where Table 12.2.1 requires a minimum height of 760 mm.

2.3.2 In ships where the load line length, L_L (*see* Ch 1,6.1), is not more than 100 m, the closing appliances are to be permanently attached to the ventilator coaming. Where not so provided in other ships, they are to be conveniently stowed near the ventilator to which they are to be fitted.

2.3.3 Where, in ferries, ventilators are proposed to be led overboard in an enclosed 'tween deck, the closing arrangements are to be submitted for approval. If such ventilators are led overboard more than 4,5 m above the main vehicle deck, closing appliances may be omitted, provided that satisfactory baffles and drainage arrangements are provided, as in the case of air intakes or exhaust openings for machinery spaces, which may be arranged in the sides of the ship.

2.3.4 On offshore supply ships, to ensure satisfactory operation in all weather conditions, machinery space ventilation inlets and outlets are to be located in such positions that closing appliances will not be necessary.

2.3.5 Mushroom ventilators closed by a head revolving on a centre spindle (screw down head) are acceptable in Position 2, and also in sheltered positions in Position 1, excluding those described in 2.1.1, but the diameter is not to exceed 300 mm if situated within the forward $0,25L_L$.

2.3.6 Mushroom ventilators with a fixed head and closed by a screw down plate (screw down cover) may be accepted in exposed positions within the forward $0,25L_L$, excluding those described in 2.1.1, up to a diameter of 750 mm.

2.3.7 Wall ventilators (jalousies) may be accepted provided they are capable of being closed weathertight by hinged steel gasketed covers secured by bolts or toggles.

2.3.8 A ventilator head not forming part of the closing arrangements is to be not less than 6,5 mm thick.

2.4 Machinery spaces

2.4.1 In general, ventilators necessary to continuously supply the machinery space are to have coamings of sufficient height to comply with 2.3.1 without having to fit weathertight closing appliances. Ventilators to emergency generator rooms are to be so positioned that closing appliances are not required.

2.4.2 Where due to ship size and arrangement this is not practicable, lesser heights for machinery space ventilator coamings fitted with weathertight closing appliances may be permitted by the administration in combination with other suitable arrangements to ensure uninterrupted, adequate supply of ventilation to these spaces.

■ *Section 3* Air and sounding pipes

3.1 General

3.1.1 Air pipes located on the exposed deck over the forward $0,25L$ of the rule length, of ships of sea-going service of length 80 m or more, where the height of the exposed deck in way of the item is less than $0,1L$ or 22 m above the summer load waterline, whichever is the lesser, are to comply with the requirements of Section 5. All other air and sounding pipes are to comply with the following requirements in addition to the applicable requirements of Pt 5, Ch 13,10 and Ch 13,15.2.

3.1.2 Striking plates of suitable thickness, or their equivalent, are to be fitted under all sounding pipes.

3.1.3 On offshore supply ships, air pipes are to be situated clear of the cargo containment areas.

3.2 Height of air pipes

3.2.1 The height of air pipes from the upper surface of decks exposed to the weather, to the point where water may have access below, is normally to be not less than:
- 760 mm on the freeboard deck;
- 450 mm on the superstructure deck;

these heights being measured above deck sheathing, where fitted.

3.2.2 Lower heights may be approved in cases where these are essential for the working of the ship, provided that the design and arrangements are otherwise satisfactory. In such cases, efficient, permanently attached closing appliances of an approved automatic type will generally be required.

3.2.3 The height of air pipes may be required to be increased on ships of Type 'A', Type 'B-100' and Type 'B-60' where this is shown to be necessary by the floatability calculations required by the *International Convention on Load Lines, 1966.* An increase in height may also be required or recommended by individual Administrations when air pipes to oil fuel and settling tanks are situated in positions where sea-water could be temporarily entrapped, e.g. in recesses in the sides and ends of superstructures or deckhouses, between hatch ends, behind high sections of bulwark, etc. This may entail an increase in tank scantlings, *see also* Chapter 3.

3.2.4 Air pipes are generally to be led to an exposed deck. For alternative arrangements in an enclosed space on a main vehicle deck, *see* Pt 4, Ch 2,9.

3.2.5 Where air pipes are led through the side of super-structures, the opening is to be at least 2,3 m above the summer load waterline.

3.2.6 The minimum wall thickness of air pipes in positions indicated in 3.2.1 is to be:

- 6,0 mm for pipes of 80 mm external diameter or smaller;
- 8,5 mm for pipes of 165 mm external diameter or greater.

Intermediate minimum thicknesses are to be determined by linear interpolation.

3.2.7 Where permitted by the National Authority, air pipe coaming heights may be reduced on ships engaged on protected or extended protected water service. Coaming heights are to be as high as practicable, with a minimum height of 450 mm on the freeboard deck and 300 mm on a superstructure deck.

3.3 Closing appliances

3.3.1 All openings of air and sounding pipes are to be provided with permanently attached, satisfactory means of closing to prevent the free entry of water, *see also* 3.2.2.

3.3.2 Closing appliances are to be of an approved automatic type.

3.3.3 Pressure/vacuum valves as required by Pt 5, Ch 15,4 may be accepted as closing appliances for cargo tanks.

■ *Section 4* Scuppers and sanitary discharges

4.1 General

4.1.1 Scuppers sufficient in number and size to provide effective drainage are to be fitted in all decks.

4.1.2 Scuppers draining weather decks and spaces within superstructures or deckhouses not fitted with efficient weathertight doors are to be led overboard.

4.1.3 Scuppers and discharges which drain spaces below the freeboard deck, or spaces within intact super-structures or deckhouses on the freeboard deck fitted with efficient weathertight doors, may be led to the bilges in the case of scuppers, or to suitable sanitary tanks in the case of sanitary discharges. Alternatively, they may be led overboard provided that:

(a) The freeboard is such that the deck edge is not immersed when the ship heels to 5°, and
(b) the scuppers are fitted with means of preventing water from passing inboard in accordance with 4.2.

4.1.4 In ships where an approved fixed pressure water spray fire-extinguishing system is fitted in vehicle or cargo spaces, deck scuppers of not less than 150 mm diameter are to be provided port and starboard, spaced about 9,0 m apart. The scupper area will require to be increased if the design capacity of the drencher system exceeds the Rule required capacity by 10 per cent or more. After installation, the two adjacent sections with the greatest aggregate drencher capacity are to be tested in operation to ensure that there is no build up of water on the deck, *see also* Pt 4, Ch 2,10.2.2. The mouth of the scupper is to be protected by bars.

4.1.5 Where a sewage system is fitted, the shipside valves on the discharge pipe from the effluent tank(s) and the by-pass system are to comply with 4.2.

4.1.6 The minimum wall thickness of pipes not indicated in 4.2.6 is to be:

- 4,5 mm for pipes of 155 mm external diameter or smaller;
- 6,0 mm for pipes of 230 mm external diameter or greater.

Intermediate minimum thicknesses are to be determined by linear interpolation.

4.1.7 For the use of non-metallic pipe, *see* Pt 5, Ch 12,5.

4.1.8 Scuppers and discharge pipes should not normally pass through oil fuel or cargo oil tanks. Where scuppers and discharge pipes pass, unavoidably, through oil fuel or cargo oil tanks, and are led through the shell within the tanks, the thickness of the piping should be at least the same thickness as Rule shell plating in way, derived from the appropriate Chapters, but need not exceed 19 mm.

4.1.9 Piping within tanks is to be tested in accordance with Ch 1,8.

4.1.10 All piping is to be adequately supported.

4.1.11 *See also* the *Rules for Ships for Liquefied Gases* or *the Rules for Ships for Liquid Chemicals*, where applicable.

4.1.12 For additional requirements for scuppers and sanitary discharges on dredging and reclamation craft, *see* Pt 4, Ch 12,15.

4.2 Closing appliances

4.2.1 In general, each separate overboard discharge is to be fitted with a screw-down non-return valve capable of being operated from a position always accessible and above the freeboard deck. An indicator is to be fitted at the control position showing whether the valve is open or closed. A machinery space, whether manned or unattended (i.e. with **UMS** notation), is considered accessible. Cargo holds or spaces with access only by hatches or bolted manholes are not considered accessible.

4.2.2 Where a drencher fire-extinguishing system is provided in an enclosed vehicle space of a ferry, the scupper controls are to be operated from a position above the bulkhead deck, and outside the vehicle space protected by the drencher system, and are to be protected from mechanical damage.

4.2.3 Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds $0,01L_L$ the discharge may be fitted with two automatic non-return valves without positive means of closing, instead of the screw-down non-return valve, provided that the inboard valve is always accessible for examination under service conditions.

4.2.4 Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds $0,02L_L$, a single automatic non-return valve without positive means of closing may be fitted, *see* Fig. 12.4.1.

4.2.5 The requirements for non-return valves are applicable only to those discharges which remain open during the normal operation of the ship. For discharges which are closed at sea, such as gravity drains from topside ballast tanks, a single screw down valve operated from the freeboard deck is considered to provide sufficient protection.

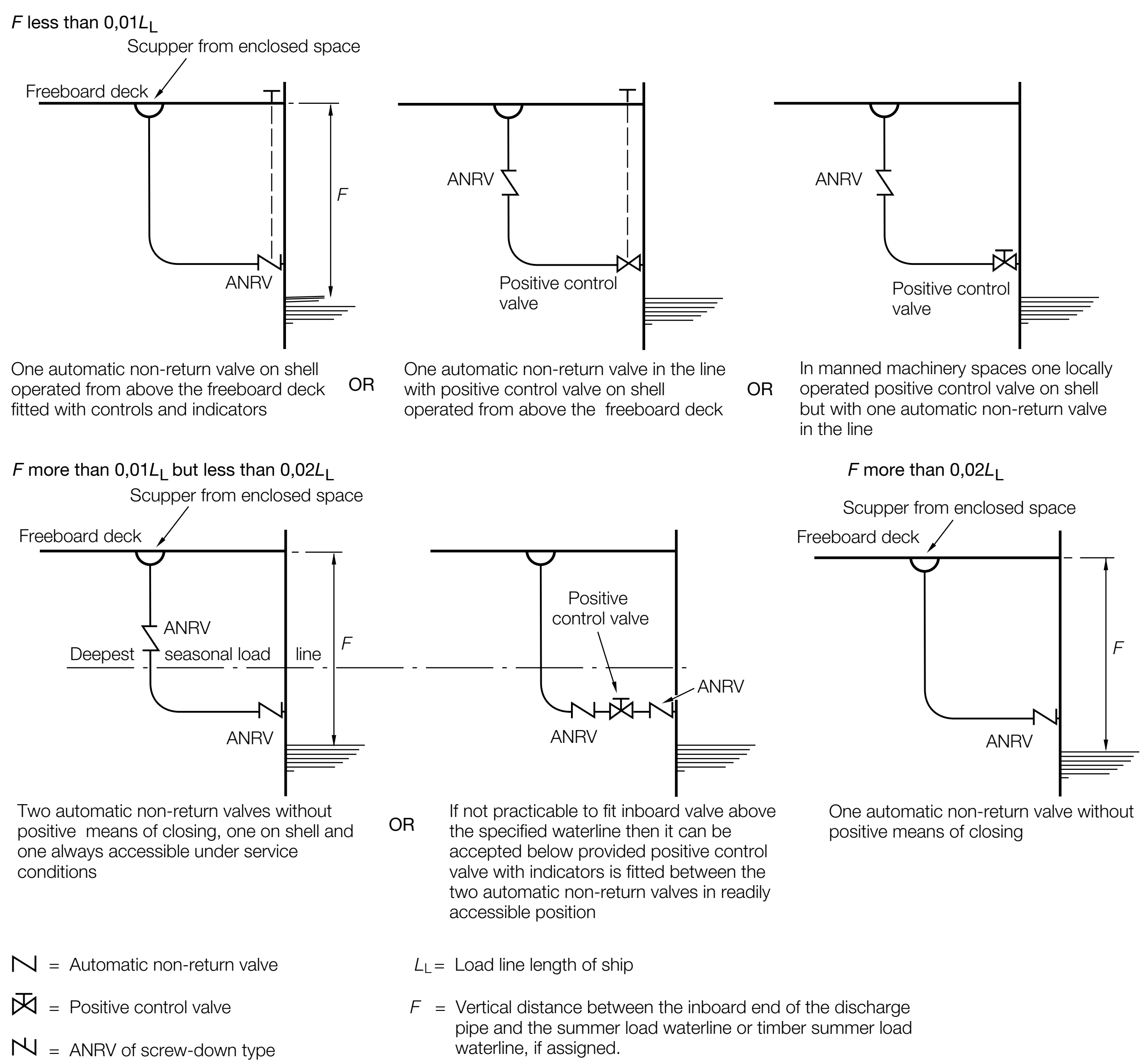


Fig. 12.4.1 Diagrammatic arrangement of discharge valves

4.2.6 Scuppers and discharge pipes originating at any level which penetrate the shell either more than 450 mm below the freeboard deck or less than 600 mm above the summer load waterline, are to be fitted with an automatic non-return valve at the shell. This valve, unless required by 4.1.3, may be omitted provided the piping has a minimum wall thickness of:

- 7,0 mm for pipes of 80 mm external diameter or smaller;
- 10,0 mm for pipes of 180 mm external diameter;
- 12,5 mm for pipes of 220 mm external diameter or greater.

Intermediate minimum thicknesses are to be determined by linear interpolation. Unless required by 4.1.8, the maximum thickness need not exceed 12,5 mm.

4.2.7 The outboard valve is to be mounted directly on the shell and secured in accordance with Pt 5, Ch 13,2.5.1. If this is impracticable, a short distance piece of rigid construction may be introduced between the valve and the shell. Valves should not be fitted in cargo tanks.

4.2.8 If a valve is required by 4.1.3, this valve should preferably be fitted as close as possible to the point of entry of the pipe into the tank. If fitted below the freeboard deck, the valve is to be capable of being controlled from an easily accessible position above the freeboard deck. Local control is also to be arranged, unless the valve is inaccessible. An indicator is to be fitted at the control position showing whether the valve is open or closed.

4.2.9 In a ship to which timber freeboards are assigned, the summer load waterline is to be regarded as that corresponding to the timber summer freeboard.

4.2.10 For ship side valves and fittings (other than those on scuppers and sanitary discharges), *see* Pt 5, Ch 13,2 and Pt 6, Ch 1,2.

4.3 Rubbish chutes, offal and similar discharges

4.3.1 Rubbish chutes, offal and similar discharges should be constructed of mild steel piping or plating of shell thickness. Other materials will be specially considered. Openings are to be kept clear of the sheerstrake and areas of high stress concentration.

4.3.2 Rubbish chute hoppers are to be provided with a hinged weathertight cover at the inboard end with an interlock so that the discharge flap and hopper cover cannot be open at the same time. The hopper cover is to be secured closed when not in use, and a suitable notice displayed at the control position.

4.3.3 Where the inboard end of the hopper is less than 0,01L_L above the summer load waterline, a suitable valve with positive means for closing is to be provided in addition to the cover and flap in an easily accessible position above the deepest seasonal waterline. The valve is to be controlled from a position adjacent to the hopper and provided with an open/shut indicator. The valve is to be kept closed when not in use, and a suitable notice displayed at the valve operating position.

4.3.4 Where damage stability requirements apply and the inboard end of the chute is below the equilibrium waterlines, or in passenger ships, where the inboard end of a rubbish chute is below the margin line; *see* Ch 11,8.2.8(b).

4.3.5 In trawlers or fish factory ships, offal discharges in the fish working spaces are to be provided with either a non-return flap, preferably fitted at the shell which can be positively secured weathertight, or a separate positively controlled valve kept closed when not in use. A suitable notice is to be displayed at the flap or valve operating position.

4.4 Materials for valves, fittings and pipes

4.4.1 All shell fittings and valves required by 4.2 are to be of steel, bronze or other approved ductile material; ordinary cast iron or similar material is not acceptable. Materials are to satisfy the requirements of the Rules for Materials (Part 2).

4.4.2 All these items, if made of steel or other approved material with low corrosion resistance, are to be suitably protected against wastage.

4.4.3 The lengths of pipe attached to the shell fittings, elbow pieces or valves are to be of galvanized steel or other equivalent approved material.

■ *Section 5* Air pipes, ventilator pipes and their securing devices located on the exposed fore deck

5.1 General

5.1.1 For the application of the following requirements relating to ventilators, *see* 2.1.1. For the application of the following requirements relating to air pipes, *see* 3.1.1. Air pipes complying with the following requirements are also to comply with the applicable requirements of Pt 5, Ch 13,10 and Pt 5, Ch 15,2.5.

5.1.2 Special care is to be taken in the design and positioning of ventilator openings and coamings, particularly in the region of the forward end of superstructures and other points of high stress. The deck plating in way of the coamings is to be efficiently stiffened.

5.1.3 Ventilators from deep tanks and tunnels passing through 'tween decks are to have scantlings suitable for withstanding the pressures to which they may be subjected, and are to be made watertight.

5.1.4 For height and location of cargo tank vent outlets, *see* Pt 5, Ch 15,4 and *see also* Ch 8,8.2.9 and 8.2.10 of the *Rules for Ships for Liquefied Gases*, or Ch 8,8.2.2, of the *Rules for Ships for Liquid Chemicals*, where applicable.

5.1.5 On offshore supply ships, air pipes are to be situated clear of the cargo containment areas.

5.2 Loading

5.2.1 The pressures, p, in kN/m^2 acting on air pipes, ventilator pipes and their closing devices may be calculated from:

$p = 0{,}5\rho V^2 C_d C_s C_p$

where

ρ = density of sea-water (1,025 t/m^3)

V = velocity of water over the fore deck (13,5 m/sec)

C_d = shape coefficient (0,5 for pipes,1,3 for air pipe or ventilator heads in general and 0,8 for an air pipe or ventilator head of cylindrical form with its axis in the vertical direction)

C_s = slamming coefficient (3,2)

C_p = protection coefficient (0,7 for pipes and ventilator heads located immediately behind a breakwater or forecastle and 1,0 elsewhere and immediately behind a bulwark).

5.2.2 Forces acting in the horizontal direction on the pipe and its closing device may be calculated from 5.2.1 using the largest projected area of each component.

5.3 Strength requirements

5.3.1 Bending moments and stresses in air and ventilator pipes are to be calculated at critical positions:

- at penetration pieces;
- at weld or flange connections; and
- at toes of supporting brackets.

5.3.2 Bending stresses in the net section are not to exceed $0{,}8\sigma_y$, where σ_y is the specified minimum yield stress or 0,2 per cent proof stress of the steel at room temperature. Irrespective of corrosion protection, a corrosion addition to the net section of 2,0 mm is then to be applied.

5.3.3 For standard air pipes of 760 mm coaming height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in Table 12.5.1. Where brackets are required, three or more radial brackets are to be fitted. Brackets are to be of gross thickness 8 mm or more, of minimum length 100 mm, and height according to Table 12.5.1 but need not extend over the joint flange for the head. Bracket toes at the deck are to be suitably supported.

5.3.4 For other configurations, loads according to 5.2 are to be applied, and means of support determined in order to comply with the requirements of 5.3.1 and 5.3.2. Brackets, where fitted, are to be of suitable thickness and length according to their height. Pipe thickness is not to be taken less than as indicated in Pt 5, Ch 12.

5.3.5 For standard ventilators of 900 mm coaming height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in Table 12.5.2. Brackets, where required, are to be as specified in 5.3.3.

Table 12.5.1 Air pipe thickness and bracket standards

Nominal pipe diameter, in mm	Minimum fitted gross thickness, in mm	Maximum projected area of head, in cm^2	Height(1) of brackets, in mm
65A	6,0	—	480
80A	6,3	—	460
100A	7,0	—	380
125A	7,8	—	300
150A	8,5	—	300
175A	8,5	—	300
200A	8,5(2)	1900	300(2)
250A	8,5(2)	2500	300(2)
300A	8,5(2)	3200	300(2)
350A	8,5(2)	3800	300(2)
400A	8,5(2)	4500	300(2)

(1) Brackets (*see* 5.3.3) need not extend over the joint flange for the head.

(2) Brackets are required where the as fitted (gross) thickness is less than 10,5 mm, or where the tabulated projected head area is exceeded.

NOTE
For other pipe heights, the relevant requirements of 5.3 are to be applied.

Table 12.5.2 900 mm Ventilator pipe thickness and bracket standards

Nominal pipe diameter, in mm	Minimum fitted gross thickness, in mm	Maximum projected area of head, in cm^2	Height of brackets, in mm
80A	6,3	—	460
100A	7,0	—	380
150A	8,5	—	300
200A	8,5	550	—
250A	8,5	880	—
300A	8,5	1200	—
350A	8,5	2000	—
400A	8,5	2700	—
450A	8,5	3300	—
500A	8,5	4000	—

NOTE
For ventilator heights other than 900 mm, the relevant requirements of 5.3 are to be applied.

5.3.6 For ventilators of coaming height greater than 900 mm, the coaming support will be specially considered. Pipe thickness is not to be taken less than as indicated in Pt 5, Ch 12.

5.3.7 All component parts and connections of the air pipe or ventilator are to be capable of withstanding the loads defined in 5.2.

5.4 Ventilator coamings

5.4.1 The heights of ventilator coamings is to be not less than 900 mm, this height being measured above deck sheathing, where fitted. In particularly exposed positions, the heights of coamings and scantlings may be required to be increased.

5.4.2 The height of ventilator coamings may be required to be increased on ships of Type 'A', Type 'B-100' and Type 'B-60' where this is shown to be necessary by the floatability calculations required by the *International Convention on Load Lines, 1966.*

5.4.3 For gooseneck ventilators, the coaming height is to be measured to the underside of the bend, this being the lowest point through which water on deck could pass freely to spaces below.

5.4.4 Where wall vents are fitted with an internal baffle which rises above the lower edge of the exterior opening, the coaming height is measured to the top of the baffle.

5.4.5 Where permitted by the National Authority, ventilator coaming heights may be reduced on ships engaged on protected or extended protected water service. Coaming heights are to be as high as practicable, with a minimum height of 450 mm.

5.5 Height of air pipes

5.5.1 The height of air pipes from the upper surface of decks exposed to the weather, to the point where water may have access below is normally to be not less than 760 mm, this height being measured above deck sheathing, where fitted.

5.5.2 Lower heights may be approved in cases where these are essential for the working of the ship, provided that the design and arrangements are otherwise satisfactory. In such cases, efficient, permanently attached closing appliances of an approved automatic type will generally be required.

5.5.3 The height of air pipes may be required to be increased on ships of Type 'A', Type 'B-100' and Type 'B-60' where this is shown to be necessary by the floatability calculations required by the *International Convention on Load Lines, 1966.* An increase in height may also be required or recommended by individual Administrations when air pipes to oil fuel and settling tanks are situated in positions where sea-water could be temporarily entrapped, e.g. in recesses in the sides and ends of superstructures or deckhouses, between hatch ends, behind high sections of bulwark, etc. This may entail an increase in tank scantlings, *see also* Chapter 3.

5.5.4 Air pipes are generally to be led to an exposed deck. For alternative arrangements in an enclosed space on a main vehicle deck, *see* Pt 4, Ch 2,9.

5.5.5 Where air pipes are led through the side of super-structures, the opening is to be at least 2,3 m above the summer load waterline.

5.5.6 Where permitted by the National Authority, air pipe coaming heights may be reduced on ships engaged on protected or extended protected water service. Coaming heights are to be as high as practicable, with a minimum height of 450 mm.

5.6 Closing appliances for ventilators

5.6.1 All ventilator openings are to be provided with efficient weathertight closing appliances unless the height of the coaming is greater than 4,5 m.

5.6.2 In ships where the load line length, L_L (*see* Ch 1,6.1), is not more than 100 m, the closing appliances are to be permanently attached to the ventilator coaming. Where not so provided in other ships, they are to be conveniently stowed near the ventilator to which they are to be fitted.

5.6.3 Where, in ferries, ventilators are proposed to be led overboard in an enclosed 'tween deck, the closing arrangements are to be submitted for approval. If such ventilators are led overboard more than 4,5 m above the main vehicle deck, closing appliances may be omitted, provided that satisfactory baffles and drainage arrangements are provided, as in the case of air intakes or exhaust openings for machinery spaces, which may be arranged in the sides of the ship.

5.6.4 On offshore supply ships, to ensure satisfactory operation in all weather conditions, machinery space ventilation inlets and outlets are to be located in such positions that closing appliances will not be necessary.

5.6.5 Rotating type mushroom ventilator heads are unsuitable for application on the exposed fore deck.

5.6.6 Wall ventilators (jalousies) may be accepted provided they are capable of being closed weathertight by hinged steel gasketed covers secured by bolts or toggles.

5.6.7 A ventilator head not forming part of the closing arrangements is to be not less than 6,5 mm thick.

5.7 Closing appliances for air pipes

5.7.1 All openings of air pipes are to be provided with permanently attached, satisfactory means of closing to prevent the free entry of water, *see also* 5.5.2.

5.7.2 Closing appliances are to be of an approved automatic type where, with the ship at its summer load water-line, the openings are immersed at an angle of heel of 40° or, the angle of down flooding if this is less than 40°, *see also* Ch 3,7.

5.7.3 Where the closing appliances are not of an automatic type, provision is to be made for relieving vacuum when the tanks are being pumped out.

5.7.4 In a ship to which timber freeboards are assigned, air pipes which will be inaccessible when the deck cargo is carried are to be provided with approved automatic closing appliances.

5.7.5 Pressure/vacuum valves as required by Pt 5, Ch 15,4 may be accepted as closing appliances for cargo tanks.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all the ship types detailed in Part 4, and requirements are given for rudders, nozzles, steering gear, bow and stern thrust unit structure, stabilizer structure, anchoring and mooring equipment, and emergency towing arrangements.

1.1.2 The requirements in this Chapter are not applicable to Double Hull Oil Tankers or Bulk Carriers with a **CSR** notation (*see* Pt 1, Ch 2,2.3) with the exception of the following:

- For Double Hull Oil Tankers; Sections 2 to 6 and Section 8 are to be complied with as applicable.
- For Bulk Carriers; Sections 3-6, 8 and 9 are to be complied with as applicable.

1.2 General symbols

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

L, B and C_b as defined in Ch 1,6.1

σ_o = minimum yield stress or 0,5 per cent proof stress of the material, in N/mm^2 (kgf/mm^2)

k = higher tensile steel factor, *see* Ch 2,1.2.

1.3 Navigation in ice

1.3.1 Where an ice class notation is included in the class of a ship, additional requirements are applicable as detailed in Chapter 9.

1.4 Materials

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

■ *Section 2* Rudders

2.1 Lateral force on rudder blade

2.1.1 The lateral rudder force at the centre of pressure is to be determined for both ahead and stern conditions from the following formula:

$$P_L = 132 c_1 c_2 c_3 C_{TH} A_R V^2 \quad \text{N}$$

where

A_R = rudder blade area, in m^2

A_T = sum of rudder blade area A_R and area of rudder post or rudder horn, if any, within the rudder mean height h_R, in m^2

c_1 = factor depending on the aspect ratio λ of the rudder area

$= \dfrac{\lambda + 2}{3}$

c_2 = rudder profile coefficient, *see* Table 13.2.1

c_3 = 1,0 in general

= 0,8 for rudders outside the propeller jet

= 1,15 for rudders behind a fixed propeller nozzle

C_{TH} = thrust coefficient, is generally to be taken as 1

P_L = lateral force acting on the rudder, in N, is to be calculated for both ahead and astern conditions. The greater of these two values is to be used throughout Section 2

V = maximum service speed, in knots, which the ship is designed to maintain, at the summer load waterline. Maximum ahead service speed means the maximum service speed which the ship is designed to maintain, at the summer load waterline at maximum propeller RPM and corresponding engine MCR. When the speed is less than 10 knots, V is to be replaced by the expression $V_{min} = \dfrac{V + 20}{3}$. For the astern condition the actual astern speed, in knots, or 0,5V, whichever is the greater is to be used (for bow rudders $V = V_A$)

$\lambda = \dfrac{h_R^2}{A_T}$, but not to be taken greater than 2

h_R = mean height, in metres, of the rudder area, *see* Fig. 13.2.2.

Table 13.2.1 Rudder profile coefficient, c_2

Profile type (*see* Fig. 13.2.1)	Ahead	Astern
NACA-00	1,1	0,8
Hollow profiles	1,35	0,9
Flat side profiles	1,1	0,9
High lift profile	1,7	to be specially considered

NOTE
For rudder profiles not defined above, the value of c_2 may be determined on the basis of experimental results. These results are to be submitted for consideration.

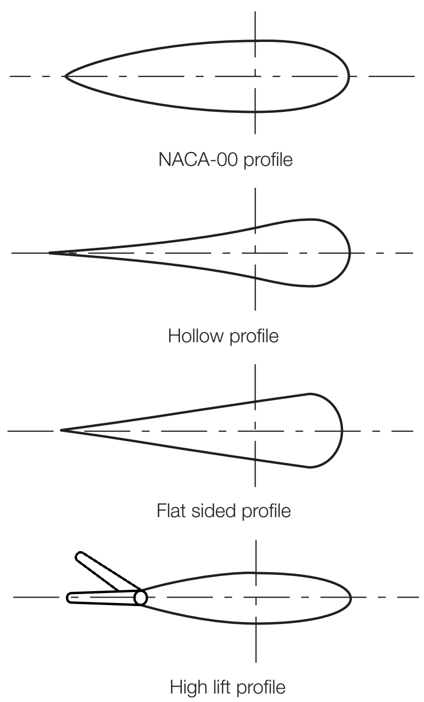


Fig. 13.2.1 Rudder profiles

2.2 Rudder torque calculation for rudders without cut-outs

2.2.1 The rudder torque, M_T, is to be determined for both the ahead and astern conditions according to the following formula:

$M_T = P_L x_P$ Nm

where

P_L = lateral force acting on rudder, as calculated in 2.1

x_P = $b_R(\alpha - k)$, in metres, but not less than $0{,}1 b_R$

b_R = mean breadth of rudder, in metres, *see* Fig. 13.2.2

α = as given in Table 13.2.2

$k = \dfrac{A_f}{A_R}$

A_f = portion of the rudder blade area, situated in front of the centreline of the rudder stock, in m^2, *see* Fig. 13.2.2.

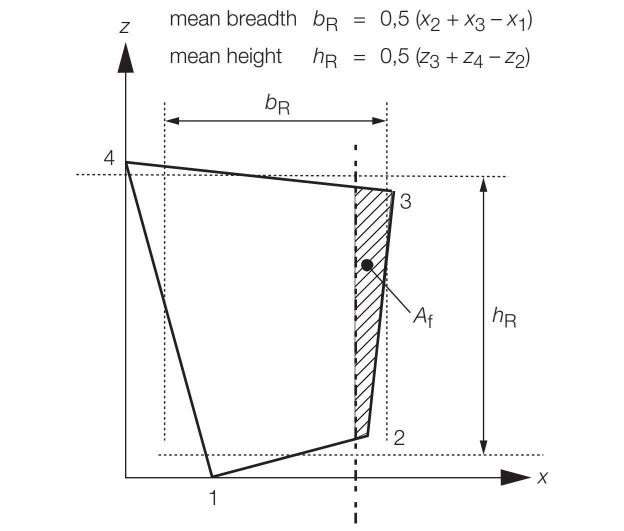


Fig. 13.2.2 Rudder co-ordinate system

Table 13.2.2 Coefficient, α

Condition	Behind fixed structure (see Note)	Not behind a fixed structure
Ahead	0,25	0,33
Astern	0,55	0,66

NOTE
For rudder parts behind a fixed structure such as a rudder horn.

2.3 Rudder torque calculation for rudders with cut-outs

2.3.1 The rudder torque, M_T, is to be determined for both the ahead and astern conditions as follows. The rudder area, A_R, used in the derivation of the rudder torque may be divided into two rectangular or trapezoidal parts with areas A_1 and A_2, so that $A_R = A_1 + A_2$, *see* Fig. 13.2.3.

$M_T = M_1 + M_2$ Nm

where

$M_1 = P_{L1} x_{P1}$ Nm

$M_2 = P_{L2} x_{P2}$ Nm

M_T = the rudder torque, in Nm, to be calculated for both ahead and astern conditions. The greater of these two values are to be used throughout Section 2

P_L = lateral force acting on the rudder, in N, as calculated in 2.1.1

$P_{L1} = \dfrac{A_1}{A_R} P_L$ N

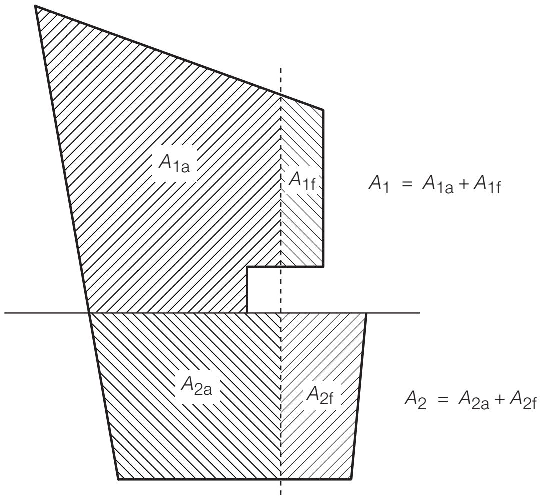


Fig. 13.2.3 Rudder areas

$$P_{L2} = \frac{A_2}{A_R} P_L \quad \text{N}$$

x_{P1} = b_{R1} ($\alpha - k_1$), in metres
x_{P2} = b_{R2} ($\alpha - k_2$), in metres
A_1 = $A_{1a} + A_{1f}$, in m^2, *see* Fig. 13.2.3
A_2 = $A_{2a} + A_{2f}$, in m^2, *see* Fig. 13.2.3
b_{R1} = mean breadth, in metres, of partial area A_1
b_{R2} = mean breadth, in metres, of partial area A_2
α = as given in Table 13.2.2

$$k_1 = \frac{A_{1f}}{A_1}$$

$$k_2 = \frac{A_{2f}}{A_2}$$

For ahead condition M_T is not to be taken less than

$$M_{T,min} = 0{,}1 P_L \frac{A_1\, b_{R1} + A_2\, b_{R2}}{A_R} \quad \text{Nm}$$

2.4 Rudder stock and main bearing

2.4.1 The scantlings of the stock are to be not less than required by Table 13.2.3.

2.4.2 For the purpose of this Section, the material factor, k_o, applicable to rudder stocks, pintles, coupling flanges, bolts, keys, etc., is defined in Table 13.2.4. For higher tensile steel rudder stocks, welding, including cladding, is not generally permitted.

2.4.3 The rudder stock diameter is to be dimensioned such that the stresses do not exceed the permissible stresses given in Table 13.2.5.

Table 13.2.3 Rudder stock diameter

Item	Requirement
(1) Basic stock diameter, δ_S, at and below lowest bearing	$\delta_S = \delta_t \sqrt[6]{1 + \frac{4}{3}\left(\frac{M_B}{M_T}\right)^2}$ mm
(2) Diameter, δ_t, in way of tiller	$\delta_t = 4{,}2 \sqrt[3]{M_T\, k_0}$ mm
Symbols	
M_T = Total rudder torque, in Nm, as calculated in 2.2 or 2.3 M_B = bending moment, in Nm, at section considered. If direct calculations of bending moment distribution are not carried out, then M_B at the lowest main bearing or rudder coupling may be taken as: $M_B = \frac{h_R}{10 C_r} P_L$, for rudders with heel support $M_B = b P_L$, for spade rudders $M_B = \frac{h_R}{10\,(1 + C_r)} P_L$, for semi-spade rudders $C_r = \frac{b_R{}^2}{A_R}$ b = distance, in metres, from centroid of rudder area to the centre of lowest bearing, *see* Fig. 13.2.4 b_R = mean breadth of rudder, in metres, *see* Fig. 13.2.2 h_R = mean depth of rudder, in metres, *see* Fig. 13.2.2 P_L = rudder force, as defined in 2.1.1 k_o = as defined in Table 13.2.4	

Table 13.2.4 Material factor k_o

σ_o	k_o
For σ_o > 235 (24)	$\left(\frac{235}{\sigma_o}\right)^{0,75}$ $\left(\frac{24}{\sigma_o}\right)^{0,75}$
For $\sigma_o \le$ 235 (24)	$\left(\frac{235}{\sigma_o}\right)$ $\left(\frac{24}{\sigma_o}\right)$
Symbols	
σ_o = minimum yield stress in N/mm^2 (kgf/mm^2) k_o = higher tensile steel correction factor	
NOTE σ_o is to be taken not greater than 70 per cent of the ultimate tensile strength or 450 N/mm^2 (45,9 kgf/mm^2), whichever is the lesser. σ_o is not to be less than 200 N/mm^2, *see* Ch 5,2.4.6 of the Rules for Materials.	

2.4.4 Where reductions in rudder stock diameter due to the application of steels with yield stresses exceeding 235 N/mm^2 are requested, evaluation of the rudder stock deformations may be required. Large deformations are to be avoided in order to avoid excessive edge pressures in way of bearings.

Table 13.2.5 Permissible stresses

Mode	Permissible stress, N/mm^2	(kgf/mm^2)
(1) Torsional shear stress, τ_T	$68/k_0$	$(6,9/k_0)$
(2) Equivalent stress, σ_e	$118/k_0$	$(12/k_0)$

Symbols and parameters

σ_T = equivalent stress

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

σ_b = bending stress

= $10,2 \dfrac{M_B}{\delta_s{}^3} 10^3$ N/mm^2 $\left(1,04 \dfrac{M_B}{\delta_s{}^3} 10^3 \text{ kgf/mm}^2\right)$

τ_T = torsional shear stress

= $5,1 \dfrac{M_T}{\delta_s{}^3} 10^3$ N/mm^2 $\left(0,52 \dfrac{M_T}{\delta_s{}^3} 10^3 \text{ kgf/mm}^2\right)$

δ_S = actual stock diameter, as calculated in Table 13.2.3

M_B = bending moment, in Nm, at the section considered. If direct calculations of bending moment distribution are not carried out, then M_B at the lowest main bearing or rudder coupling may be taken as given in Table 13.2.3

M_T = total rudder torque, in Nm, as calculated in 2.2 or 2.3

k_o = as defined in Table 13.2.4

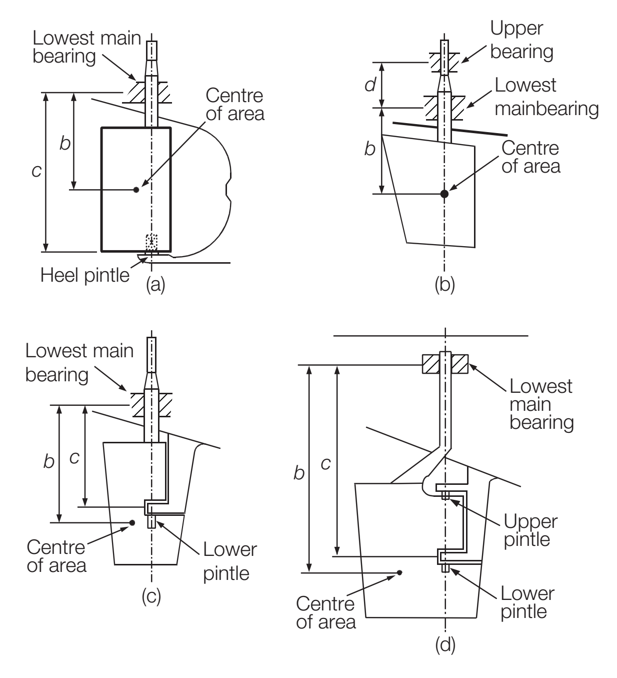


Fig. 13.2.4
Centroid of rudder area for common rudder types

2.4.5 For spade rudders the stock diameter corrected for higher tensile steel is to be greater than 90 per cent of the uncorrected stock diameter unless direct calculations are submitted showing that the slope of the stock at the lowest main bearing does not exceed 0,0035 when the rudder blade is loaded by a lateral force of P_L, acting at the centre of pressure.

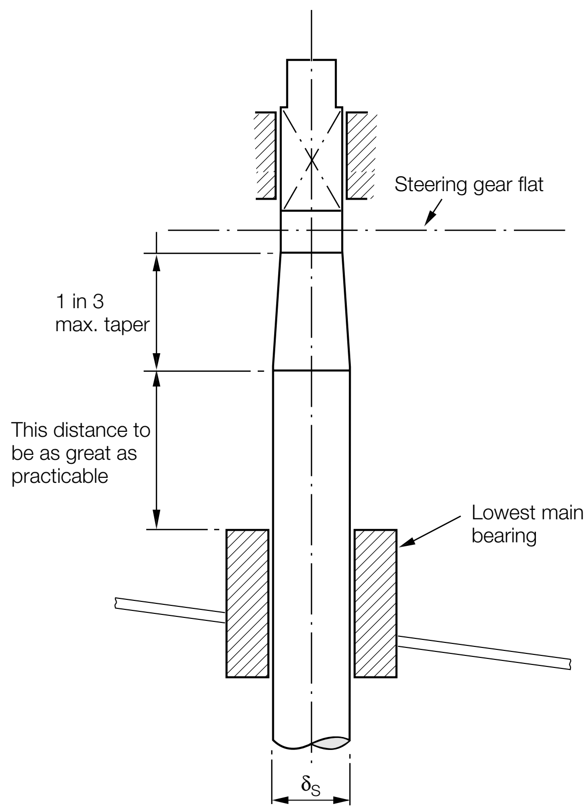


Fig. 13.2.5 Rudder stock taper

Table 13.2.6 Bearing requirements for rudder stock and pintles

Item	Requirement	
(1) Bearing surface area	$A_B = \dfrac{B}{q_a}$ mm^2	
(2) Bearing length	The length/diameter ratio of the actual bearing surface is not to be greater than 1,2	
(3) Clearance	Bearing material	Minimum clearance (on diameter)
	Metal	$0{,}001\delta + 1{,}0$
	Synthetic	*See* Notes 1, 3, 4 and 5
(4) Rudder stock main bearing wall thickness	Lesser of $0{,}2\delta$ or 100	*See* Note 2
(5) Gudgeon thickness in way of pintle (measured outside bush if fitted)	$b_G \geq 0{,}25\delta$ but need not normally exceed 125 mm	

Symbols

A_B = bearing surface area, in mm^2, defined as the projected area (length x diameter) of liner
b = distance, in metres, from centre of rudder area to the centre of lowest bearing
b_G = thickness of gudgeon material in way of pintle, in mm
c = distance, in metres, from centre of lower pintle to the centre of lowest bearing
d = distance, in metres, from centre of lowest bearing to the centre of upper bearing. In the case of semi spade rudder with two pintles, d, is to be measured between the centre of upper pintle and centre of upper bearing
δ = diameter of stock, δ_S, given in Table 13.2.3, or pintle, δ_{PL}, given in Table 13.2.11, in mm
l_B = length of bearing, in mm
q_a = maximum surface pressure, *see* Table 13.2.7
B = bearing force, in N. If direct calculations are not carried out, the bearing force at various positions can be taken as:
$B_2 = \left(1 - \dfrac{b}{c}\right)P_L$, at lowest main bearing for single pintle rudders and semi-spade rudders, *see* Fig. 13.2.4(a), (c) and (d). B_2 is not to be less than $0{,}35P_L$
$B_2 = P_L + B_3$, at lowest main bearing for spade rudders, *see* Fig. 13.2.4(b).
$B_3 = \dfrac{M_B}{d}$, at upper bearing for spade rudders, *see* Fig. 13.2.4(b). For bearing force at pintles, see Table 13.2.11.

NOTES
1. If non-metallic bearing material is applied, the bearing clearance is to be specially determined considering the material's swelling and thermal expansion properties. This clearance is normally not to be less than 1,5 mm on bearing diameter.
2. Where web stiffening is fitted on the bearing, a reduction in wall thickness will be considered.
3. For bearings which are pressure lubricated the clearance must be restricted to enable the pressure to be maintained.
4. The value of the proposed minimum clearance is to be indicated on plans submitted for approval.
5. Proposals for higher pressures or other materials will be specially considered on the basis of satisfactory test results.

2.4.6 For rudders having an increased diameter of the rudder stock in way of the rudder, the increased diameter is to be maintained to a point as far as practicable above the top of the lowest bearing. The diameter may then be tapered to the diameter required in way of the tiller. The length of the taper is to be at least three times the reduction in diameter. Particular care is to be taken to avoid the formation of a notch at the upper end of the taper, *see* Fig. 13.2.5.

2.4.7 Sudden changes of section or sharp corners in way of the rudder coupling, jumping collars and shoulders for rudder carriers, are to be avoided. Jumping collars are not to be welded to the rudder stock. Keyways in the rudder stock are to have rounded ends and the corners at the base of the keyway are to be radiused. For stainless steel liners formed by weld deposit, *see* 2.8.3.

2.4.8 The design of the lowest bearing is to comply with the requirements of Table 13.2.6. Fitting of bearings is to be carried out in accordance with the bearing manufacturer's recommendations to ensure that they remain secure under all foreseen operating conditions.

Table 13.2.7 Maximum surface pressure

Bearing material	q_a (N/mm^2) (*see* Note 1)
Lignum vitae	2,5
White metal, oil lubricated	4,5
Synthetic material with hardness between 60 and 70 Shore D (*see* Note 2)	5,5
Steel (*see* Note 3) and bronze and hotpressed bronze-graphite materials	7,0

NOTES
1. Proposals for higher pressures will be specially considered on the basis of satisfactory test results.
2. Indentation hardness test at 23°C and with 50% moisture, according to a recognized standard. Synthetic bearing materials are to be of an approved type.
3. Stainless and wear-resistant steel in an approved combination with stock liner.

2.4.9 On dredging and reclamation craft classed **A1 protected water service**, the rudder stock diameter may be 84 per cent of that required for ships classed **100A1**.

2.5 Rudder construction – Double plated

2.5.1 The scantlings of a double plated rudder are to be not less than required by Table 13.2.8.

Table 13.2.8 Single and double plated rudder construction

Type	Item	Requirement
Double plated rudder construction	(1) Rudder side, top and bottom plating	$t = 5{,}5 s_{min}\, s_e \sqrt{\left(T + \dfrac{P_L\, 10^{-4}}{A_R}\right) k} + 2{,}5$ mm
	(2) Webs vertical and horizontal	t_W = 0,7t from (1) but is not to be less than 8 mm
	(3) Nose plate	t_N = 1,25t from (1) but need not exceed 22 mm
	(4) Mainpiece fabricated rectangular, *see* Note 1	Breadth and width $\geq \delta_S$ $t_M = 8{,}5 + 0{,}56\sqrt{\delta_S}\ \sqrt[3]{k}$ mm Minimum fore and aft extent of side plate = 0,2b_R Stress due to bending, *see* Table 13.2.9
	(5) Mainpiece tubular, *see* Note 1	Inside diameter $\geq \delta_S$ t_M as for (4) Side plating as for (1) Bending stress as for (4)
	(6) Mainpiece semi-spade (Mariner) type rudders in way of lower pintle regions, *see* Note 2	Bending moment applied at section 'AA' (*see* Fig. 13.2.6) by the underhung position to result in stresses not greater than those given in Table 13.2.9
Single plated rudder construction	(7) Blade thickness	$t_B = 0{,}0015 V\, y_w + 2{,}5$ mm with a minimum of 10 mm
	(8) Arms	Spacing ≤ 1000 mm $Z_A = 0{,}0005\, V^2 x_a^2\, y_w$ cm^3 thickness = t_B in mm with a minimum of 10 mm
	(9) Mainpiece	Diameter $\geq \delta_S$ for spade rudders, the lower third may be tapered down to 0,75δ_S mm at the bottom end

Symbols

b_R = mean breadth of rudder at centreline of stock, in mm
k = *see* Note 3
$s_e = \sqrt{1{,}1 - 0{,}5\left(\dfrac{s_{min}}{s_{max}}\right)^2}$ but not more than 1,00 if $s_{max}/s_{min} \geq 2{,}5$
s_{max} = greatest unsupported width of plating, in metres
s_{min} = smallest unsupported width of plating, in metres
t = thickness, in mm
t_W = thickness of webs, in mm
t_M = thickness of side plating and vertical webs forming mainpiece, in mm
t_N = thickness of nose plate, in mm
x_a = horizontal distance from the aft edge of the rudder to the centre of the rudder stock, in metres
y_w = vertical spacing of rudder arms, in mm. Not to exceed 1000 mm
A_R = rudder area, in m^2
P_L = rudder force, as defined in 2.1.1
T = as given in Pt 3, Ch 1,6.1
V = as defined in 2.1.1
Z_A = section modulus of arm, in cm^3
δ_S = basic stock diameter, given by Table 13.2.3, in mm

NOTES
1. The value of the basic stock diameter δ_S, used in (4) and (5), is that for mild steel, as given in Table 13.2.3.
2. The effective breadth of the side plate may be taken as 0,16h_R.
3. For higher tensile steels, the material factor k = 0,78 for steels with δ_y = 315 N/mm^2 and k = 0,72 for steels with δ_y = 355 N/mm^2.

2.5.2 The rudder is to be dimensioned such that the stresses do not exceed the permissible stresses given in Table 13.2.9.

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

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

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

(b) The thickness of the main vertical web is to be not less than two times the thickness required by Table 13.2.8(4) from the top of the rudder to the lower pintle. The thickness is to be not less than required by Table 13.2.8(4) from the lower pintle to approximately a point midway between the lower pintle and bottom of the rudder. Below this the thickness, t_2, is to be not less than the thickness required by Table 13.2.8(2). *See* Fig. 13.2.6.

(c) Where an additional continuous main vertical web is arranged to form an efficient box mainpiece structure, the thickness of each web is to be not less than that required by Table 13.2.8(4) from the top of the rudder to approximately a point midway between the lower pintle and bottom of the rudder. Below this the thickness, t_2, is not to be less than that required by Table 13.2.8(2).

(d) The internal radius, r, of the cut-out for the rudder pintle is to be as large as practicable. *See* Fig. 13.2.6.

(e) To reduce the notch effect at the corners of the cut-out for the lower pintle, an insert plate 1,6 times the Rule thickness of the side plating is to be fitted. The insert plate is to extend aft of the main vertical web and to have well rounded corners.

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

Table 13.2.9 Permissible stresses for rudder blade scantlings

Item	Permissible stresses, in N/mm^2 (kgf/mm^2)		
	Bending stress	Shear stress	Equivalent stress
Rudder blades clear of cut-outs, *see* Fig. 13.2.2	$\frac{110}{k}$ $\left(\frac{11,2}{k}\right)$	$\frac{50}{k}$ $\left(\frac{5,1}{k}\right)$	$\frac{120}{k}$ $\left(\frac{12,2}{k}\right)$
Rudder blades in way of cut-outs, *see* Fig. 13.2.2 and Note	$\frac{75}{k}$ $\left(\frac{7,6}{k}\right)$	$\frac{50}{k}$ $\left(\frac{5,1}{k}\right)$	$\frac{100}{k}$ $\left(\frac{10,2}{k}\right)$
Symbols			
k is as defined in 1.2.1			
NOTE Requirements in way of cut-outs apply to semi-spade/mariner type rudders.			

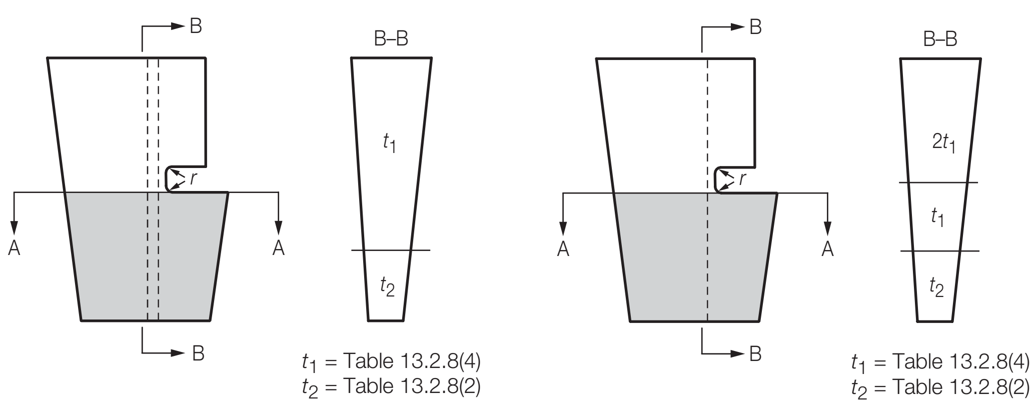


Fig. 13.2.6 Main vertical web thickness

2.5.6 Connection of rudder side plating to vertical and horizontal webs, where internal access for welding is not practicable, is to be by means of slot welds on to flat bars on the webs. The slots are to have a minimum length of 75 mm and, in general, a minimum width of twice the side plating thickness. The ends of the slots are to be rounded. The space between the slots is not to exceed 150 mm and welding is to be based on a weld factor of 0,44.

2.5.7 For testing of rudders, *see* Table 1.8.1 in Chapter 1.

2.5.8 Where the fabricated mainpiece of a spade rudder is connected to the horizontal coupling flange by welding, a full penetration weld is required.

2.6 Rudder construction – Single plated

2.6.1 The scantlings of a single plated rudder are to be not less than required by Table 13.2.8.

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

2.7 Rudder couplings

2.7.1 Rudder coupling design is to be in accordance with Table 13.2.10.

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

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

2.7.4 For a spade rudder, the fillet radius between the rudder stock and the flange is to conform to the requirements of Fig. 13.2.7. Where space permits between the upper face of the flange and the lowest main bearing, it is preferable to use a compound fillet design of the parabolic or Morgenbrod form having similar dimensions to those of Fig. 13.2.7. Alternative arrangements will be specially considered.

2.7.5 The connecting bolts for coupling the rudder to the rudder stock are to be positioned with sufficient clearance to allow the fitting and removal of the bolts and nuts without contacting the palm radius, *R*, *see* Fig. 13.2.8(a). The surface forming the palm radius is to be free of hard and sharp corners and is to be machined smooth to the Surveyor's satisfaction. The surface in way of bolts and nuts is to be machined smooth to the Surveyor's satisfaction.

2.7.6 For spade rudders fitted with a fabricated rectangular mainpiece, the mainpiece is to be designed with its forward and aft transverse sections at equal distances forward and aft of the rudder stock transverse axis, *see* Fig. 13.2.8(b).

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

2.7.8 Where a keyed conical fitting of a rudder stock to a rudder is proposed, a securing nut is to be provided. Minimum dimensions for the securing nut are given in Table 13.2.10. After final fitting of the stock to the rudder, positive means are to be used for locking this nut.

2.7.9 Guidelines for keys and keyways are given in Table 13.2.10.

2.8 Pintles

2.8.1 Rudder pintles and their bearings are to comply with the requirements of Table 13.2.11.

2.8.2 The distance between the lowest rudder stock bearing and the upper pintle should be as short as possible.

2.8.3 Where liners are fitted to pintles, they are to be shrunk on or otherwise efficiently secured. If liners are to be shrunk on, the shrinkage allowance is to be indicated on the plans. Where liners are formed by stainless steel weld deposit, the pintles are to be of weldable quality steel and details of the procedure are to be submitted, *see also* 2.9.7.

2.8.4 The bottom pintle on semi-spade (Mariner) type rudders and all pintles over 500 mm in diameter are:

(a) if inserted into their sockets from below, to be keyed to the rudder or sternframe as appropriate or to be hydraulically assembled, with the nut adequately locked, or

(b) if inserted into their sockets from above, to be provided with an appropriate locking device, the nut being adequately secured.

2.8.5 Fitting of pintle bearings is to be carried out in accordance with the bearing manufacturer's recommendations to ensure that they remain secure under all foreseen operating conditions.

2.8.6 Where an ***IWS** (In-water Survey) notation is to be assigned (*see* Pt 1, Ch 2,2.3.11), means are to be provided for ascertaining the rudder pintle and bush clearances and for verifying the security of the pintles in their sockets with the vessel afloat.

Table 13.2.10(a) Rudder couplings to stock – Bolted couplings

Item	Requirement	
	Horizontal coupling	Vertical coupling
Number of bolts in coupling	$n \geq 6$	$n \geq 8$
Diameter of coupling bolts	$\delta_b = 0{,}62\sqrt{\dfrac{\delta_S{}^3\, k_b}{l_a\, n\, k_S}}$	$\delta_b = 0{,}81\delta_S\sqrt{\dfrac{k_b}{n\, k_S}}$
First moment of area of bolts about centre of coupling	$m = 0{,}00071 n\, \delta_S\, \delta_b{}^2\sqrt{\dfrac{k_b}{k_S}}$	$m = 0{,}00043\delta_S{}^3\sqrt{\dfrac{k_b}{k_S}}$
Thickness of coupling flange	$t_f = \delta_b\sqrt{\dfrac{k_b}{k_S}}$ (*see* Notes 1 & 2)	$t_f = \delta_b$
Stress concentration factor for as built scantlings	$\alpha_{as\ built} \leq \alpha_{max}$ (*see* Note 3)	—
Maximum allowable stress concentration factor	$\alpha_{max} = (53{,}82 - 35{,}29 k_{max})\dfrac{\delta_S{}^3}{hP_L\, 10^3} - \left(1{,}8 - 6{,}3\dfrac{R}{\delta_S}\right)\dfrac{t_f - t_{fa}}{t_{fa}}$ (*see* Note 3)	—
Width of flange material outside the bolt holes	$w_f = 0{,}67\delta_b$	$w_f = 0{,}67\delta_b$

Symbols

$\alpha_{as\ built}$ = stress concentration factor for as built scantlings

$= \dfrac{0{,}73}{\sqrt{\dfrac{R}{\delta_S}}}$

α_{max} = maximum allowable stress concentration factor
δ_b = diameter of coupling bolts, in mm
δ_S = basic stock diameter as defined in Table 13.2.3, in mm
b_f = breadth of the flange, in mm
h = vertical distance, in metres, between the centre of pressure and the centre point of the palm radius, *see* Fig. 13.2.8
k_b = coupling bolt material factor, *see* 2.4.2
k_{max} = the greater of k_s and k_f
k_f = upper coupling flange material factor, *see* 2.4.2
k_S = rudder stock material factor, *see* 2.4.2
l_a = the mean of the horizontal distances between the centres of the bolts and the centre of the coupling, in mm
m = first moment of area of bolts about a longitudinal axis through centre of coupling, in cm^3
n = number of bolts in coupling
P_L = lateral force on rudder as defined in 2.1.1, in N (tonne-f)
R = palm radius, in mm, between the rudder stock and connection flange, *see* 2.7.4 and 2.7.5.
t_f = minimum thickness of coupling flange, in mm
t_{fa} = as built flange thickness, in mm
w_f = width of flange material outside the bolt holes, in mm

NOTES
1. For spade rudders with horizontal couplings, t_f is not to be less than $0{,}33\delta_S\sqrt[3]{k_s}$. The mating plate on the rudder is to have the same thickness as the flange on the stock
2. For a twin spade rudder arrangement with single screw where the rudders are within the slipstream of the propeller:
   (a) the thickness of the palm is not to be less than $0{,}35\delta_S\sqrt[3]{k_s}$
   (b) where the stock is welded to the palm plate, the stock diameter, δ_S is to be increased by 14 per cent.
3 This requirement is applicable only for spade rudders with horizontal couplings, *see* Fig. 13.2.6.

2.8.7 For axle type rudder support used with Simplex rudders, *see* Ch 6,7.

2.9 Ancillary items

2.9.1 Internal surfaces of double plate rudders are to be efficiently coated, and means for draining the rudder are to be provided.

Table 13.2.10(b) **Rudder couplings to stock – Conical couplings** (*see continuation*)

Item	Requirement
Taper of conical coupling on the diameter	$\theta_t \leq \dfrac{1}{K_1}$
Length of taper	$l_t \geq 1{,}5\delta_S$
Required mean grip stress – keyless connection	$p_M = \dfrac{P_R\,\theta_t\,\delta_{CTM} + 4M_T\,10^3\sqrt{K_2\left(\left[\dfrac{P_R\,\delta_{CTM}}{2000M_T}\right]^2 + 1\right) - \left(\dfrac{\theta_t}{2}\right)^2}}{5{,}66\delta_{CTM}^2\,l_t\left(K_2 - \left(\dfrac{\theta_t}{2}\right)^2\right)}$
Required mean grip stress – keyed connection	$p_M = 20$
Corresponding push-up of rudder stock	$w = \dfrac{9{,}6\;10^{-6}\,p_M\,\delta_{CTM}}{\theta_t\left(1 - f_M{}^2\right)}$ $\left(\dfrac{0{,}95\;10^{-4}\,p_M\,\delta_{CTM}}{\theta_t\left(1 - f_M{}^2\right)}\right)$
Corresponding push-up load	Approximately equal to $P_U = 2{,}83p_M\,l_t\,\delta_{CTM}\left(K_3 + \dfrac{\theta_t}{2}\right)$
Corresponding pull-off load	Approximately equal to $P_O = 2{,}83p_M\,l_t\,\delta_{CTM}\left(K_3 - \dfrac{\theta_t}{2}\right)$
Minimum yield stress of stock and gudgeon	$\sigma_o = \dfrac{123\,500\,w\,\theta_t\sqrt{3 + f^4}}{\delta_{CT}}$ $\left(\dfrac{12600\,w\,\theta_t\sqrt{3 + f^4}}{\delta_{CT}}\right)$
Recommended minimum effective sectional area of the key in shear	$A_{key} = \dfrac{M_T\,k_{min}}{3{,}3\delta_{CTM}}$ (*see* Note)
Minimum thickness of key	$\delta_{key} = \dfrac{67A_{key}}{H}$
Minimum dimensions of securing nut	$\delta_g = 0{,}65\delta_S$ $\delta_n = 1{,}2\delta_{SU}$ or $1{,}5\delta_g$ whichever is the greater $h_n = 0{,}6\delta_g$

2.9.2 Where it is intended to fill the rudder with plastic foam, details of the foam are to be submitted.

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

2.9.4 Where a bow rudder is fitted for use when navigating astern, a locking device is to be arranged to ensure that the rudder is kept in the central position when the ship is navigating ahead.

2.9.5 Where the weight of the rudder is supported by a carrier bearing attached to the rudder head, the structure in way is to be adequately strengthened. The plating under all rudder head bearings or rudder carriers is to be increased in thickness.

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

2.9.7 Where it is proposed to use stainless steel for liners or bearings for rudder stocks and/or pintles, the chemical composition is to be submitted for approval. Synthetic rudder bearing materials are to be of a type approved by Lloyd's Register (hereinafter referred to as 'LR'). When this type of lining material is used, arrangements to ensure an adequate supply of sea-water to the bearing are to be provided.

Table 13.2.10(b) **Rudder couplings to stock – Conical couplings** (*conclusion*)

Symbols

h_n = minimum required length of securing nut, in mm, *see* Fig. 13.2.9

$f = \dfrac{\delta_{CT}}{\delta_{GH}}$

$f_M = \dfrac{\delta_{CTM}}{\delta_{GHM}}$

k_{min} = taken as k_0, where σ_0 is the minimum nominal upper yield point of the key, stock or coupling material, in N/mm^2, whichever is less

k_0 = material factor as defined in Table 13.2.3, for the appropriate item

l_t = length of taper, in mm

p_M = required mean grip stress, in N/mm^2

w = corresponding push-up of rudder stock, in mm

A_{key} = recommended minimum effective sectional area of the key in shear, in cm^2

H = length of the key, in mm

M_T = rudder torque, in Nm, as given in Table 13.2.5

P_R = effective weight of rudder, in N (kgf)

P_u, P_0 = corresponding push-up, pull-off loads respectively, in N (kgf)

δ_g = minimum external thread diameter, in mm, *see* Fig. 13.2.9

δ_n = minimum outer diameter of nut, in mm, *see* Fig. 13.2.9

δ_{CT} = diameter of coupling taper in any position, in mm

δ_{CTM} = mean diameter of coupling taper, in mm

$= \dfrac{\delta_S + \delta_{SU}}{2}$

δ_{GH} = external diameter of gudgeon housing at any position, in mm

δ_{GHM} = mean external diameter of gudgeon housing, in mm

δ_{key} = minimum thickness of key. *See* Fig. 13.2.9

δ_S = basic stock diameter as defined in Table 13.2.3, in mm

δ_{SU} = *see* Fig. 13.2.9, in mm

σ_0 = minimum yield stress of stock and gudgeon material, in N/mm^2 (kgf/mm^2) σ_0 is not to be taken greater than 70 per cent of the ultimate tensile strength or 450 N/mm^2 (45,9 kgf/mm^2) whichever is the lesser

θ_t = taper of conical coupling, on the diameter, e.g. $\dfrac{1}{15}$ = 0,067

K_1, K_2, K_3 = constants depending on the type of assembly adopted as follows:

Type of assembly		K_1	K_2	K_3
Oil injection	With key	12	–	0,025
	Without key	15	0,0036	0,025
Dry fit method	With key	8	–	0,170
	Without key	12	0,0072	0,170

NOTE
The keyway is to have a smooth fillet at the bottom of the keyway. The radius of the fillet is to be at least 0,0125 of the diameter of the rudder stock at the top of the cone.

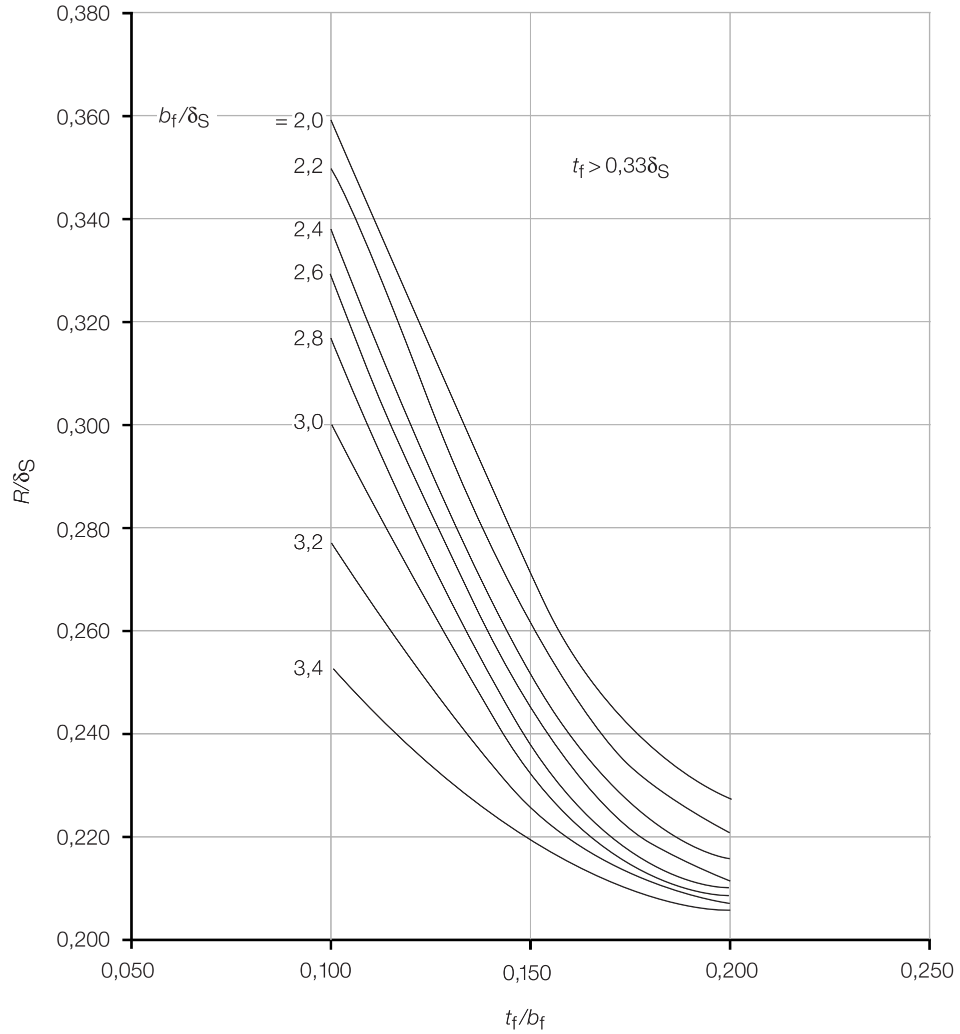


Fig. 13.2.7 Rudder stock horizontal flange fillet radius for spade rudders

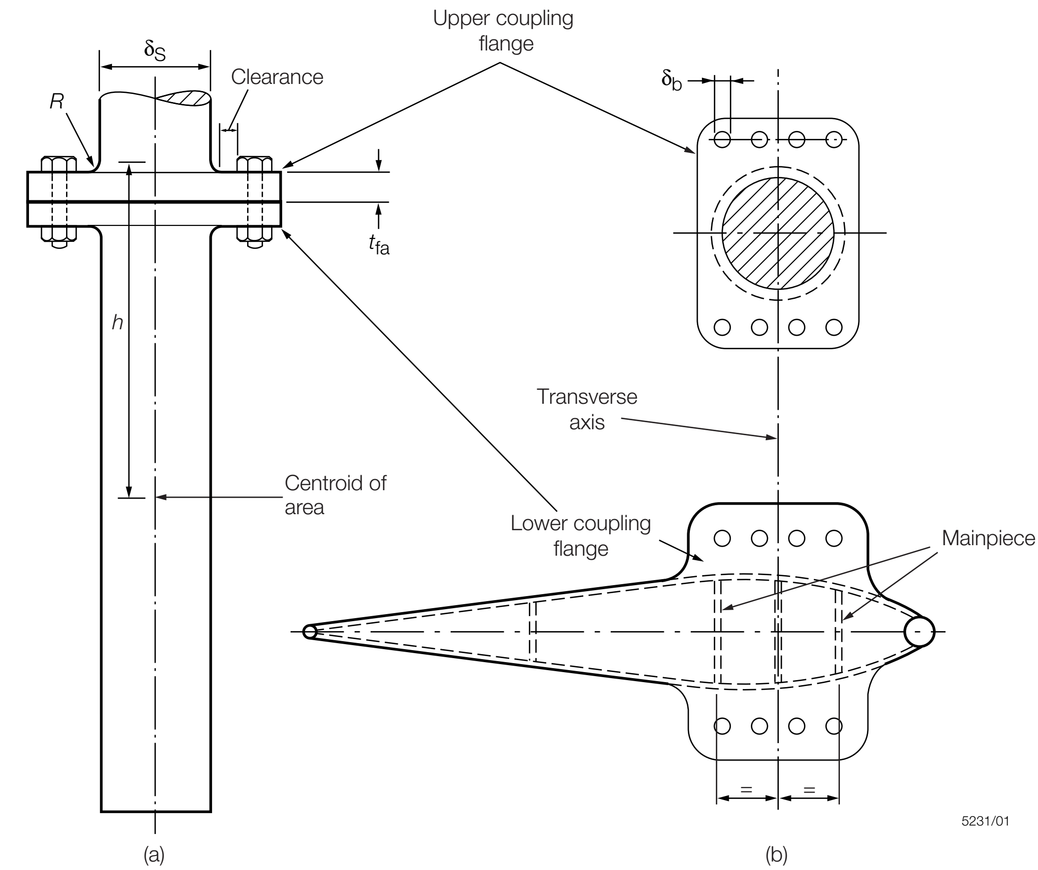


Fig. 13.2.8 Rudder stock connection

Table 13.2.11 Pintle requirements

Item	Requirement	
(1) Pintle diameter (measured outside liner if fitted)	$\delta_{PL} = 0{,}35\sqrt{B\,k_o}$ mm	
(2) Pintle taper	Method of assembly	Taper (on diameter)
	Keyed and other manually assembled pintles	1:8 – 1:12
	Pintles mounted with oil injection and hydraulic nut	1:12 – 1:20
Symbols		

b = distance in metres, from centroid of rudder area to the centre of lowest main bearing, *see* Fig. 13.2.4
c = distance, in metres, from centre of bearing of lower pintle to the centre of lowest main bearing, *see* Fig. 13.2.4
k_o = as defined in Table 13.2.3 or 13.2.4
B = bearing force, in N. If direct calculations are not carried out, the bearing force at various positions can be taken as:

$B_{1L} = \frac{b}{c} P_L$ for single pintle rudders and lower pintle of semi-spade rudders

$B_{1U} = \left(1 - \frac{b}{c}\right) P_L$ at upper pintle on semi-spade rudder. B_{1U} is not to be less than $0{,}35 P_L$

$B = \frac{1}{N_{PL}} P_L$ for rudders with two or more pintles (except semi-spade rudders)

N_{PL} = number of pintles on the rudder
P_L = rudder force, as defined in 2.1.1

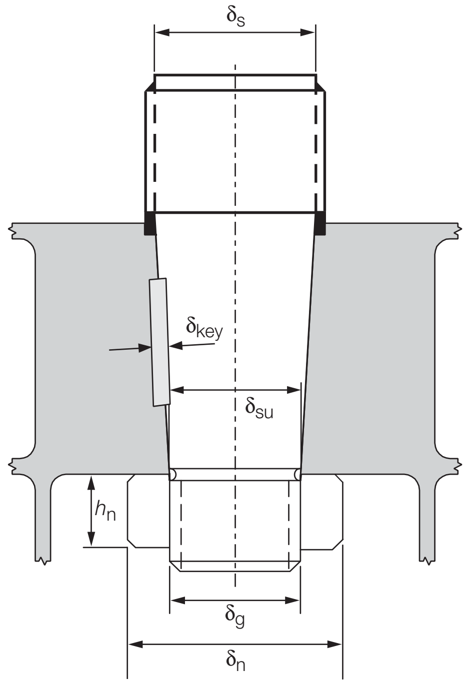


Fig. 13.2.9 Conical coupling

■ *Section 3*
Fixed and steering nozzles

3.1 General

3.1.1 The requirements for scantlings for fixed and steering nozzles are given, for guidance only, in 3.2 to 3.4 and Table 13.3.1.

3.1.2 The requirements, in general, apply to nozzles with a numeral not greater than 200, *see* Table 13.3.1. Nozzles exceeding this value will be specially considered.

3.2 Nozzle structure

3.2.1 For basic scantlings of the structure, *see* Table 13.3.1, in association with Fig. 13.3.1.

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

3.2.3 Fore and aft webs are to be fitted between the inner and outer skins of the nozzle. Both sides of the headbox and pintle support structure are to be connected to fore and aft webs of increased thickness. For thicknesses, *see* Table 13.3.1.

Table 13.3.1 Nozzle construction requirements

Item	Requirement
(1) Nozzle numeral	$N_N = 0{,}01 P \delta_p$ ($N_N = 0{,}00736 H \delta_p$)
(2) Shroud plating in way of propeller blade tips	For $N_N \leq 63 t_s =$ $(11 + 0{,}1 N_N)$ mm For $N_N > 63 t_s =$ $(14 + 0{,}052 N_N)$ mm
(3) Shroud plating clear of blade tips, flare and cone plating, wall thickness of leading and trailing edge members	$t_p = (t_s - 7)$ mm but not less than 8 mm
(4) Webs and ring webs	As item (3) except in way of headbox and pintle support where $t_W = (t_s + 4)$ mm
(5) Nozzle stock	Combined stresses in stock at lower bearing $\leq 92{,}7$ N/mm^2 (9,45 kgf/mm^2) Torsional stress in upper stock $\leq 62{,}0$ N/mm^2 (6,3 kgf/mm^2)
(6) Solepiece and strut	Bending stresses not to exceed 70,0 N/mm^2 (7,1 kgf/mm^2)

Symbols

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

NOTE
Thicknesses given are for mild steel. Reductions in thickness will be considered for certain stainless steels.

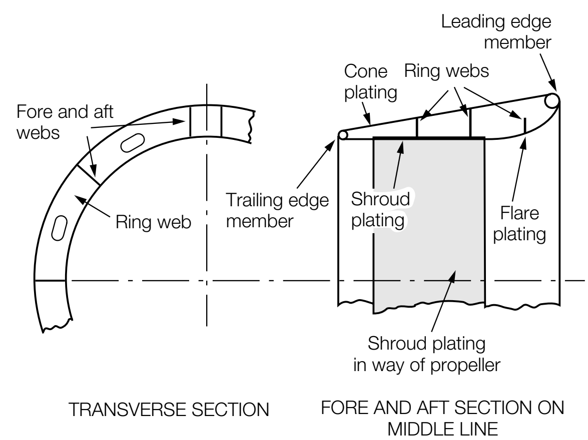


Fig. 13.3.1 Nozzle construction

3.2.4 The transverse strength of the nozzle is to be maintained by the fitting of ring webs. Two ring webs are to be fitted in nozzles not exceeding 2,5 m diameter. Nozzles between 2,5 and 3,0 m in diameter are generally to have two full ring webs and a half-depth web supporting the flare plating. The number of ring webs is to be increased as necessary on nozzles exceeding 3,0 m in diameter. Where ring webs are increased in thickness in way of the headbox and pintle support structure in accordance with Table 13.3.1, the increased thickness is to be maintained to the adjacent fore and aft web.

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

3.2.6 Fin plating thickness should be not less than the cone plating, and the fin should be adequately reinforced. Solid fins should be not less than 25 mm thick.

3.2.7 Care is to be taken in the manufacture of the nozzle to ensure its internal preservation and watertightness. The preservation and testing are to be as required for rudders, *see* 2.6 and Table 1.8.1 in Chapter 1.

3.3 Nozzle stock and solepiece

3.3.1 Stresses, derived using the maximum side load on the nozzle and fin acting at the assumed centre of pressure, are not to exceed the values given in Table 13.3.1, in both the ahead and astern conditions.

3.4 Ancillary items

3.4.1 The diameter and first moment of area about the stock axis of coupling bolts and the diameter of pintles, are to be derived from 2.4 and 2.5.

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

■ *Section 4*
Steering gear and allied systems

4.1 General

4.1.1 For the requirements of steering gear, *see* Pt 5, Ch 19.

■ *Section 5*
Bow and stern thrust unit structure

5.1 Unit wall thickness

5.1.1 The wall thickness of the unit is, in general, to be in accordance with the manufacturer's practice, but is to be not less than either the thickness of the surrounding shell plating plus 10 per cent or 15 mm, whichever is greater.

5.2 Framing

5.2.1 The unit is to be framed to the same standard as the surrounding shell plating.

5.2.2 The unit is to be adequately supported and stiffened.

■ *Section 6*
Stabilizer structure

6.1 Fin stabilizers

6.1.1 The box into which the stabilizers retract is to have perimeter plating of the same thickness as the surrounding Rule shell plating plus 2 mm, but is to be not less than 12,5 mm, and is to be stiffened to the same standard as the shell.

6.1.2 The stabilizer machinery and surrounding structure are to be adequately supported and stiffened. Where bending stresses are induced in the structure under fatigue conditions the maximum stress is not to exceed 39,0 N/mm^2 (4 kgf/mm^2).

6.2 Stabilizer tanks

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

■ *Section 7*
Equipment

7.1 General

7.1.1 To entitle a ship to the figure **1** in its character of classification, equipment in accordance with the requirements of Table 13.7.1 is to be provided. The regulations governing the assignment of the character figure **1** for equipment are given in Pt 1, Ch 2,2.

Table 13.7.1 Equipment requirements (*see continuation*)

Ship type	Service	Required equipment
Cargo ships, bulk carriers, tankers, ferries, dredgers, etc. (*see* 1.1.2)	Unrestricted service	(1) *See* Tables 13.7.2 and 13.7.3, using N_C
Ferries	Certain restricted services, *see* Pt 1, Ch 2,2.3.9	(2) *See* Tables 13.7.2 and 13.7.3, using N_C and N_A as appropriate Mass of bower anchor, Chain cable length and diameter: N_A = one grade below N_C Stream anchor may be omitted
Dredging and reclamation craft	Extended protected waters service, *see* Pt 1, Ch 2,2.3.7	(3) *See* Tables 13.7.2 and 13.7.3, using N_C and N_A as appropriate $N_A = N_C$ reduced by two grades, except for stream anchors, or mooring lines Stream anchor – not required if ship fitted with positioning spuds
	Protected waters service, *see* Pt 1, Ch 2,2.3.6	(4) *See* Tables 13.7.2 and 13.7.3 using N_C and N_A as appropriate Mass of bower anchor, Chain cable diameter: $N_A = 0{,}5N_C$ Bower anchors: powered ships – two anchors; unpowered (manned) ships – one anchor Chain cable length – greater of $2L$ m or $10{,}0T_D$ m, but need not exceed requirements for an ordinary cargo ship with anchors of the same mass Mooring lines – as required for N_C Wire ropes – may be substituted for chain cable on bower anchors if breaking strength ≥1,5 times that of the chain cable. To consist of six strands of a 'parallel lay' construction on independent wire rope core ('cross lay' strands over fibre core not acceptable)
Trawlers, stern trawlers, fishing vessels	Unrestricted service	(5) *See* Table 13.7.4, and Notes to Table 13.7.3 using N_C Anchor chains: Where $L < 30$ m, may be replaced with wire ropes of equal strength. Where 30 m $\le L \le 40$ m, one chain cable may be replaced with wire rope of equal strength provided normal chain cable maintained for the second line. Wire ropes of trawl winches complying with above may be used as anchor cables. Wire ropes substituted for anchor chains should (a) have a length 1,5 times that for chain cable required by Table 13.7.4 and (b) have a short length of chain not less than 12,5 m between anchor and wire rope. Hawsers and warps – Sufficient in number and strength for proper working of the ship
For symbols, *see* continuation of Table		

7.1.2 For ships intended to be operated only in suitable areas or conditions which have been agreed by the Committee, as defined in Pt 1, Ch 2,2.3.6 to 2.3.10, equipment differing from these requirements may be approved if considered suitable for the particular service on which the ship is to be engaged, *see also* Table 13.7.1.

7.1.3 Where the Committee has agreed that anchoring and mooring equipment need not be fitted in view of the particular service of the ship, the character letter **N** will be assigned, *see also* Pt 1, Ch 2,2.2.2.

7.1.4 Where the ship is intended to perform its primary designed service function only while it is anchored, moored, towed or linked, the character letter **T** will be assigned, *see also* Pt 1, Ch 2,2.2.2.

7.1.5 For classification purposes, the character figure **1**, or either of the character letters **N** or **T**, is to be assigned.

Table 13.7.1 Equipment requirements (*conclusion*)

Ship type	Service	Required equipment
Tugs	Unrestricted and restricted service	(6) *See* Table 13.7.2 using N_C except as stated below Stream anchor – not required Towlines – adequate for tug's maximum bollard pull with factor of safety ≥ 2,0
	Service restricted, *see* Pt 1, Ch 2,2.3.7 to 2.3.10	(7) *See* Table 13.7.2 using N_C Mass of bower anchor, Chain cable diameter } reduced to correspond to two Equipment Letters below that required for N_C
	Protected waters service, *see* Pt 1, Ch 2,2.3.6	(8) *See* Table 13.7.2 using N_A Mass of bower anchor, Chain cable diameter } $N_A = 0{,}5N_C$ Chain cable length = 0,5 times length required by N_A Where $N_C < 90$, the requirements for anchors and chain cable will be specially considered
Offshore supply ships	Unrestricted service	(9) *See* Tables 13.7.2 and 13.7.3, using N_C Chain cable length and diameter – increased to correspond to two Equipment Letters above that required for N_C
Manned barges and pontoons	Service restricted, *see* Pt 1, Ch 2,2.3.7 to 2.3.10	(10) As item (3) in this Table
Unmanned barges and pontoons	Unrestricted service, or service restricted, *see* Pt 1, Ch 2,2.3.7 to 2.3.10	(11) *See* Tables 13.7.2 and 13.7.3, using N_C and N_A as appropriate Anchors { $L < 30$ m, no anchor need be carried; $L \geq 30$ m, one anchor to be fitted Anchor cable length – greater of 40 m or 2L m (a) Unrestricted service: mass of anchors and chain cable diameters as for N_C (b) Protected water service, *see* Pt 1, Ch 2,2.3.6: mass of anchors and chain cable diameters, $N_A = 0{,}5N_C$ (c) Service restriction, *see* Pt 1, Ch 2,2.3.7 to 2.3.10: mass of anchor and chain cable diameter, N_A reduced to correspond to two Equipment Letters below N_C Mooring lines { $L < 65$ m, two mooring lines to be fitted; $L \geq 65$ m, three mooring lines to be fitted length of mooring lines to be the greater of 2L or 80 m, but need not exceed that for manned ships Strength of each line to be that required by N_C Consideration will be given to proposals to omit anchoring equipment in association with the assignment of the character figure **1**, *see* Pt 1, Ch 2,2.2. Where $L < 65$ m consideration will be given to the omission of anchoring and mooring equipment, in which case the character letter **N** will be assigned in the character of classification, *see* Pt 1, Ch 2,2.2
Symbols		
L = length of ship as defined in Ch 1,6.1 N_A = actual equipment number to be used, if different from N_C N_C = calculated equipment number for ship as required by Ch 1,7 T_D = maximum depth at which ship is designed to dredge, in metres		

7.2 Anchors

7.2.1 Anchors are to be of an approved design. The design of all anchor heads is to be such as to minimize stress concentrations, and in particular, the radii on all parts of cast anchor heads are to be as large as possible, especially where there is considerable change of section.

7.2.2 Anchors which must be specially laid the right way up, or which require the fluke angle or profile to be adjusted for varying types of sea bed, will not generally be approved for normal ship use, but may be accepted for offshore units, floating cranes, etc. In such cases suitable tests may be required.

7.2.3 The mass of each bower anchor given in Table 13.7.2 is for anchors of equal mass. The masses of individual anchors may vary by ± 7 per cent of the masses given in the Table, provided that the total mass of the anchors is not less than would have been required for anchors of equal mass.

7.2.4 The mass of the head, including pins and fittings, of an ordinary stockless anchor is to be not less than 60 per cent of the total mass of the anchor.

7.2.5 When stocked bower or stream anchors are to be used, the mass 'ex-stock' is to be not less than 80 per cent of the mass given in Table 13.7.2 for ordinary stockless bower anchors. The mass of the stock is to be 25 per cent of the total mass of the anchor, including the shackle, etc., but excluding the stock.

7.3 High holding power anchors

7.3.1 When high holding power anchors are used as bower anchors, the mass of each such anchor may be 75 per cent of the mass given in the Table for ordinary stockless bower anchors.

7.4 Chain cables

7.4.1 Chain cables may be of mild steel, special quality steel or extra quality steel in accordance with the requirements of Chapter 10 of the Rules for Materials and are to be graded in accordance with Table 13.7.5.

7.4.2 Grade U1 material having a tensile stress of less than 400 N/mm^2 (41 kgf/cm^2) is not to be used in association with high holding power anchors. Grade U3 material is to be used only for chain 20,5 mm or more in diameter.

7.4.3 Where stream anchors are used in association with chain cable, this cable may be either stud link or short link.

7.4.4 The form and proportion of links and shackles are to be in accordance with Chapter 10 of the Rules for Materials.

7.4.5 Where Owners require equipment for anchoring at depths greater than 82,5 m, it is their responsibility to specify the appropriate total length of the chain cable required for this purpose. In such cases, consideration can be given to dividing the chain cable into two unequal lengths.

7.5 Towlines and mooring lines

7.5.1 **Ships under 90 m** require mooring lines as specified in Table 13.7.3. Towlines are not required for classification and the details given in the Table are for guidance purposes only. Mooring lines may be of wire, natural fibre or synthetic fibre. The diameter, construction and specification of wire or natural fibre mooring lines are to comply with the requirements of Chapter 10 of the Rules for Materials. Where it is proposed to use synthetic fibre ropes, the size and construction will be specially considered.

7.5.2 The lengths of individual mooring lines in Table 13.7.3 may be reduced by up to seven per cent of the Table length, provided that the total length of mooring lines is not less than would have resulted had all lines been of equal length.

7.5.3 **Ships 90 m and over** in length do not require towlines and mooring lines as a classification item. It is recommended, however, that the sum of the strengths of all the mooring lines supplied to such ships should be not less than the Rule breaking load of one anchor cable as required by Table 13.7.2, based on Grade U2 chain for ships with equipment numbers up to 12400 and on Grade U3 chain for ships with higher equipment numbers. On ships regularly using exposed berths, twice the above total strength of mooring ropes is desirable. Where a separate towline is supplied, it is recommended that its strength be not less than 40 per cent of the strength of the anchor cable.

7.5.4 It is recommended that not less than four mooring lines be carried on ships exceeding 90 m in length, and not less than six mooring lines on ships exceeding 180 m in length. The length of mooring lines should be not less than 200 m, or the length of the ship, whichever is the lesser.

7.5.5 For ease of handling, fibre ropes should be not less than 20 mm diameter. All ropes having breaking strengths in excess of 736,0 kN (75,0 tonne-f) and used in normal mooring operations are to be handled by, and stored on, suitably designed winches. Alternative methods of storing should give due consideration to the difficulties experienced in manually handling ropes having breaking strengths in excess of 490,0 kN (50,0 tonne-f).

7.5.6 Mooring winches should be fitted with drum brakes, the strength of which is sufficient to prevent unreeling of the mooring line when the rope tension is equal to 80 per cent of the breaking strength of the rope as fitted on the first layer on the winch drum.

7.6 Windlass design and testing

7.6.1 A windlass of sufficient power and suitable for the size of chain is to be fitted to the ship. Where Owners require equipment significantly in excess of Rule requirements, it is their responsibility to specify increased windlass power.

Table 13.7.2 Equipment – Bower anchors and chain cables

Equipment number		Equipment Letter	Stockless bower anchors		Stud link chain cables for bower anchors			
						Diameter, in mm		
Exceeding	Not exceeding		Number	Mass of anchor, in kg	Total length, in metres	Mild steel (Grade 1 or U1)	Special quality steel (Grade U2)	Extra special quality steel (Grade U3)
50	70	A	2	180	220	14	12,5	—
70	90	B	2	240	220	16	14	—
90	110	C	2	300	247,5	17,5	16	—
110	130	D	2	360	247,5	19	17,5	—
130	150	E	2	420	275	20,5	17,5	—
150	175	F	2	480	275	22	19	—
175	205	G	2	570	302,5	24	20,5	—
205	240	H	2	660	302,5	26	22	20,5
240	280	I	2	780	330	28	24	22
280	320	J	2	900	357,5	30	26	24
320	360	K	2	1020	357,5	32	28	24
360	400	L	2	1140	385	34	30	26
400	450	M	2	1290	385	36	32	28
450	500	N	2	1440	412,5	38	34	30
500	550	O	2	1590	412,5	40	34	30
550	600	P	2	1740	440	42	36	32
600	660	Q	2	1920	440	44	38	34
660	720	R	2	2100	440	46	40	36
720	780	S	2	2280	467,5	48	42	36
780	840	T	2	2460	467,5	50	44	38
840	910	U	2	2640	467,5	52	46	40
910	980	V	2	2850	495	54	48	42
980	1060	W	2	3060	495	56	50	44
1060	1140	X	2	3300	495	58	50	46
1140	1220	Y	2	3540	522,5	60	52	46
1220	1300	Z	2	3780	522,5	62	54	48
1300	1390	A†	2	4050	522,5	64	56	50
1390	1480	B†	2	4320	550	66	58	50
1480	1570	C†	2	4590	550	68	60	52
1570	1670	D†	2	4890	550	70	62	54
1670	1790	E†	2	5250	577,5	73	64	56
1790	1930	F†	2	5610	577,5	76	66	58
1930	2080	G†	2	6000	577,5	78	68	60
2080	2230	H†	2	6450	605	81	70	62
2230	2380	I†	2	6900	605	84	73	64
2380	2530	J†	2	7350	605	87	76	66
2530	2700	K†	2	7800	632,5	90	78	68
2700	2870	L†	2	8300	632,5	92	81	70
2870	3040	M†	2	8700	632,5	95	84	73
3040	3210	N†	2	9300	660	97	84	76
3210	3400	O†	2	9900	660	100	87	78
3400	3600	P†	2	10 500	660	102	90	78
3600	3800	Q†	2	11 100	687,5	105	92	81
3800	4000	R†	2	11 700	687,5	107	95	84
4000	4200	S†	2	12 300	687,5	111	97	87
4200	4400	T†	2	12 900	715	114	100	87
4400	4600	U†	2	13 500	715	117	102	90
4600	4800	V†	2	14 100	715	120	105	92
4800	5000	W†	2	14 700	742,5	122	107	95
5000	5200	X†	2	15 400	742,5	124	111	97
5200	5500	Y†	2	16 100	742,5	127	111	97
5500	5800	Z†	2	16 900	742,5	130	114	100
5800	6100	A*	2	17 800	742,5	132	117	102
6100	6500	B*	2	18 800	742,5	—	120	107
6500	6900	C*	2	20 000	770	—	124	111
6900	7400	D*	2	21 500	770	—	127	114
7400	7900	E*	2	23 000	770	—	132	117
7900	8400	F*	2	24 500	770	—	137	122
8400	8900	G*	2	26 000	770	—	142	127
8900	9400	H*	2	27 500	770	—	147	132
9400	10 000	I*	2	29 000	770	—	152	132
10 000	10 700	J*	2	31 000	770	—	157	137
10 700	11 500	K*	2	33 000	770	—	157	142
11 500	12 400	L*	2	35 500	770	—	162	147
12 400	13 400	M*	2	38 500	770	—	—	152
13 400	14 600	N*	2	42 000	770	—	—	157
14 600	16 000	O*	2	46 000	770	—	—	162

Table 13.7.3 Equipment – Stream anchors, stream wires, towlines and mooring lines (*continued*)

Equipment number		Equip-ment Letter	Mass of stock-less stream anchor, in kg	Stream wire or chain			Towline (1)		Mooring lines		
Exceeding	Not exceeding			Minimum length in metres	Minimum breaking strength, in kN	(tonne-f)	Minimum length in metres	Minimum breaking strength, in kN	Number	Minimum length of each line, in metres	Minimum breaking strength, in kN (tonne-f)
50	70	A	60	80	64,7	(6,60)	180	98	3	80	34
70	90	B	80	85	73,5	(7,50)	180	98	3	100	37
90	110	C	100	85	81,4	(8,30)	180	98	3	110	39
110	130	D	120	90	89,2	(9.10)	180	98	3	110	44
130	150	E	140	90	98,1	(10,00)	180	98	3	120	49
150	175	F	165	90	107,9	(11,00)	180	98	3	120	54
175	205	G	190	90	117,7	(12,00)	180	112	3	120	59
205	240	H	—	—	—	—	180	129	4	120	64
240	280	I	—	—	—	—	180	150	4	120	69
280	320	J	—	—	—	—	180	174	4	140	74
320	360	K	—	—	—	—	180	207	4	140	78
360	400	L	—	—	—	—	180	224	4	140	88
400	450	M	—	—	—	—	180	250	4	140	98
450	500	N	—	—	—	—	180	277	4	140	108
500	550	O	—	—	—	—	190	306	4	160	123
550	600	P	—	—	—	—	190	338	4	160	132
600	660	Q	—	—	—	—	190	370	4	160	147
660	720	R	—	—	—	—	190	406	4	160	157
720	780	S	—	—	—	—	190	441	4	170	172
780	840	T	—	—	—	—	190	479	4	170	186
840	910	U	—	—	—	—	190	518	4	170	201
910	980	V	—	—	—	—	190	559	4	170	216
980	1060	W	—	—	—	—	200	603	4	180	230
1060	1140	X	—	—	—	—	200	647	4	180	250
1140	1220	Y	—	—	—	—	200	691	4	180	270
1220	1300	Z	—	—	—	—	200	738	4	180	284
1300	1390	A†	—	—	—	—	200	786	4	180	309
1390	1480	B†	—	—	—	—	200	836	4	180	324
1480	1570	C†	—	—	—	—	220	888	5	190	324
1570	1670	D†	—	—	—	—	220	941	5	190	333
1670	1790	E†	—	—	—	—	220	1024	5	190	353
1790	1930	F†	—	—	—	—	220	1109	5	190	378
1930	2080	G†	—	—	—	—	220	1168	5	190	402
2080	2230	H†	—	—	—	—	240	1259	5	200	422
2230	2380	I†	—	—	—	—	240	1356	5	200	451
2380	2530	J†	—	—	—	—	240	1453	5	200	480
2530	2700	K†	—	—	—	—	260	1471	6	200	480
2700	2870	L†	—	—	—	—	260	1471	6	200	490
2870	3040	M†	—	—	—	—	260	1471	6	200	500
3040	3210	N†	—	—	—	—	280	1471	6	200	520
3210	3400	O†	—	—	—	—	280	1471	6	200	554
3400	3600	P†	—	—	—	—	280	1471	6	200	588
3600	3800	Q†	—	—	—	—	300	1471	6	200	618
3800	4000	R†	—	—	—	—	300	1471	6	200	647
4000	4200	S†	—	—	—	—	300	1471	7	200	647
4200	4400	T†	—	—	—	—	300	1471	7	200	657
4400	4600	U†	—	—	—	—	300	1471	7	200	667
4600	4800	V†	—	—	—	—	300	1471	7	200	677
4800	5000	W†	—	—	—	—	300	1471	7	200	686
5000	5200	X†	—	—	—	—	300	1471	8	200	686
5200	5500	Y†	—	—	—	—	300	1471	8	200	696
5500	5800	Z†	—	—	—	—	300	1471	8	200	706
5800	6100	A*	—	—	—	—	300	1471	9	200	706
6100	6500	B*	—	—	—	—	—	—	9	200	716
6500	6900	C*	—	—	—	—	—	—	9	200	726
6900	7400	D*	—	—	—	—	—	—	10	200	726
7400	7900	E*	—	—	—	—	—	—	11	200	726
7900	8400	F*	—	—	—	—	—	—	11	200	736
8400	8900	G*	—	—	—	—	—	—	12	200	736
8900	9400	H*	—	—	—	—	—	—	13	200	736
9400	10000	I*	—	—	—	—	—	—	14	200	736
10000	10700	J*	—	—	—	—	—	—	15	200	736
10700	11500	K*	—	—	—	—	—	—	16	200	736
11500	12400	L*	—	—	—	—	—	—	17	200	736
12400	13400	M*	—	—	—	—	—	—	18	200	736
13400	14600	N*	—	—	—	—	—	—	19	200	736
14600	16000	O*	—	—	—	—	—	—	21	200	736

Table 13.7.3 Equipment – Stream anchors, stream wires, towlines and mooring lines (*conclusion*)

NOTES
1. Towline specified for guidance only, *see* 7.5.1. For tugs *see* Table 13.7.1 item (6).
2. The rope used for stream wire is to be constructed of not less than 72 wires, made up into six strands.
3. Wire ropes used for towlines and mooring lines are generally to be of a flexible construction with not less than:
   144 wires in six strands with seven fibre cores for strengths up to 490 kN (50 tonne-f).
   222 wires in six strands with one fibre core for strengths exceeding 490 kN (50 tonne-f).
   The wires laid round the fibre centre of each strand are to be made up in not less than two layers.
4. Wire ropes for towlines and mooring lines used in association with mooring winches (on which the rope is stored on the winch drum) are to be of suitable construction.
5. Irrespective of strength requirements, no fibre rope is to be less than 20 mm diameter.
6. Tests. *See* Pt 2, Ch 10 for wire ropes and fibre ropes respectively.

Table 13.7.4 Trawlers, stern trawlers and fishing vessels

Equipment number		Stockless bower anchors		Stud link chain cables for bower anchors		
					Diameter, in mm	
Exceeding	Not exceeding	Number	Mass of anchor in kg	Total length in metres	Mild steel (Grade 1 or U1)	Special quality steel (Grade U2)
50	60	2	120	192,5	12,5	–
60	70	2	140	192,5	12,5	–
70	80	2	160	220,0	14,0	12,5
80	90	2	180	220,0	14,0	12,5
90	100	2	210	220,0	16,0	14,0
100	110	2	240	220,0	16,0	14,0
110	120	2	270	247,5	17,5	16,0
120	130	2	300	247,5	17,5	16,0
130	140	2	340	275,0	19,0	17,5
140	150	2	390	275,0	19,0	17,5
150	175	2	480	275,0	22,0	19,0
175	205	2	570	302,5	24,0	20,5
205	240	2	660	302,5	26,0	22,0
240	280	2	780	330,0	28,0	24,0
280	320	2	900	357,5	30,0	26,0
320	360	2	1020	357,5	32,0	28,0
360	400	2	1140	385,0	34,0	30,0
400	450	2	1290	385,0	36,0	32,0
450	500	2	1440	412,5	38,0	34,0
500	550	2	1590	412,5	40,0	34,0
550	600	2	1740	440,0	42,0	36,0
600	660	2	1920	440,0	44,0	38,0
660	720	2	2100	440,0	46,0	40,0

7.6.2 The following performance criteria are to be used as a design basis for the windlass:

(a) The windlass is to have sufficient power to exert a continuous duty pull over a period of 30 minutes of:

- for specified design anchorage depths up to 82,5 m:

Chain cable grade	Duty pull, P, in N (kgf)
U1	$36{,}79d_c^2$ $(3{,}75d_c^2)$
U2	$41{,}68d_c^2$ $(4{,}25d_c^2)$
U3	$46{,}60d_c^2$ $(4{,}75d_c^2)$

- for specified design anchorage depths greater than 82,5 m:

  $P_1 = P + (D_a - 82{,}5)\ 0{,}214d_c^2$ N

  $[P_1 = P + (D_a - 82{,}5)\ 0{,}0218d_c^2$ kgf$]$

  where

  d_c is the chain diameter, in mm

  D_a is the specified design anchorage depth, in metres

  P is the duty pull for anchorage depth up to 82,5 m

  P_1 is the duty pull for anchorage depths greater than 82,5 m.

(b) The windlass is to have sufficient power to exert, over a period of at least two minutes, a pull equal to the greater of:

(i) short term pull:
1,5 times the continuous duty pull as defined in 7.6.2(a).

(ii) anchor breakout pull:

$$12{,}18W_a + \frac{7{,}0L_c\,d_c^2}{100}\ \text{N}$$

$$\left(1{,}24W_a + \frac{7{,}1L_c\,d_c^2}{1000}\ \text{kgf}\right)$$

where:

L_c is the total length of chain cable on board, in metres, as given by Table 13.7.2

W_a is the mass, in kilograms, of bower anchor as given in Table 13.7.2.

(c) The windlass, with its braking system in action and in conditions simulating those likely to occur in service, is to be able to withstand, without permanent deformation or brake slip, a load, applied to the cable, given by:

$K_b d_c^2\ (44 - 0{,}08d_c)$ N

$(K_b d_c^2\ (44 - 0{,}08d_c)$ kgf$)$

where K_b is given in Table 13.7.6.

Table 13.7.5 Chain cable steel grades

Grade	Material	Tensile strength N/mm^2	Tensile strength (kgf/mm^2)
U1	Mild steel	300 – 490	(31 – 50)
U2 (a)	Special quality steel (wrought)	490 – 690	(50 – 70)
U2 (b)	Special quality steel (cast)	490 – 690	(50 – 70)
U3	Extra special quality steel	690 min.	(70 min.)

The performance criteria are to be verified by means of shop tests in the case of windlasses manufactured on an individual basis. Windlasses manufactured under LR's *Type Approval Scheme for Marine Engineering Equipment* will not require shop testing on an individual basis.

Table 13.7.6 Values of K_b

Cable grade	K_b			
	Windlass used in conjunction with chain stopper		Chain stopper not fitted	
	N	(kgf)	N	(kgf)
U1	4,41	(0,45)	7,85	(0,8)
U2	6,18	(0,63)	11,0	(1,12)
U3	8,83	(0,9)	15,7	(1,6)

7.6.3 Where shop testing is not possible and Type Approval has not been obtained, calculations demonstrating compliance with 7.6.2 are to be submitted together with detailed plans and an arrangement plan showing the following components:

- Shafting
- Gearing
- Brakes
- Clutches.

7.6.4 During trials on board ship, the windlass is to be shown to be capable of:

(a) for all specified design anchorage depths: raising the anchor from a depth of 82,5 m to a depth of 27,5 m at a mean speed of 9 m/min; and

(b) for specified design anchorage depths greater than 82,5 m: in addition to (a), raising the anchor from the specified design anchorage depth to a depth of 82,5 m at a mean speed of 3 m/min.

Where the depth of the water in the trial area is inadequate, suitable equivalent simulating conditions will be considered as an alternative. Following trials, the ship will be eligible to be assigned a descriptive note **specified design anchorage depth ... metres**, which will be entered in column 6 of the *Register Book*.

7.6.5 Windlass performance characteristics specified in 7.6.2 and 7.6.4 are based on the following assumptions:

(a) one cable lifter only is connected to the drive shaft;

(b) continuous duty and short term pulls are measured at the cable lifter;

(c) brake tests are carried out with the brakes fully applied and the cable lifter declutched;

(d) the probability of declutching a cable lifter from the motor with its brake in the off position is minimized;

(e) hawse pipe efficiency assumed to be 70 per cent.

7.6.6 The design of the windlass is to be such that the following requirements or equivalent arrangements will minimize the probability of the chain locker or forecastle being flooded in bad weather:

(a) a weathertight connection can be made between the windlass bedplate, or its equivalent, and the upper end of the chain pipe, and

(b) access to the chain pipe is adequate to permit the fitting of a cover or seal, of sufficient strength and proper design, over the chain pipe while the ship is at sea.

7.7 Testing of equipment

7.7.1 All anchors and chain cables are to be tested at establishments and on machines recognized by the Committee and under the supervision of LR's Surveyors or other Officers recognized by the Committee, and in accordance with Chapter 10 of the Rules for Materials.

7.7.2 Test certificates showing particulars of weights of anchors, or size and weight of cable and of the test loads applied are to be furnished. These certificates are to be examined by the Surveyors when the anchors and cables are placed on board the ship.

7.7.3 Steel wire and fibre ropes are to be tested as required by Chapter 10 of the Rules for Materials.

7.7.4 For holding power testing requirements relating to high holding power anchors, *see* Ch 10,1.7 of the Rules for Materials

7.8 Structural requirements associated with anchoring

7.8.1 The windlass is to be efficiently bedded and secured to the deck. The thickness of the deck in way of the windlass is to be increased, and adequate stiffening is to be provided, to the Surveyor's satisfaction. The structural design integrity of the bedplate is the responsibility of the Shipbuilder and windlass manufacturer.

7.8.2 An easy lead of the cables from the windlass to the anchors and chain lockers is to be arranged. Where cables pass over or through stoppers, these stoppers are to be manufactured from ductile material and be designed to minimize the probability of damage to, or snagging of, the cable. They are to be capable of withstanding without permanent deformation a load equal to 80 per cent of the Rule breaking load of the cable passing over them.

7.8.3 Hawse pipes and anchor pockets are to be of ample thickness and of a suitable size and form to house the anchors efficiently, preventing, as much as practicable, slackening of the cable or movements of the anchor being caused by wave action. The shell plating and framing in way of the hawse pipes are to be reinforced as necessary. Reinforcing is also to be arranged in way of those parts of bulbous bows liable to be damaged by anchors or cables. Substantial chafing lips are to be provided at shell and deck. These are to have sufficiently large, radiused faces to minimize the probability of cable links being subjected to high bending stresses. Alternatively, roller fairleads of suitable design may be fitted. Where unpocketed rollers are used, it is recommended that the roller diameter be not less than eleven times the chain diameter. Where hawse pipes are not fitted, alternative arrangements will be specially considered.

7.8.4 The chain locker is to be of a capacity and depth adequate to provide an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. Chain or spurling pipes are to be of suitable size and provided with chafing lips. The port and starboard cables are to be separated by a division in the locker.

7.8.5 Where means of access is provided to the chain locker it is to be closed by a substantial cover and secured by closely spaced bolts.

7.8.6 Chain lockers and spurling pipes are to be watertight up to the exposed weather deck and the space is to be efficiently drained. However, bulkheads between separate chain lockers, or which form a common boundary of chain lockers, need not be watertight.

7.8.7 Spurling pipes are to be provided with permanently attached closing appliances to minimise water ingress. It is recommended that steel plates in halves, hooked over the spurling pipe tops, be provided on top of which cement may be laid before lashing a canvas cover. Suitable alternatives will be considered.

7.8.8 Provision is to be made for securing the inboard ends of the cables to the structure. This attachment should have a working strength of not less than 63,7 kN (6,5 tonne-f) or 10 per cent of the breaking strength of the chain cable, whichever is the greater, and the structure to which it is attached is to be adequate for this load. Attention is drawn to the advantages of arranging that the cable may be slipped from an accessible position outside the chain cable locker. The proposed arrangement for slipping the chain cable, if constructed outside the chain locker, must be made watertight.

7.8.9 Satisfactory arrangements are to be made for the stowage and working of the stream anchor, if provided.

7.8.10 On dredging and reclamation craft the following are to be complied with:

(a) On unpowered ships, the windlass may be hand operated.
(b) When wire rope instead of chain is used for the anchor cable, it is to be stored on a properly designed drum or reel.
(c) Fairleads intended for use with wire rope cable are to be designed to minimize wear and to avoid kinking or other damage occurring to the rope. Fairleads should, in general, be fitted with rollers having a diameter not less than eleven times the diameter of the anchor cable, but a ratio of not less than 15,7 to 1 is recommended.
(d) On split type vessels, the arrangements are to be such that jamming of the anchor cable during opening and closing operations of the hull will not occur.

7.9 Structural requirements for windlasses on exposed fore decks

7.9.1 Windlasses located on the exposed deck over the forward 0,25*L* of the rule length, of ships of sea-going service of length 80 m or more, where the height of the exposed deck in way of the item is less than 0,1*L* or 22 m above the summer load waterline, whichever is the lesser, are to comply with the following requirements. Where mooring winches are integral with the anchor windlass, they are to be considered as part of the windlass.

7.9.2 The following pressures and associated areas are to be applied, *see* Fig. 13.7.1:

- 200 kN/m^2 normal to the shaft axis and away from the forward perpendicular, over the projected area in this direction;
- 150 kN/m^2 parallel to the shaft axis and acting both inboard and outboard separately, over the multiple of *f* times the projected area in this direction;

where

f = 1+ B/H, but not greater than 2,5
B = width of windlass measured parallel to the shaft axis, in metres
H = overall height of windlass, in metres.

7.9.3 Forces in the bolts, chocks and stoppers securing the windlass to the deck are to be calculated. The windlass is supported by *N* bolt groups, each containing one or more bolts, *see* Fig. 13.7.2.

7.9.4 The axial force R_i in bolt group (or bolt) *i*, positive in tension, may be calculated from:

$R_{xi} = P_x h x_i A_i / I_x$ in kN
$R_{yi} = P_y h y_i A_i / I_y$ in kN

and

$R_i = R_{xi} + R_{yi} - R_{si}$ in kN

where

P_x = force acting normal to the shaft axis, in kN
P_y = force acting parallel to the shaft axis, either inboard or outboard whichever gives the greater force in bolt group *i*, in kN
h = shaft height above the windlass mounting, in cm
x_i, y_i = *x* and *y* coordinates of bolt group *i* from the centroid of all *N* bolt groups, positive in the direction opposite to that of the applied force, in cm
A_i = cross sectional area of all bolts in group *i*, in cm^2
I_x = $\Sigma A_i x_i^2$ for *N* bolt groups, in cm^4
I_y = $\Sigma A_i y_i^2$ for *N* bolt groups, in cm^4
R_{si} = static reaction at bolt group *i*, due to weight of windlass, in kN.

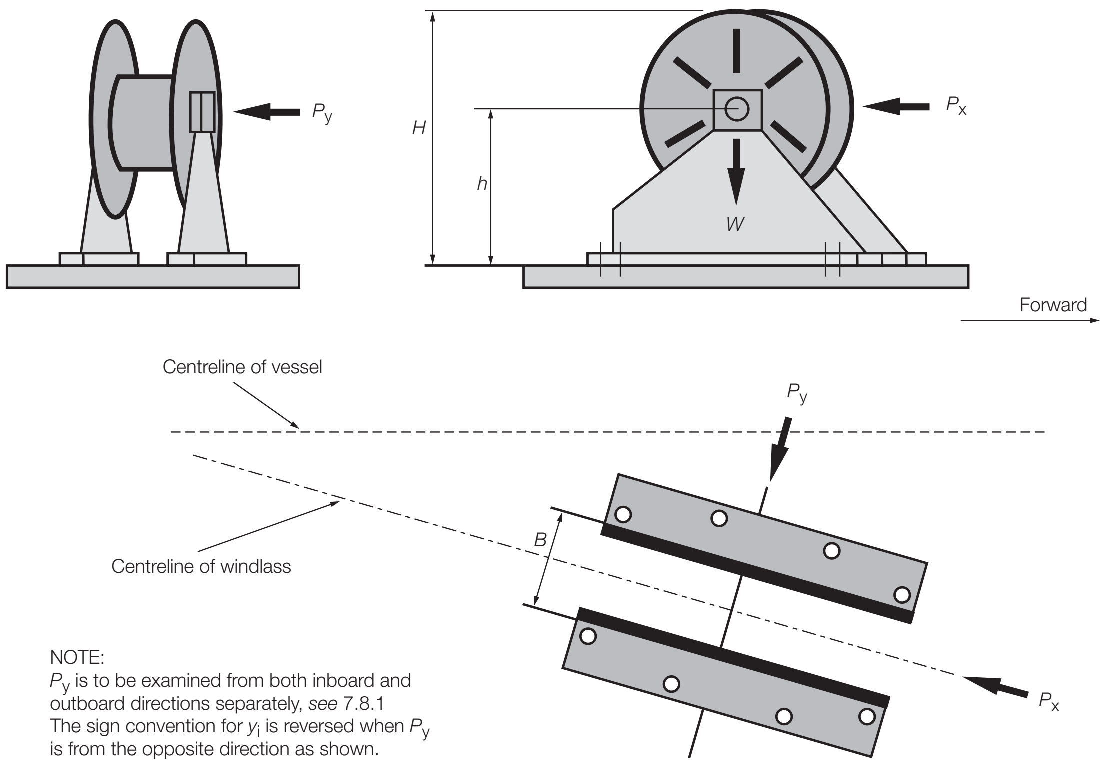


Fig. 13.7.1 Windlass loading

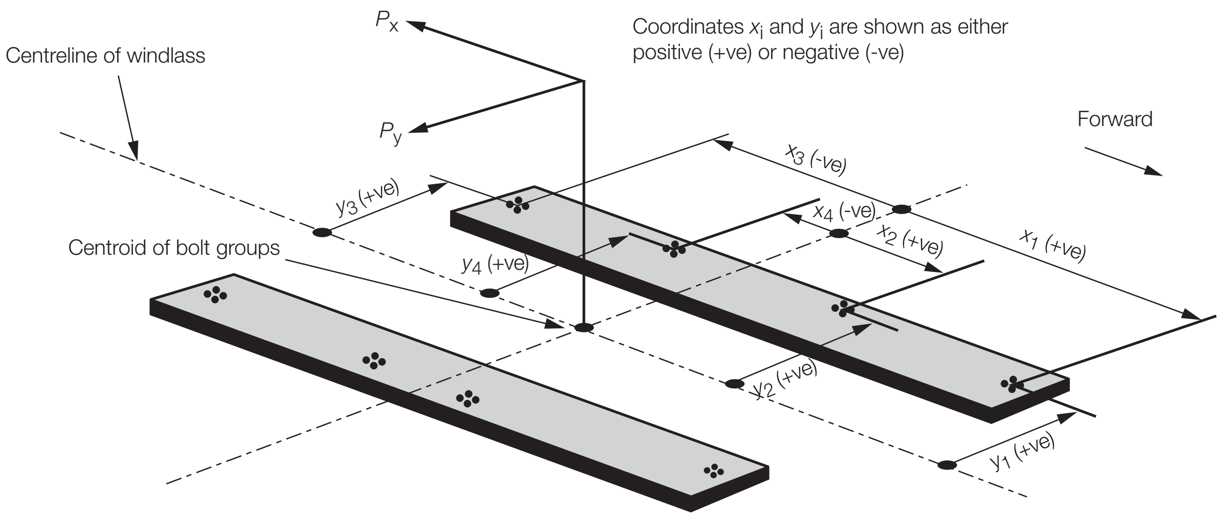


Fig. 13.7.2 Direction of forces and weight

7.9.5 Shear forces F_{xi}, F_{yi} applied to the bolt group *i*, and the resultant combined force F_i may be calculated from:

$F_{xi} = (P_x - \alpha\, g\, M)/N$ in kN

$F_{yi} = (P_y - \alpha\, g\, M)/N$ in kN

and

$F_i = \sqrt{(F_{xi}^2 + F_{yi}^2)}$ kN

where

α = coefficient of friction (0,5)

M = mass of windlass, in tonnes

g = gravity acceleration (9,81 m/sec^2)

N = number of bolt groups.

7.9.6 Tensile axial stresses in the individual bolts in each bolt group *i* are to be calculated. The horizontal forces F_{xi} and F_{yi} are normally to be reacted by shear chocks. Where 'fitted' bolts are designed to support these shear forces in one or both directions, the von Mises equivalent stresses in the individual bolts are to be calculated, and compared to the stress under proof load. Where pourable resins are incorporated in the holding down arrangements, due account is to be taken in the calculations.

7.9.7 The safety factor against bolt proof strength is to be not less than 2.0.

7.9.8 The windlass is to be efficiently bedded and secured to the deck. The thickness of the deck in way of the windlass is to be increased. Adequate stiffening of the deck in way of the windlass is to be provided. The scantlings of the supporting structure and deck are to be determined by additional calculations applying the weight of the windlass combined with the resultant force on the seat due to the application of the following design loads:

- P_x (as defined in 7.9.4);
- P_y;
- P_x and P_y combined;
- a load no less than the maximum pull developed by the windlass under normal operating conditions;
- a load no less than the ultimate breaking strength of the chain stopper, but need not be taken greater than the maximum brake holding capacity of the windlass. Requirements for chain stoppers are described in Section 8.

The allowable stresses given in Table 13.7.7 are not to be exceeded.

Table 13.7.7 Allowable stress in windlass supporting structure

	Bending stress, in N/mm^2	Shear stress, in N/mm^2	Combined stress, in N/mm^2
Allowable stress	$\frac{150}{k}$	$\frac{87}{k}$	$\frac{213}{k}$
k = material factor, see Pt 3, Ch 2,1.2			

7.9.9 The axial tensile and compressive forces in 7.9.4 and the lateral forces in 7.9.5 are also to be considered in the design of the supporting structure.

7.10 Structural requirements associated with towing and mooring

7.10.1 The following requirements are applicable to bollards and bitts, fairleads, stand rollers and chocks used for the normal mooring and towing of the vessel, the supporting structure and their attachment to it. They are also applicable to the supporting structure of capstans, winches and similar items used for the normal mooring and towing of the vessel. Any weld, bolt or equivalent device connecting the shipboard fitting to the supporting structure is part of the shipboard fitting and is subject to the National or International standard applicable to that shipboard fitting.

7.10.2 The design criteria in this sub-Section are to be used to derive the net scantlings of the supporting structure. A corrosion addition of 2 mm is to be added to the net thickness derived.

7.10.3 Shipboard fittings for towing or mooring are to be located on longitudinals, beams and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the load. Other arrangements will be specially considered provided that the strength is confirmed as adequate for the service.

7.10.4 The design load applied to shipboard fittings and supporting hull structure is not to be less than that given in Table 13.7.8.

Table 13.7.8 Minimum design load for deck fittings and supporting structure

Use/Item	Minimum design load(1)
Normal towing (harbour/manoeuvring)	1,25 times the intended maximum towing load as indicated on the towing and mooring arrangements plan
Escort towing	minimum breaking strength of the towline given in Table 13.7.3 for the ship's corresponding equipment number(2)
Mooring	1,25 times the breaking strength of the mooring line given in Table 13.7.3 for the ship's corresponding equipment number(2)
Winches, etc.	1,25 times the intended maximum brake holding power
Capstans	1,25 times the maximum hauling in force

NOTES
1. If a greater design load is specified by the designer this load is to be used.
2. The equipment number calculation is to include the maximum projected area of all deck cargo.

7.10.5 The design load is to be applied according to the arrangement shown on the towing and mooring arrangement plan. The point of action of the force on the fitting is to be taken as the point of attachment of the mooring line or towline or at a change in its direction. The total design load applied to a fitting need not be more than twice the design load, *see* Fig. 13.7.3.

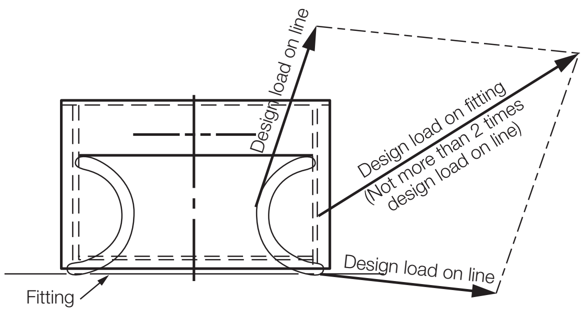


Fig. 13.7.3 Design load applied to fittings

7.10.6 The selection of shipboard fittings is to be made by the shipyard in accordance with an acceptable National or International standard (e.g. ISO3913 Shipbuilding Welded Steel Bollards). If the shipboard fitting is not selected from an acceptable National or International standard then the design load used to assess its strength and its attachment to the ship is to be in accordance with the design load given in Table 13.7.8 and the design is to be submitted for approval.

7.10.7 The reinforced members beneath shipboard fittings are to be effectively arranged for any variation of the direction, in both the lateral and vertical plane, of the forces acting through the arrangement.

7.10.8 The stress within the supporting structure of fittings is not to exceed that given in Table 13.7.9.

Table 13.7.9 Allowable stress within the supporting structure of shipboard fittings

	Normal stress, in N/mm^2	Shear stress, in N/mm^2
Allowable stress	$\dfrac{235}{k}$	$\dfrac{141}{k}$

where

$k = \dfrac{235}{\sigma_0}$

σ_0 = specified minimum yield strength of the material in N/mm^2

7.10.9 The Safe Working Load (SWL) of a shipboard fitting used for normal towing and mooring is not to be greater than 80 per cent of the design load. The SWL of a shipboard fitting used for escort towing is not to be greater than the design load. For fittings used for both operations, the greater design load is to be used.

7.10.10 The SWL of each shipboard fitting is to be marked, by weld bead or equivalent, on the fitting and relates to a single post basis.

7.10.11 When determining the minimum design load for deck fitting and supporting structure the 'Mooring Equipment Number' is to be calculated as follows:

$$\text{Mooring Equipment Number} = \Delta^{2/3} + 2BH + \frac{A}{10}$$

where

A = area, in m^2, in profile view of the hull including the projected area of all deck cargo, within the Rule length of the vessel, and of superstructures and houses above the summer load waterline, which are within the Rule length of the vessel, and also having a breadth greater than $\dfrac{B}{4}$

See also 7.10.12 and 7.10.13

B = greatest moulded breadth, in metres

H = freeboard amidships, in metres, from the summer load waterline to the upper deck, plus the sum of the heights at the centreline, in metres, of each tier of houses having a breadth greater than $\dfrac{B}{4}$

See also 7.10.12, 7.10.13 and 7.10.14

Δ = moulded displacement, in tonnes, to the summer load waterline.

7.10.12 In the calculation of H and A, sheer and trim are to be ignored. Where there is a local discontinuity in the upper deck, H is to be measured from a notional deckline.

7.10.13 If a house having a breadth greater than $\dfrac{B}{4}$ is above a house with a breadth of $\dfrac{B}{4}$ or less, then the wide house is to be included, but the narrow house ignored.

7.10.14 Screens and bulwarks more than 1,5 m in height are to be regarded as parts of houses when determining H and A. Where a screen or bulwark is of varying height, the portion to be included is to be that length, the height of which exceeds 1,5 m.

Section 8
Mooring of ships at single point moorings

8.1 General

8.1.1 These requirements are applicable to ships intended to utilize the fittings standardized for single point moorings and include the type, strength and location of the required fittings.

8.1.2 A ship provided with mooring arrangements in accordance with the requirements of this Section will be eligible to be assigned the Class notation **SPM**.

8.2 Arrangements

8.2.1 The ship is to be fitted with bow chain stoppers and/or Smit-Type Brackets, and bow fairleads. In addition, pedestal roller fairleads may be required for alignment purposes.

8.2.2 In order to ensure matching with terminal mooring equipment, the requirements for shipboard fittings are specified in association with ranges of ship deadweight as shown in Table 13.8.1.

Table 13.8.1 Deadweight group for shipboard fittings requirements

Group	Deadweight in tonnes	
I	< 150 000	
II	≥ 150 000	< 350 000
III	≥ 350 000	

8.2.3 Bow chain stoppers:

(a) The number, chain cable size and minimum safe working load of bow chain stoppers should be as given in Table 13.8.2.

(b) Bow chain stoppers should be located between 2,7 m and 3,7 m aft of the bow fairlead and should be positioned so as to give correct alignment with the bow fairlead and the pedestal fairlead or the drum end of the winch or capstan, *see* Fig. 13.8.1.

(c) The leading edge of the stopper base plate is to be suitably faired to allow unimpeded entry of the combination chafe chain into the stopper. The chain referred to, forms part of the standardized SPM equipment.

(d) Details of bow chain stoppers should be submitted for approval.

Table 13.8.2 Fittings requirements for deadweight group

Group	Chain size, in mm	No. of chain stoppers	SWL, in kN (tonnes)
I	76	1	1960 (200)
II	76	2	1960 (200)
III	76	2	2450 (250)

8.2.4 Smit-Type Brackets:

(a) Smit-Type Brackets may be fitted in lieu of bow chain stoppers. The required number and safe working load are as given in Table 13.8.2 for bow chain stoppers.

(b) The scantlings of the pin, connecting brackets and welded attachments to the baseplate are to be determined in association with a horizontal load of 1,5 x SWL and a permissible shear stress of 78 N/mm^2 (8 kg/mm^2).

(c) Where fitted, Smit-Type Brackets should be located between 2,7 m and 3,7 m aft of the bow fairlead and should be positioned so as to give correct alignment with the bow fairlead and pedestal fairlead or drum end of the winch or capstan, *see* Fig. 13.8.1.

(d) To facilitate connection to the terminal equipment it is recommended that each Smit-Type Bracket be provided with a length of chain cable comprising a pear link, an open link, and a special shackle, *see* Fig. 13.8.2. The safe working load should be as given in Table 13.8.2 for bow stoppers.

(e) Adjacent to each Smit-Type Bracket a lug with a recommended safe working load of 490 kN (50 tonnes) should be attached to the doubler plate. The lug should be provided with a hole of sufficient size to accept the pin of a 490 kN (50 tonnes) SWL shackle and should be used as a securing point for the chafe chain holding stopper.

(f) Details of Smit-Type Brackets should be submitted for approval.

8.2.5 The forecastle deck in way of bow chain stoppers or Smit-Type Brackets is to have a minimum thickness of 15 mm and is to be suitably reinforced to resist horizontal loads equal to 1,5 x SWL as given in Table 13.8.2.

8.2.6 Bow fairleads:

(a) One centrally located bow fairlead should be provided for ships up to 150,000 tonnes deadweight (Group I). Two bow fairleads should be provided for ships larger than 150,000 tonnes deadweight (Groups II and III).

(b) Bow fairlead openings should be at least 600 x 450 mm for 76 mm chafe chain size. Where more than one bow fairlead is installed, the spacing of centres should be between 2 m and 3 m.

(c) The height of the centre of the bow fairlead opening above the forecastle deck should be determined by the extension, parallel to the deck, of the lead line of the chain cable to the bow chain stopper or Smit-Type Bracket, *see* Fig. 13.8.1. The fairlead should have a minimum radius equal to seven times the chain radius.

(d) Details of bow fairleads and their attachment to the bulwark should be submitted for approval.

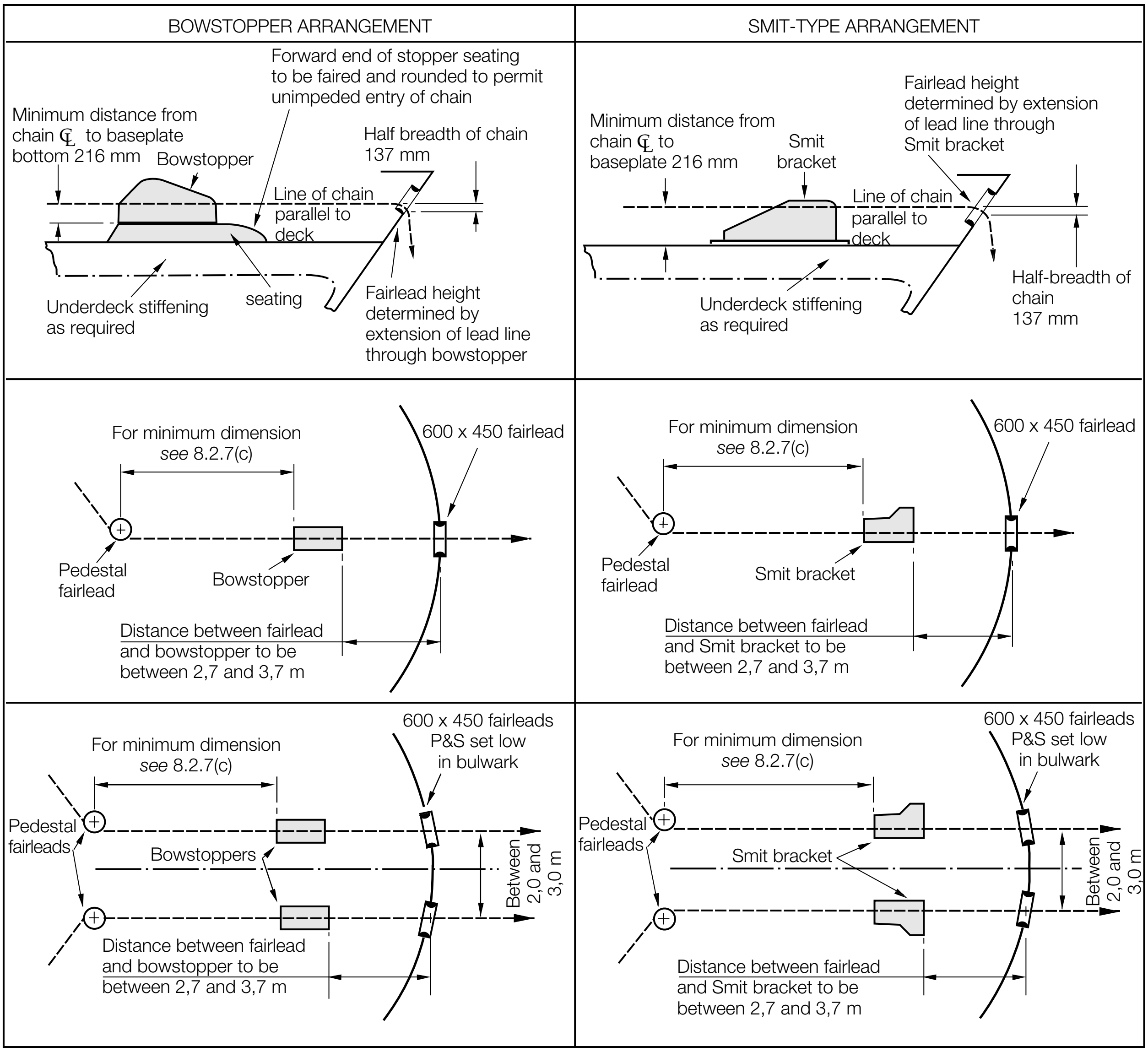


Fig. 13.8.1 Positioning of fairleads, chainstoppers and pedestal roller leads

8.2.7 Pedestal roller fairleads:

(a) Pedestal roller fairleads should have a minimum radius equal to 10 times the radius of wire mooring ropes with a fibre core, seven times the radius of wire mooring ropes with a steel core or three times the radius of synthetic mooring ropes.

(b) The number of pedestal roller fairleads should correspond to the number of bow chain stoppers or Smit-Type Brackets.

(c) The minimum distance of pedestal roller fairleads from the bow chain stopper or Smit-Type Bracket should be 4,5 m. Any variation in the minimum distance will be specially considered.

(d) Details of local strengthening of the forecastle deck in way of pedestal roller fairleads should be submitted for approval.

8.2.8 The winch drum or capstan used for handling the mooring gear should be capable of exerting a continuous duty pull of not less than 147 kN (15 tonnes).

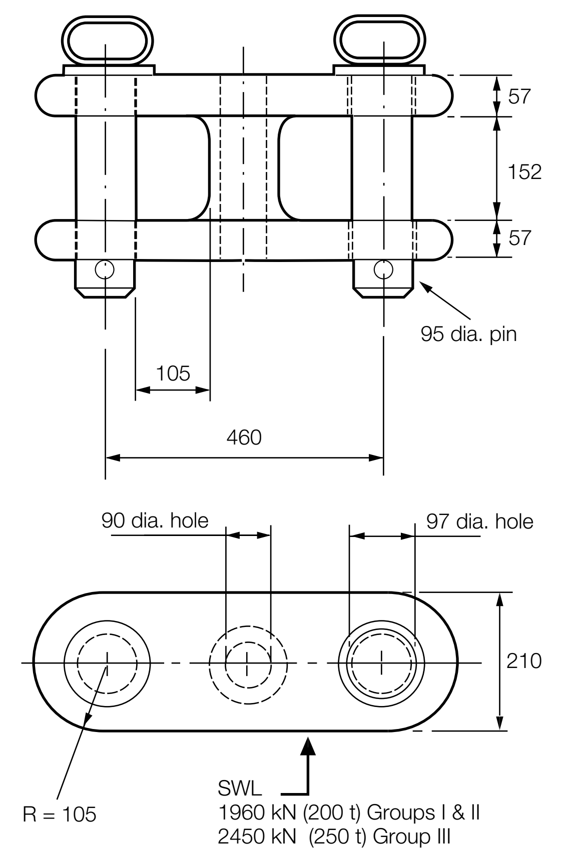


Fig. 13.8.2 Special shackle
Dimensions in mm unless otherwise stated

■ *Section 9*
Emergency towing arrangements

9.1 Structural requirements

9.1.1 For ships equipped with emergency towing arrangements in accordance with IMO Resolution MSC 35(63), the deck and its supporting structure in way of strongpoints and fairleads are to be suitably reinforced to resist design loads of at least 1,3 x specified breaking strength of the weakest component of the emergency towing arrangement, for angles of tow as specified in IMO Resolution MSC 35(63). The deck in way of strongpoints and fairleads is to have a minimum thickness of 15 mm.

9.1.2 Where a ship is provided with an emergency towing arrangement and the supporting structure complies with the requirements of this Section, the ship will be eligible to be assigned the descriptive note **ETA** which will be entered in column 6 of the *Register Book*.

9.1.3 Stresses induced in the supporting structure and welds in way of strongpoints and fairleads, determined using the design loads from 9.1.1, are not to exceed the permissible values given in Table 13.9.1. The capability of the structure to withstand buckling is also to be assessed.

Table 13.9.1 Permissible stress values

	Permissible stress N/mm^2 (kgf/mm^2)
Direct stress	σ_o
Shear stress	$\frac{\sigma_o}{\sqrt{3}}$
Combined stress	σ_o
Symbols	
σ_o = specified minimum yield stress, in N/mm^2 (kgf/mm^2)	

9.1.4 The structural arrangement is to be such that continuity will be ensured. Abrupt changes of shape or section, sharp corners and other points of stress concentration are to be avoided.

9.2 Chafing chain and wire or fibre rope for Emergency Towing Arrangements

9.2.1 Chafing chains are to be manufactured, tested and certified in accordance with Ch 10,2 of the Rules for Materials Grades U2 and U3.

9.2.2 The outboard end of the chafing chain is to include a pear-shaped link allowing connection to a shackle corresponding to the type of ETA and chain grade. A typical arrangement is shown in Fig. 13.9.1.

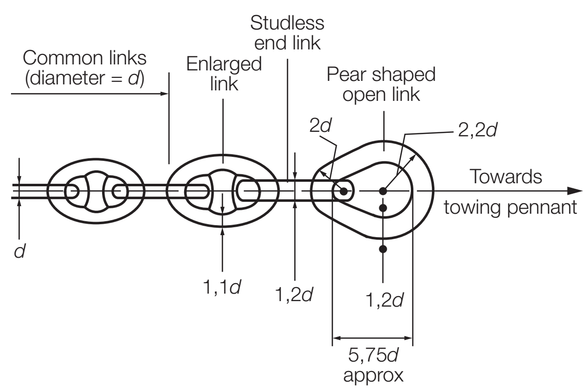


Fig. 13.9.1 Typical outboard chafing chain end

9.2.3 The chafing chain is to be able to withstand a breaking load not less than twice the safe working load (SWL). The nominal diameter of common link for chafing chains is to comply with the value indicated in Table 13.9.2.

Table 13.9.2 Nominal diameter of common link for chafing chains for ETA

Type of ETA	Nominal diameter of common link, *d*, min	
	Grade U2	Grade U3
ETA 1000	62 mm	52 mm
ETA 2000	90 mm	76 mm

9.2.4 Steel wire ropes are to be manufactured, tested and certified in accordance with Ch 10,6 of the Rules for Materials.

9.2.5 Fibre ropes are to be manufactured, tested and certified in accordance with Ch 10,7 of the Rules for Materials.

Section

Section 1 General

1.1 Application

1.1.1 All cargo ships, regardless of tonnage, except those engaged solely in the carriage of either liquid or solid bulk cargoes are to be provided with a Cargo Securing Manual approved by the Flag Administration, as required by SOLAS 1974 (as amended). Sections 2, 4 and 10 apply to all ships for which a Cargo Securing Manual is required.

1.1.2 Where the design and construction of the system comply with Sections 2, 4 and 10, and all the proposed fixed cargo securing fittings have been certified by an organisation acceptable to Lloyd's Register (hereinafter referred to as 'LR'), the ship will be eligible to be assigned the descriptive note **fsa** (fixed securing arrangements) and for an entry to be made in column 6 of the *Register Book*.

1.1.3 Where container securing arrangements are fitted, and the design and construction of the system are in accordance with this Chapter, the ship will be eligible to be assigned the special features notation **CCSA** (certified container securing arrangements). Where loose container securing fittings are supplied for part container stowage only, the special features notation will be suitably modified.

1.1.4 Where container securing arrangements are fitted and the design and construction of the system are in accordance with this Chapter, but an Initial Survey in accordance with 10.1.1 has not been requested, the descriptive note **fcsa (plans)** will be entered in column 6 of the *Register Book*.

1.1.5 The requirements for container securing arrangements have been framed in relation to ISO Standard Series 1 Freight Containers. Proposals for the securing of other types of containers will be specially considered.

1.1.6 In general, the containers are to be assumed loaded to their maximum operating gross weight. Where, however, specified loading patterns are proposed, the securing arrangements may be considered on the basis of these loading patterns which are to be clearly indicated on the approved arrangement plan carried on board the ship.

1.1.7 Containers may be approved and certified using LR's *Container Certification Scheme*.

1.2 Plans and information required

1.2.1 For all fixed cargo securing arrangements, except container securing arrangements, the following information and plans are to be submitted:

(a) Details of certification including safe working load (SWL), of fixed cargo securing fittings.
(b) Plans of structure in way of fixed cargo securing fittings.
(c) Direction of loads imposed on the ship's fixed cargo securing fittings.
(d) A general arrangement of fixed cargo securing fittings.

1.2.2 For container securing arrangements, the following plans and information are to be submitted:

(a) General arrangement plan showing the disposition and design weights of the containers.
(b) Details of materials, design, scantlings of cell guides structure, lashing bridges, pedestals, and other container securing arrangements, where fitted.
(c) Details of certification, including safe working loads, of fixed and loose container securing fittings.
(d) Plans of structure in way of fixed container securing fittings and arrangements.
(e) Design values of the following ship parameters for the container load departure and arrival conditions:
    Moulded draught (T_C)
    Longitudinal centre of flotation (LCF)
    Transverse metacentric height (GM)
(f) Design wind speed.
(g) Where available, details of the long term distribution of ship motions, particularly roll, pitch and heave, in irregular seas which the ship will encounter during its operating life. Where simplified dynamic response data, or other means of assessing the maximum motions of the ship, are proposed they are to be submitted for consideration. In other cases the motions defined in Section 8 will be used.

1.2.3 Where containers of types other than ISO containers are to be incorporated in the stowage arrangement, the container stowage plan is to indicate clearly the locations where these containers are stowed. The plan is also to indicate the container weights and required securing arrangements for stacks composed entirely of ISO standard containers.

1.3 Securing systems

1.3.1 Containers are to be secured by one, or a combination, of the following systems:

- Corner locking devices.
- Rod, wire or chain lashings.
- Buttresses, shores or equivalent structural restraint.
- Cell guides.

Alternative systems will be considered on the basis of their suitability for the intended purpose.

1.3.2 Dunnage is not to be used in association with approved container securing systems except where forming part of an approved line load stowage, *see* 5.5.

1.4 Symbols and definitions

1.4.1 The following definitions are applicable to this Chapter, except where otherwise stated:

a = breadth of the container, in metres
b = length of the container, in metres
e = base of natural logarithms, 2,7183
GM = transverse metacentric height of the ship in the container load condition, in metres. It is recommended that for the purpose of design of the container securing system, GM should be taken as not less than 0,05B m.
x = longitudinal horizontal distance from O_m to the centre of the container, in metres
y = transverse horizontal distance from the centreline of the ship to the centre of the container, in metres
z_m = vertical distance from O_m to the centre of gravity of the container, in metres
A = projected side area of the container, in m^2
B = moulded breadth of the ship, in metres
D = moulded depth of the ship, in metres
L_{pp} = length between perpendiculars of the ship, in metres
O_m = centre of motion, to be taken on the centreline at the longitudinal centre of flotation of the ship and at a distance T_c or D/2, whichever is the greater, above the keel
R = the rating, or maximum operating gross weight for which the container is certified, and is equal to the tare weight plus payload of the container, in tonnes
T_c = moulded draught in the container load condition, in metres
T_h = full period of heave of the ship, in seconds
T_p = full period of pitch of the ship, in seconds
T_r = full period of roll of the ship, in seconds
V = wind speed, in m/s
W = design weight of the container and contents. In general W is to be taken as R unless reduced maximum weights are specified
ϕ = maximum single amplitude of roll, in degrees
ψ = maximum single amplitude of pitch, in degrees.

Section 2
Fixed cargo securing fittings, materials and testing

2.1 General

2.1.1 Randomly selected samples of fixed cargo securing fittings are to be subjected to prototype testing and, upon satisfactory completion, will be granted General Approval.

2.1.2 Randomly selected samples drawn from production runs are to be subjected to production testing prior to delivery to the ship.

2.1.3 Cargo securing fittings, certified by an organization other than LR, will be accepted where the certification scheme is to the satisfaction of LR.

2.2 Materials and design

2.2.1 Steel used for the construction of the fixed cargo securing fittings is to comply with the requirements of the Rules for Materials or with an equivalent specification acceptable to LR. Due account is to be taken of the grade and tensile strength of the hull material in way of the attachment. The chemical composition of the steel is to be such as to ensure acceptable qualities of weldability. Where necessary, tests are to be carried out to establish specific welding procedures.

2.2.2 Where securing arrangements are intended to operate at low ambient temperatures, special consideration is to be given to the specification of the steel.

2.2.3 Proposals for the use of materials other than steel will be specially considered.

2.2.4 Attention is drawn to the need for measures to be taken to prevent water accumulation in pockets or recesses that could lead to excessive corrosion.

2.3 Prototype testing

2.3.1 Prototype tests to determine the breaking or failure loads are to be carried out on at least two randomly selected samples of each item used in the securing system. The relationship between design breaking load and safe working load (SWL) is to be as indicated in Table 14.2.1.

2.3.2 The Surveyor is to be satisfied that the design and materials of the fittings are in accordance with the approved plans.

Table 14.2.1 Design breaking loads and proof loads for fixed cargo securing fittings

Minimum design breaking load		Minimum proof load	
SWL ≤ 40 tonnes	SWL > 40 tonnes	SWL ≤ 40 tonnes	SWL > 40 tonnes
2 x SWL	SWL + 40 tonnes	1,5 x SWL	SWL + 20 tonnes

NOTE
Breaking and proof loads for fixed cargo securing fittings of a material other than steel will be specially considered.

2.3.3 For acceptance, no permanent deformation (other than due to initial embedding of component parts) is to be induced by test loads up to the proof load given in Table 14.2.1.

2.3.4 When considering the test modes, all expected directions of operation are to be taken into account. Jigs are to be employed, where necessary, in order that satisfactory simulation is obtained.

2.3.5 In the interests of standardization of the strength of container securing fittings, safe working loads in accordance with Table 14.2.2 are recommended.

2.3.6 Where one of the required two randomly selected test samples required fails before the design breaking load is reached, this can be accepted provided that:

(a) the failure is not less than 95 per cent of the design breaking load;
(b) an additional randomly selected sample is tested satisfactorily; and
(c) the average failure load of the three randomly selected samples is equal to or greater than the design breaking load.

2.4 Production testing

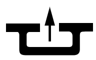
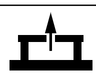
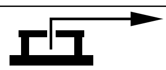
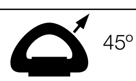
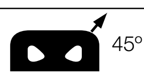
2.4.1 The nature and extent of proposed production testing will be considered by LR, but the arrangements are to be at least equivalent to one of the following testing procedures:

(a) One randomly selected sample from every 50 pieces, or from each batch if less than 50 pieces, is to be proof loaded in accordance with Table 14.2.1.
(b) All fittings are to be proof loaded to the SWL of the item.

2.4.2 Consideration will be given to a reduced frequency of the mechanical production testing proposed in 2.4.1, provided that:

(a) the prototype test results indicate a breaking load at least 50 per cent greater than that required by Table 14.2.1; and
(b) a suitable non-destructive inspection procedure is agreed.

Table 14.2.2 Test loads and test modes for fixed container securing fittings

Item No.	Description	Required test modes		Recommended minimum, in tonnes		
				SWL	Proof load	Breaking load
1	Flush socket		Pull-out load	20	30	40
2	Pedestal socket		Pull-out load	20	30	40
			Tangential load	15	22,5	30
3	'D' ring		Tensile load	18	27	36
4	Lashing plate		Tensile load	18	27	36

NOTES
1. For items 3 and 4, where specially designed for use with chain or steel wire rope (SWR) lashings, a lesser SWL may be considered. A greater SWL will be required for use with item 2 in Table 14.3.2.
2. For items 1 and 2, where multiple flush sockets or pedestal sockets are involved, test loads are to be applied simultaneously to each socket opening which can be loaded simultaneously in service.
3. For item 4, where multiple lashing points are fitted in one deck plate fitting, testing is to be similarly arranged as for Note 2.
4. Where containers with strength higher than required for ISO containers are used, consideration will be given to the required minimum loads.
5. The test modes illustrated above are diagrammatic only.

2.4.3 Permanent deformation (other than that due to initial embedding of component parts) will not be accepted unless tests are conducted in accordance with 2.4.1(a) and the SWL of the sample is 25 tonnes or greater. In this case, consideration may be given to acceptance of permanent deformation in the load range between SWL + 12,5 tonnes and the proof load, provided that satisfactory manual operation can be achieved after completion of tests.

2.4.4 In the event of premature failure or serious plastic deformation occurring in a test sample, a further randomly selected sample is to be selected for testing. In the event that this sample is found to be unsatisfactory, the associated batch will be rejected.

■ *Section 3* Loose container securing fittings, materials and testing

3.1 General

3.1.1 Randomly selected samples of loose container securing fittings are to be subjected to prototype testing and, upon satisfactory completion, will be granted General Approval.

3.1.2 Randomly selected samples drawn from production runs are to be subjected to production testing prior to delivery to the ship in accordance with 3.4.

3.1.3 Loose container securing fittings, certified by an organization other than LR, will be accepted where the certification scheme is to the satisfaction of LR.

3.2 Materials and design

3.2.1 Steel used for loose container securing fittings is to comply with the requirements of the Rules for Materials (Part 2) or with an equivalent specification acceptable to LR.

3.2.2 Where loose container securing fittings are intended to operate at low ambient temperatures, special consideration is to be given to the specification of the steel.

3.2.3 Proposals for the use of materials other than steel will be specially considered.

3.2.4 Locking devices are to be such as to minimize the risk of working loose under the effects of vibration.

3.3 Prototype testing

3.3.1 Prototype tests are to be in accordance with 2.3.1 to 2.3.6, except that Tables 14.3.1 and 14.3.2 are to be applied in lieu of Tables 14.2.1 and 14.2.2 respectively.

3.4 Production testing

3.4.1 The nature and extent of proposed production testing will be considered by LR, but the arrangements are to be at least equivalent to one of the following testing procedures:

(a) For:
   (i) **Loose container securing fittings except chain or wire rope lashings**. One randomly selected sample from every 50 pieces, or from each batch if less than 50 pieces, is to be proof loaded in accordance with Table 14.3.1.
   (ii) **Chain or wire rope lashings**. One randomly selected sample from every 50 pieces or from each batch if less than 50 pieces, is to be tested to breaking.

(b) All fittings, securing devices and lashings are to be proof loaded to the SWL of the item and in addition, one randomly selected sample from every batch of chain or wire rope lashings is to be tested to breaking.

3.4.2 Permanent deformation (other than that due to initial embedding of component parts) will not be accepted unless tests are conducted in accordance with 3.4.1(a)(i) and the SWL of the sample is 25 tonnes or greater. In this case, consideration may be given to acceptance of permanent deformation in the load range between SWL + 12,5 tonnes and the proof load, provided that satisfactory manual operation can be achieved after completion of tests.

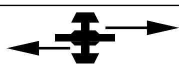
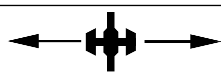
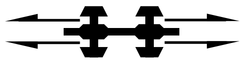
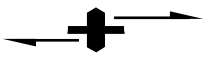
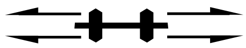
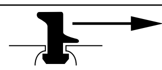
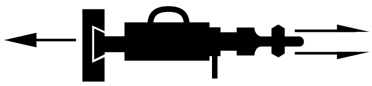
3.4.3 In the event of premature failure or serious plastic deformation occurring in a test sample a further randomly selected sample is to be selected for testing. In the event that this sample is found to be unsatisfactory, the associated batch will be rejected.

Table 14.3.1 Design breaking loads and proof loads for loose container securing fittings

Item	Min. design breaking load		Min. proof load	
	SWL ≤ 40 tonnes	SWL > 40 tonnes	SWL ≤ 40 tonnes	SWL > 40 tonnes
Lashings				
Wire rope	3 x SWL			
Rod: higher tensile steel	2 x SWL		1,5 SWL	
Chain: mild steel	3 x SWL			
higher tensile steel	2,5 x SWL			
Other loose container securing fittings	2 x SWL	SWL + 40 t	1,5 x SWL	SWL + 20 t

NOTES
1. Higher tensile steel is defined for this purpose as steel having a yield stress not less than 315 N/mm^2 (32 kgf/mm^2).
2. Breaking and proof loads for lashings of material other than steel will be considered.

Table 14.3.2 Test loads and test modes for loose container securing fittings

Item No.	Description	Required test modes	Recommended minimum, in tonnes		
			SWL	Proof load	Breaking load
1	Lashing rod (HTS)	 Tensile load	18	27	36
2	Lashing rod (high strength)		25	37,5	50
3	Lashing chain (HTS)		8	—	20
4	Lashing chain (M.S.)		10	—	30
5	Lashing steel wire rope		12	—	36
6	Turnbuckle	 Tensile load	18	27	36
7	Twistlock (single)	 Shear load	15	22,5	30
		 Tensile load	20	30	40
8	Twistlock (double)	 As for item 7 + Tensile load	5	7,5	10
9	Stacker (single)	 Shear load	15	22,5	30
10	Stacker (double)	 As for item 9 + Tensile load	5	7,5	10
11	Penguin hook	 Tangential load	18	27	36
12	Bridge fitting	 Tensile load	5	7,5	10
13	Buttress	 Tensile load	*See* Note 3		

NOTES
1. For items 6 and 11, where specially designed for use with chain or SWR lashings, a lesser SWL may be considered.
2. For items 8, 10 and 12, the recommended minimum loads quoted in the Table refer to the fittings when employed in a location in container stacks which do not transfer load to an adjacent stack. Where items 8, 10 and 12 are fitted in line with a buttress/shore support at stowage sides, then test loads are to be determined in association with Note 3.
3. For item 13, test loads for buttress fittings are to be determined by detailed consideration of the individual stowage arrangement proposed in association with Table 14.3.1.
4. Where containers with strength higher than required for ISO containers are used, consideration will be given to the required minimum loads.
5. The test modes illustrated above are diagrammatic only.
6. HTS denotes high tensile steel.

■ *Section 4* Ship structure

4.1 General

4.1.1 The ship structure and hatch covers in way of fixed cargo securing fittings are to be strengthened as necessary.

4.2 Strength

4.2.1 The SWL of the fixed cargo securing fitting is to be used as the design load when approving the weld attachments and the support structure of the fixed cargo securing fitting.

4.2.2 For container securing arrangements, the design load when approving the weld attachment and supporting structure is to be calculated in accordance with Section 9.

4.2.3 When considering the loads, all expected directions of operation are to be taken into account.

4.2.4 Stresses induced in the weld attachments, supporting structure, cell guides, lashing bridges and other structures serving as fixed cargo securing points, determined using the design loads from 4.2.1 to 4.2.3, are not to exceed the permissible values given in Table 14.4.1.

Table 14.4.1 Permissible stress values

	Permissible stress, N/mm^2 (kgf/mm^2)
Normal stress (bending, tension, compression)	$0,67\sigma_o$
Shear stress	$0,4\sigma_o$
Combined stress	$0,86\sigma_o$
Symbols	
σ_o = specified minimum yield stress, in N/mm^2 (kgf/mm^2)	

■ *Section 5* Container securing arrangements for stowage on exposed decks without cell guides

5.1 General

5.1.1 Containers stowed on deck or on hatch covers are generally to be aligned in the fore and aft direction, but alternative arrangements will be considered.

5.1.2 Containers are to be stowed so that they do not extend beyond the ship's side. Adequate support is to be provided where they overhang hatch coamings or other deck structures. The stowage arrangements are to be such as to permit safe access for personnel in the necessary working of the ship, and to provide sufficient access for operation and inspection of the securing devices.

5.1.3 Where containers are stowed on hatch covers, the covers are to be effectively restrained against sliding by approved type stoppers or equivalent. Details of the locations of stoppers relative to the supporting structure are to be submitted at as early a stage as possible.

5.1.4 Stanchions and similar structure supporting containers and securing devices such as D-rings for lashings, are to be of adequate strength for the imposed loads and of sufficient stiffness to minimize any deflection which could lead to a reduction in the effectiveness of the securing device.

5.1.5 In the region forward of $0,25L_{pp}$ abaft the fore perpendicular additional securing devices may be required, *see* 8.1.8.

5.2 Containers in one tier

5.2.1 Containers are to be secured at their lower corners by approved locking devices.

5.2.2 Alternatively, containers may be secured by lashings fitted diagonally or vertically at both ends of each container, in association with cone fittings at each container corner.

5.3 Containers in two tiers

5.3.1 Containers are to be secured at their lower corners at each tier by approved locking devices.

5.3.2 Where the calculations indicate that separation forces will not occur at any point in the stack, double stacking cones may be fitted at all internal corners of the stack and bridge fittings used to connect the tops of the rows in the transverse direction. Locking devices are to be fitted at all external corners.

5.3.3 Alternatively, containers may be secured by lashings in association with stacking cones or, where the calculations indicate that separation forces may occur, with locking devices.

5.4 Containers in more than two tiers

5.4.1 Containers are to be secured at their lower corners at each tier by approved locking devices.

5.4.2 Alternatively, containers may be secured by lashings. One or two tiers of lashings may be fitted in association with stacking cones or, where the calculations indicate that separation forces may occur, with locking devices.

5.4.3 Proposals to use lashings in pairs will be considered. Lashings in pairs are generally to be attached one to the bottom corner fitting of the upper tier and the other to the top corner fitting of the lower tier container. Suitable connections are to be provided at the lower ends. The effectiveness of paired lashings is to be taken as equal to 1,5 times that of a single lashing, unless a suitable load-equalizing device is fitted.

5.4.4 Where a fourth tier of containers is fitted, it is generally to be secured to the third tier by locking devices at each corner.

5.4.5 Proposals to stow more than four tiers will be specially considered.

5.5 Line Load stowage

5.5.1 Where the containers are supported on bearers placed to distribute the stackweight as uniform Line Loads, the following requirements are to be complied with:

(a) The stack is, in general, to comprise a maximum of two tiers of loaded containers.

(b) The load from the upper tier is to be transferred through the container corners. Line Loading is not to be used between tiers.
(c) The load on each vertical corner post of the bottom tier, calculated in accordance with Section 9, is not to exceed one half the Rated Load of the container.
(d) Where the calculations indicate that lifting forces may occur, locking devices are to be fitted at the container corners.
(e) The clearance below the bottom container corner casting is to be such that the stacking cone or equivalent cannot be dislodged under shear loading.

5.5.2 Where an approved Line Load stowage system is installed the special features notation will be suitably modified.

5.6 Systems incorporating structural restraint

5.6.1 Containers may be secured by the use of a fixed structure providing permanent buttresses in association with portable frameworks. Proposals to adopt such systems will be considered on the basis of the loads developed in the structure and the corresponding stresses.

5.6.2 The framework or other devices securing the containers are to be aligned with the container corner fittings and any clearance gap is to be kept to the minimum to reduce shifting.

■ *Section 6* Container securing arrangements for underdeck stowage without cell guides

6.1 General

6.1.1 Containers are generally to be stowed in holds and 'tween decks in the fore and aft direction, but alternative arrangements will be considered. The securing arrangements are to be designed on the basis of the most severe distribution of loads which may arise in the container stack.

6.1.2 Containers may be secured by locking devices only or by a combination of locking devices, buttresses, shores or lashings. Containers are, in general, to be restrained at every corner at the base of the stack and at all intermediate levels.

6.1.3 Where stacks consist of one or two tiers only, consideration will be given to the omission of corner locking devices. Containers must, however, be secured by a minimum of two corner locking devices.

6.1.4 Where the calculations indicate that separation forces could occur at any particular level, twistlocks or equivalent means of securing are to be fitted at that level. Elsewhere, consideration will be given to the use of double stacking cones.

6.1.5 Where the calculations indicate that separation forces will not occur between containers at any level, consideration will be given to the use of stacking cones in lieu of locking devices throughout.

6.1.6 Buttresses are generally to be of the tension and compression type and are to be provided with means of adjustment to ensure tightness when fitted in place. Where applicable, the attachment to the ship's structure is also to include means for vertical adjustment of the buttress to match container stacks of different heights.

6.1.7 Shores of the compression only type may be permanently attached to the ship structure or they may be hinged or portable. When in place they are to abut the container corner fittings with minimal clearance. Means are to be provided to prevent slackening of the device.

6.1.8 Adjacent stacks of containers are to be linked in line with buttresses or shores in order to transmit lateral loads. The fittings used for these linkages are to be of adequate strength to transmit the loads imposed.

6.1.9 The ship's structure supporting shores and buttresses is to be reinforced as necessary.

6.1.10 Proposals for alternative securing systems, including systems relying on minimal clearance between containers and hull structure, will be specially considered.

■ *Section 7* Container securing arrangements for stowage using cell guides

7.1 General

7.1.1 Cell guide systems may be fitted to support containers stowed in holds or on exposed decks.

7.1.2 The cell guides are not to form an integral part of the ship's structure. The guide system is generally to be so designed as to keep it free of the main hull stresses.

7.1.3 Cell guides are to be designed to resist loads caused by loading and unloading of the containers, to prevent shifting of the containers and to transmit the loads caused by motions of the ship into the main hull structure.

7.2 Arrangement and construction

7.2.1 Cell guides are to be of robust construction and generally fabricated from steel plate and rolled sections. They are to have sufficient vertical extent and continuity to provide efficient support to containers. Guide bars are to be effectively attached to the supporting structure to prevent tripping or distortion resulting from container loading.

7.2.2 The intersection between cell guide and cross-ties is to provide adequate torsional stability.

7.2.3 Intermediate brackets are to be fitted to vertical cell guides at suitable intervals, *see* Fig. 14.7.1.

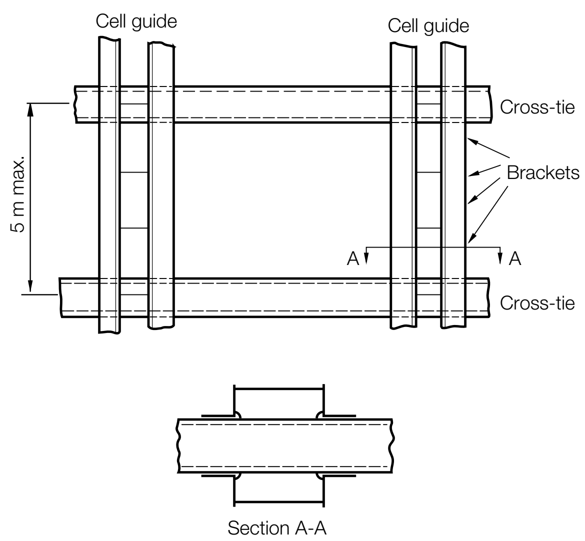


Fig. 14.7.1 Typical arrangement of cell guides

7.2.4 The cell guides are to give a total clearance between the container and guide bars not exceeding 25 mm in the transverse direction and 40 mm in the longitudinal direction. The deviation of the cell guide bar from its intended line is not generally to exceed 4 mm in the transverse direction and 5 mm in the longitudinal direction.

7.2.5 Athwartship cross-ties are to be fitted between cell guides at a spacing determined from the loading on the guides but, generally, not more than 5 m apart. Wherever possible, cross-ties are to be arranged in line with the corners of the containers as stowed and are to be supported against fore and aft movement at a minimum of two points across the breadth of the hold. Where, however, the maximum fore and aft deflection in the cross-tie can be shown not to exceed 20 mm, then one support point may be accepted.

7.2.6 Longitudinal tie bars may be required to be fitted where shown necessary by the force calculations for the structure. Where fitted they are to comply with the requirements of 7.2.5.

7.2.7 Where, at the sides or ends of holds, the guide rails are fitted to transverse or longitudinal bulkheads, the bulkhead is to be locally reinforced to resist the additional loads.

7.3 Mixed stacks of 20 ft and 40 ft containers

7.3.1 Where the cell guides are arranged for the carriage of 40 ft containers, provision may be made for the installation of temporary intermediate cell guides for 20 ft containers. The permanent structure is to be designed such that it is suitable for either loading pattern.

7.3.2 Alternatively, permanent means for the support of 20 ft containers at the mid-length of a cell arranged for 40 ft containers will be considered. Such means may include the following:

(a) A pillar (inboard) and vertical rest bar (on the longitudinal bulkhead) against which the container stack may rest. The pillar is to be supported laterally by the deck structure over and is to be sufficiently stiff to control lateral deflection of the container stacks.
(b) Guide bars supported transversely by slim structure within the gap between containers and with longitudinal ties as necessary.

Details of proposals will be individually considered, taking into account the loads on the support structure and the resulting deflections.

7.3.3 Where it is desired to stow 20 ft containers in the lower tiers without external support at the mid-bay location, arrangements meeting the following requirements will be considered:

(a) Maximum container weights for 20 ft containers stowed in cell guides with no 40 ft container overstowed, can be derived from Tables 14.7.1 and 14.7.3 depending on the transverse acceleration and the number of tiers in the stack.
(b) Maximum container weights for 20 ft containers stowed in cell guides with at least one 40 ft container overstowed, can be derived from Tables 14.7.2 and 14.7.4 depending on the transverse acceleration and the number of tiers in the stack.
(c) Where a mixed stack not covered by Tables 14.7.1 to 14.7.4 is proposed, two-thirds of the transverse components of forces acting on 20 ft containers are to be assumed to be transmitted to the cell guides and one-third transmitted as a racking force through the unsupported end wall. The container weights are to be such that the racking force on the container end walls does not exceed 15 tonnes at the mid-hold end of the stack of 20ft containers.
The allowable compressive forces in the container corner posts are not to be exceeded, taking due account of 40 ft containers above as per 7.3.3(e), if applicable. The container weights are to be defined to ensure separation is minimized.
(d) Means are to be provided to prevent transverse sliding of the bottom of the stacks of 20 ft containers at the mid-hold end. This is to be in the form of permanently attached chocks at the inner bottom or equivalent.
(e) Stacking cones are to be fitted between each tier of the 20 ft containers to prevent transverse sliding. In addition, where a 40 ft container is required to be stowed above 20 ft containers, stacking cones are to be fitted at the ends of the 40 ft container between the 40 ft container and the 20 ft containers below.
(f) The 20 ft containers are to have steel walls and top (no open frame containers) and are to be of specially strengthened design, where necessary, to correspond to the vertical compressive load at the cell guide end of the 40 ft containers above.

Table 14.7.1 Maximum container weights of ISO 1496-1:1984 20 ft containers stowed in 40 ft cell guides with no overstow

Lowest tier Transverse acceleration (g)	Maximum container weights, in tonnes					
	3 Tiers	4 Tiers	5 Tiers	6 Tiers	7 Tiers	8 Tiers
0,4	24,0	23,5	18,9	14,3	11,0	8,9
0,405	24,0	23,4	18,7	14,2	11,0	8,8
0,41	24,0	23,2	18,5	14,1	10,9	8,8
0,415	24,0	23,0	18,3	14,0	10,8	8,7
0,42	24,0	22,8	18,2	13,9	10,7	8,7
0,425	24,0	22,6	18,0	13,8	10,7	8,6
0,43	24,0	22,4	17,8	13,7	10,6	8,5
0,435	24,0	22,2	17,6	13,6	10,5	8,5
0,44	24,0	22,0	17,5	13,6	10,5	8,4
0,445	24,0	21,8	17,3	13,5	10,4	8,3
0,45	24,0	21,6	17,1	13,4	10,3	8,3
0,455	24,0	21,4	16,9	13,3	10,3	8,2
0,46	24,0	21,2	16,8	13,2	10,2	8,2
0,465	24,0	21,0	16,6	13,1	10,1	8,1
0,47	24,0	20,8	16,4	13,0	10,1	8,0
0,475	24,0	20,6	16,2	12,9	10,0	8,0
0,48	24,0	20,4	16,1	12,8	9,9	7,9
0,485	24,0	20,2	15,9	12,7	9,9	7,8
0,49	24,0	20,0	15,7	12,6	9,8	7,8
0,495	24,0	19,8	15,5	12,5	9,7	7,7
0,5	24,0	19,6	15,4	12,4	9,7	7,7
0,505	24,0	19,4	15,2	12,3	9,6	7,6
0,51	24,0	19,2	15,0	12,3	9,5	7,5
0,515	24,0	19,0	14,9	12,1	9,4	7,5
0,52	24,0	18,8	14,7	12,0	9,4	7,4
0,525	24,0	18,6	14,5	11,8	9,3	7,4
0,53	24,0	18,4	14,3	11,7	9,2	7,3
0,535	24,0	18,2	14,2	11,5	9,2	7,2
0,54	24,0	18,0	14,0	11,4	9,1	7,2
0,545	24,0	17,8	13,8	11,2	9,0	7,1
0,55	24,0	17,6	13,6	11,1	9,0	7,0

(g) Where fore and aft tension/pressure approved adapter cones are used to link two 20 ft containers to equate to a 40 ft container, the storage of 40 ft containers above is not required. Special consideration is to be given to the maximum stack weight which is stowed in association with this method of securing. In general, each stack of 20 ft containers is not to exceed 120 tonnes.

Proposals for stowage arrangements other than the above will be individually considered and are to be accompanied by supporting calculations.

7.4 Cell guide systems on exposed decks

7.4.1 Analysis methods for the strength of the cell guide structure are to take due account of the interactive effects between guide structure and supporting deck structure and also of the deformation of the hull girder.

7.4.2 At its lower end the guide structure is to be efficiently connected to the deck structure. Cross-ties are to be arranged between guides in a transverse direction at a spacing determined by the loading on the guides but in general not more than 3 m apart. Cross-bracing members of adequate strength and sufficient number are to be fitted in the transverse and longitudinal directions to prevent excessive deflection of the guide structure.

7.4.3 The height of guide bars above the deck is to be sufficient to ensure adequate restraint to the uppermost container tiers.

7.4.4 Where the cell guide structure is attached to highly stressed hull or deck elements, such as sheerstrake, special attention is to be given to the design of the connection and the grade and quality of steel utilized.

Table 14.7.2 Maximum container weights of ISO 1496-1:1984 20 ft containers stowed in 40 ft cell guides with overstow

Lowest tier Transverse acceleration (g)	Maximum container weights, in tonnes, *see* Note					
	3 Tiers	4 Tiers	5 Tiers	6 Tiers	7 Tiers	8 Tiers
0,4	24,0	24,0	24,0	19,4	16,5	13,7
0,405	24,0	24,0	23,6	19,3	16,4	13,7
0,41	24,0	24,0	23,3	19,1	16,3	13,6
0,415	24,0	24,0	22,9	19,0	16,2	13,5
0,42	24,0	24,0	22,5	18,8	16,1	13,5
0,425	24,0	24,0	22,1	18,7	15,9	13,4
0,43	24,0	24,0	21,8	18,5	15,8	13,3
0,435	24,0	24,0	21,5	18,4	15,7	13,2
0,44	24,0	24,0	21,2	18,2	15,6	13,2
0,445	24,0	24,0	21,0	18,0	15,5	13,1
0,45	24,0	24,0	20,8	17,9	15,4	13,0
0,455	24,0	24,0	20,6	17,7	15,2	13,0
0,46	24,0	24,0	20,5	17,6	15,1	12,9
0,465	24,0	24,0	20,3	17,4	15,0	12,8
0,47	24,0	24,0	20,2	17,3	14,9	12,8
0,475	24,0	24,0	20,1	17,1	14,8	12,7
0,48	24,0	23,9	19,9	17,0	14,7	12,6
0,485	24,0	23,8	19,8	16,8	14,5	12,6
0,49	24,0	23,6	19,6	16,7	14,4	12,5
0,495	24,0	23,4	19,4	16,5	14,3	12,4
0,5	24,0	23,2	19,3	16,4	14,2	12,4
0,505	24,0	23,1	19,1	16,2	14,1	12,3
0,51	24,0	22,9	18,9	16,1	13,9	12,2
0,515	24,0	22,7	18,8	15,9	13,8	12,1
0,52	24,0	22,5	18,6	15,7	13,6	12,0
0,525	24,0	22,4	18,5	15,6	13,5	11,8
0,53	24,0	22,3	18,3	15,4	13,3	11,7
0,535	24,0	22,2	18,2	15,3	13,2	11,6
0,54	24,0	22,1	18,1	15,1	13,0	11,4
0,545	24,0	22,0	18,0	15,0	12,9	11,3
0,55	24,0	21,8	17,9	14,8	12,8	11,2

NOTE
40 ft overstow containers not included in the number of tiers.

7.5 Entry guide devices

7.5.1 A device to pre-centre the container and direct it into the cell guides is normally to be fitted at the top of the guide bars. Such devices include:

- fixed even peaks;
- fixed high and low peaks;
- 'flip-flop' systems;

but other devices will be considered. The device is to be of robust construction.

Table 14.7.3 Maximum container weights of ISO 1496-1:1990 20 ft containers stowed in 40 ft cell guides with no overstow

Lowest tier Transverse acceleration (g)	Maximum container weights, in tonnes					
	3 Tiers	4 Tiers	5 Tiers	6 Tiers	7 Tiers	8 Tiers
0,4	24,0	23,5	18,9	15,6	13,4	11,6
0,405	24,0	23,4	18,7	15,5	13,2	11,5
0,41	24,0	23,2	18,5	15,3	13,1	11,4
0,415	24,0	23,0	18,3	15,2	12,9	11,3
0,42	24,0	22,8	18,2	15,0	12,8	11,1
0,425	24,0	22,6	18,0	14,9	12,7	11,0
0,43	24,0	22,4	17,8	14,7	12,5	10,9
0,435	24,0	22,2	17,6	14,6	12,4	10,8
0,44	24,0	22,0	17,5	14,4	12,3	10,6
0,445	24,0	21,8	17,3	14,3	12,1	10,5
0,45	24,0	21,6	17,1	14,1	12,0	10,4
0,455	24,0	21,4	16,9	14,0	11,8	10,2
0,46	24,0	21,2	16,8	13,8	11,7	10,1
0,465	24,0	21,0	16,6	13,7	11,6	10,0
0,47	24,0	20,8	16,4	13,5	11,4	9,9
0,475	24,0	20,6	16,2	13,4	11,3	9,7
0,48	24,0	20,4	16,1	13,2	11,2	9,6
0,485	24,0	20,2	15,9	13,1	11,0	9,5
0,49	24,0	20,0	15,7	12,9	10,9	9,4
0,495	24,0	19,8	15,5	12,7	10,8	9,2
0,5	24,0	19,6	15,4	12,6	10,6	9,1
0,505	24,0	19,4	15,2	12,4	10,5	9,0
0,51	24,0	19,2	15,0	12,3	10,3	8,8
0,515	24,0	19,0	14,9	12,1	10,2	8,7
0,52	24,0	18,8	14,7	12,0	10,1	8,6
0,525	24,0	18,6	14,5	11,8	9,9	8,5
0,53	24,0	18,4	14,3	11,7	9,8	8,3
0,535	24,0	18,2	14,2	11,5	9,7	8,2
0,54	24,0	18,0	14,0	11,4	9,5	8,1
0,545	24,0	17,8	13,8	11,2	9,4	8,0
0,55	24,0	17,6	13,6	11,1	9,2	7,8

Table 14.7.4 Maximum container weights of ISO 1496-1:1990 20 ft containers stowed in 40 ft cell guides with overstow

Lowest tier Transverse acceleration (g)	Maximum container weights, in tonnes, *see* Note					
	3 Tiers	4 Tiers	5 Tiers	6 Tiers	7 Tiers	8 Tiers
0,4	24,0	24,0	24,0	19,6	17,1	15,2
0,405	24,0	24,0	23,6	19,4	17,0	15,1
0,41	24,0	24,0	23,3	19,2	16,8	14,9
0,415	24,0	24,0	22,9	19,1	16,7	14,8
0,42	24,0	24,0	22,5	18,9	16,5	14,7
0,425	24,0	24,0	22,1	18,8	16,4	14,5
0,43	24,0	24,0	21,8	18,6	16,2	14,4
0,435	24,0	24,0	21,5	18,4	16,1	14,3
0,44	24,0	24,0	21,2	18,3	15,9	14,1
0,445	24,0	24,0	21,0	18,1	15,8	14,0
0,45	24,0	24,0	20,8	18,0	15,7	13,9
0,455	24,0	24,0	20,6	17,8	15,5	13,7
0,46	24,0	24,0	20,5	17,7	15,4	13,6
0,465	24,0	24,0	20,3	17,5	15,2	13,5
0,47	24,0	24,0	20,2	17,3	15,1	13,3
0,475	24,0	24,0	20,1	17,2	14,9	13,2
0,48	24,0	23,9	19,9	17,0	14,8	13,1
0,485	24,0	23,8	19,8	16,9	14,6	12,9
0,49	24,0	23,6	19,6	16,7	14,5	12,8
0,495	24,0	23,4	19,4	16,5	14,3	12,7
0,5	24,0	23,2	19,3	16,4	14,2	12,5
0,505	24,0	23,1	19,1	16,2	14,1	12,4
0,51	24,0	22,9	18,9	16,1	13,9	12,2
0,515	24,0	22,7	18,8	15,9	13,8	12,1
0,52	24,0	22,5	18,6	15,7	13,6	12,0
0,525	24,0	22,4	18,5	15,6	13,5	11,8
0,53	24,0	22,3	18,3	15,4	13,3	11,7
0,535	24,0	22,2	18,2	15,3	13,2	11,6
0,54	24,0	22,1	18,1	15,1	13,0	11,4
0,545	24,0	22,0	18,0	15,0	12,9	11,3
0,55	24,0	21,8	17,9	14,8	12,8	11,2

NOTE
40 ft overstow containers not included in the number of tiers.

■ *Section 8*
Determination of forces for container securing arrangements

8.1 General

8.1.1 The forces acting in the securing system are to be determined for each loading condition and associated set of motions of the ship.

8.1.2 The following forces are to be taken into account:

- Static gravity forces.
- Inertial forces generated by accelerations due to roll, pitch and heave motions of the ship.
- Wind forces.
- Forces imposed by the securing arrangements.
- Wave impact forces.

8.1.3 Where ship response data is not available the values for roll, pitch and heave as given in Table 14.8.1 will be used for the calculation.

Table 14.8.1 Ship motions

Motion	Maximum single amplitude	Periods, in seconds
Roll	$\phi = \sin^{-1}\theta$ degrees but need not exceed 30° and is not to be taken less than 22° where $\theta = \sin\phi$ $= \left(0{,}45 + 0{,}1\dfrac{L}{B}\right)\left(0{,}54 - \dfrac{L}{1270}\right)$	$T_r = \dfrac{0{,}7B}{\sqrt{GM}}$
Pitch	$\psi = 12e^{-0{,}0033L_{pp}}$ but need not exceed 8°	$T_p = 0{,}5\sqrt{L_{pp}}$
Heave	$\dfrac{L_{pp}}{80}$ m	$T_h = 0{,}5\sqrt{L_{pp}}$

8.1.4 Wind forces are generally to be based on a maximum wind speed of 40 m/s.

8.1.5 Wind forces are to be taken as acting athwartships on the exposed faces of the container stack so as to increase the transverse force. Where the air gap between adjacent rows of containers does not exceed one metre, wind forces on the adjacent inner stack may be taken as zero. Where the air gap is five metres or more, the adjacent inner stack is to be treated as fully exposed. Wind forces on the inner stack for intermediate air gaps may be obtained by linear interpolation.

8.1.6 The individual components of force due to gravity, wind and ship motions acting on a particular container are to be determined in accordance with Table 14.8.2.

8.1.7 Forces due to pretensioning the securing devices need not, in general, be included in the calculation provided they do not exceed 500 kg in any one item. Special consideration will be given to cases where forces obtained from pre-stressing are an integral part of the design of the system.

8.1.8 Consideration is to be given to the forces from wave impact and shipping green seas where the form and proportions of the ship are such that these may occur. In general the strength of containers and the strength of the securing arrangements in the forward $0{,}25L_{pp}$ are to be suitable for forces increased by 20 per cent above the values calculated from these requirements, except where it can be shown that the containers are adequately protected by breakwaters or similar structure.

Table 14.8.2 Components of forces

Source	Component of force, in tonnes		
	Pressure (normal to deck)	Sliding (parallel to deck)	
		transverse	longitudinal
STATIC			
Roll	$W \cos \phi$	$W \sin \phi$	
Pitch	$W \cos \psi$		$W \sin \psi$
Combined	$W \cos (0{,}71\phi) \cos (0{,}71\psi)$	$W \sin (0{,}71\phi)$	$W \sin (0{,}71\psi)$
DYNAMIC			
Roll	$0{,}07024W \dfrac{\phi}{T_r^2} y$	$0{,}07024W \dfrac{\phi}{T_r^2} z_m$	
Pitch	$0{,}07024W \dfrac{\psi}{T_p^2} x$		$0{,}07024W \dfrac{\psi}{T_p^2} z_m$
Heave:			
Roll	$0{,}05W \dfrac{L_{pp}}{T_h^2} \cos \phi$	$0{,}05W \dfrac{L_{pp}}{T_h^2} \sin \phi$	
Pitch	$0{,}05W \dfrac{L_{pp}}{T_h^2} \cos \psi$		$0{,}05W \dfrac{L_{pp}}{T_h^2} \sin \psi$
WIND		$8{,}25AV^2 \cos \phi \times 10^{-5}$	

NOTES
1. For definition of terms, *see* 1.4.1 and Fig. 14.8.1.
2. The appropriate signs are to be used in calculating vector components of forces.

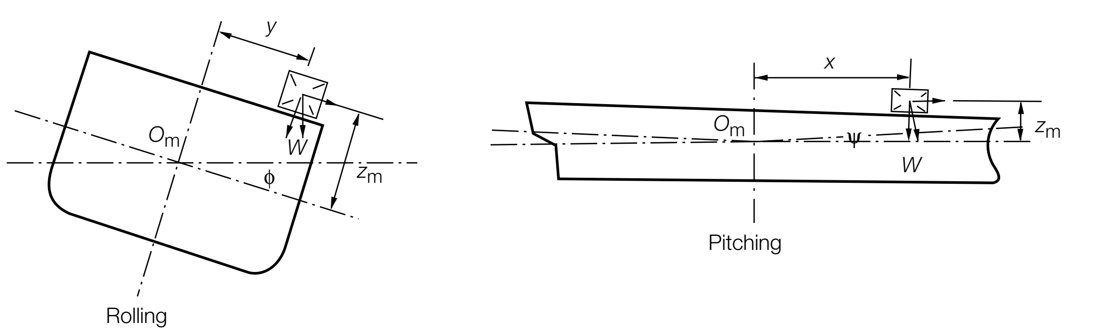


Fig. 14.8.1 Diagrammatic representation of symbols used in Table 14.8.2

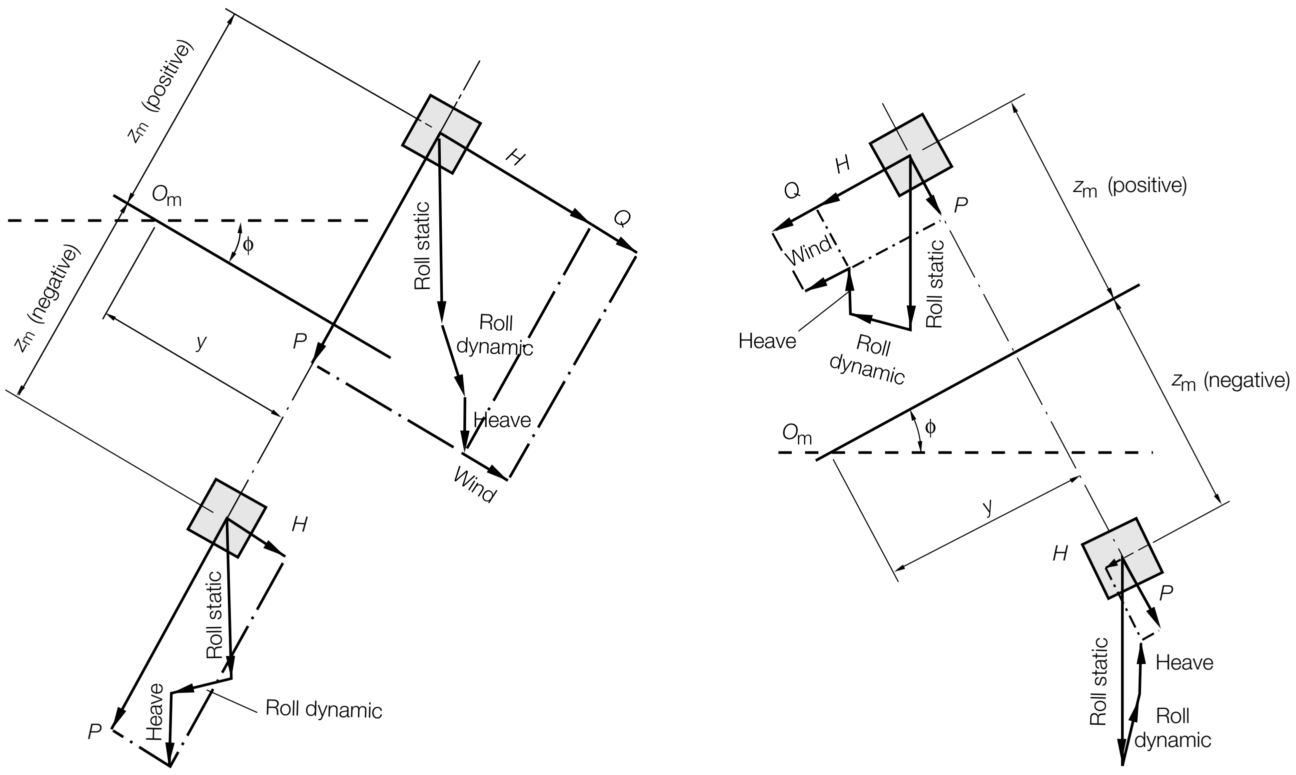


Fig. 14.8.2 Components of force on one container (Rolling condition)

8.2 Resultant forces

8.2.1 The resultant force acting on the container is the vectorial summation of the individual directional components of all forces acting at a given instant, *see* Fig. 14.8.2. The securing system is to be designed on the basis of the most severe combination of these forces in such a manner that the forces on the containers and securing devices are within allowable limits. Where different arrangements of securing devices are proposed for different locations on the ship, the forces are to be calculated for the most severe condition applicable to each arrangement.

8.2.2 The instantaneous maximum value of the resultants of the forces depends upon the phase relationship between the ship motions. This relationship may be derived from model testing where carried out for the specific ship, from strip theory or from full scale measurements if carried out for a ship of similar geometry.

8.2.3 Alternatively, the resultants in each of the three co-ordinate axes may be derived from the individual components of force determined from Table 14.8.2 for the instantaneous positions in the motion cycle as follows:

(a) Rolling condition:
  (i) Maximum roll (descending) with maximum heave (descending).
  (ii) Maximum roll (ascending) with maximum heave (ascending).

(b) Pitching condition:
  (i) Maximum pitch (descending) with maximum heave (descending).
  (ii) Maximum pitch (ascending) with maximum heave (ascending).

(c) Combined condition:
  (i) 0,71 [Maximum roll (descending) with maximum pitch (descending)].
  (ii) 0,71 [Maximum roll (ascending) with maximum pitch (ascending)].

8.2.4 The summation of the individual components of force for one container above or below the centre of motion is shown for the Rolling condition in Fig. 14.8.2, and the resultants are obtained from the following expressions:

(a) Bottom of motions, *see* 8.2.3 (a)(i):
Pressure

$$P_{max} = W\left[\left(1 + \frac{0,05L_{pp}}{T_h^2}\right)\cos\phi + \frac{0,07024\phi}{T_r^2}\,y\right]$$

Sliding (transverse)

$$H_{max} = W\left[\left(1 + \frac{0,05L_{pp}}{T_h^2}\right)\sin\phi + \frac{0,07024\phi}{T_r^2}\,z_m\right]$$

(b) Top of motions, *see* 8.2.3(a)(ii):
Pressure

$$P_{min} = W\left[\left(1 - \frac{0,05L_{pp}}{T_h^2}\right)\cos\phi - \frac{0,07024\phi}{T_r^2}\,y\right]$$

Sliding (transverse)

$$H_{min} = W\left[\left(1 - \frac{0,05L_{pp}}{T_h^2}\right)\sin\phi + \frac{0,07024\phi}{T_r^2}\, z_m\right]$$

The corresponding summations for the Pitching and Combined conditions may be written similarly.

■ *Section 9*
Strength of container securing arrangements

9.1 Resultant applied forces

9.1.1 The resultant forces derived for each container in the stack in accordance with Section 8 are assumed to be divided equally between the walls of the container as follows:

H_i = sliding force in one transverse end = $\frac{H}{2}$ tonnes

J_i = sliding force in one longitudinal side = $\frac{J}{2}$ tonnes

P_i = vertical force in each corner post = $\frac{P}{4}$ tonnes

Q_i = wind force in one transverse end = $\frac{Q}{2}$ tonnes

The subscript i refers to any particular container.

9.1.2 The sliding forces H_i and J_i are taken to act at a mean height of one third the height of the container above its base. That is, the force may be distributed as to $\frac{H_i}{3}$ $\left(\text{or } \frac{J_i}{3}\right)$ acting at the top of the container and $\frac{2H_i}{3}$ $\left(\text{or } \frac{2J_i}{3}\right)$ acting at the bottom, *see* Fig. 14.9.1.

9.1.3 Wind force is taken as uniformly distributed over the side of the container and is therefore divided equally between the top and bottom of the container, *see* Fig.14.9.1.

9.2 Forces in an unlashed stack

9.2.1 Where the stack is supported only by approved devices between the tiers of containers and at the base of the stack, the forces in the stack are determined from Table 14.9.1.

9.2.2 To illustrate this calculation, the equations for the three tier stack shown in Fig. 14.9.1 are listed below for the Rolling condition. In these equations the values of P and H are the maxima or minima derived from 8.2.4 as appropriate. Similar equations may be written for the Pitching and for the Combined conditions.

(a) Racking force, per end wall:
Tier 3: F_3
Tier 2: $F_3 + F_2$
Tier 1: $F_3 + F_2 + F_1$

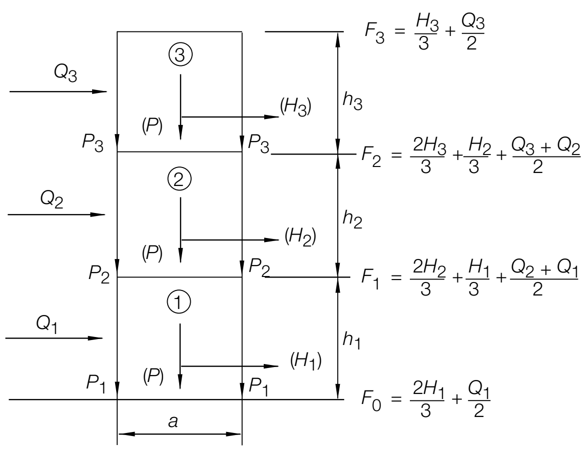


Fig. 14.9.1
Forces in a three tier stack (Rolling condition)

(b) Shear force, per corner:
Tier 3: 0,55 ($H_3 + Q_3$)
Tier 2: 0,55 ($H_3 + H_2 + Q_3 + Q_2$)
Tier 1: 0,55 ($H_3 + H_2 + H_1 + Q_3 + Q_2 + Q_1$)

(c) Maximum compressive force per bottom corner (i.e. force on the container below):

Tier 3: $P_3 + \frac{F_3}{a} h_3$

Tier 2: $P_3 + P_2 + \frac{F_3}{a}(h_3 + h_2) + \frac{F_2}{a} h_2$

Tier 1:

$P_3 + P_2 + P_1 + \frac{F_3}{a}(h_3 + h_2 + h_1) + \frac{F_2}{a}(h_2 + h_1) + \frac{F_1}{a} h_1$

(d) Minimum compressive force per bottom corner:
Case (i) (maximum amplitude descending):

Tier 3: $P_3 - \frac{F_3}{a} h_3$

Tier 2: $P_3 + P_2 - \frac{F_3}{a}(h_3 + h_2) - \frac{F_2}{a} h_2$

Tier 1:

$P_3 + P_2 + P_1 - \frac{F_3}{a}(h_3 + h_2 + h_1) - \frac{F_2}{a}(h_2 + h_1) - \frac{F_1}{a} h_1$

Case (ii) (maximum amplitude ascending):

Tier 3: $P_3 - \frac{F_3}{a} h_3$

Tier 2: $P_3 + P_2 - \frac{F_3}{a}(h_3 + h_2) - \frac{F_2}{a} h_2$

Tier 1:

$P_3 + P_2 + P_1 - \frac{F_3}{a}(h_3 + h_2 + h_1) - \frac{F_2}{a}(h_2 + h_1) - \frac{F_1}{a} h_1$

A negative value in these equations indicates a separation force at that level. The minimum is the lesser value from the two cases.

9.2.3 The resultant forces calculated from 9.2.1 are not to exceed the allowable loads for which the container is suitable, *see* 9.7.

Table 14.9.1 Forces in an unlashed stack

Force	Symbol	Expression	Unit
Racking force per container wall:			
transverse	F	$\sum_{i=1}^{i} F_i$	t
longitudinal	G	$\sum_{i=1}^{i} G_i$	t
Shear force per corner:			
transverse	S_{yz}	$0{,}55 \sum_{i=1}^{i} H_i + Q_i$	t
longitudinal	S_{xz}	$0{,}55 \sum_{i=1}^{i} J_i$	t
Vertical reaction to tipping per corner:			
transverse	R_{yz}	$\frac{1}{a} \sum_{i=1}^{i} F_i z_i$ *See* Notes 1 and 2	t
longitudinal	R_{xz}	$\frac{1}{b} \sum_{i=1}^{i} G_i z_i$ *See* Notes 1 and 2	t
Vertical pressure per corner	P_i	$\sum_{i=1}^{i} P_i$ *See* Note 2	t
Resultant compressive force per corner:			
Maximum transverse		P_i max. + R_{yz} max.	t
Minimum transverse		P_i max. – R_{yz} max.	t
		or P_i min. – R_{yz} min. *See* Note 3	t
Maximum longitudinal		P_i max. + R_{xz} max.	t
Minimum longitudinal		P_i max. – R_{xz} max.	t
		or P_i min. – R_{xz} min. *See* Note 3	t

NOTES
1. z_i is the distance from the level under consideration to the top of each container above that level, in metres.
2. Both the maximum and the minimum values are to be calculated.
3. Whichever is the lesser. A negative value indicates separation.

9.2.4 The resultant forces in the securing devices and supports are not to exceed the allowable working loads for which the device has been approved, *see* Section 3.

9.2.5 For exposed stacks in the forward $0{,}25L_{pp}$, *see* 8.1.7.

9.3 Arrangements incorporating lashings or buttresses

9.3.1 Where the securing arrangements incorporate lashings, proper allowance is to be made for flexibility of the system. For this purpose, the following values may be adopted:

(a) **Racking deformation of the container.** Full scale testing of containers indicates that values of the spring constant (*see* Fig. 14.9.3) may be taken as in Table 14.9.2.

(b) **Horizontal movement of the containers.** Initial displacement of containers due to tolerances in container fittings will be considered in conjunction with the stowage arrangement proposed. Generally, initial displacement may be neglected in calculation procedures for conventional stowages.

(c) **Elongation of lashings.** Elongation is to be determined by reference to the effective modulus of elasticity of the lashing (allowance for straightening and stretching) which, in the absence of actual test values, may be taken as:

steel rod lashings	9,8 t/mm^2
steel wire rope lashings	9,0 t/mm^2
steel chain lashings (based on the nominal diameter of the chain)	8,0 t/mm^2

Adjustable tension/ compression buttress	12,0 t/mm^2
Aluminium or other materials	To be considered.

Table 14.9.2 Spring constants for containers

Height (m)	Door end (t/mm)	Closed end (t/mm)	Side wall (t/mm)
2,438	0,37	1,67	0,61
2,591	0,35	1,54	0,57
2,743	0,33	1,43	0,54
2,896	0,32	1,33	0,51

9.3.2 Any other element introducing flexibility into the structure between the lashing point and the base of the container stack is to be evaluated and taken into account, if necessary. Examples of this could be flexibility of a lashing bridge, sliding of a hatch cover, or torsional deformations of the hull.

9.3.3 When paired lashings are used, a cross-sectional area equal to 150 per cent of the cross-sectional area of one lashing is to be used unless an equalizing system is fitted. If an equalizing system is fitted, the sum of the cross-sectional areas is to be used.

9.3.4 The resultant applied forces are determined in accordance with 9.1. The distribution of forces in the stack is obtained by equating the total movement of the containers with the corresponding component of elongation of the associated support element under the influence of the imposed forces.

9.3.5 The calculations are to be made for each end of the container stack, that is with all door ends together and with all closed ends together.

9.3.6 The load system for a four tier stack of containers with upper and lower lashings is illustrated in Fig. 14.9.2. The containers and lashings are modeled as a system of springs whose stiffness may be calculated and hence the equilibrium condition for the system may be found, *see* Fig. 14.9.3.

9.3.7 Having established the tension in the lashings, the residual forces in the containers are transmitted through the stack in accordance with the method given in 9.5. The model assumes that the securing devices between tiers of containers are capable of resisting negative (separation) forces. That is, where separation forces are found, suitable locking devices are assumed to be fitted and transmitting load.

9.3.8 A buttress or shore may be modeled in a similar way to a lashing. Where, however, more than one stack is supported by the use of linkages between adjacent containers in line with the buttress or shore, the model is to take this into account.

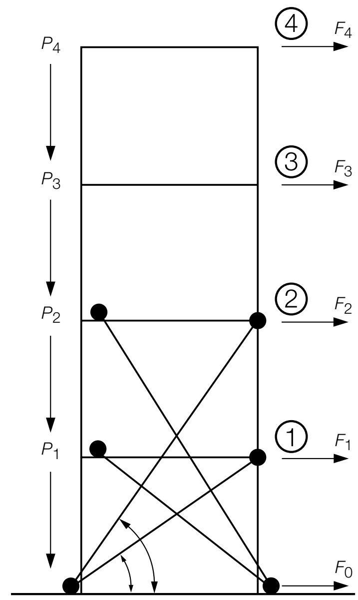


Fig. 14.9.2 Container stack load system

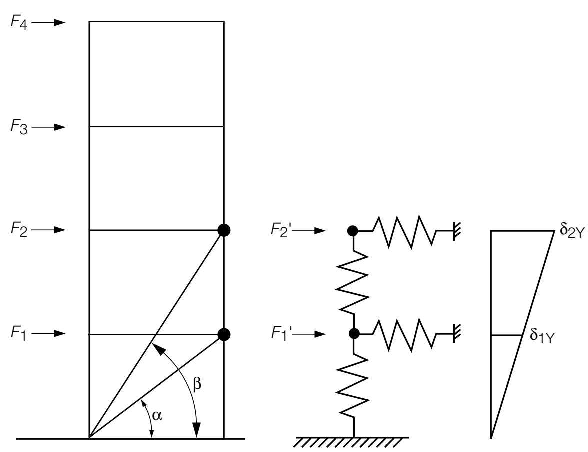


Fig. 14.9.3 Container stack load system

9.4 Tensions in the lashing rods

9.4.1 For conventional arrangements, the spring constant for the lashing rod may be determined using the expression:

$$k_L = \frac{E \cdot A \cdot \text{Cos}^2\, \theta_L}{l_L}$$

However, some stowage arrangements may result in considerable longitudinal displacement between the base of the lashing and the fitting in the container corner, i.e. 40' container in a 45' bay. In such cases the spring constant of the lashing rod should be determined using the following expression:

$$k_L = \frac{E \cdot A \cdot l_y^2}{l_L^3}$$

where

y = transverse span of lashing, in mm

E = Effective Modulus of Elasticity (t/mm^2)

A = cross-section area of lashing rod, in mm^2

l_L = length of lashing (mm) given by

$l_L = \sqrt{l_x^2 + l_y^2 + l_z^2}$

l_x = longitudinal separation of lashing ends measured parallel to ship's X axis, in mm

l_y = transverse separation of lashing ends measured parallel to ship's Y axis, in mm

l_z = vertical separation of lashing ends measured parallel to ship's Z axis, in mm

θ_L = lashing angle, in degrees.

9.4.2 The expressions for the tensions in the lashing rods will vary with the lashing arrangement used, however, for the three cases below the expressions for the lashing rod tensions are summarised in Table 14.9.4:

(a) Single cross lashed stack.
(b) Double cross lashed stack.
(c) Double cross lashed stack to lashing bridge.

9.5 Residual forces

9.5.1 The residual transverse force in the containers at the level of the lashing is:

Lower $F_{1,RES} = F_1 - T_{L1} \cos \alpha$ (tonnes)

Upper $F_{2,RES} = F_2 - T_{L2} \cos \beta$ (tonnes)

The racking and shearing forces in the container stack may then be determined in accordance with 9.2.2 using the residual transverse forces. The maximum and minimum vertical forces in the corner posts may be determined similarly taking due account of the vertical component of lashing tension where applicable.

9.5.2 The resultant forces in the containers are not to exceed the allowable values given in 9.7.

9.5.3 The lashing tensions are not to exceed the allowable working loads of the lashings as determined from Pt 3, Ch 14,3 of the Rules for Ships.

9.5.4 Where external support is provided by a buttress or shore the load is to be transmitted between adjacent stacks by linkages in line with the support. The force in the transverse end frame members of the containers adjacent to the support is given by:

$F_b \left(\frac{2N-1}{2N}\right)$ tonnes and the force in the linkage to the adjacent container is $F_b \left(\frac{N-1}{N}\right)$ tonnes

where

F_b = calculated force in the buttress or shore, in tonnes

N = number of rows of containers supported by the buttress or shore.

9.6 Structural restraint systems

9.6.1 Where open framework systems are fitted on deck to provide structural restraint, they are to be designed to absorb the full horizontal component of force at that level and to prevent movement of the container stack. For the purpose of these calculations the deformation of the ship's structure in way of supports may be neglected.

9.7 Allowable forces on containers

9.7.1 For ISO containers, the securing arrangements are to be designed so that the forces on the containers do not exceed the values shown in Table 14.9.4. The maximum forces for ISO 1496-1: 1984 containers are illustrated in Fig. 14.9.4.

9.7.2 The allowable forces for containers of other dimensions will be determined on the basis of the values in Table 14.9.3 and of the forces for which the container has been certified.

Table. 14.9.3 Summary of container securing methods

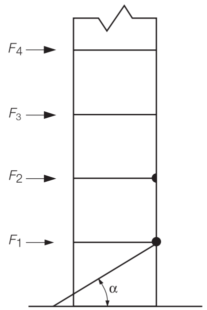
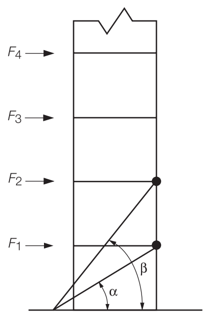
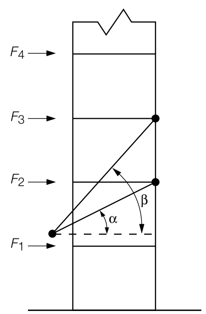
Arrangement	F'_x	Tension in lashing	Residual transverse Forces at lashing level
	$F'_1 = \sum_{i=1}^{n} F_i$	$T_{L1} = \dfrac{k_{L1} \cdot F'_1}{(k_{C1} + k_{L1}) \cos\alpha}$	$F_{1,RES} = F_1 - T_{L1} \cdot \cos\alpha$
	$F'_2 = \sum_{i=2}^{n} F_i$	$T_{L1} = \dfrac{k_{L1}}{\cos\alpha} \cdot \dfrac{(k_{C2} + k_{L2}) F'_1 + k_{C2} \cdot F'_2}{(k_{C1} + k_{C2} + k_{L1})(k_{C2} + k_{L2}) - k^2_{C2}}$ $T_{L2} = \dfrac{k_{L2}}{\cos\beta} \cdot \dfrac{k_{C2} \cdot F_1 + (k_{C1} + k_{C2} + k_{L1}) F'_2}{(k_{C1} + k_{C2} + k_{L1})(k_{C2} + k_{L2}) - k^2_{C2}}$	$F_{1,RES} = F_1 - T_{L1} \cdot \cos\alpha$ $F_{2,RES} = F_2 - T_{L2} \cdot \cos\beta$
	$F'_3 = \sum_{i=3}^{n} F_i$	$T_{L1} = \dfrac{k_{L1}}{\cos\beta} \cdot \dfrac{F_1 [(k_{C3} + k_{L2,Y}) k_{C2}] + F_2 [(k_{C1} + k_{C2})(k_{C3} + k_{L2.Y})] + F_3 [(k_{C1} + k_{C2}) k_{C3}]}{(k_{C1} + k_{C2}) [(k_{C2} + k_{C3} + k_{L1,Y})(k_{C3} + k_{L2,Y}) - k^2_{C3}] - k^2_{C2} (k_{C3} + k_{L2,Y})}$ $T_{L2} = \dfrac{k_{L2}}{\cos\beta} \cdot \dfrac{F_1 (k_{C2} \cdot k_{C3}) + F_2 [(k_{C1} + k_{C2}) k_{C3}] + F_3 [(k_{C1} + k_{C2})(k_{C2} + k_{C3} + k_{L1.Y}) - k^2_{C2}]}{(k_{C1} + k_{C2}) [(k_{C2} + k_{C3} + k_{L1,Y})(k_{C3} + k_{L2,Y}) - k^2_{C3}] - k^2_{C2} (k_{C3} + k_{L2,Y})}$	$F_{2,RES} = F_2 - T_{L1} \cdot \cos\alpha$ $F_{3,RES} = F_3 - T_{L2} \cdot \cos\beta$

Table 14.9.4 Allowable forces on ISO containers

	ISO 1496-1:1984 20 ft	ISO 1496-1:1984 40 ft	ISO 1496-1:1990 20 ft	ISO 1496-1:1990 40 ft
	in tonnes			
Horizontal force from lashing on container fitting acting parallel to the side face, *see* Note 1	15,0	15,0	15,0	15,0
Horizontal force from lashing on container fitting acting parallel to the end face, *see* Note 1	22,5	22,5	22,5	22,5
Vertical force from lashing on container fitting acting parallel to the end or side face, *see* Note 1	30,0	30,0	30,0	30,0
Racking force on container end	15,0	15,0	15,0	15,0
Racking force on container side	10,0	10,0	10,0	10,0
Vertical forces at each top corner, tension	15,0	15,0	25,0	25,0
Vertical forces at each bottom corner, tension	20,0	20,0	25,0	25,0
Vertical forces at each corner post, compression	2,25*R*	2,25*R*	86,4	86,4
Transverse forces acting at the level of and parallel to the top face, tension or compression, *see* Note 2	22,5	34,0	34,0	34,0
Transverse forces acting at the level of and parallel to the bottom face, tension or compression, *see* Note 2	35,0	50,0	50,0	50,0

NOTES
1. In no case is the resultant of the horizontal and the vertical forces to exceed the limiting value derived from Fig. 14.9.3(a).
2. Where a buttress supports the stack at an intermediate level, the total transverse force in the containers at the level is not to exceed the sum of the appropriate top and bottom forces.

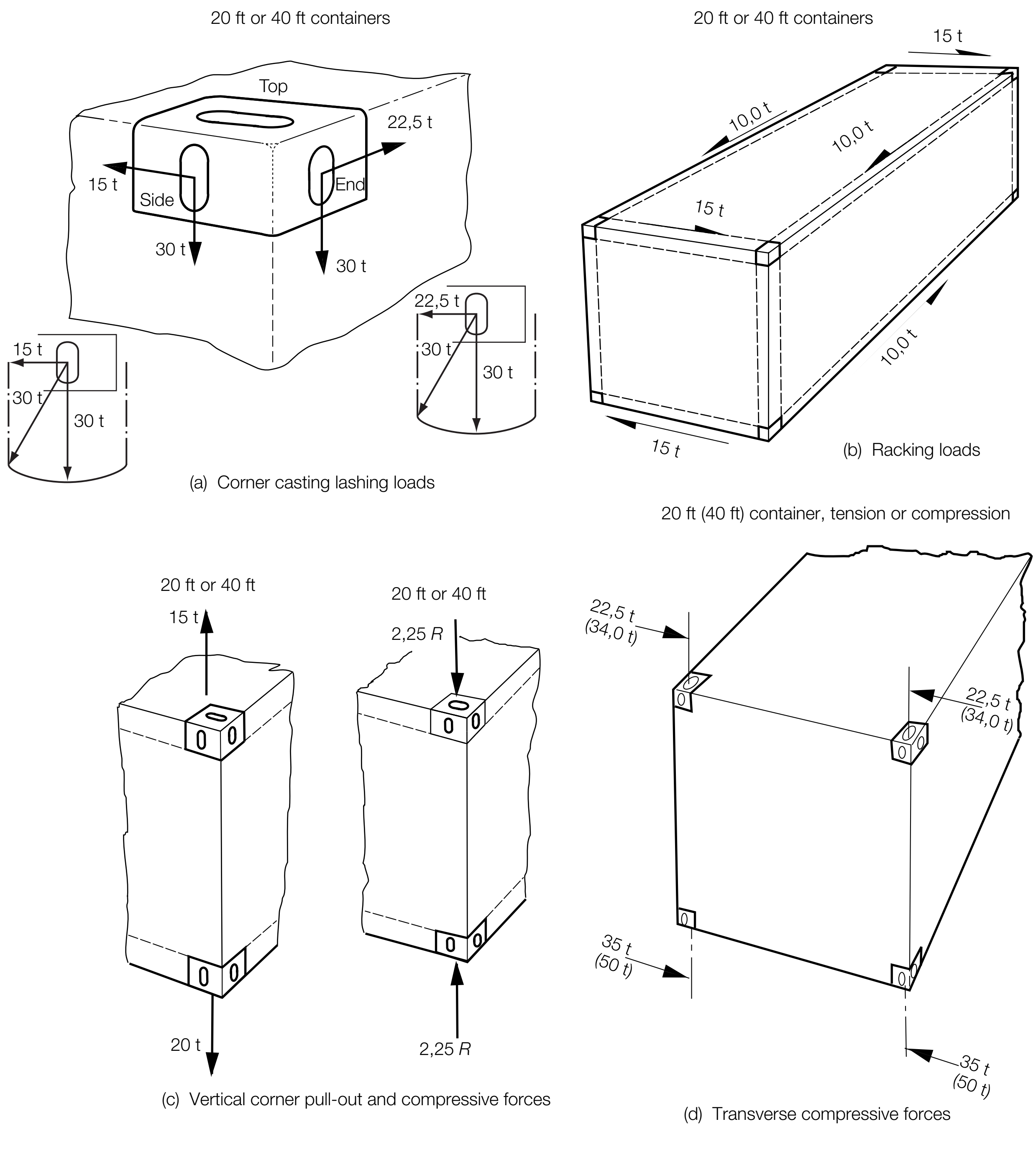


Fig. 14.9.4 Allowable forces for 20 ft or 40 ft ISO 1496-1: 1984 containers

■ *Section 10*
Surveys

10.1 Initial Survey

10.1.1 The Surveyor is to be satisfied that the materials, workmanship and arrangements are satisfactory and in accordance with the requirements and the approved plans. Any items found not to be in accordance with the requirements or the approved plans, or any material, workmanship or arrangements found to be unsatisfactory are to be rectified.

10.1.2 A Register of fixed and loose cargo securing fittings, when approved, is to be kept on board and up to date, and is to be made available to the Surveyor upon request. The Register is to contain sufficient details to enable all the fixed and loose cargo securing fittings to be identified, including:

- a simple sketch;
- the name of the item;
- the number supplied;
- the manufacturer's mark or code; and
- the safe working load with the corresponding breaking load.

10.1.3 For container securing arrangements, a suitable container stowage arrangement plan is to accompany the Register. Where containers of types other than ISO containers are proposed to be carried, their stowage locations are to be clearly indicated on the plan.

10.1.4 The Register and stowage plans, if applicable, may be included in the Cargo Securing Manual.

10.2 Periodical Surveys

10.2.1 For the requirements for Periodical Surveys *see* Pt 1, Ch 3,2.2.28 and Pt 1, Ch 3,5.3.19.

Section

■ *Section 1* General

1.1 Definitions

1.1.1 **Quality Assurance Scheme.** Lloyd's Register's (hereinafter referred to as 'LR') Quality Assurance requirements for the hull construction of ships are defined as follows:

- **Quality Assurance.** All activities and functions concerned with the attainment of quality including documentary evidence to confirm that such attainment is met.
- **Quality system.** The organization structure, responsibilities, activities, resources and events laid down by Management that together provide organized procedures (from which data and other records are generated) and methods of implementation to ensure the capability of the shipyard to meet quality requirements.
- **Quality programme.** A documented set of activities, resources and events serving to implement the quality system of an organization.
- **Quality plan.** A document derived from the quality programme setting out the specific quality practices, special processes, resources and activities relevant to a particular ship or series of sister ships. This document will also indicate the stages at which, as a minimum, direct survey and/or system monitoring will be carried out by the Classification Surveyor.
- **Quality control.** The operational techniques and activities used to measure and regulate the quality of hull construction to the required level.
- **Inspection.** The process of measuring, examining, testing, gauging or otherwise comparing the item with the approved drawings and the shipyard's written standards including those which have been agreed by LR for the purposes of classification of the specific ship type concerned.
- **Assessment.** The initial comprehensive review of the shipyard's quality systems, prior to the granting of approval, to establish that all the requirements of these Rules have been met.
- **Audit.** A documented activity aimed at verifying by examination and evaluation that the applicable elements of the quality programme continue to be effectively implemented.
- **Hold point.** A defined stage of manufacture beyond which the work must not proceed until the inspection has been carried out by all the relevant personnel.
- **System monitoring.** The act of checking, on a regular basis, the applicable processes, activities and associated documentation that the Shipbuilder's quality system continues to operate as defined in the quality programme.
- **Special process.** A process where some aspects of the required quality cannot be assured by subsequent inspection of the processed material alone. Manufacturing special processes include welding, forming and the application of protective treatments. Inspection and testing processes classified as special processes include non-destructive examination and pressure and leak testing.

1.2 Scope of the Quality Assurance Scheme

1.2.1 This Chapter specifies the minimum Quality System requirements for a shipyard to construct ships under LR's Quality Assurance Scheme.

1.2.2 For the purposes of this Chapter of the Rules, hull construction comprises the hull structure; containment systems, including those which are independent of the main hull structure; appendages; superstructures; deckhouses; and closing appliances all as required by the Rules.

1.2.3 Although the requirements of this Scheme are, in general, for steel ships of all welded construction, other materials for use in hull construction will be considered.

■ *Section 2* Application

2.1 Certification of the shipyard

2.1.1 LR will give consideration to a shipyard's Quality Assurance System provided, at all times, there is full commitment by all the shipyard personnel to the implementation and maintenance of this system. On satisfactory completion of assessments and audits LR will issue certificates of approval to the shipyard as indicated in 2.1.2.

2.1.2 LR's Quality Assurance Scheme comprises:

Part 1 The requirements of the Quality System for hull construction which are applicable to shipyards operating a quality programme but not necessarily constructing to LR's Class. Certificates of approval valid for three years will be issued, with intermediate audits at intervals of 6 months.

Part 2 The Quality System requirements for hull construction for application to ships under construction to LR's Class as part of the Special Survey. LR's particular requirements for construction of ships to its Class, and the continuous involvement in the hull construction process by a combination of direct survey and systems monitoring by LR's Surveyors, are provided for by Part 2. Where LR considers that there is a stage in construction at which a high degree of direct inspection by the Surveyors is desirable, this stage will be described on the Part 2 Approval Certificate.

Certificates of approval for Part 2 will be valid for one year, and will be issued after satisfactory assessment/audit carried out at a suitable stage during construction to LR's Class. Part 1 certification will automatically be issued, or re-issued as applicable, on attainment of Part 2 approval.

2.1.3 Chemical carriers with cargo tank structure of material other than carbon manganese steel and the cargo containment system on ships for liquefied gases will be specially considered. The procedure relating to the construction of such structure on chemical carriers and liquefied gas containment systems is to be separately prescribed in the Quality Plan which will be subject to approval by LR.

2.1.4 The Quality System at a shipyard will be examined for compliance with these Rules by the assessments and audits as laid down in Sections 4, 5 and 6. Initial and periodical approval of the system will be considered by the Committee on receipt of satisfactory assessment and audit reports.

2.1.5 All information and data submitted by a Shipbuilder for approval under this Scheme and for maintenance of approval will be treated by LR in strict confidence and will not be disclosed to any third party without the prior written consent of the Shipbuilder.

2.1.6 A list of shipyards approved under the Scheme will be held in the *List of Shipyards Approved to the Requirements of the Quality Assurance Scheme*.

■ *Section 3* Particulars to be submitted

3.1 Documentation and procedures

3.1.1 Under either Part of the Scheme, the documentation to meet the requirements of Section 4 is to be submitted. This documentation includes the Quality Manual, Quality Plans, documented procedures and work instructions.

3.1.2 Additionally, under Part 2 of the Scheme the documentation to meet the requirements of Section 5 is to be submitted for approval. Construction plans and all necessary particulars are also to be submitted for approval in accordance with the relevant requirements of the Rules, *see* Pt 1, Ch 2,3.2.1.

3.2 Amendments

3.2.1 Any major changes to the documentation or procedures required by Sections 4 or 5 are to be re-submitted.

■ *Section 4* Requirements of Parts 1 and 2 of the Scheme

4.1 General

4.1.1 The requirements of this Section are applicable to shipyards seeking approval under Parts 1 and 2 of the Scheme.

4.2 Policy statement

4.2.1 A policy statement, signed by the Chief Executive of the shipyard concerned, confirming the full commitment of all levels of personnel in the shipyard to the implementation and sustained operation of quality assurance methods is to be included in the Quality Manual.

4.3 Responsibility

4.3.1 Personnel responsible for functions affecting quality are to have defined responsibility and authority to identify, control and evaluate quality.

4.4 Management Representative

4.4.1 The Shipbuilder is to appoint a Management Representative, who is to be independent of other functions unless specifically agreed otherwise by LR, and who is to have the necessary authority and responsibility for ensuring that the requirements of the Scheme are complied with.

4.4.2 The Management Representative is to have the authority to stop production if serious quality problems arise.

4.5 Quality control and testing personnel

4.5.1 The Shipbuilder is to utilise quality control and testing personnel whose performance and continued freedom of influence from production pressures is to be systematically confirmed by the Management Representative.

4.6 Resources

4.6.1 Sufficient resources shall be provided by the shipyard to enable the requirements identified by the Quality Management System to be effectively implemented.

4.7 The Quality Management System

4.7.1 The Shipbuilder is to establish, document and maintain an effective Quality Management System that will ensure and demonstrate that materials and consumables used, and working processes employed, conform to the requirements for hull construction.

4.7.2 **Quality Manual**. The basic documentation is to be in the form of a Quality Manual which sets out the general quality policies and which references the detailed procedures, standards, etc., and includes the requirements of 4.2 to 4.24 and, where appropriate, 5.1 to 5.10.

4.7.3 **Procedures**. The Shipbuilder is to establish, document and maintain an adequate and defined control of the hull construction process comprising:

(a) defined and documented controls, processes, procedures, tolerances, acceptance/rejection criteria and workmanship standards; and
(b) the provision of Quality Plans for each ship or series of sister ships for the processes and procedures for manufacture, inspection and testing involved from receipt of material through to completion of the hull construction process.

4.7.4 **Work instructions**. The Shipbuilder is to develop and maintain clear and complete documented work instructions for the processes and standards involved in the construction of the hull. Such instructions are to provide directions to various levels of personnel.

4.8 Regulatory requirements

4.8.1 The Shipbuilder is to establish that the requirements of all applicable Regulations are clearly specified and agreed with the Owner/Classification Society/Regulatory Authority. These Regulations are to be made available for all functions that require them and their suitability is to be reviewed.

4.8.2 The Shipbuilder is to establish a design verification procedure to ensure that the regulatory requirements have been incorporated into the design output.

4.9 Control of hull drawings

4.9.1 The Shipbuilder is to establish, document and maintain a procedure for the submission to the Classification Society and other regulatory bodies of all the necessary drawings required for approval sufficiently early and in such a manner that the requirements of the Classification Society and other regulatory bodies can be included in the design before construction commences. This procedure is to include a provision which ensures that all amendments to approved drawings are incorporated in the working drawings and that design revisions are re-submitted for approval.

4.10 Documentation and change control

4.10.1 The Shipbuilder is to establish a procedure to ensure that:

(a) valid drawings, specifications, procedures, work instructions and other documentation necessary for each phase of the fabrication process are prepared;
(b) all necessary documents and data are made readily available at all appropriate work, testing and inspection locations;
(c) all amended drawings and changes to documentation are processed in a timely manner to ensure inclusion in the production process;
(d) records are maintained of amendments and changes to documentation; and
(e) provision is made for the prompt removal or immediate identification of all superseded drawings and documentation throughout the shipyard.

4.11 Purchasing data and receipt

4.11.1 The Shipbuilder is to maintain purchasing documents containing a clear description of the materials ordered for use in hull construction and the standards to which material must conform, and the identification and certification requirements.

4.11.2 For the requirements for receiving inspection of purchased items, *see* 4.15.

4.12 Owner supplied material

4.12.1 The Shipbuilder is to have procedures for the inspection, storage and maintenance of Owner supplied materials and equipment.

4.13 Identification and traceability

4.13.1 The Shipbuilder is to establish and maintain a procedure to ensure that materials and consumables used in the hull construction process are identified (by colour-coding and/or marking as appropriate) from arrival at the shipyard through to erection in such a way as to enable the type and grade to be readily recognized. The procedure is to ensure that the Shipbuilder has the ability to identify material in the completed vessel and ensure traceability to the mill sheets.

4.14 Fabrication control

4.14.1 The Shipbuilder is to establish, document and maintain suitable procedures to ensure that fabrication and construction operations are carried out under controlled conditions. Controlled conditions are to include:

(a) clearly documented work instructions defining material treatment, marking, cutting, forming, sub-assembly, assembly, erection, fitting of closing appliances, use of fabrication aids and associated fit-up, weld preparation, welding and dimensional control procedures;

(b) criteria for workmanship and manufacturing tolerances. These are to be documented in a clear manner and made available to the appropriate workforce, and are to include acceptance/rejection criteria; and
(c) documented instructions for the control of equipment and machines used in fabrication. These are to be made available to the appropriate workforce and supplied to individuals where necessary.

4.14.2 The Shipbuilder is to establish and control welding, non-destructive examination and painting which are part of the fabrication system, the equipment used in such processes and the environment in which they are employed. Operators of these special processes are to be properly qualified. Details of these processes are to be included in the relevant Quality Plans.

4.14.3 A list of approved welding procedures is to be maintained and made available to relevant personnel. Records of the results of testing for approval are also to be maintained. Lists of appropriately qualified welders are to be maintained. Procedures for distribution and recycling of welding consumables are to be implemented.

4.14.4 The Shipbuilder is to establish, document and maintain adequate maintenance schedules and standards for all equipment associated with the hull construction process.

4.15 Control of inspection and testing

4.15.1 The Shipbuilder is to be responsible for ensuring that all incoming plates, sections, castings, components, fabrications and consumables and other materials used in the hull construction process are inspected or otherwise verified as conforming to purchase order requirements.

4.15.2 The Shipbuilder is to provide an inspection system at suitable stages of the fabrication process from the material delivery to the completion of hull construction. The inspection system is to confirm and record the inspections carried out.

4.16 Indication of inspection status

4.16.1 The Shipbuilder is to establish and maintain a system for identifying the inspection status of structural components at appropriate stages of the fabrication process. This may include the direct marking of components. Records of inspection and measurements are to be identifiable to components to which they refer and be readily accessible to production and inspection personnel and to Classification Surveyors.

4.17 Inspection, measuring and test equipment

4.17.1 The Shipbuilder is to be responsible for the control, calibration, and maintenance of the inspection, measuring and test equipment used in the fabrication and non-destructive examination of the hull structure.

4.17.2 The calibration system is to allow traceability back to appropriate National Standards. Where these do not exist the basis of calibration is to be defined.

4.18 Non-conforming materials and corrective action

4.18.1 The Shipbuilder is to establish and define procedures to provide for:
(a) the clear identification and segregation from production areas of all plates, sections, castings, components, fabrications, consumables and other materials which do not conform to the agreed specification; and
(b) the initiation of authorized corrective or alternative action.

4.19 Protection and preservation of quality

4.19.1 The Shipbuilder is to establish and maintain a procedure to control handling and preservation processes for both the material used in fabrication and the structural components at all stages of the fabrication process. This procedure is to ensure conformance to specified requirements and established standards.

4.19.2 Welding consumables are to be stored, handled and recycled according to maker's recommendations.

4.20 Records

4.20.1 The Shipbuilder is to develop and maintain records that demonstrate achievement of the required quality and the effective operation of the Quality System. Records demonstrating sub-contractor achievement of these requirements are to be maintained. These records are to be retained and available for a defined period. These records are to include identification of materials and consumables used in fabrication, the number and class of defects found during fabrication and information regarding corrective action taken. Records of particular processes, e.g. plate surface preparation and priming, marking, cutting, forming, accuracy control, non-destructive examination, audits and all other records pertaining to the operation of the Quality System are also to be maintained.

4.21 Internal audit and management review

4.21.1 Internal audits of the performance of all aspects of the systems relating to design, production and testing are to be carried out systematically by appointed staff and recorded under the authority of the Management Representative. These staff members will not normally audit functions for which they are directly responsible.

4.21.2 Using data obtained from the audits and any other available relevant information, management reviews are to take place at specified intervals or more frequently as deemed necessary in order to review the performance of the Quality System.

4.21.3 The Shipbuilder is to establish, document and maintain a procedure for corrective application of data feedback from previous construction, including previous ships during the guarantee period.

4.21.4 The Shipbuilder is to establish, document and maintain a procedure to provide for the analysis of departures from manufacturing standards, steel material scrapped, reworked or repaired during the fabrication and construction process in order to detect trends, investigate the cause to determine the action needed to correct the processes and work procedures, or to identify the further training of operators as appropriate.

4.21.5 Agreed improvements to the Quality System are to be implemented within a time scale appropriate to the nature of the improvement.

4.22 Training

4.22.1 The Shipbuilder is to establish and maintain a system to identify training needs and ensure that all personnel involved in the fabrication, erection and quality-involved functions have adequate experience, training and qualifications. This requirement extends to sub-contractor personnel working within the shipyard. Records are to be available to the Classification Surveyor.

4.23 Sampling

4.23.1 Any sampling processes used by the Shipbuilder are to be in accordance with specified or Statutory Requirements or to the satisfaction of the Classification Surveyor as applicable.

4.24 Sub-contracted personnel, services and components

4.24.1 The requirements of the Scheme are applicable, as appropriate, to all sub-contractor personnel and sub-contracted services operating within the shipyard.

4.24.2 The requirements of the Scheme are not applicable to sub-contractor personnel or sub-contracted services operating at locations outside the shipyard. In these circumstances it will be necessary for inspections to be carried out by the LR Surveyor using conventional survey methods.

■ *Section 5* Additional requirements for Part 2 of the Scheme

5.1 Quality System procedures

5.1.1 The procedures detailed in 4.7 are to be submitted for approval.

5.2 Quality Plans

5.2.1 Quality Plans for ships which are to be classed by LR are to be submitted for approval well in advance of commencement of work, irrespective of any submissions that may have been made for sister ships under Part 1 of the Scheme. Such Quality Plans are to outline all of the manufacturing, testing and inspection operations to be performed by the Shipbuilder and by which personnel they will be carried out. The Quality Plans are then to be submitted to the LR Surveyors who will indicate all the stages at which they will perform system monitoring, carry out direct inspection and participate in hold point inspections. These hold points will include, but not be limited to, the following:

(a) Radiographs and other test records of non-destructive examinations as required for Classification purposes, *see* Ch 10,2.13.
(b) The items described in Ch 1,8 relevant to the scope of this Chapter.

5.2.2 Notwithstanding what may have been agreed in the Quality Plans, the LR Surveyors have the discretion to increase their involvement, see also 8.1.5.

5.3 Material supplier approval

5.3.1 The Shipbuilder is to ensure that hull construction materials and consumables used are selected from manufacturers who are approved by LR.

5.4 Identification and traceability

5.4.1 The procedure required by 4.13.1 is to be submitted for approval.

5.5 Fabrication control

5.5.1 The information required by 4.14.1(b) will be examined for acceptability.

5.5.2 Procedures for material treatment, forming, weld preparation and welding are to be submitted for approval.

5.5.3 Procedures required by 4.14.3 are to be submitted to the LR Surveyors for approval.

5.6 Control of inspection and testing

5.6.1 The inspection stages incorporated into the Scheme are to include specific checks for fit-up and welding which are to be carried out at each sub-assembly, assembly, pre-erection and erection stage as well as self-checking by the operator. The number of recorded checks at each stage will be agreed with the LR Surveyor, after consideration of documentary evidence of quality being achieved. Repairs, where required, are to be effected after each check. Collated Quality Control data to demonstrate the efficiency of the above self-check system are to be made available to the LR Surveyor by the Shipbuilder. The Quality Plans referred to in 4.7.3(b) provide the opportunity for the Shipbuilder and the LR

Surveyor to consider the structural design and ship type fully in order to determine the most efficient and effective inspection stages.

5.7 Control of non-conforming materials and corrective action

5.7.1 All predetermined repair procedures are to be consistent with the requirements of 4.7.3(a) and are to be to the satisfaction of the LR Surveyor. Where a defect is found, whether by the LR Surveyor or through shipyard inspection, for which no agreed repair procedure exists, approval is to be obtained from the LR Surveyor before any corrective action is effected.

5.8 Records

5.8.1 The shipyard is to make data available to the LR Surveyor, to demonstrate the efficiency of the inspection system, *see* 5.6.1.

5.9 Training

5.9.1 The competence of the welding operators, non-destructive examination and other personnel involved in special processes and inspection are to be to the satisfaction of the LR Surveyor.

5.10 Sub-contracted personnel, services and components

5.10.1 The requirements of the Scheme are not applicable to those services operating at locations outside the shipyard. It will be necessary for inspections to be carried out by the LR Surveyor using conventional survey methods.

5.10.2 The methods of control for the requirements of 4.24.1 are to be submitted to the LR Surveyor.

■ *Section 6*
Initial assessment of the shipyard

6.1 General

6.1.1 In the first instance applications for approval under this Scheme will be considered on the recommendation of the local Surveyors.

6.1.2 After receipt and appraisal of the main quality documentation, an assessment of the shipyard is to be carried out by the Surveyors to examine all aspects of the Quality System applicable to hull construction.

6.1.3 The Surveyors will review the quality arrangements proposed by the Shipbuilder at the shipyard. They may advise as to how the proposed Quality System might be improved and where it is considered inadequate, advise how it might be revised to be acceptable to LR.

6.1.4 For assessment to Part 1 of the Scheme, the Surveyors will review the Quality System in association with the quality documentation and will check that all aspects of the System are established and in accordance with the requirements of Section 3.

6.1.5 For assessment of Part 2 of the Scheme, the Surveyors will confirm that the requirements given in Section 3 have been fully implemented and are complied with by a detailed examination of work in progress and by confirming that workmanship and the quality level being consistently achieved are to their satisfaction.

■ *Section 7*
Approval of the shipyard

7.1 General

7.1.1 If the initial assessment confirms that the shipyard's quality arrangements are satisfactory, the Committee will issue Part 1 or Part 2 and Part 1 of LR's Quality Assurance Approval Certificates as appropriate. Maintenance of approval will be subject to the provisions of Section 8.

7.1.2 Approval by another organization will not be accepted as sufficient evidence that the arrangements for hull construction comply with these requirements.

■ *Section 8*
Maintenance of approval

8.1 General

8.1.1 For Part 2 of the Scheme, the arrangements approved at the shipyard are to be kept under review by the Surveyors to ensure that the approved Quality System is being maintained in a satisfactory manner. This is to be carried out by:

(a) Regular and systematic audits by the LR Surveyor.
(b) Comprehensive Annual Audits. The audit team leader will be formally nominated by LR.

8.1.2 Where a comprehensive audit cannot be carried out due to lack of a current building programme to Class, demonstration that the requirements of Part 1 of the Scheme are being maintained may be confirmed by audit review at intervals of six months, normally by the local Surveyors. Where necessary a comprehensive triennial audit would be carried out by a Surveyor formally nominated by LR. The degree of re-assessment for re-approval at the recommencement of building to LR's Class would be at the discretion of the Committee.

8.1.3 All documentation, including reports, is to be available to the Surveyors.

8.1.4 Minor alterations in the approved procedures may be permitted provided that the Surveyors are advised and their prior concurrence obtained. Major alterations would need to be submitted for approval and may require an additional audit.

8.1.5 In a shipyard constructing ships to LR's Class, the following are applicable:

(a) The LR Surveyor is to be allowed access at all reasonable times to all records pertaining to quality and to all parts of the shipyard involved in the implementation and maintenance of the Quality Assurance Programme.
(b) The LR Surveyor is immediately to advise the Management Representative of any matter pertaining to the Quality System with which he is not satisfied.
(c) When minor deficiencies in the approved procedures are discovered during audits, or if workmanship is considered unsatisfactory, the LR Surveyor will apply more intensive auditing and inspection.
(d) Notwithstanding any of the provisions of the Quality System, all work related to Classification of ships with LR is to be to the satisfaction of the LR Surveyor.

■ *Section 9* Suspension or withdrawal of approval

9.1 General

9.1.1 When the Surveyors have drawn attention to significant faults or deficiencies in the Quality System or its operation and these have not been rectified within a period of time acceptable to LR, the approval of the system, together with the associated certification, will be withdrawn and the shipyard's name deleted from the *List of Shipyards Approved to the Requirements of the Quality Assurance Scheme*.

9.1.2 If a significant period of time elapses between such withdrawal and any application for reinstatement, the reapproval procedures, if agreed to by the Committee, may require a restructuring of the Quality Management System and will always require a complete re-examination as for an initial assessment.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter is applicable to all ship types and components with the exception of Sections 2 and 3 which are not applicable to Bulk Carriers or Double Hull Oil Tankers with a **CSR** notation (*see* Pt 1, Ch 2,2.3). The requirements are to be applied in conjunction with the relevant Chapters of Parts 3 and 4 applicable to the particular ship type, and the ShipRight procedures.

1.1.2 Details of Lloyd's Register's (hereinafter referred to as 'LR') ShipRight procedures are given in the *ShipRight Procedures Manual* and in this Chapter where related to particular items and notations.

1.1.3 Details of machinery ShipRight procedures are to be found in Pt 5, Ch 21.

1.2 Classification notations and descriptive notes

1.2.1 In addition to the hull class notations defined in Pt 1, Ch 2, ships complying with the requirements of this Chapter will be eligible to be assigned the additional class notations defined in Pt 1, Ch 2,2.1 and Ch 2,2.3 or descriptive notes as defined in Pt 1, Ch 2,2.7 and associated with the ShipRight procedures.

1.3 Information and plans required to be submitted

1.3.1 The information and plans required to be submitted are as specified in the relevant Chapters of Parts 3 and 4 applicable to the particular ship type and in this Chapter where related to particular items and notations.

■ *Section 2* Structural design assessment

2.1 Structural Design Assessment notation – SDA

2.1.1 The ship structure is to be examined using finite plate element methods to assess both the overall and detailed structural capability to withstand static and dynamic loadings. *See*:

- the applicable *ShipRight SDA Procedures Manual* for the procedure for each ship type; and
- the Section dealing with direct calculations in the relevant Chapter of Part 4 applicable to the particular ship type.

2.1.2 This procedure is mandatory, and additional to normal Rule structural design approval, for:

(a) bulk carriers and oil tankers without a CSR notation (*see* 1.1.1) greater than 190 m in length;
(b) container ships with a beam of Panamax size or greater;
(c) The primary structure of LNG ships;
(d) The primary structure of Type A LPG ships:
(e) Other ships of Type B and C where the type, size and structural configuration demand;
(f) passenger ships where it is considered that the superstructure will be subjected to a significant load from flexure of the hull girder; or, where it is required to utilise the load carrying capability of the superstructure for longitudinal strength; and
(g) other ships where type, size and structural configuration demand, *see also* Pt 1, Ch 2,2.3 and Ch 2,2.7.

2.1.3 In addition, and where applicable, the ship structure is to be examined for the structural capability to withstand dynamic loadings from partially filled tanks or the influence of thermal loadings.

■ *Section 3* Fatigue design assessment

3.1 Fatigue Design Assessment notation – FDA

3.1.1 The ShipRight FDA procedure is to be applied in conjunction with the construction control tolerances and limits, in addition to the normal Rule structural detail design appraisal. These procedures are mandatory for bulk carriers and oil tankers (*see* 1.1.1) greater than 190 m in length and for other ships where the type, size, and structural configuration demand, *see also* Pt 1, Ch 2,2.3 and Ch 2,2.7.

■ *Section 4* Construction monitoring

4.1 Construction Monitoring notation – CM

4.1.1 Extended controls on structural alignment, fit up and workmanship standards will be applied to areas, shown by the structural design assessment and fatigue design assessment procedures specified in Sections 2 and 3, to be in need of particular attention. This procedure is mandatory for all ship types where either the SDA and/or FDA procedures have been applied on a mandatory basis. The procedure may also be applied on a voluntary basis in conjunction with the voluntary application of SDA and FDA procedures to ensure that the ship is designed and constructed to an enhanced structural standard. The requirements of Chapter 10, and the relevant procedures contained in the *Construction Monitoring Procedure* are to be complied with, *see also* Pt 1, Ch 2,2.3 and Ch 2,2.7.

4.1.2 The procedure is mandatory for all Bulk Carriers or Double Hull Oil Tankers greater than 190 m in length with a **CSR** notation (*see* Pt 1, Ch 2,2.3).

■ *Section 5* Ship Event Analysis

5.1 Ship Event Analysis – Descriptive notes SEA(HSS-n)

5.1.1 At the Owner's request, and in order to enhance safety and awareness on board during ship operation, provisions can be made for a hull surveillance system that monitors the hull girder stresses and motions of the ship and warns the ship's personnel that these levels or the frequency and magnitude of slamming motions are approaching a level where corrective action is advisable.

5.1.2 Where a hull surveillance system is fitted, the descriptive note **SEA(HSS-n)** will be assigned. The extension **-n** signifies the number of fitted strain gauges connected to the system. The following option extensions will be added to the descriptive note:

- **L** The display of the relevant information in the cargo control area.
- **M** The display and recording of the ship's motion.
- **N** The facility to display and record navigational information.
- **VDR** An interface with the ship's voyage data recorder system to enable the recording of hull stress, ship motion and hull pressure information.

The appropriate descriptive note will be entered in column 6 of the *Register Book*, *see also* Pt 1, Ch 2,2.7.

5.1.3 For the requirements, *see* the ShipRight Procedures and the *Provisional Rules for the Classification of Ship Event Analysis Systems*.

■ *Section 6* Enhanced scantlings

6.1 Enhanced Scantlings – Descriptive note ES

6.1.1 Where scantlings in excess of the approved Rule minimum are fitted at defined locations, a descriptive note **ES**, Enhanced Scantlings, will be entered in column 6 of the *Register Book*. For example, the note **ES+1** will indicate that an extra 1 mm has been fitted to the hull envelope plating (i.e. deck, side and bottom).

■ *Section 7* Protective coating in water ballast tanks

7.1 Protective Coating in Water Ballast Tanks – Descriptive note PCWBT

7.1.1 It is mandatory for all ship types that all salt water spaces having boundaries formed by the hull envelope are to have a corrosion protection coating applied, *see* Ch 2,3.

7.1.2 If the Owner so wishes, a descriptive note **PCWBT**, 'Protective Coating in Water Ballast Tanks', will be entered in column 6 of the *Register Book* to indicate that the ship's water ballast tanks are coated with a recognized corrosion control coating and that the coating remains efficient and is maintained in good condition. If the coatings have broken down, particularly at more critical areas, and no effort is being made to maintain the coatings, then this note will be placed in parentheses, i.e. (**PCWBT**). In either case the date of the last survey will be placed in parentheses after the note.

7.1.3 Recognized corrosion control coatings are listed in the *List of Paints, Resins, Reinforcements and Associated Materials*, which is published on LR's website, http://www.lr.org, and on the CD-Rom version of the *Rules and Regulations for the Classification of Ships* by LR. Guidance on coating condition is given in Chapter 1 of this List.

■ *Section 8* Hull planned maintenance

8.1 Descriptive note HPMS

8.1.1 Where an Owner operates an approved Planned Maintenance Scheme as part of the Continuous Survey Hull (CSH) Cycle, the descriptive note **HPMS** will, at the Owner's request, be entered in column 6 of the *Register Book*.

8.1.2 The descriptive note will indicate that procedures and documentation are in place to control and record the inspection of selected hull survey items by suitably qualified and trained personnel.

8.1.3 For the requirements and approval procedures, *see* the appropriate procedures in the *ShipRight Procedures Overview*.

■ *Section 9* Ship Emergency Response Service

9.1 Ship Emergency Response Service – Descriptive note SERS

9.1.1 This service, offered by LR, provides a rapid computer assisted analysis of a damaged ship's stability and damaged longitudinal strength in the event of a casualty to the ship.

9.1.2 Where an Owner adopts this service, the descriptive note **SERS**, 'Ship is registered with LR's Ship Emergency Response Service', will be entered in column 6 of the *Register Book*.

■ *Section 10* Assessment of Ballast Water Management Plans

10.1 Ballast Water Management Plan – Descriptive note BWMP

10.1.1 Compliance with this procedure is optional. A ship meeting the requirements of this procedure will be eligible for an appropriate **ShipRight BWMP** descriptive note, which will be recorded in column 6 of the *Register Book*.

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