VOLUME II

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HULL
INTERNAL MEMBERS & SUBDIVISIONS

Volume II

Contenido

PART A: HULL

CHAPTER 1: TERMS

The following terms appear in these Principles:

1.1. LENGTH

L is a length measured in meters on the summer water line, from the fore side of the stem to the after side of the rudder post; where there is no rudder post, *L* is to be measured to the centreline of therudder stock. For use with the Principles *L* is not to be less than 96% and need not be greater than 97% of the length on the summer load line.

1.2. BREADTH

B is the greatest moulded breadth in meters.

1.3. DEPTH

D is the moulded depth at side in meters, measured at the middle of *L*, from the moulded base line to thetop of the freeboard-deck beams. In cases where watertight bulkheads extend to a deck above the freeboard deck and are to be recorded in the Record as effective to that deck, *D* is to be measured to the bulkhead deck. The depth D_s for use in the determination of the requirements for shell plating and for use in association with the strength requirements of Chapter 5 is measured to the strength deck.

1.4. DRAUGHT

d is the moulded draft in meters from the moulded base line to the summer load line.

1.5. FREEBOARD DECK.

The freeboard deck normally is the uppermost continuous deck having permanent means for closing all openings. In cases where a ship is designed for a special draught considerably less than that corresponding to the least freeboard obtainable under the International Load Line Regulations, the freeboard deck for the purpose of the Principles may be taken as the lowest actual deck from which the draught can be obtained under those regulations.

1.6. BULKHEAD DECK

The bulkhead deck is the highest deck to which the watertight bulkheads extend. See 15.1.3

1.7. STRENGTH DECK

The strength deck is the deck, which forms the top of the effective hull girder at any part of its length.See Chapters 5 and 7.

1.8. SUPERSTRUCTURE DECK

A superstructure deck is a deck above the freeboard deck to which the side shell plating extends. Except where otherwise specified the term superstructure deck where used in the Principles refers to the first such deck above the freeboard deck.

1.9. CATEGORY A MACHINERY SPACES.

Machinery spaces of Category A are those spaces and trunks to such spaces which contain: internal combustion machinery used for main propulsion, or internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or any oil-fired boiler or oil fuel unit.

CHAPTER 2: GENERAL

2.1. MATERIAL AND FABRICATION

2.1.1. Material: The Principles are intended for ships to be constructed of ordinary-strength steel complying with the requirements for such steels. These Principles are meant to satisfy the relevant regulations of the International Convention for the Safety of Life at Sea 1974 as amended and the IMOProtocol of 1978. Special attention should be given to any relevant statutory requirements of the nationalauthority of the country in which the ship is to be registered. Where it is intended to use higher-strength steel complying with the requirements for such steels, the applicable parts of the Principles dealing with theuse of and scantlings based on higher-strength steels are to be complied with and it is recommended thatplans showing the location and extent of application be placed aboard the ship. Where it is intended to usematerial of cold flanging quality for important longitudinal strength members, this steel is to be indicatedon the plans. The requirements for shapes used for external effective longitudinal material involving weldedconstruction will be specially considered. Where it is intended to use steel or other material having physical properties differing from those specified, the use of such material and the corresponding scantlings are to be specially considered. In connection with the use of steels higher in strength than the structuralsteels, other steels of special characteristics, any material intended for low-temperature service, or where special welding procedures are required, it is recommended that a set of plans showing exact location and extent of application, together with a description of the material and special welding techniquesemployed, be placed aboard the ship. Where scantlings are reduced in connection with the use of high-strength steels, adequate buckling strength is to be provided.

2.1.2. Fabrication: The requirements of the principles apply to steel ships of welded construction.

2.2. SCANTLINGS

2.2.1 General: The midship scantlings as specified in the Principles are to apply throughout the midship 0.4*L;* end scantlings are not to extend for more than 0.1*L* from each end of the ship. The reduction from the midship to the end scantlings is to be affected in as gradual a manner as practicable. Sections having appropriate section module, in accordance with their functions in the structure as stiffeners, columns or combinations of both, are to be adopted, due regard being given to the thickness of all parts of the sections to provide a proper margin for corrosion. It may be required that calculations be submitted in support of resistance to buckling for any part of the ship's structure.

2.2.2 Corrosion Control: Where corrosion control is intended for reduction of scantlings by special protective coatings, the particulars are to be stated when the plans are submitted for approval. Anodes may be used to supplement the coatings. These plans are to show the required scantlings and the proposed reduced scantlings, both suitably identified. Where any of the proposed reductions are approved, a notation will be made in the Record that such reductions have been taken. Maximum permissible reductions are indicated in the appropriate sections of the Principles.

2.3 PROPORTIONS

These Principles are valid for a ship having depth not less than one-fifteenth of her length, *L,* and breadth notmore than twice her depth to the strength deck. Ships beyond these proportions will be specially considered.

2.4 WORKMANSHIP

All workmanship is to be of commercial marine quality and acceptable to the Surveyor. Welding is to be in accordance with the requirements.

2.5 DRY-DOCKING

For ships 228.5 m and over in length, information indicating docking arrangements is to be prepared and furnished to the ship for guidance.

2.6 STRUCTURAL SECTIONS.

The scantling requirements of these Principles are applicable to structural angles, channels, bars, and rolled or built-up sections. The required section modulus of members such as girders, webs, etc., supporting frames and stiffeners is to be obtained on an effective width of plating basis in accordance with this subsection. The section is to include the structural member in association with an effective width of plating not exceeding one-half the sum of spacing on each side of the member or 33% of the unsupported span *l*, whichever is less. For girders and webs along hatch openings, an effective breadth of plating not exceeding one-half the spacing or 16.5% of the unsupported span *l*, whichever is less, is to be used. The stiffener and a maximum of one frame space of the plating to which it is attached provide the required section modulus of frames and stiffeners.

2.7 STRUCTURAL DESIGN DETAILS.

2.7.1 General: The designer is to give consideration to the following:

a) The thickness of internals in locations susceptible to rapid corrosion.
b) The proportions of built-up members to comply with established standards for buckling strength.
c) The design of structural details such as noted below, against the harmful effects of stress concentrations and notches:
    1. Details of the ends, the intersections of members and associated brackets.
    2. Shape and location of air, drainage, or lightening holes.
    3. Shape and reinforcement of slots or cut-outs for internals.
    4. Elimination or closing of weld scallops in way of butts, “softening” of racket toes, andreducing abrupt changes of section or structural discontinuities.

d) Proportions and thickness of structural members to reduce fatigue response due to engine,propeller or wave-induced cyclic stresses, particularly for higher-strength steels.

A booklet of standard construction details based on the above consideration is to be submitted forreview.

2.7.2 Termination of structural members: Structural members are to be effectively connected to the adjacent structures in such a manner to avoid hard spots and other harmful stress concentrations. Where members are not required to be attached at their ends, special attention is to be given to the entaper, by using soft-toed concave brackets or by a sniped end of not more that 30º. Where the end bracket has a face bar it is to be sniped and tapered not more than 30º. Bracket toes or sniped ends areto be kept within 25 mm of the adjacent member and the depth at the toe or snipe end is generally notto exceed 15 mm. Where a strength deck (or shell longitudinal) terminates without end attachment it isto extend into the adjacent transversely framed structure (or stop at a local transverse member fitted at about one transverse frame space). See Chapter 7.2.

CHAPTER 3: KEELS, STERN FRAMES AND RUDDER HORNS

3.1 KEELS

3.1.1 Plate keels: The thickness of the plate keel throughout is to be not less than the bottom shell amidships required in 7.2.7, increased by 1.5 mm. Where, for longitudinal strength, the plate keel amidships exceeds this thickness, it may be gradually reduced to this thickness forward and aft of the midship 0.4L.

3.1.2 Bar keel: The scantlings of a bar keel are not to be less than:

Depth: $h = 100 + 5L$

[mm] Thickness: $t = 10$

$+ 0.6L$ [mm]

3.2 STEMS

3.2.1. Plate stems: Plate stems are not to be less in thickness at the design load waterline than required by the following equations.

$t = 1.46 + L/12$ mm $\quad L \leq 245$ m

$t = 22$ mm $\quad 245 < L \leq 427$ m

Above and below the design load waterline the thickness may taper to the thickness of the shell at endsat the freeboard deck and to the thickness of the flat-plate keel at the forefoot, respectively.

3.2.2 Bar Stems: The dimensions of bar stem cross-section from the keel to the summer load waterlineare not to be less than

Length: $l = 1.2\,L + 95$ [mm] for $L < 120$m

$l = 0.75L + 150$ [mm] for $L \geq 120$ m

Breadth: $b = 0.4L + 15$ [mm]

But not more than 100 mm

Above the summer load waterline the cross-section area of the stem may be gradually tapered to 70% ofthe area obtained from the scantlings given above.

3.2.3 Cast-steel stems: Cast-steel stems of special shape are to be proportioned to provide a strength atleast equivalent to that of a plate stem.

3.3 STERN POST WITHOUT PROPELLER BOSS

Stern posts without propeller bosses are to be of the sizes obtained from the following equations below the shell;above the shell they may be gradually reduced till the area at the head is half that size.

t = $0.73L + 10$ mm for $L \leq$ 180 m

t = $20.6\sqrt{(L - 135)}$ mm for $L >$

180 mb = $80 + 1.64L - 0.0039L^2$ mm for $L \leq$

180 m

b = $175 + 5.5\sqrt{L}$ mm for $L >$ 180m

L = length of ship as defined in 1.1 in m

t = thickness of stern post in mm. (see

figure 3.1)b= breadth of stern post in

mm. (see figure 3.1)

3.4 STERN FRAMES WITHOUT SHOEPIECE

3.4.1 Scantlings: The stern post below the propeller boss in single-screw ships is to be of the size obtained from the following equations, where L, t, and b are as defined in 3.3. Above the boss the stern post may be 85% of the calculated breadth.

t = $1.4L + 14$ mm for $L \leq 180$ m

t = $34.2\sqrt{(L - 193)}$ mm for $L >$ 180 m

b= $80 + 1.64L - 0.0039L^2$ mm for $L \leq$ 180 m

b = $175 + 5.5\sqrt{L}$ mm for $L >$ 180 m

When the moulded draft exceeds $0.05L$, the thickness of the inner post is to be increased at the rate of

1.0 mm per 100 mm of draught.

3.4.2 Transom floors: The stern post is to be attached to a transom floor having a thickness 5.0-mm greater than required for double-bottom floors by 6.2.4 and a depth sufficient to allow room for welded attachments.

3.5 STERN FRAMES WITH SHOEPIECE

3.5.1. Scantlings: In stern frames having shoepiece, the post above the boss is to be of the size required by 3.5.1 for stern frames without shoepiece; below the boss the breadth and thickness are to be gradually increased above the requirements of 3.4.1 to provide strength and stiffness in proportion to those of the shoepiece.

3.5.2 Shoepieces: Shoepieces are to have a width approximately twice the depth and an area of not less than 1.44 times the square of the breadth b as obtained by 3.4.1; where the draught exceeds 0.05*L*, the breadth and depth of the shoe piece are each to be increased at the rate of 1.00 mm for each 100 mm of increased draught. In no case are the dimensions of the shoe piece to be less than required to suit the following equation.

$$Zy = cAV^2l/1000$$

Zy= minimum section modulus of any section of shoepiece about a vertical axis,

in Cm^3.c = a coefficient varying with speed, from Table 3.1.

A = total projected area of rudder, in m^2.

V = design speed in knots with a vessel running ahead at the maximum continuous
Rated shaftrpm and at the summer load waterline.

l = horizontal distance between centreline of rudder stock and the particular section of the stern frame shoe, in mm (see Figure 3.2).

3.6 CAST-STEEL STERN FRAME

Where stern posts and shoepieces are of cast steel, the strength is to be not less than required by 3.3, 3.4, or 3.5. The steel castings are to be effectively attached to the adjacent structure preferably by a flushbutt type of joint with backing bars where necessary. The castings are to be cored out to avoid large masses of thick material likelyto contain defects and to maintain a relatively uniform section throughout. Suitable radii are to be provided in way of changes in section.

Table 3.1 Values of c

Intermediate values of care to be obtained by interpolation.

Metric units							
Speed, V	≤10	11	12	13	14	15	≥16
c	2.054	1.811	1.617	1.464	1.339	1.235	1.138

3.7 RUDDER HORNS

3.7.1 Scantlings: The stress K in kg/cm² in the rudder horn at any section is to be obtained from thefollowing equation:

$K = 0.5\ f_b + 0.5\ \sqrt{(f_b^2+4q^2)}$

The strength of the rudder horn is to be based on the most critical location at any point up to and in wayof the connection into the hull.

K is not to exceed the following permissible values except where special consideration is given for higherstrength steels.

	K, kg/cm²
Steel plating	599
Cast steel	472

$F_b = 14.47A\ V^2 l v l_A\ (SM) l_p$

kg/cm²$q = 72.38\ AV^2 l_h l_A/$

atl_p kg/cm²

A = total projected area of rudder in m²

V = design speed in knots, but not less than 11 knots.

l_v = vertical distance in cm from the centre of the pintle bearing to the section of the rudderhorn being considered up to the entry of the horn into the shell (See Figure 3.3)

l_h = horizontal distance in cm from the centre pintle bearing to the centre of area of the horizontal plane of the rudder horn at the section of the rudder horn being considered (seeFigure 3.3)

SM=section modulus of the rudder horn about the longitudinal axis, in cm³ at the section of therudder horn being considered.

a = area in cm² enclosed by the outside lines of the rudder horn at the section of the rudderhorn being considered

t = minimum wall thickness of the rudder horn in mm at the section being considered.

l_A = Vertical distance in m from the centre of the neck bearing to the centroid of A (see Figure3.3)

l_p = vertical distance in m from the centre of the neck bearing to the centre of the pintle bearing(see Figure 3.3).

Webs, extending down into the horn as far as practicable are to be fitted and effectively connected to theplate floors in the after peak. At the shell, the change in section of the horn is to be as gradual as possible. Generous radii are to be provided at abrupt changes of section where there are stress concentrations.

Where the rudder horn supports upper pintle gudgeons, l_A and l_p may be measured from the centre of the upper pintle bearing and l_v is measured from the centre of the lower pintle bearing. In determining the stress in the rudder horn at a section above the centre of the upper pintle consideration may be givento the upper pintle load.

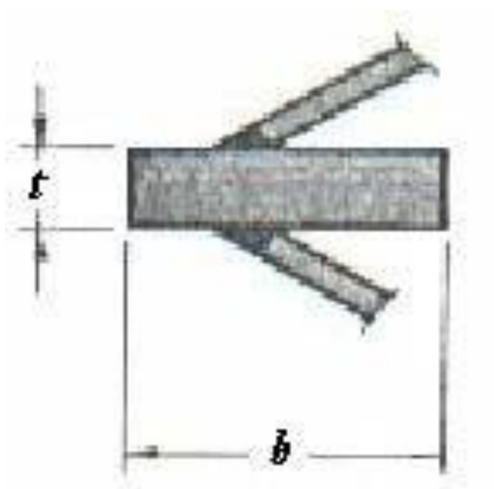


Figure 3.1. Stern Post

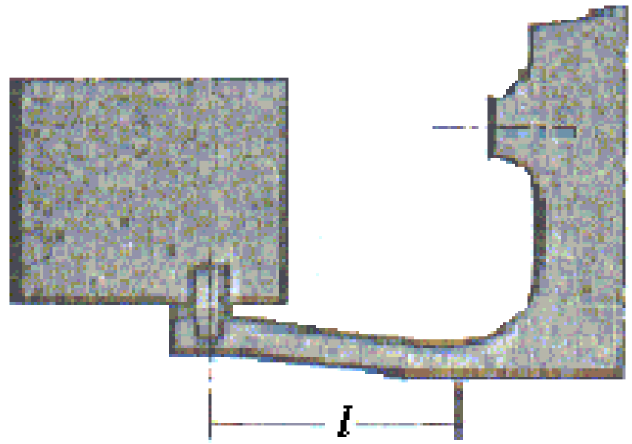


Figure 3.2. Shoepiece

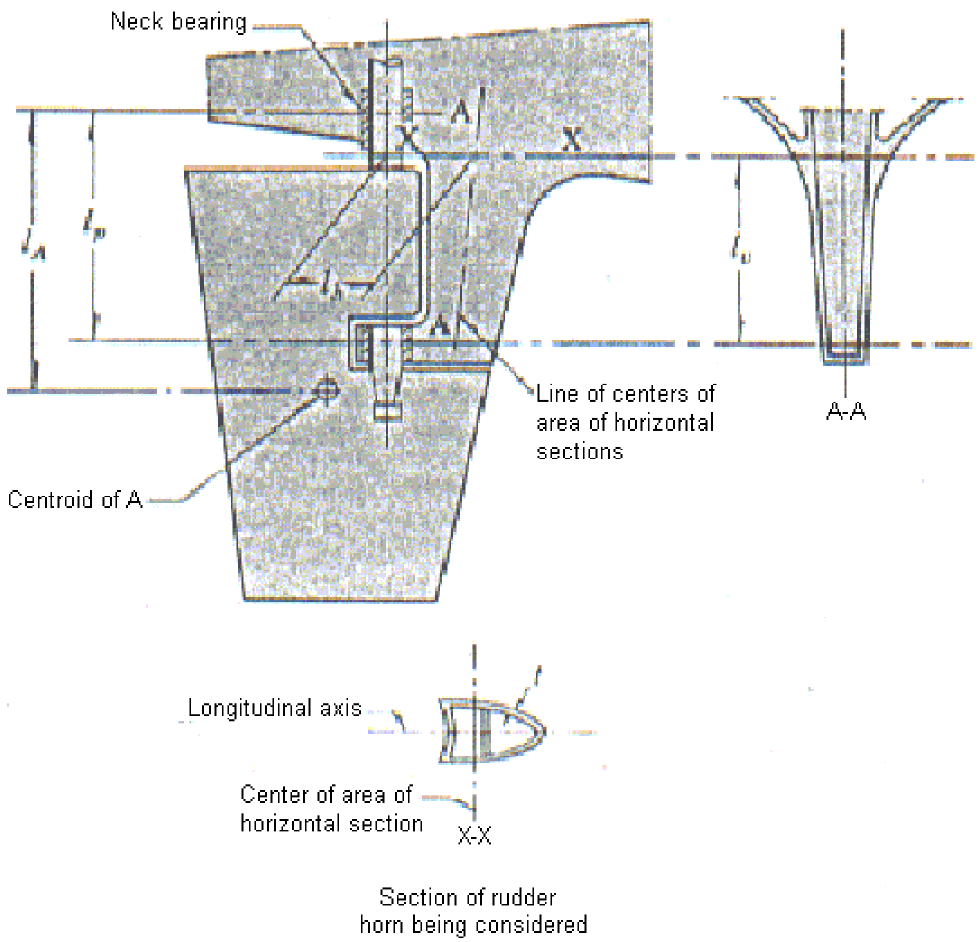


Figure 3.3. Rudder Horn.

3.7.2 Floors: Heavy plate floors are to be fitted in way of the after face of the horn and in line with the webs required by 3.7.1. They may be required to be carried up to the first deck.

3.7.3 Shell Plating: Heavy shell plates are to be fitted in way of the heavy plate floors required by 3.7.2. Above the heavy floors, the heavy shell plates may be reduced in thickness in as gradual a manner as practicable.

3.7.4 Water Exclusion: Rudder horns are to be provided with means of extracting water except where rudder horns are filled with an approved waterproof material.

3.8 RUDDER GUDGEONS

Rudder gudgeons are to be an integral part of the stern frame; where special circumstances render it necessary to bolt the gudgeons to the frame, the full area is to be provided in way of the bolt holes and the proposed arrangements are to be specially submitted for approval. The depth of the gudgeons is not to be less than 1.2 times the required diameter of ordinary strength steel pintles; the thickness of unbushed gudgeons is not to be less than 44% and that of bushed gudgeons not less than 40% of the diameter of ordinary strength steelpintles required by Chapter 4.

3.9 INSPECTION OF CASTINGS

The location of radiographic inspections of large stern–frame and rudder-horn castings is to be indicated on the approved plans.

CHAPTER 4: RUDDERS AND STEERING GEARS

4.1 GENERAL

Rudder stocks, pintles and keys are to be made from material in accordance with the requirements of Part F of the Principles. Material tests for rudder stocks and pintles are to be witnessed by the Surveyor. The Surveyor need not witness coupling bolts and torque transmitting keys material tests. The surfaces of rudder stocks in wayof exposed bearings are to be of non-corrosive material.

4.2 RUDDER TORQUE

The torque considered necessary to operate the rudder in accordance with the requirements of the Principles is to be indicated on the submitted rudder.

4.3 RUDDER STOCKS

4.3.1 Upper stocks: The upper stock requirements apply to that part of the rudder stock above the neckbearing. The diameter of the upper stock is not to be less than obtained from the following equation.

$S = 21.66 \sqrt[3]{bAV^2}$ mm

S = diameter of upper stock in mm

b = horizontal distance in m from the centre of the pintles to the centroid of A (see Figure 4.1a, b,and c)

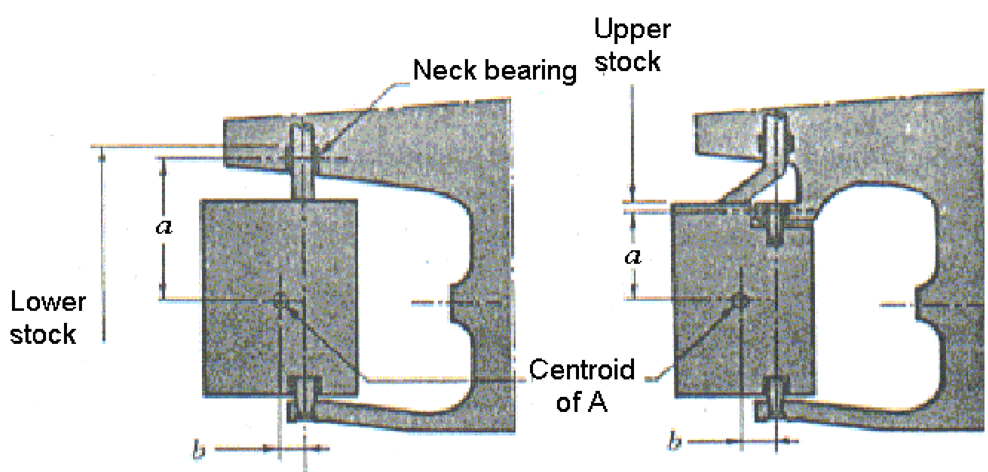
A = total projected area of

rudder in m²V = design speed in

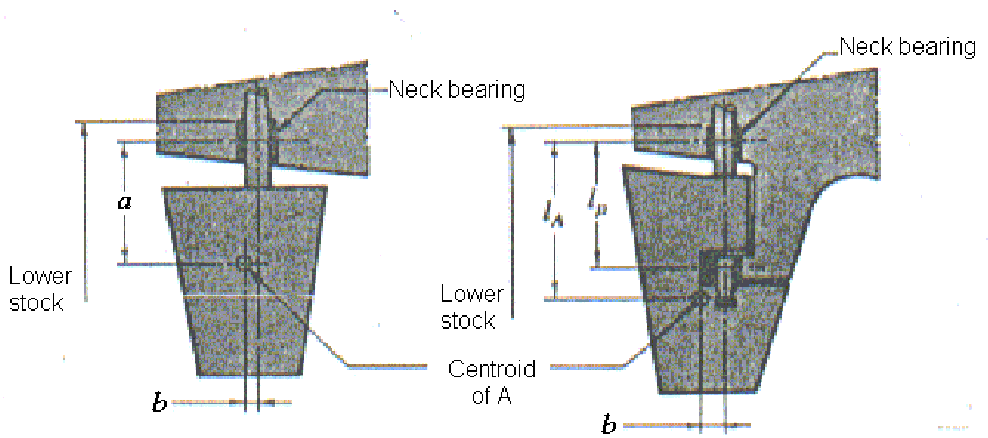
knots.

Where rudders are of streamlined shape of coefficient in the above equation may be taken

as 19.2.The stock diameter is to be adequate for the maximum astern speed.



a. Rudder on Ship with shoepiece (Balanced)



b. Space rudder c. Rudder on Ship with horn (Semibalanced)

Figure 4.1 Rudder Types

4.3.2 Lower Stocks

a. ***Balanced rudders:*** The stock in and below the neck bearing where a top pintle is not fitted is tohave a diameter not less than obtained from the following equation:

$S_l = 21.66 \sqrt[3]{(RAV^2)}$ mm

S_l = diameter of lower stock in mm

$R = 0.25 \left(a + \sqrt{a^2 + 16\, b^2} \right)$

A = total projected area of rudder in m^2

a = vertical distance in m from the centre of neck bearing to the centroid of A (see Figure4.1a)

b = horizontal distance in m from the centre of the pintles to the centroid of A (see Figure4.1a)

V = design speed in knots.

The stock is to be of the full diameter for at least two-thirds of the distance from the neck to the bottom bearing and the diameter may be gradually reduced below this point until it is not less than $0.75S_l$ at the bottom of the rudder. The lower stock in the bottom bearing is to comply with the requirements of 4.9 for a pintle in the same location. Where the diameter of the lower stock in the bottom bearing is less than the diameter of the lower stock at the bottom of the rudder, a suitable transition is to be provided. The bearings are to be bushed, and the bushing is to be effectively secured against movement.

b. *Spade rudders*: The stock in way of and below the neck bearing is to have a diameter not lessthan:

$S_l = 21.66\ \sqrt[3]{RAV^2}$ mm

S_l = diameter of lower stock in mm

$R = a + \sqrt{a^2 + b^2}$

A = total projected area of rudder in m²

a = vertical distance in m from the centre of neck bearing to the centroid of A (see Figure4.1b)

b = horizontal distance in m from the centreline of the rudder stock to the centroid of A(see Figure 4.1b)

V = design speed in knots.

The stock is to be of the full diameter to the top of the rudder; the diameter may be gradually reduced below this point until it is $0.33S_l$ at the bottom. Above the neck bearing a gradual transition is to be provided where there is a change in the diameter of the rudder stock. The length of the neck bearing is to be at least $1.5S_l$. An effective upper bearing is to be provided above the neck bearing. This upper bearing may be either part of or separate from the rudder carrier. Both the upper and neck bearings are to be bushed and the bushings are to be effectively secured against movement.

c. *Semi-balanced rudders*. The stock in way of and below the neck bearing is to have a diameternot less than:

$S_l = 21.66\ \sqrt[3]{(RAV^2)}$ mm

S_l = diameter of lower stock in mm

$R = 0.33\ n + \sqrt{0.11\ n^2 + b^2}$

A = total projected area of

rudder in m²n = $l_A - l_p$ where

$l_A \underline{>} l_p$

= (l_A/l_p) (l_p-l_A), Where $l_p > l_A$

l_A = vertical distance in m from the centre of the neck bearing to the centroid of A (seeFigure 4.1c)

l_p = vertical distance in m from the centre of the neck bearing to the centre of the pintlebearing (see Figure 4.1c)

b = horizontal distance in m from the centreline of the pintle to the centroid of A (seeFigure 4.1c)

V = design speed in knots.

The lower stock is to be of the full diameter to the top of the rudder; below this the requirements for strength of rudder in 4.6.1 apply. The bearing is to be bushed and the bushing effectively secured against movement.

Where the rudder horn supports an upper pintle gudgeon, l_A and l_p may be measured from thecentre of the upper pintle bearing, and the vertical extent of the upper stock for a rudder with an upper pintle may be as shown in Figure 4.1 a.

4.3.3 Higher-strength materials.

a. Diameter: Where rudder stocks are made from material of higher strength than specified in 43.9the required diameter is to be not less than :

S_{HTS} = $S\sqrt[3]{(42/U)}$ mm

S = stock diameter required by 4.3.1 or 4.3.2

U= specified minimum tensile strength of the higher strength material in kg/mm^2

b. Bearing area: The neck bearing area is to be not less than required for a rudder stock of ordinarystrength steel.

4.4 RUDDER COUPLINGS

4.4.1 Flange couplings: Rudder couplings are to be supported by an ample body of metal worked out from the rudder stock and are to have flanges of not less thickness than $0.25S_c$; if keyways are cut in couplings, the thickness is to be increased by the depth of the keyway. The material outside the bolt holes is not to be less than two-thirds the diameter of the bolt, and there are to be at least 6 bolts in the coupling. The total area in mm² of the bolts is not to be less than obtained from the following equations:

a. Horizontal couplings.

Bolt area = $0.3\ Sc^3/r$

Sc = required diameter of stock in way of coupling, S or S_l, depending upon type of rudderand pintle arrangement, in mm.

r = mean distance in mm of the bolt centres from the centre of the system of bolts.

b. Vertical couplings.

$0.33\ Sc^2$= Bolt area at the bottom of threads

c. Scarphed Couplings.

$0.4Sc^2$= bolt area at the bottom of

threads.2.5Sc = length of scarf

1,75Sc= width of scarf at top where there are two bolts in end.

2.5 Sc = width of scarf at bottom
0.13Sc = thickness of scarf tips

The nuts on coupling bolts are to be of standard proportions and are to be efficiently locked inposition after having been tightened.

4.4.2 Tapered stock couplings:

a. General: The following requirements are intended for spade rudders. Special consideration will be given to lesser lengths of tapered stock in the casting for other types of rudders.

b. Taper ratio: Tapered stocks secured to the rudder casting by a nut on the end of the stock are to have a length of taper in the casting generally not lee than 2.2 times de diameter of the stock at the top of the rudder. In general, the taper on the diameter is not to be greater than 1 in 6. The minimum diameter on the tapered part of the stock is to be not less than about 0.65 times the stock diameter at the top of the rudder. The stock diameter at the root of threads is to be not less than
0.90 times the diameter of the small end on the taper.

c. Keying: The stock is to be keyed to the casting to provide torsional strength equivalent to that of the required upper stock diameter and the top of the stock keyway is to be kept well below the top of the rudder.

d. Locking nut: A suitably proportioned nut is to be fitted with an effective locking device.

4.4.3 Keyless couplings: Hydraulic and shrink fit keyless couplings will be specially considered. The calculated torsional holding capacity is to be at least 2.0 times the transmitted torque based on the steering gear relief valve setting.

Preload stress is not to exceed 70% of the minimum yield strength.

4.4.4 Higher-strength material: Where higher-strength material stocks are used, care is to be taken that the requirements for couplings in 4.4.1 are based on the tensile strength of the materials used for the flange and the bolts as appropriate.

4.5 PINTLES

The diameter of the pintles in mm is not to be less than obtained from Table 4.1. The pintles of both types of rudders shown in Figure 4.1a are not to be less in diameter than is required for rudders having two pintles. Where the value of $V\sqrt{A}$ is below 45 or above 75 or for horn type rudders having one pintle, the diameter of the pintle is to be not less.

$$d = cV\sqrt{A}$$

d = diameter of pintle in mm

A = total projected area of

rudder in m² V = design speed in

knots.

C = 4.52 for values of $V\sqrt{A}$ below 45 and 3.37 for values of $V\sqrt{A}$ over 75 for rudders having two pintles, in metric units.

= $4.19 \sqrt{l_A / l_p}$ metric units for horn type rudders having one pintle.

Table 4.1 Pintle diameters

Millimetres	
V √ A	**2 Pintles**

45	202
50	216
55	228
60	237
65	244
70	249
75	253

l_A = Vertical distance in m from the centre of the neck bearing to the centroid of A. l_p = Vertical distance in m from the centre of the neck bearing to the centre of the pintle bearing.

The depth of the pintle boss is not to be less than 1.2d. Pintles are to extend for the full depth of the gudgeons (see 4.9); where fitted, the top pintle is to be placed as high as practicable. In general, pintles are to be fitted as taper bolts; there is to be no shoulder on the pin, the taper is not to be greater than 1 in 12 on the diameter, and the nuts are to be effectively locked to the pintles. Where pintles of 90-mm diameter and greater are required and are protected by metal sleeves shrunk onto the pintle, the diameter may be measured over the sleeve. The pintle bushing is to be effectively secured against movement.

Where pintles are made from higher strength material the diameter is to be not less than:

a. $d_{hts} = 1.2\, d^2 / l_b$ mm

d= required diameter for a pintle of ordinary strength steel

l_b= bearing length in the pintle boss in mm, not to be taken as more than 1.5 d_{HTS}

b. $d_{HTS} = d\sqrt{42/U}$ mm d_{HTS} = D

$\sqrt{60000/U}$ id is a defined above and U is as

defined in 4.3.3 a

4.6 DOUBLE PLATE RUDDER

4.6.1 Strength: The structure in way of the axis of the stock is to have strength and stiffness not less thanthat of the lower stock required by 4.3.2a or 4.3.2b.

For semi-balanced rudders, the section modulus SM of the rudder in way of and below a horizontal linethrough the centre of the pintle bearing is to be not less than obtained from:

$SM = A_l\, v^2 l_b / 32.63K$ cm³

A_l = Projected rudder area in m² below the section of the rudder being considered (seeFigure 4.2)

V = design speed in knots.

l_b = vertical distance from the section of the rudder being considered to the centroid ofarea A_l in cm. (see Figure 4.2)

K = 1.0 for steel castings

= 1.27 for steel plating or forgings

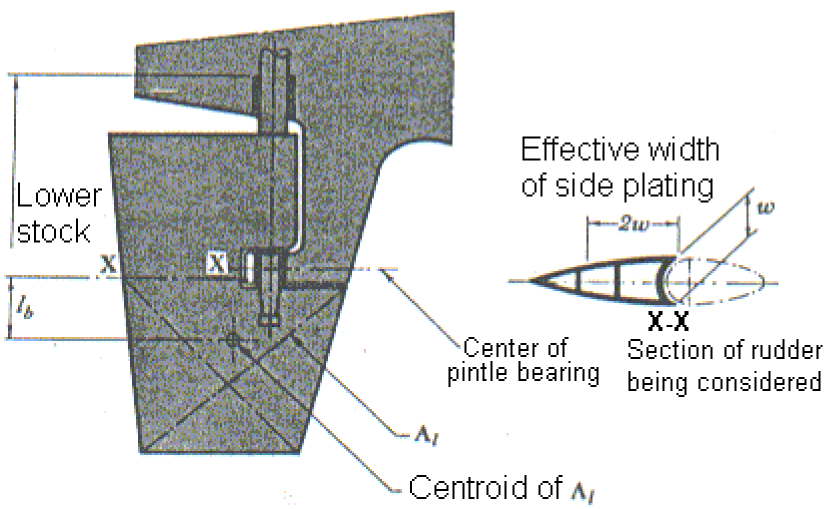


Figure 4.2 Double Plate Rudder

The above required strength of the rudder, with one pintle, in way of the horizontal line through the centre of the pintle bearing may be gradually reduced above that point till at the top of the rudder (rudder strength and stiffness equivalent to that of the lower stock required by 4.3.2c).

Where the rudder supported by two pintles, the required strength of the rudder in way of the horizontal line through the centre of the lower pintle bearing may be gradually reduced above that point until at thecentre of the upper pintle bearing the rudder has strength and stiffness equivalent to that of the lower stock required by 4.3.2 c. At the bottom of the rudder, the section modulus of the rudder is to be notless than 0.33 times the SM required in way of the horizontal line through the centre of the pintle bearingor where two pintles are fitted, through the centre of the lower pintle.

In determining the strength of the rudder, the effective width of side plating is to be taken as not greater than twice the athwartship dimension of the rudder. Generous radii are to be provided at abrupt changes in section where there are stress concentrations. Welded or bolted cover plates on access openings to pintles are not to be considered effective in determining the section modulus of the rudder. Rudders of unsymmetrical shape are to have lower stocks as required by 4.5.4 and details are to be submitted.

4.6.2 Side Plating and Diaphragms: Vertical and horizontal diaphragms are to be fitted within the ruddereffectively attached to each other and to the side plating. Side plating and diaphragms are to be of not less thickness T than obtained from the following equation, where A and V have the same values as given in 4.5 in association with the spacing of horizontal diaphragms $S_{P.}$

$$T = (0.117V\sqrt{A}) + 6.35 \text{ mm}$$

$$S_p = (2.41V\sqrt{A}) + 585 \text{ mm}$$

The thickness T of plating is to be increased at the rate of 0.015 mm for each millimetre of spacing S_p greater than given by the equation, and may be reduced at the same rate for lesser spacing, except that in no case is the side or bottom plating to be less than required by 13.2.1 for deep tank plating in association with a head h measured to the summer load line, plus 2 mm.

The thickness of plating and diaphragms is not to be less than 8 mm and diaphragms are not to be spacedmore than 610 mm where $V\sqrt{A}$ equals 12.20 or less; thickness need not exceed 19 mm with a spacing of 840 mm where $V\sqrt{A}$ exceeds 107. Vertical diaphragms are to be spaced approximately 1.5 times the spacing of horizontal diaphragms. Welding is to be in accordance with Table 30.1 or 30.2. Where inaccessible for welding inside the rudder, it is recommended that diaphragms be fitted with flat bars andthe side plating be connected to these flat bars by continuous welds. The rudder is to be watertight.

4.7 RUDDER STOPS

Effective rudder stops are to be fitted. Where adequate positive stops are provided within the gear, structural stops will not be required.

4.8 SUPPORTING ARRANGEMENTS.

Effective means are to be provided for supporting the weight of the rudder assembly and the horizontal force on the rudder stock without excessive bearing pressure. They are to be arranged to prevent accidental unshipping or undue movement of the rudder, which may cause damage to the steering gear.

4.9 STEERING GEAR

4.9.1 General: Requirements are to satisfy the relevant regulations of the International Conventionfor the Safety of Life at Sea 1974 as amended, and the IMO Protocol of 1978.

4.9.2 Plans: Detailed plans of the steering arrangement are to be submitted for approval. The ratedtorque of the unit is to be indicated in the data submitted for review. See 4.2.

4.9.3 Piping arrangement

a. ***General:*** Piping for hydraulic gears is to be arranged so that transfer between units can be readily effected. The arrangement is to be such that a single failure in one part of the piping will not impair the integrity of remaining parts of the system. Where necessary, arrangements for bleeding air fromthe hydraulic system are to be provided.

b. ***Requirements:*** Piping systems are to meet the requirements.

c. ***Valves:*** In general, valves are to comply with the requirements. Isolating valves are to be fitted atthe connections of pipe to the rudder actuator, and are to be directly mounted on the actuator.

d. ***Filtration***: A means is to be provided to maintain cleanliness of the hydraulic fluid.

e. ***Testing*.** After installation in the vessel, the complete piping system, including power units and hydraulic cylinders is to be subjected to hydrostatic test equal to 1.5 times the design pressure, including a check of the relief-valve operation. These tests are to be performed in the presence of the Surveyor.

4.9.4 Operating Instructions: Appropriate operating instructions with a block diagram showing the changeover procedures for steering gear control systems and steering gear power units are to be permanently displayed on the navigating bridge and in the steering gear compartment.

4.9.5 Trials: The steering gear is to be tried out on the trial trip in order to demonstrate to the Surveyor'ssatisfaction that the requirements of these Principles have been met. The trial is to include the operationof the following:

a. The steering gear, including demonstration of the performance requirements with the rudder fully submerged. Where full rudder submergence cannot be obtained in ballast conditions, special consideration may be given to specified trials with less than full rudder submergence. Trials are to be carried out at the ship's maximum continuous rated ahead shaft rpm.

b. The power units, including transfer between power units.

c. The emergency power supply

d. The steering gear controls, including transfer of control, and local control.

e. The means of communications between the navigating bridge, engine room, and the steeringgear compartment.

f. The alarms and indicators.

g. The storage and recharging system.

h. The isolation and automatic starting provisions.

CHAPTER 5: LONGITUDINAL STRENGTH

5.1 GENERAL

5.1.1 Ships of 65 m or more in length, intended to be classed for unrestricted areas, are to have longitudinal strength in accordance with the requirements of this Chapter. The equations in this Chapter are valid for ships having depths not less than one-fifteenth of their lengths *L* as defined in 1.1. Ships, whose depths are less than this limit, will be subject to special consideration.

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 ballastdistribution.

For ships where *L* is less than 65 m, longitudinal strength calculations may be required.

5.2 LONGITUDINAL HULL-GIRDER STRENGTH

5.2.1 Strength standard

a. Section modulus. The required hull-girder section modulus amidships, expressed in centimetressquared meters, is to be obtained from the following equation, or 5.2.1 b, whichever is greater.

SM= M_t /f_P

M_t = total bending moment as obtained from 5.2.2

f_p = nominal permissible bending stress in metric tons per centimetre squared

$$= 1.663 - \frac{(240 - L)}{1620} \text{ t/cm}^2 \qquad 61 \leq l \leq 240 \text{ m}$$

$$= 1.663 + \frac{(L - 240)}{4000} \text{ t/cm}^2 \qquad 240 < L \leq 427 \text{ m}$$

L = length of ship as defined in 1.1 in m

The value of f_p may be increased 10% where the strength deck and bottom structure are longitudinally framed for general cargo ships, for bulk carriers with uniform loading and for specialised carriers in which the cargo is designed to be stowed into specific cells.

Where envelope curves of still water and wave-induced bending moments are submitted, the required hull-girder section modulus at locations other than amidships may be obtained using the f_p values given above. For ships under 90 m in length, for which still-water bending moment calculations are not required to be submitted, the requirements of 5.2.1.b may apply where they areless than required by the above equation.

b. Minimum section modulus. The minimum hull girder section modulus amidships expressed in centimetres squared meters for all ships with lengths from 90 to 427 m is not to be less than obtained from the following equation.

$$SM = 0.01C_1L^2B(C_b+0.70)$$

$$C_1 = 10.75-\left(\frac{300-L}{100}\right)^{1.5} \qquad 90 \leq L \leq 300 \text{ m}$$

$$= 10.75 \qquad 300 < L \leq 350 \text{ m}$$

$$= 10.75-\left(\frac{L-350}{150}\right)^{1.5} \qquad 350 < L \leq 427 \text{ m}$$

L = length of ship as defined in 1.1 in m.

B = breadth of ship as defined in 1.3 m

C_b = block coefficient at summer load waterline, based on L as defined in 1.1. For thisequation, C_b is not to be taken as less than 0.60

c. Section-modulus calculation: In general, the following items may be included in the calculation of the section modulus, provided they are continuous developed.

- Deck plating
- Shell and inner–bottom plating
- Deck and bottom girders
- Plating and longitudinal stiffeners of longitudinal bulkheads
- All longitudinals of deck, sides, bottom and inner bottom
- Continuous longitudinal hatch coamings.

Where the still-water bending moment envelope curve is not submitted, the items included in the hull girder section modulus are to be extended throughout the 0.4*L* amidships and gradually taperedbeyond. Where bending moment envelope curves are used, items included in the hull girder section modulus amidships are to be extended as necessary to meet the hull girder section modulus required at the location being considered.

In general, the net sectional areas of longitudinal-strength members are to be used in the hull-girder section-modulus calculations. The section modulus to the deck is obtained by dividing the momentof inertia by the distance from the neutral axis to the moulded deck line at side.

For continuous longitudinal hatch coamings in accordance with 5.3 the section modulus to the top ofthe coaming is to be obtained by dividing the moment of inertia by the distance from the neutralaxis to the deck at side plus the coaming height. This distance need not exceed y_t, provided y_t is not less than the distance to the moulded deck line at *B* side.

$y_t = y(0.9+0.2x/B)$ m

y = distance, in m from the neutral axis to the top of the continuous coaming

x = distance, in m from the top of the continuous coaming to the centreline of the ship.

B= breadth of ship as defined in 1.1 in m.

x and y are to be measured to the point giving the largest value of y_t

d. Hull-girder Moment of Inertia: The hull–girder moment of inertia of a ship amidships, expressedin centimetres squared or meters squared is to be not less than obtained from:

$I = L(SM)/34.1$

I = hull-girder moment of inertia

L= Length of ships as defined in 1.1 in m

SM= hull–girder section modulus required for the ship in 5.3.1

5.2.2 Total bending moment: The total bending moment, expressed in metric tons-meters is to be obtained from the following equation.

$M_t = M_{sw} + M_w$

M_{sw} = still-water bending moment in metric tons-meters. Where the envelope curve of still-

w

ater bending moments is not available the maximum value within 0.4L amidships it to be assumed throughout0.4L amidships. Special consideration will be given where the maximum value of still-water bendingmoment is shown to occur outside the 0.4L amidshipsM_w = maximum wave-induced bending moment inaccordance with 5.2.2b or 5.2.2c in metric tons-meters.

a. Still-water bending moment and shear force. For ships required by SOLAS to have a loading manual, still-water bending moment and shear force calculations for the anticipated loaded and ballasted conditions are to be submitted. For other ships the necessity of submitting these calculations will be considered in each case. Where the type of ship or the proposed loading conditions are such that still-water bending moments or still-water shear forces greater than M_s or F_{sw} given by $5.0M_s/L$ may occur, still-water bending moment or still-water shear force calculations are to be submitted. The results of these calculations are to be submitted in the form of curves showing hull-girder shear forces and bending moment values along the entire ship length.

In case the detailed information needed for calculating the stillwater bending moment is not available at the early design stages, a standard still-water bending moment M_s as specified by the following equations, in metric tons-meters, may be used within 0.4L amidships.

$M_s = C_{st} L^{2.5} B(C_b + 0.5)$

$C_{st} = [0.618 + \frac{(110 - L)}{462}]10^{-2}$ $61 \leq L \leq 110$ m

$= [0.564 + \frac{(160 - L)}{925}]10^{-2}$ $110 < L \leq 160$ m

$= [0.544 + (210 - L)]10^{-2}$

160<L

$\leq$210 m2500

= $[0.544]10^{-2}$ 210<L$\leq$250 m

= $[0.544- (\underline{L-250})]10^{-2}$

250<L

<427 m1786

L = length of ship as defined in 1.1 in m

B = breadth of ship as defined in 1.3 in m

C_b = block coefficient at summer load waterline, based on the length *L* as defined in 1.1.

For this equation, C_b is not to be taken less than 0.64.

b. Wave-induced bending moment amidships. The wave-induced bending moment, expressed in metric tons-meters, may be obtained from the following equation.

$M_w = C_2 L^2 \; BHK_b$

$K_b = 1.0$ for $C_b \geq 0.80$

$= 1.4 - 0.5C_b$ for $0.64 < C_b < 0.80$

$C_2 = [2.34C_b + 0.2]10^{-2}$ metric units.

L = length of ship as defined in 1.1 in m
B = breadth of ship as defined in 1.3 in m

C_b = block coefficient at summer load waterline, based on *L* as defined in 2.1. For this equation, C_b is not to be taken as less than 0.64.

H = wave parameter in m for use in the equation

= $0.0172\,L + 3.653$ $61 \leq L \leq 150$ m

= $0.0181\,L + 3.516$ $150 < L \leq 220$ m

= $[4.50L - 0.0071L^2 + 103]10^{-2}$ $220 < L \leq 305$ m

= 8.151 $305 < L \leq 427$ m

Consideration will be given to the wave-induced bending moment calculated by means of a statistical analysis based on the ship motion calculation in realistic sea states. In such cases, the calculations, computer programs used, and the computed results are to be submitted for review.

c. Envelope curve of wave-induced bending moment: The wave induced bending moment along the length of the ship *L* may be obtained by multiplying the midship value by the distribution factorgiven in Table 5.1. Consideration will be given to the wave-induced bending moment distribution calculated by means of a statistical analysis.

5.2.3 Permissible Shear Stress: In general, the thickness of the side shell and longitudinal bulkhead, where fitted, are to be such that the nominal total shear stressed as obtained from 5.2.3a are not greaterthan 1.065 metric tons per centimetre squared.

For longitudinal bulkhead plating within the middle eight-tenths depth of the bulkhead, the total shear stresses may be increased to 1.225 metric tons per centimetre squared if the critical shear buckling stress for the bulkhead plate panel between stiffeners is satisfactory.

a. Calculation of shear stresses: In calculation of the nominal total shear stresses due to still-water and wave-induced loads in the side shell and longitudinal bulkhead plating, the maximum numerical sum of the shearing force in still-water F_{sw} and that induced by wave F_w at the station examined are to be used. Where cargo is carried in alternate holds, the value of F_{sw} may be modified to account for the shearing loads transmitted through the double bottom structure to the transverse bulkhead. For this modification, unless a detailed calculation is performed, the method described in 5.3.7c is to be used as guidance. Alternative methods of calculation will also be considered. For ships without continuous longitudinal bulkheads, the nominal total shear stress f_s in the side shell plating may be obtained from the following equation.

$$f_s = (F_{sw} + F_w)m / 2tI$$

f_s = nominal total shear stress in metric tons per centimetre squared.

I = moment o inertia of the hull-girder section in cm^4 at the section underconsideration.

m = first moment in cm^3 about the neutral axis, of the area of the effective longitudinal material between the vertical level at which the shear stress is being determined and thevertical extremity of effective longitudinal material, taken at the section under consideration

t = thickness of the side shell plating, in cm at the position under

considerationF_{sw}, F_w = as specified by 5.2.3b

For ships having continuous longitudinal bulkheads the total shear stress in the side shell and longitudinal bulkhead plating is to be calculated by an acceptable method. The method described in 5.2.3d may be used as a guide in calculating the permissible still-water shear stress. Alternative methods of calculation will also be considered. In determining the still-water shear force, consideration is to be given to the effects of non-uniform athwartship distribution of loads.

Table 5.1 Wave-induced bending moment distribution factor.

Intermediate values of distribution factor may be determined by interpolation.

The distribution factor for ships with block coefficient less than 0.64 or ships with considerable flare will bespecially considered.

Station

Position	Distribution Factor
0	0
2	0.10
4	0.35
6	0.68
8	0.95
9	1.00
10 Amidships	1.00

11	0.99
12	0.94
14	0.74
16	0.43
18	0.13
20 (FP)	0

b. Hull-girder shearing force: The hull-girder shearing forces in still water F_{sw} are to be submitted as required by 5.2.3a The envelope of maximum shearing forces induced by waves F_w as shown in Figure 6.1 may be obtained from the following equation.

$F_w = KM_W/L$

F_W = maximum shearing force induced by wave in metric tons

M_w = maximum wave-induced hull-girder bending moment in metric ton-meters asspecified by 5.2.3b

L = length of ship as defined in

1.1 in mK = 2.6 between 0.15L

and 0.30L

1.6 between 0.40L and 0.55L

2.5 between 0.65L and 0.80L

0.0 at FP and aft end.

The K value is measured from the FP and at intermediate locations may be obtained by interpolation. Ships having C_b less than 0.64 will be subject to special consideration.

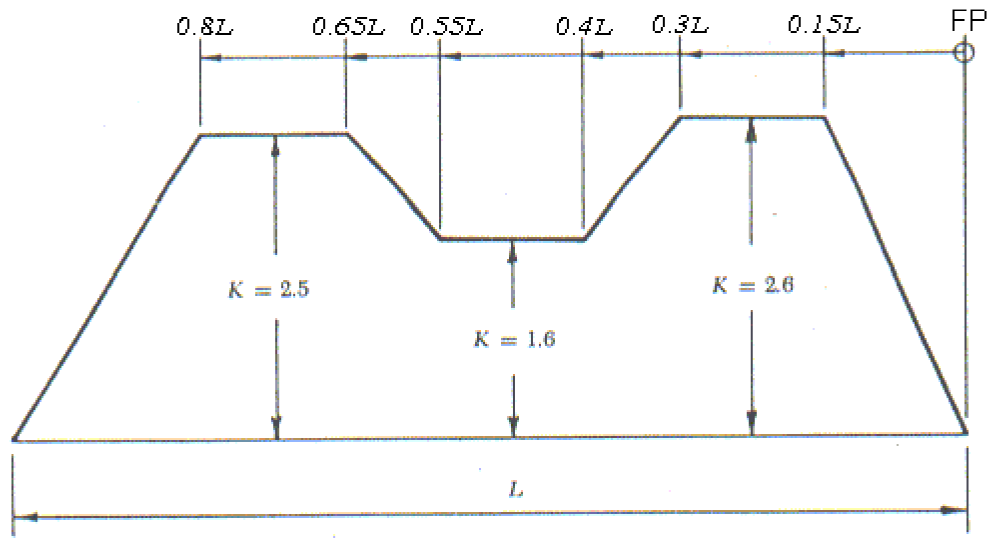


Figure 5.1 Envelope of Wave-Induced Shearing Forces

For ships where the still water hull-girder shearing force calculations are not required to be submitted, the maximum value of F_{sw} for uniform loading conditions may be obtained from the following equation.

$F_{sw} = 5.0\ M_s\ /L$

F_{sw} = hull-girder shearing force in still water in metric tons.

M_s = "standard" still water bending moment in metric ton-meters as specified by 5.2.3a

L = length of ship as defined in 1.1 in m

The value of F_{sw} given above may also be used in he early design stage for a preliminary check of the hull-girder shear strength of vessels for which still-water shear force calculations are required to be submitted.

c. Modification of hull-girder shearing force for ships carrying cargo in alternate holds or with other non-uniform loading: The hull-girder shearing force in still water to be used for calculating shear stresses in the side shell plating may be modified for ships carrying cargo in alternate holds to account for the shear loads transmitted through the double bottom structure to the transverse bulkheads. Where a detailed structural analysis for determining the shear force distribution has not been performed, the following equation may be used to determine the shear carried by the sideshell at transverse bulkhead (see Figure 5.2), provided the girders in the double bottom are arranged.

$F_s = F_{sw} - F_B$

Fs = still-water shear force distributed to the side shell, in metric tons.

F_{sw} = hull-girder shearing force in still water as obtained by the conventional directintegration method, in metric tons.

$F_B = F_{BE}$ or F_{BL}, whichever is the

lesser$F_{BE} = (0.45 – 0.2\ l_E / b_E)$

$W_E b_E/B$

$F_{BL} = (0.45 – 0.2\ l_L / b_L)\ W_L\ b_L /B$

W_E, W_L = total load (net weight or net buoyancy) in the adjacent holds with lesser weightE and greater weight L respectively, in metric tons. Where alternate holds are

empty, weight E is to be for the empty hold.

l_E , l_L = length of the adjacent holds respectively, containing W_E and W_L in m b_E ,

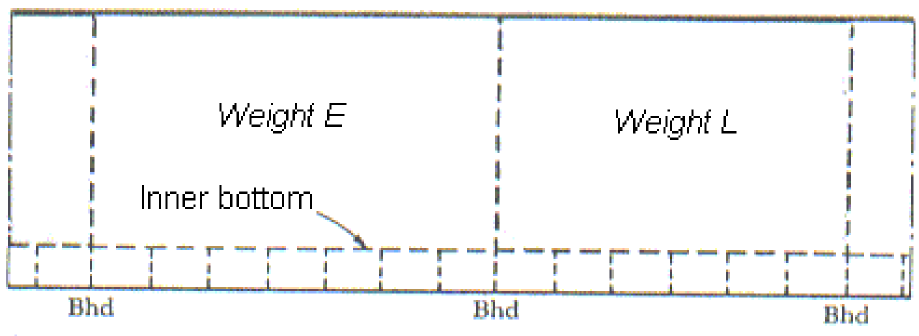
b_L = breadth of the double bottom structure in the weight E and weight L holds respectively , in m. For ships having lower wing tanks with sloping tops, making and angle of about 45 degrees with the horizontal, the breadth may be measured betweenthe midpoints of the sloping plating. For ships having double skins with flat inner bottom, it may be measured between the inner skins.

B = breadth of ship as defined

in 1.3.E = empty hold or lesser

loaded hold

L = loaded hold or greater loaded hold.



Weight *E* < Weight *L*

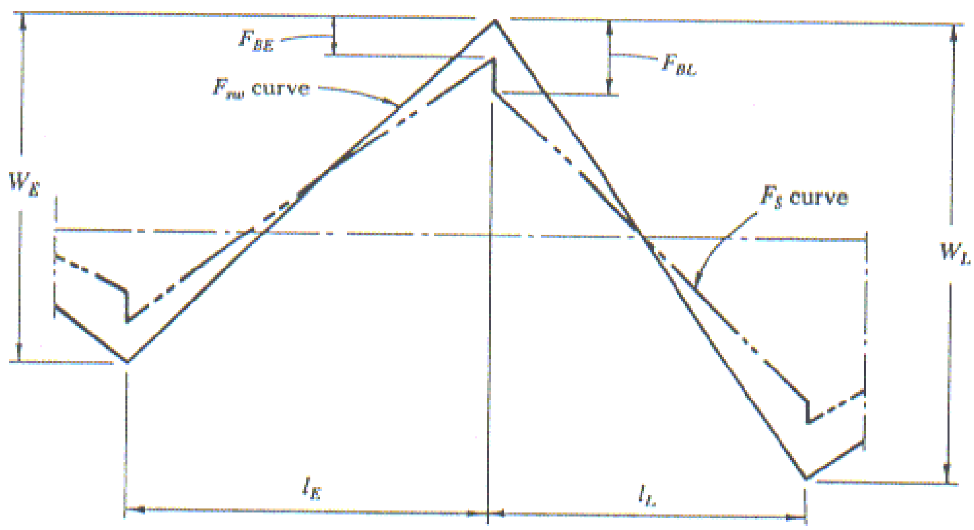


Figure 5.2 Shear Force Distribution

d. Calculation of shear stresses for ships having longitudinal bulkheads:

1. *Methods of calculation* The nominal total shear stress f_s in the side shell or longitudinal bulkheadplating is related to the shear flow N at that point by the following equation.

$F_s = N/t$

N = shear flow

t = thickness of the plating

2. *Calculation of the shear flow around closed sections* The shear flow of a closed and prismaticstructure is expressed by the following equation:

$N = (Qm/I) + N_i$

Q = total shear force at the section under consideration

M = first moment about the neutral axis of the section, of the are of the longitudinal material between the zero shear level and the vertical level, at which the shear stress isbeing calculated.

$$m = \int^{p} Zt\ ds + \sum aizj$$

0 $i=0$

I = moment of inertia of the section

N_i = constant shear flow around the cell regarded as an integration constant of unknownvalue arising from substituting the statically indeterminate structure by statically determinate one.

Z = distance from section neutral axis to a point in the girth, positive downward

a = equivalent sectional area of the stiffener or girder attached to the deck shell andbulkhead platings

s = length along girth and longitudinal bulkhead

3. *Calculation of m.* To calculate the value of m, it requires the knowledge or assumption of a zero shear point in the closed cell. As an example, in the case of a simplified tanker section the deck point at the centreline is a known point of zero shear in the absence of the centreline girder.

An arbitrary point may be chosen in the wing tank cell. Superposition of the constant N_i to the shear flow resulting from the assumption of zero shear point will be yield to the correct shear flow around the wing cell.

4. *Determination of* Ni N_i is determined by using Bredt's torsion formula, making use of the assumption that there is no twist in the cell section, i.e., the twist moment resulting from the shear flow around a closed cell should equal zero, or

$\int N \frac{ds}{t} = 0$ In a multiple structure of n number of cells, the formula can be written for the i^th^ cell as follows.

$$\int_i N \frac{ds}{t} = \frac{Q}{I} \int_i mi \frac{ds}{t} + \{N_{(i-1)} \int_{div} (\frac{ds}{t} + Ni)$$

$\int \frac{ds}{t} + N_{(i+1)} \int_{div} \frac{ds}{t} = 0$

Div= Common division between cell i and the adjacent cells i–1 and i+1.

The first term represents twist moment around cell i at the assumed statically determined status. The m values are calculated upon arbitrary zero shear points in the cell i and the adjacent cells. The remaining terms in the equations represent the balancing twist moments around cell i and of those carried out by the common divisions in the adjacent cells i – 1 and i + 1.

To determine the constant shear flow in the cells N_1, N_2....... N_i.... N_n, n number of similar equations
are formed for each cell and are solved simultaneously.

5.3 STRENGTH DECKS

5.3.1 Definition: The uppermost deck to which the side shell plating extends for any part of the length ofthe ship is to be considered the strength deck for that portion of the length, except in way of other superstructures where it may be desired to adopt the modified scantlings for the side shell (see 7.2) and the modified requirements for the superstructure deck as given in 16.1.2. In way of such superstructures, the deck on which the superstructures are located is to be considered the strength deck.In general, the effective sectional area of the deck for calculating the section modulus is to exclude hatchways and other openings through the deck.

5.3.2 Tapering of deck sectional areas: In general, where the still-water bending moment envelope curve is not submitted or where 5.2.1b governs, the deck sectional areas used in the section modulus calculations are to be maintained throughout 0.4*L* amidships, the strength deck area may be reduced to approximately 70% of the deck area required at that location if there were no superstructure. Where bending moment envelope curves are used to obtain M_t, the deck sectional areas are to be adequate to meet the hull-girder section modulus requirements at the location being considered.

5.4 CONTINUOUS LONGITUDINAL HATCH COAMINGS AND ABOVE-DECK GIRDERS

Where strength deck longitudinal coamings of length greater than 0.14L are effectively supported by longitudinal bulkheads or deep girders, the coaming and longitudinal stiffeners are to be in accordance, the section modulus amidships to the top of the coaming is to be as required by 5.2.1a, 5.2.1b and 5.3.1c but the section modulus to the deck at side, excluding the coaming, need not be determined. Continuous longitudinal girders on top of the strength deck are to be considered similarly, scantlings are also to be in accordance with Chapter 10.

5.5 EFFECTIVE LOWER DECKS

To be considered effective for use in calculating the hull-girder section modulus, the thickness of the stringer plates and deck plating are to comply with the requirements of 15.3. The sectional areas of lower decks used in calculating the section modulus are to be obtained as described in 5.4.1, but should exclude the cutouts in the stringer plate in way of through frames. In general, where the still-water bending moment envelope curve is not submitted or where 5.2.3b governs, theses areas are to be maintained throughout the midship 0.4*L* and may be gradually reduced to one-half their midship value at 0.15*L* from the ends. Where bending moment envelope curves are used, the deck sectional areas are to be adequate to meet the hull girder, section modulus requirements at the location being considered.

5.6 LOADING GUIDANCE INFORMATION

5.6.1. General: 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. This information is to be provided by means of a Loading Manual and in addition, whererequired, by means of an approved loading instrument, according SOLAS.

5.6.2. Loading manual: A Loading Manual is to be supplied to all ships where longitudinal strength calculations have been required. 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. The Manual is to be based on the final data of the ship. Details of the loading conditions are to be included in the Manual as applicable.

The Manual is also to contain:

a) Values of actual and permissible still water bending moments and shear forces.

b) The allowable local loading for the structure. 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.

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 bygrabs.

The Manual is also to contain the procedure for ballast exchange and sediment removal at sea.

5.6.3. Loading instrument: 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 limited possibilities for variations in the distribution of cargo

b) Ships with a regular trading pattern.

The loading instrument is to be capable of calculating shear forces and bending moments, in any condition at specified readout points. On container ships cargo torque is also to be calculated.

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. The instrument is to be certified in accordance with a recognised International standard program.The instrument readout points are selected at the position of the transverse bulkheads.

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”. Where alteration to structure or cargo distribution is proposed, the loading Instrument is to be modified accordingly.

The operation of the loading instrument is to be verified by the Surveyors upon installation and at Annualand Periodical Surveys in the Principles. An operation Manual for the instrument is to be verified as being available on board.

Where a loading instrument is also provided with a stability computation capability then the system is to be certified for such use.

5.7 LONGITUDINAL DECK STRUCTURES INBOARD OF LINES OF OPENINGS.

5.7.1 General: Where deck structures are arranged with two or more large openings abreast, as shown in Figure 5.3, the degree of effectiveness of that portion of the longitudinal structure located between the openings is to be determined in accordance with the following paragraph. Plating and stiffening members forming theses structures may be included in the hull-girder section-modulus calculation to the extent indicated in the following paragraphs, provided they are substantially constructed, well supported both vertically and laterally, and developed at their ends to be effectively continuous with other longitudinal structure located forward and abaft that point.

5.7.2 Effectiveness: The plating and longitudinal stiffening members of longitudinal deck structures complying with the basic requirements of the foregoing paragraph, supported by longitudinal bulkheads, in which the transverse slenderness ratio l/r is not greater than 60, may be considered as fully effective in the hull-girder modulus. Longitudinal deck structures, not supported by longitudinal bulkheads, but of a substantial construction having a slenderness ratio l/r about any axis not greater than 60, based on the span between transverse bulkheads, or other major supports, may be considered as partially effective in accordance with the product of the net section area and the factor H as derived from Table 5.2 whichmay be used in the section-modulus calculation.

Table 5.2 Values of H

s/ b Values (Minimum Ratio for Ship)	l / B Values 1.2	0.8	0.6 or less
0.15 (minimum)	0.32	0.34	0.35
0.30	0.38	0.43	0.47
0.50	0.48	0.56	0.62
0.80	0.60	0.70	0.76
1.20	0.72	0.81	0.86
1.80	0.82	0.89	0.92
and above			

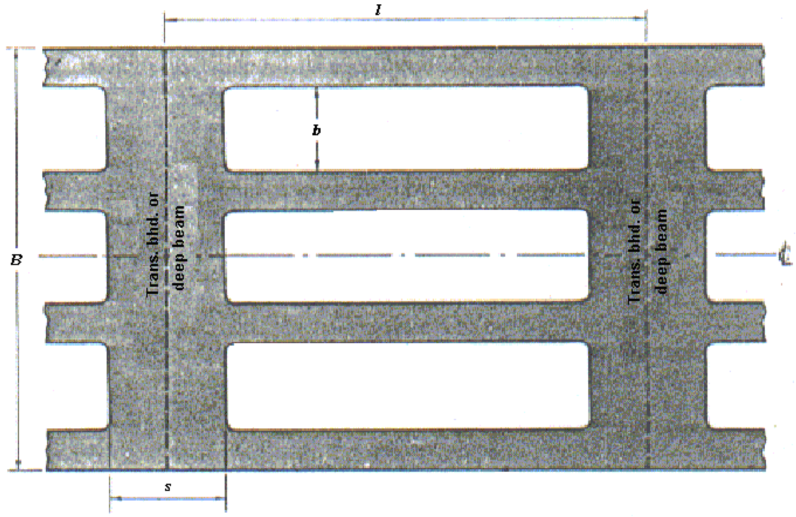
Intermediate values of H may be determined by interpolation. Where the length of the longest cargo holdexceeds 0.8*B* and there is no pillar installed at about mid-length of hold, H is to be multiplied by a factor of 0.9

s= length of deck plating between hatch

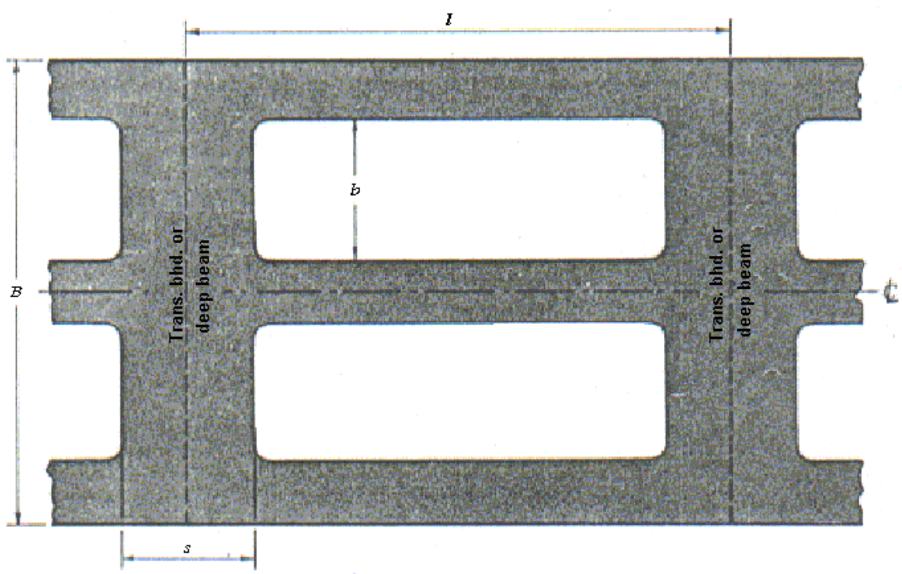
openings in mb width of hatch opening in m

l= length as shown in Figure 5.3 in m

B= breadth of ship as defined in 1.3 in m



Triple-hatch arrangement



Twin-hatch arrangement

FIGURE 5.3 Hatch Arrangements

5.8 LONGITUDINAL STRENGTH WITH HIGHER–STRENGTH MATERIALS

5.8.1 General: Ships in which the effective longitudinal material of either the upper or lower flanges of the main hull girder, or both, are constructed of materials having mechanical properties greater than those of ordinary-strength hull structural steelare to have longitudinal strength generally in accordance with the preceding paragraphs of this Chapter, but the value of the hull-girder section modulus may be modified as permitted by the following paragraphs. Applications of higher-strength material are to be continuous over the length of the ship to locations where the stress levels will be suitable for theadjacent mild-steel structure. Higher-strength steel is to be extended to suitable locations below the strength deck and above the bottom, so that the stress levels will be satisfactory for the remaining mild steel structure. Longitudinal framing members are to be essentially of the same material as the plating they support and are to be continuous throughout the required extent of higher-strength steel. Calculations, showing that adequate strength has been provided against buckling, are to be submitted forreview, and care is to be exercised against the adoption of reduced thickness of material, which may be subject to damage during normal operations.

5.8.2 Hull-girder Moment of Inertia: The hull-girder moment of inertia is to be not less than required by 5.2.1d.

5.8.3 Hull-girder Section Modulus: When either the top or bottom flange of the hull girder, or both, is constructed of higher-strength material, the section modulus as obtained from 5.2.1 may be reduced by the factor Q . Special consideration will be given to the application of Q less than 0.66, includingreference to fatigue strength and plate stability.

$$SM_{hts} = Q(SM)$$

$$Q = 49.92 / [Y+(2U/3)] \qquad Q = 70900 / (Y + 2U / 3)$$

Y = specified minimum yield point in kg/mm^2, as defined in 43.1.7 for the higher-strength material or 72%of the specified minimum tensile strength, whichever is the lesser.

U = specified minimum tensile strength of the higher – strength material, kg / mm^2

5.8.4 Hull–girder shearing force: Where the side shell or longitudinal bulkhead is constructed of higher strength material the permissible shear stresses may be increased by the factor l/Q. For plate panel stability.

CHAPTER 6: BOTTOM STRUCTURE

6.1 SINGLE BOTTOMS

6.1.1 Centre keelsons: All single–bottom ships are to have centre keelsons formed of continuous centre girder plates with horizontal top plates. When the length of the ship does not exceed 93 m, the thicknessof the keelson and the area of the horizontal top plate are to be obtained from the following equations.

a. Centre-girder thickness amidships

$t = 0.063L + 5$ mm

b. Centre–girder thickness at ends.

t = 85% of centre keelson thickness amidships

c. Horizontal top-plate area amidships

$A = 0.168\ L^{3/2} - 8$ cm²

d. Horizontal top-plate area at ends.

$A = 0.127L^{3/2} - 1$ cm²

t = thickness of centre-girder plate in mm

L= length of ship as defined in

1.1 in mA = area of horizontal

top plate in cm²

6.1.2 Side keelsons: Side keelsons are to be arranged so that there are not more than 2.13 m from the centre keelson to the inner side keelson, from keelson to keelson and from the outer keelson to the lower turn of bilge; forward of the midship one-half length the spacing of keelsons on the flat of floor is not to exceed 915 mm. Side keelsons in ships over 76m in length are to be formed of continuous rider plates on top of the floors; they are to be connected to the shell plating by intercostal plates. The intercostal plates are to be attached to the floor plates. In the engine space the intercostal plates are to be of not less thickness than the centre girder plates. The thickness of intercostal plates in way of boilers is to be increased 1.5 mm. For ships whose lengths do not exceed 93 m the scantlings of the side keelsons are to be obtained from the following equations.

a. Side keelson and intercostal thickness amidships

$t = 0.063L + 4$ mm

b. Side keelson and intercostal thickness at ends.

t = 0.85 of the thickness amidships.

c. Side keelson and intercostal, horizontal top plate area amidships

$A = 0.038L^{3/2} + 17$ cm²

d. Side keelson and intercostal, horizontal top plate area at ends.

$A = 0.025 L^{3/2} + 20$ cm²

t, *L* and A are as defined in 6.1.1.

6.1.3 Floor plates: A floor plate similar to that shown in Figure 6.1 is to be fitted on every frame and is to be of the scantlings necessary to obtain a section modulus SM as obtained from the following equation.

SM = 4.74

chsl² cm³c=

0.9

h= *d* or 0.66D whichever is

greater, in ms = spacing of the

floors in m

l = span in m between the toes of the frame brackets plus 0.30 m; where no brackets are fitted the lengthl is to be taken as the span in m between the intersection of the top of the floor with the inside of the frame plus 0.30 m; where curved floors are fitted the length l may be suitably modified.

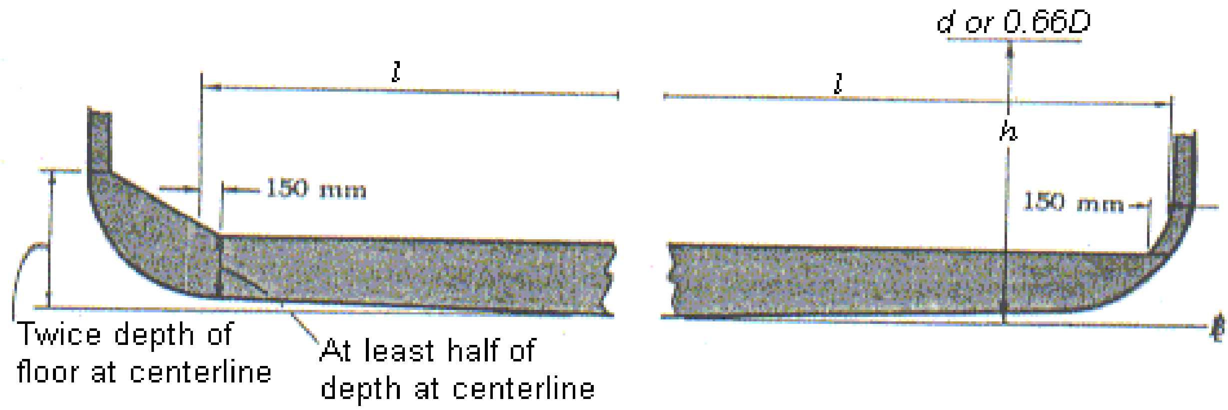


Figure 6.1 Single-bottom floors

The depth at the centreline is not to be less than 0.0625 l. The thickness is not to be less than 1 mm per 100 mm of depth plus 3 mm, but need not exceed 11.5 mm. The thickness is to be maintained throughout the midship one-half length, but may be reduced by 10% at ends.

Floors under engines are to be of ample depth and of not less thickness than the centre girder plate. Floors under boilers are to be at least 2 mm thicker than the midship floors where boilers are not less than 457 mm clear of the floors, where the clearance is less, the thickness is to be further increased. Forward of the midship three-fifths length, either the depth of the floors or the area of the flanges orface bars is to be increased, where the machinery is aft both measures are to be adopted. See 6.6.

6.1.4 Floor flanges: Flanges are to have sectional areas not less than required by 6.1.3. The area of the faceplates is to be doubled on engine and boiler bearer floors and on the floors forward of the midship three-fifths length where the depth of the floor is not increased. Alternatively the floors may be flanged at their upper edges to provide an arrangement of equivalent strength. Where engines are aft these requirements apply forward of the midship one-half length and the depth of the floors is to be increased forward of the midship three-fifths length.

6.1.5 Bulkhead floors: Bulkhead floors are to extend from 0.6 to 0.9 m above the top of ordinary floors and are to be of not less thickness than required for bulkhead plating. See Chapters 12 and 13.

6.1.6 Floors remote from boilers: Where the floors are remote from boilers or the boilers are of such type as will preclude excessive temperature of the structure in the vicinity of the boilers, local increases required for the structure in the vicinity of the boilers may be modified.

6.2DOUBLE BOTTOMS

6.2.1 General: Inner bottoms are to be fitted all fore and aft between the peaks or as near thereto as practicable in ships of ordinary design having lengths of 93 m and above. It is recommended that the inner bottom be arranged to protect the bilges as much as possible and that it is extended to the sides of the ship forward of the midship three-fifths length. Details of construction at the ends of partial double bottoms are to be clearly shown on the plans submitted for approval. Where boilers are remote from the inner bottom, local increases required for the structure in the vicinity of the boilers may be modified.

6.2.2 Centre girders.

a. **General.** Centre girders are to extend as far forward and aft as practicable and they are to be attached to the stern frame. The plates are to be continuous within the midship three-quarters length**,** elsewhere they may be intercostal between the floors. Where double bottoms are to be used for fuel oil or fresh water, the girders are to be intact, but need not be tested under pressure; this requirement may be modified in narrow tanks at the ends of the ship or where other intact longitudinal divisions are provided at about 0.25 B from the centreline. Where the girders are not required to be intact, manholes may be cut in every frame space outside the midship three-quarters length. They may be cut in alternate frame spaces within the midship three-quarters length in ships under 90 m in length, provided the depth of the hole does not exceed one-third the depth of the centre girder Manholes within the midship three-quarters length in ships 90 m in length and above are to be compensated for and specially approved.

b. **Scantlings** Centre-girder plates are to be of the thickness and depths given by the following equations between the peak bulkheads. In peaks the centre-girder plates are to be of the thickness of the peak floors. Where longitudinal framing is adopted, the centre-girder plate is to be suitably stiffened between floors, and docking brackets are to be provided where the spacing of floors exceeds 2.28 m. Where special arrangements such as double skins or lower wing tanks effectively reduce the unsupported breadth of the double bottom in association with closely spaced transverse bulkheads, the depth of centre girder may be reduced by substituting for *B* thedistance between sloping plating of the wing tanks at the inner-bottom plating level or between the inner skins. Where this distance is less than 0.9*B*, an engineering analysis for the double bottom structure may be required. Where the length of the cargo hold is greater than 1.2 times*B*, or where the ship is intended to carry heavy cargoes, the thickness and depth of centre–girder plates are to be specially considered.

1. Thickness amidships

$t = 0.056\,L + 5.5$ mm where $L \leq 427$m

2. Thickness at ends

85% of that given for amidships

3. Depth

$d_{DB} = 32B + 190\sqrt{d}$ mm where $L \leq 427$ m

t = thickness of plating in mm

L = length of ship as defined in

1.1 in md_{DB} = depth of double

bottom in mm

d = moulded draft of ship as defined in 1.7 in m

B = breadth of ship as defined in 1.3 in m.

6.2.3. Pipe tunnels: Pipe tunnels may be substituted for centre girders provided the sides of the pipe tunnels have not less thickness than required for tank-end floors. The arrangement and details of construction of pipe tunnels are to be clearly shown on the plans submitted for approval.

6.2.4 Solid floors: Solid floors of the thickness obtained from the following equations in **a** and **b** are to befitted on every frame under machinery and transverse boiler bearers, under the outer ends of bulkhead stiffener brackets and at the forward end (see 6.11). Elsewhere they may have a maximum spacing of
3.66 m in association with intermediate open floors or longitudinal framing of bottom or inner bottom. With the latter, the floors are to be of the thickness required in the engine space and are to have stiffeners at each longitudinal. When partial floors are fitted on every frame outboard, the outboard portion of solid floors and the partial floors may be of thickness required for normal floors. Where boilers are mounted on the tank top, the thickness of the floors and intercostals in way of the boilers are to be increased 1.5 mm above engine-space requirements.

a. Floors, side girders and brackets in engine space and floors with longitudinal framing.

$t = 0.036L + 6.2$ mm where $L \leq 427$ m

b. Floors, side girders and brackets elsewhere

$t = 0.036L + 4.7$ mm where $L \leq 427$ m

t = thickness in mm

L = length of ship as defined in 1.1 in m.

6.2.5 Tank-end floors: Tank-end floors of the thickness not less than required for floors in the boiler space are to be so arranged that the subdivision of the double bottom generally correspond with that of the ship.

6.2.6 Floor stiffeners: Stiffeners spaced not more than 1.53 m apart are to be fitted on solid floors forward and on every solid floor in ships of 85-m length and above. Where the depth of the double bottom exceeds 915 mm, stiffeners on tank-end floors are to be of the sizes required for stiffeners on deep-tank bulkheads and the spacing is not to exceed 915 mm. Stiffeners may be omitted on non-tight floors with transverse framing, provided the thickness of the floor plate is increased 10% above the thickness obtained from 6.2.4.

6.2.7 Open floors: Open floors in accordance with this paragraph are to be fitted at each frame between the solid floors where the solid floors are not fitted on every frame as permitted in 6.2.4.

a. ***Frames and reverse frames:*** Each frame and reverse frame similar to that shown in Figure 6.2, in association with the plating to which they are attached, is to have a section modulus SM as obtained from the following equation.

$SM = 7.9\ chsl^2\ cm^3$

s= spacing of frames in m

c= 1.0 Where struts are fitted in accordance with 6.3.19c and spaced not more than1.53m, c may be taken as 0.5

h= distance in m from the keel to the load line. In the case of reverse bars without strutsthe distance may be measured from the top of the double bottom.

l= distance in m between the connecting brackets on the centreline girder and themargin plate plus 0.09m.

The frames under the boilers are to be increased 1 mm in thickness.

b. ***Centre and side brackets:*** Centre and side brackets are to overlap the frames and reverse frames for a distance equal to 0.05*B*; they are to be of the thickness required for solid floors in the same location and are to be flanged on their outer edges.

c. ***Struts:*** The permissible load $W_{a\ for}$ struts is to be determined in accordance with 10.3.1 The calculated load W is to be determined by W=1.07 phs in metric tonnes where s and h have the values as defined in 6.3.19a and p is equal to the distance in m between the centre of the struts. Struts are to be increased 1.5 mm in thickness in way of the boilers.

6.2.8 Bottom longitudinals: Each bottom longitudinal frame similar to that shown in Figure 6.3, in association with the plating to which it is attached, is to have a section modulus SM not less than obtained from the following equation.

$$SM = 7.90\ chsl^2\ cm^3$$

c = 1.30. Where effective struts are fitted, the value of c may be taken as 0.715 and in such cases, the value of l is to be the distance in m between floors, but is not to be taken as less than 2.44 m. In effectivestruts are fitted and where the tank top is intended to be uniformly loaded with cargo, c may be taken as
1.30 and the length, l may be taken as 60% of the distance between

floors.h= distance in m from the keel to the load line.

s= spacing of longitudinals in m

l= distance in m between the floors. The value of l is not to be taken as less than 1.83 m.

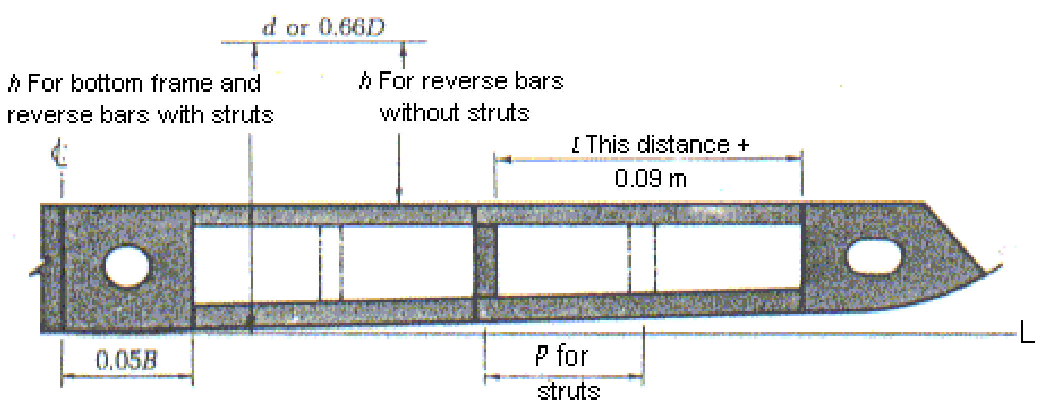


Figure 6.2 Double bottom open floors

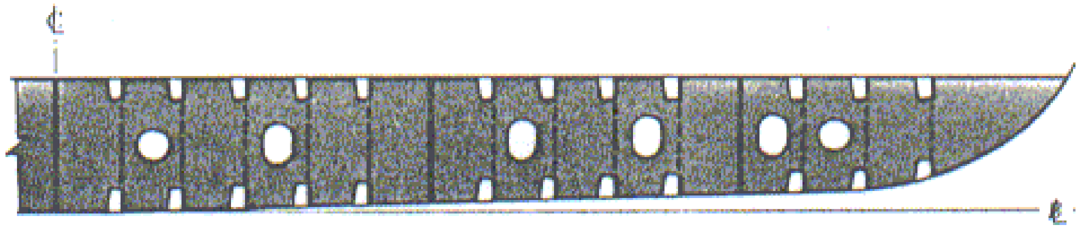


Figure 6.3 Double bottom solid floors

Where the bottom hull-girder section modulus $SM_{A\ is,}$

a. Greater than required by 5.2.1
b. Still-water bending moment calculations are submitted
c. Adequate buckling strength is maintained.

The section modulus SM of the bottom longitudinals may be obtained from the above equations multiplied by R_l . The bottom longitudinals, with this modified section modulus are to meet all other Procedures requirements.

$R_l = 0.852 / [0.852 + f_p \{1-(SM_R/SM_A)\}]$ metric

units.but is not to be taken less than 0.69

f_p = nominal permissible bending stress as given in 5.2.1 a

SM_R = hull-girder section modulus required by 5.2.1 in centimetres squared meter.

SM_A = bottom hull- girder section modulus, in centimetres squared meters, with thelongitudinals modified as permitted above.

6.2.9 Inner-bottom longitudinals: Inner-bottom longitudinals may have values of SM equal to 85% of that required for the bottom longitudinals.

6.2.10 Continuous longitudinals: Bottom and inner-bottom longitudinals are to be continuous to develop effectively the sectional area and the resistance to bending.

6.3 INNER-BOTTOM PLATING.

6.3.1 Inner-bottom plating thickness: Inner-bottom plating is not to be of less thickness t than obtained from a, b and c below or 12.5; where there is no ceiling under hatchways, the required thickness is to be increased 2 mm.

a. Engine space.

$t = 0.037L + 0.009s + 1.5mm$ where $L \leq 427$ m

L = length of ship as defined in

1.1 in ms = frame spacing in mm

b. Elsewhere. Elsewhere the thickness of the inner-bottom plating may be 2.0 mm less than thatrequired for engine spaces.

c. Longitudinally framed inner bottom. For ships with longitudinally framed inner bottoms, theminimum thickness of inner bottom plating, as obtained above, may be reduced by 1 mm.

6.3.2 Centre strakes: Centre strakes are to have a thickness determined from 6.3.1; in way of pipe tunnels the thickness may be required to be suitably increased.

6.3.3 Under boilers: Under boilers there is to be a clear space of at least 457 mm. Where the clear space is necessarily less, then thickness of the plating is to be increased as may be required.

6.3.4 In way of engine bed plates or thrust blocks: In way of engine bed plates or thrust blocks which are bolted directly to the inner bottom, the plating is to be at least 19 mm thick; the thickness is to be increased according to the size and power of the engines. Holding-down bolts are to pass through angle flanges of sufficient breadth to take the nuts.

6.3.5 Margin plates: Where the margin plate is approximately vertical, the plate amidships is to extend for the full depth of the double bottom with a thickness as obtained from the equation in 6.3.1a. Where approximately horizontal, margin plates may be of the thickness of the adjacent tank-top plating.

6.3.6 Recommendations where cargo is handled by grabs: For ships engaged in regular trades where the cargo is handled by grabs, it is recommended that flush inner-bottom plating be adopted throughout the cargo space, and that the plating requirements of 6.3.1 be suitably increased, but the increase need not exceed 5 mm. It is also recommended that the minimum thickness be not less than 12.5 mm with 610-mm frame spacing and 19 mm with 915-mm frame spacing with intermediate thickness obtained by interpolation.

6.3.7 Wheel loading: Where provision is to be made for the operation or stowage of vehicles having rubber tires, and after all other requirements are met, the thickness of the inner bottom plating is to be not less than obtained from this regulations.

6.4 HOLD FRAME BRACKETS

Brackets connecting hold frames to margin plates are to be of not less thickness than required for floors in the engine space except in the boiler space where they are to be of not less thickness than required for boiler-space floors and flanged on their upper edges. Where the shape of the ship requires exceptionally long brackets, they may be required to be increased in thickness and additional stiffness is to be provided by increasing the flange area. Where the double bottom is longitudinally framed, brackets are to be fitted below the margin at every transverse frame between floors, extending to the outboard longitudinals.

6.5 SIDE GIRDERS

Amidships and aft side girders of the scantlings obtained from 6.2.4 are to be so arranged that the distance from the centre girder to the first side girder, between the girders, or from the outboard girder to the centre of the margin plate does not exceed 4.57 m. At the fore end they are to be arranged as required by 6.6. Additional full or half-depth girders are to be fitted beneath the inner bottom as required in way of machinery and thrust seatings and beneath wide-spaced pillars. Where the bottom and inner bottom are longitudinally framed, this requirement may be modified.

6.6 FORE-END STRENGTHENING

6.6.1 General: Where the heavy weather ballast draft forward is less than 0.04L, strengthening of the flat of bottom forward is to be in accordance with 6.11.4, 6.11.7, 6.11.10 and 14.5.3. Information on the heavy weather ballast draft forward used for the required fore-end strengthening is to be furnished to the master for guidance. The heavy weather ballast draught is also to be indicated on the shell expansionplan.

6.6.2 Extent of strengthening: The flat of bottom forward is forward of the locations indicated in Table 6.1. For intermediate values of Cb, the locations are to be obtained by interpolation. Aft of these locations, a suitable transition is to be obtained between the increased scantlings and structural arrangements of the flat of bottom forward and the structure aft of the locations given in Table 6.1.

Table 6.1

Cb is the block co-efficient at the summer load waterline, based on *L* as defined in 1.1

Cb	**Location Forward of Amidships**
0.6 or less	0.25*L*
0.8 or more	0.30*L*

6.6.3 Longitudinal framing: When longitudinal framing is used for the bottom and inner bottom, longitudinals and side girders are to be continued as far forward as practicable at not more than their amidship spacing. The section modulus of flat of bottom longitudinals forward of the location indicated in Table 6.1 is to be not less than required by the following equation nor less than required by 6.2.8.

$$SM = 8.47\ (0.005L^2 - 1.3d^2f)\ s1^2/dfcm^3$$

d_f = heavy weather ballast draught at the forward perpendicular in m.

= df x 214/L m where L > 214 m

L = length of ships as defined in

1.1 in ms = spacing of

longitudinals in m

l = distance in m between floors.

The spacing of floors forward of 0.25L forward of amidships is to be not greater than that given in Table 6.2 nor greater than the spacing amidships.

Table 6.2 Spacing of floors

d_f is the heavy weather ballast draught at the forward perpendicular and C_b is the block co-efficient at the summer load waterline, based on *L* as defined in 1.1 s is the spacing of transverse side frames, or s in 7.2, where the side shell is longitudinally framed.

For values of d_f between 0.02*L*, 0.035*L* and 0.04*L* the floor spacing may be obtained by interpolation.

d_f	C_b	From 0.25*L* to 0.3*L* from amidships	Forward of 0.3*L* from amidships
0.02*L* and less	0.60 or less	3s	2s
	greater than	3s	2S
	0.60	3s	3S
0.035*L*	All values	3s	3s
0.04*L* and more	all values	As required elsewhere in the Principles	

6.6.4 Transverse framing: Where the heavy weather ballast draught forward is less than 0.04*L*, solid floors are to be fitted on every frame. Additional full-depth and half-depth side girders are to be introduced so that the spacing of full-depth girders forward of the location in Table 6.1 does not exceed 2.13 m; and so that the spacing of alternating half and full-depth girders forward of the locationin Table 6.1 does not exceed 1.07 m. Where the heavy weather ballast draught forward is 0.04*L* or more,the arrangement of solid floors and side girders may be in accordance with 6.2.4 and 6.5.

6.7 HIGHER-STRENGTH MATERIALS.

6.7.1 General: In general applications of higher-strength materials for bottom structures are to meet therequirements of this Chapter, but may be modified as permitted by the following paragraphs. Care is to be exercised to avoid the adoption of reduced thickness of material such as might be subject to damage during normal operation and calculations are to be submitted to show adequate provision against buckling. Longitudinal framing members are to be of essentially the same material as the plating theysupport.

6.7.2 Inner-bottom plating: Inner-bottom plating, where constructed of higher-strength material and where longitudinally framed, is to be not less in thickness than required y 6.3.1a, b or c or 12.3 as modified by the following equation.

$t_{hts}= [t_{ms} - C] \; [(Q + 2\sqrt{Q}) / 3] + C$

t_{hts} = thickness of higher-strength material in mm

t_{ms} = thickness of mild steel, as required by 6.3.1a, b or c or 12.3, in mm increasedwhere required by 6.3.1 for no ceiling

C = 3 mm or 5 mm where the plating is required by 6.3.1 to be increased for no

ceiling.Q = as defined in 5.8.3

The thickness of inner-bottom plating where transversely framed will be specially considered.

Where grabs or similar mechanical appliances handle cargo, the recommendations of 6.5.16 are applicable to $t_{hts.}$

6.7.3 Bottom and inner-bottom longitudinals: The section modulus of bottom and inner-bottom longitudinals, where constructed of higher-strength material and in association with the higher-strengthplating to which they are attached, are to be determined as indicated in 6.2.8 and 6.2.9 except the valuemay be reduced by the factor Q as defined in these regulations.

6.7.4 Centre girders, side girders, and floors: Centre girders, side girders, and floors, where constructed of higher-strength materials, generally are to comply with the requirements of 6.2.2 or 6.2.4 but may be modified as permitted by the following equation.

$t_{hts} = [t_{ms} - C] \, [(Q+ 2\sqrt{Q}) / 3] + C$

$t_{hts,}$ t_{ms} and C are as defined in

6.7.2Q is as defined in 5.8.3

6.8 STRUCTURAL SEA CHESTS

In addition to the requirements of 6.2 and 6.3, where the inner-bottom or the double-bottom structure form partof a sea chest the thickness of the plating is to be not less than required by 7.3.1 for the shell at 0.1*L*, where *s* is the maximum unsupported width of plating. The thickness need not exceed that required in 14.2 for side or bottom shell as appropriate.

6.9 DRAIN WELLS

The depth of drain wells in the double bottom is not to be greater than that of the double bottom within this region decreased by 460 mm. The well adjacent to the outer bottom plating may be arranged only in the shaft tunnel after body.

6.10 MANHOLES AND HOLES

Manholes and lightening holes are to be cut in all non-tight members to ensure accessibility and ventilation; the proposed locations of holes are to be indicated on the plans submitted for approval. Manholes in tank tops are to be sufficient in number to secure free ventilation and ready access to all parts of the double bottom. Care is to be taken in locating the manholes to avoid the possibility of interconnection of the main subdivision compartments through the double bottom insofar as practicable. Covers are to be of steel or equivalent materialand where no ceiling is fitted in the cargo holds, they are to be effectively protected from damage by the cargo.

6.11 AIR AND DRAINAGE HOLES

Air and drainage holes are to be cut in all parts of the structure to ensure the free escape of air to the vents and the free drainage to the suction pipes.

6.12 TESTING

Requirements for testing are contained in these regulations.

CHAPTER 7: SHELL PLATING

7.1 GENERAL

Shell plating is to be of not less thickness than is required for purposes of longitudinal hull-girder strength. Where hull-girder shear values are abnormal, the thickness of the side-shell plating may be required to be increased.

7.2 SHELL PLATING AMIDSHIPS

7.2.1 Ships with no partial superstructures above uppermost continuous deck: In ships which have no partial superstructures above the uppermost continuous deck, the thickness of the bottom and side plating is to be obtained from the appropriate equations where D_s is the moulded depth in m to the uppermost continuous deck.

7.2.2 Superstructures fitted above uppermost continuous deck (Extended side plating): Where superstructures are fitted above the uppermost continuous deck to which the side plating extends throughout the midship 0.4*L*, the thickness of the bottom and side plating is to be obtained from the appropriate equations where D_s is the moulded depth in m to the superstructure deck. In such cases, the sheerstrake beyond the superstructure is to be proportioned from the thickness as required for the sheerstrake amidships where D_s is measured to the uppermost continuous deck.

7.2.3 Superstructures fitted above uppermost continuous deck (No extended side plating): Where superstructures are fitted above the uppermost continuous deck to which the side plating extends throughout the midship 0.4*L*, the thickness of the bottom and side plating is to be obtained from the appropriate equations where D_s is the moulded depth in m to the uppermost continuous deck.

7.2.4 In way of comparatively short superstructures: In way of comparatively short superstructure decks, the thickness of the bottom and side plating is to be obtained from the appropriate equations where D_s is the moulded depth in m to the uppermost continuous deck. In such cases, the thickness of the side plating above the uppermost continuous deck is to be specially considered.

7.2.5 Side Shell Plating: The minimum thickness t of the side shell plating for the midship 0.4*L* for ships having lengths up to 427 m is to be obtained from the following equations.

$$t = (s/645)\sqrt{[(L-15.2)(d/D_s)]} + 2.5 \text{ mm} \quad \text{for} \quad L \leq 305 \text{ m}$$

$$t = (s/828)\sqrt{[(L-175)(d/D_s)]} + 2.5 \text{ mm} \quad \text{for} \quad 305 < L \leq 427 \text{ m}$$

s = spacing of transverse frames or longitudinals in mm

L = length of ship as defined in 1.1 in m

d= moulded draught as defined in 1.7 in m

D_s = moulded depth in m as defined in 7.2.1 through 7.3.4

The d/D_s ratio is not to be taken less than 0.65

7.2.6 Sheerstrake: The minimum width of the sheerstrake for the midship 0.4*L* is to be obtained from the following equations.

$b = 5L + 916$ mm for $L < 120$ m

$b = 1525$ mm for $120 \leq L \leq 427$ m

L = length of ship as defined in 1.1 in m

b= width of sheerstrake in mm

In general, the thickness of the sheerstrake is to be not less than the thickness of the side-shell plating, reduced outside 0.4*L* as permitted by 15.3.1a**.** The thickness of the sheerstrake is to be increased 25% in way of breaks of superstructures, but this increase need not exceed 6.5 mm. Where the breaks of the forecastle or poop are appreciably beyond the midship 0.5*L*, this requirement may be modified.

The top of the sheerstrake is to be smooth and free of notches. Fittings and bulwarks are not to be welded to the top of the sheerstrake within 0.8*L* amidships nor in way of superstructure breaks throughout.

7.2.7 Bottom shell plating amidships

a. Extent of bottom plating amidships. The term bottom plating refers to the plating from the keel to the upper turn of the bilge for 0.4*L* amidships.

b. Bottom shell plating. The thickness t of the bottom shell plating for the midship 0.4*L* is to be obtained from the following equations.

1. For ships with transversely-framed bottoms

$t = (s/519\sqrt{[(L-19.8)(d/D_s)]} + 2.5$ mm for $L \leq 183$ m

2. For ships with longitudinally framed bottoms

$t = (s/671)\sqrt{[(L-18.3)(d/D_s)]} + 2.5$ mm for $L \leq 122$ m

$t = (s/508)\sqrt{[(L-62.5)(d/D_s)]} + 2.5$ mm for $122 \leq L \leq 305$ m

$t = (s/661)\sqrt{[(L+105)(d/D_s)]} + 2.5$ mm for $305 < L \leq 427$ m where *L, d* and D_s are as defined in 7.3.13. The d/D_s ratio is not to be taken less than 0.65.

Where the bottom hull-girder section modulus SM_A is greater than required by 5.3.1 and still-water bending moment calculations are submitted, the thickness of the bottom shell may be obtained from the above equations multiplied by the factor, R_n.

Special consideration will be given to ships constructed of higher-strength steel.

Rn = √[1/{Fp/{σt)(1–SMR/SMA)} + 1}] is not to be taken less than 0.85

fp = nominal permissible bending stress in metric tons per centimetre squared as given in 5.2.1 a.

σt = KPt (s/t)² in metric tons per centimetre squared .

K = 0.5 for transverse framing and 0.34 for longitudinal framing.

Pt = (0.638H + d) 1.025 x 10-4 metric tons per centimetre squared.

SMR = hull-girder section modulus required by 5.2.1 in centimetres squared meters.

SMA = bottom hull-girder section modulus, in centimetres squared meters of ship with the greater of the bottom shell plating thickness obtained when applying Rn or Rb.

t= bottom shell plating thickness required by equation 1 or equation 2 in mm.

H = wave parameter as given in 5.2.2 b in m.

s and d are as defined in 7.2.5

SMR/SMA is not to be taken as less than 0.70

c. Plate keels: For plate keels see 3.1

7.2.8 Minimum thickness: After all other requirements are met, the thickness, tmin of shell plating amidships below the upper turn of bilge for ships of unrestricted class and service is not to be less than obtained from the following equation.

a. Transverse Framing

Tmin = s(L + 45.73) / (25L + 6082) mm for $L \leq$ 183 m

s= frame spacing in mm but is not to be taken as less than that given in 8.3

L = length of ship as defined in 1.1 in m

b. Longitudinal Framing

T min = s(L-18.3) / (42L + 1070) mm for $L \leq 427$ m

s= frame spacing in mm but is not to be taken as less than 88% of that given in 7.3 or 813 mm whichever is less

L= length of ship as defined in 1.1 in m

Where the bottom hull-girder section modulus SM_A is greater than required by 5.3.1 and still-water bending moment calculations are submitted, the thickness of bottom shell may be obtained from the above equations multiplied by the factor $R_{b.}$ Special consideration will be given to ships constructed of higher-strength steel.

$R_b = \sqrt{(SM_R / SM_{A)}}$ is not to be taken less than 0.85

Where $SM_{R\ and}$ SM_A are as defined in 7.3.19b.

For transverse framing $R_{b\ is}$ to be taken as not less than (1.2285 - L/533.55) metric units. *L* is as defined above and is not to be taken as less than 122 m

7.3 SHELL PLATING AT ENDS

7.3.1 Minimum shell plating thickness: The minimum shell plating thickness t at ends is to be obtained from the following equations and is not to extend for more than 0.1*L* at the ends. Between the midship 0.4*L* and the end 0.1*L* the thickness of the plating may be gradually tapered.

t= 0.0455 (*L* +3) + 0.009_S mm for *L* < 85 m

t = 0.035 (*L* +29) + 0.009s mm for $85 \leq L \leq 305$ m

t = (11.70 + 0.009s)√(D/35 mm for $305 < L \leq 427$ m

s = fore or aft peak frame spacing in mm

L= length of ship as defined in 1.1 in m

D= moulded depth in m as defined in 1.5

Where the strength deck at the ends is above the freeboard deck, the thickness of the side plating above the freeboard deck may be reduced to the thickness given for forecastle and poop sides at the forward and after ends respectively.

7.3.2 Immersed bow plating: The thickness t of the plating below the load water line for 0.16*L* from the stem is not to be less than is given by the following equation, but need not be greater than the thickness of the side shell plating amidships.

$t = 0.051\ (L + 17) + 0.009_S$ mm for L <85m

$t = 0.05\ (L + 20) + 0.009_S$ mm for $85 \leq L < 305$ m

$t = (16.25 + 0.009_S)\ \sqrt{(D/35)}$ mm for $305 < L \leq 427$ m

s= fore peak frame spacing in mm .

L= length of ship as defined in 1.1 in m

D =moulded depth in m as defined in 1.3.

7.3.3 Bottom forward: Where the heavy weather ballast draught forward is less than 0.04L, the plating on the flat of bottom forward, forward of the location given in Table 6.1 is to be not less than required bythe following equation.

$t = 0.0046s\sqrt{[(0.005L^2 - 1.3\ d^2_f)/d_{f]}}$ mm

s = frame spacing in mm

L = length of ship as defined in 1.1 in m but need not be taken as greater than 214 m

d_f = heavy weather ballast draft at the forward perpendicular in m

= $d_f \times 214/L$ m where $L > 214$ m

The required thickness of the flat of bottom forward plating is also to be in accordance with the requirements given by 7.2.7, 7.3.1 and 7.5.2 as appropriate.

7.3.4 Special Heavy Plates: Special heavy plates of the thickness t given in the following equations are to be introduced at the attachments to the stern frame for heel and boss plates and in way of spectacle bossing. Heavy plates may also be required to provide increased lateral support in the vicinity of the stern tube in ships of fine form and high power. Thick or double plating is to be fitted around hawse pipes, of sufficient breadth to prevent damage from the flukes of stockless anchors.

a. Spectacle bossing

$t = 0.0609\ (L + 5.5) + 0.009s$ mm for $L \leq 85$ m

$t = 0.088 (L – 23) + 0.009s$ mm for $85 < L \leq 427$ m

b. Other plates on stern frame

$t = 0.0685 (L + 10) + 0.009s$ mm for $L \leq 85$ m

$t = 0.094 (L – 16) + 0.009s$ mm for $85 < L \leq 427$ m

t = thickness in mm

L = length of ship as defined in 1.1 in m

s= frame spacing in mm

c. Boss and heel plates. The thickness of the boss and heel plating is to be 20% greater than the thickness of spectacle bossing obtained in 7.3.4.a

7.3.5 Forecastle and poop side plating.

a. Forecastle side plating: The thickness, t, of the plating is to be not less than obtained from the following equations.

$t = 0.05 (L + 76) + (s – S) 0.006$ mm $L < 106.5$ m

$t = 0.035 (L+154) + (s – S) 0.006$ mm $L \geq 106.5$ m

s= spacing of longitudinal or transverse frames in mm

S= standard frame spacing in mm given by the equation in 8.3, with an upper limit of 1070 mm, except that in way of the fore peak, the standard frame spacing is not to exceed 610 mm.

L = length of ship as defined in 1.1 in m but need not be taken more than 305 m

b. Poop side plating: The thickness, t, of the plating is to be not less than obtained from the following equation.

$t = 0.0416 (L + 91.5) + (s – S) 0.006$ mm $L < 91.5$ m

$t = 0.0315 (L+150) + (s – S) 0.006$ mm $L \geq 91.5$ m

s= spacing of longitudinal or transverse frames in mm

S= standard frame spacing in mm given by the equation in 8.3, with an upper limit of 1070 mm, except that in way of the aft peak, the standard frame spacing is not to exceed610 mm

L = length of ship as defined in 1.1 in m

7.3.6 Bow and stern thruster tunnels: The thickness of the tunnel plating is to be not less than required by 7.3.1, where s is to be taken as the standard frame spacing given by the equation in 8.3, nor is the thickness to be less than obtained from the following equation.

$$t = 0.008\, d + 3.3 \text{ mm}$$

d = inside diameter of the tunnel in mm but is to be taken not less than 968 mm

Where the outboard ends of the tunnel are provided with bars or grids, the bars or grids are to be effectively secured.

7.4 CORROSION CONTROL

Where special protective coatings are applied to the external surfaces of the shell above the deepest service waterline as a means of corrosion control (see 2.2.2) (and after all thickness as required by 7.2, 7.3, 7.8 and strength requirements as specified in Chapter 5 have been satisfied), the thickness of the shell plating may be reduced by 10%

7.5 COMPENSATION

Compensation is to be made where necessary for openings in the shell. All openings are to have well-rounded corners. Those for cargo, gangway, fuelling ports, etc, are to be kept well clear of discontinuities in the hull girder. Local provision is to be made to maintain the longitudinal and transverse strength of the hull; where it isproposed to fit portlights in the shell plating, the locations and sizes are to be clearly indicated on the midship- section drawing when first submitted for approval.

7.6 BREAKS

Breaks in ships having partial superstructures are to be specially strengthened to limit the local increases in stresses at these points. The stringer plates and sheerstrakes at the lower level are to be doubled or increased in thickness well beyond the break in both directions. The thickness is to be increased 25% in way o breaks in both directions. The thickness is to be increased 25% in way of breaks of superstructures, but this increase need not exceed 6.5 mm. The side plating of the superstructure is to be increased in thickness, the side plating is to extend well beyond the end of the superstructure in such fashion as to provide a long gradual taper. Where the breaks of the forecastle or poop are appreciably beyond the midship 0.5L, these requirements may be modified. Gangways, large freeing ports and other openings in the shell or bulwarks are to be kept well clear of the breaks, and any holes which must unavoidably be cut in the plating are to be kept as small as possible and are to be circular or oval in form.

7.7 BILGE KEELS

Bilge keels are to be attached to the shell by a doubler. In general, both the bilge keel and the doubler is to be continuous. The connection of the bilge keel to the doubler and the doubler to the shell, are to be by double continuous fillet welds.

Butt welds in the bilge keel and doubler are to be full penetration and are to be kept clear of master erection butts. In general, shell butts are to be flush in way of the doubler; doubler butts are to be flush in way of the bilge keel. In general, scallops and cutouts are not to be used.

The ends of the bilge keel are to be suitably tapered and are to terminate on an internal stiffening member. The material tensile properties for bilge keels, and doublers are to be as required for the bottom shell plating.

7.8 HIGHER–STRENGTH MATERIALS

7.8.1 General: In general, applications of higher –strength materials for shell plating are to take into consideration the suitable extension of the higher-strength material above and below the bottom and deck respectively, as required by 5.8.1 Calculations to show adequate provision against buckling are to be submitted. Care is to be exercised against the adoption of reduced thickness of material that might be subject to damage during normal operation. The thickness of bottom and side-shell plating, where constructed of higher-strength materials are to be not less than required for purposes of longitudinal hull-girder strength; nor are they to be less than required by the foregoing paragraphs of this section when modified as indicated by the following paragraphs.

7.8.2 Bottom plating of higher-strength material: Bottom shell plating where constructed of higher-strength material is to be not less in thickness than obtained from the following equation.

$$t_{hts} = (t_{ms} - C)\,Q + C$$

t_{hts} = thickness of higher-strength material in mm

t_{ms} = thickness in mm of ordinary-strength steel as required by preceding paragraphs of this Chapter. The requirements t_{min} or t given respectively in 7.2.8 and 22.19.1a1 are to be used in the above equation with the factor $0.92/\sqrt{Q}$ for Q. The value of $0.92/\sqrt{Q}$ is not to be taken as less than 1.00.

C = 4.3 mm

Q = as defined in 5.8.3

The thickness of bottom shell plating, where transversely framed, will be specially considered.

7.8.3 Side plating of higher–strength material: Side-shell plating where constructed of higher-strength material is to be not less in thickness than obtained from the following equation.

$$t_{hts} = [t_{ms}-C]\,[(Q+ 2\sqrt{Q})/3] + C$$

t_{hts}, t_{ms}, C and Q are as defined in 7.8.2 for bottom plating.

The thickness of side-shell plating, where transversely framed, will be specially considered.

7.8.4 End plating: End-plating thickness, where constructed of higher-strength materials, will be subject to special consideration.

PART B: INTERNAL MEMBERS / SUBDIVISION

CHAPTER 8: FRAMING

8.1 GENERAL

8.1.1 Basic Considerations: The sizes of frames are to be as shown in Figure 8.1; the equations apply to ships which have well-rounded lines and bulkhead support not less effective than that specified in Chapter 12. Additional stiffness will be required where bulkhead support is less effective or where the areas of flat surface are abnormally large. Frames are not to have less strength than is required for bulkhead stiffeners in the same location. In way of deep tanks they are not to have less strength than is required for stiffeners on deep-tank bulkheads. Framing sections are to have sufficient thickness and depth in relation to the spans between supports.

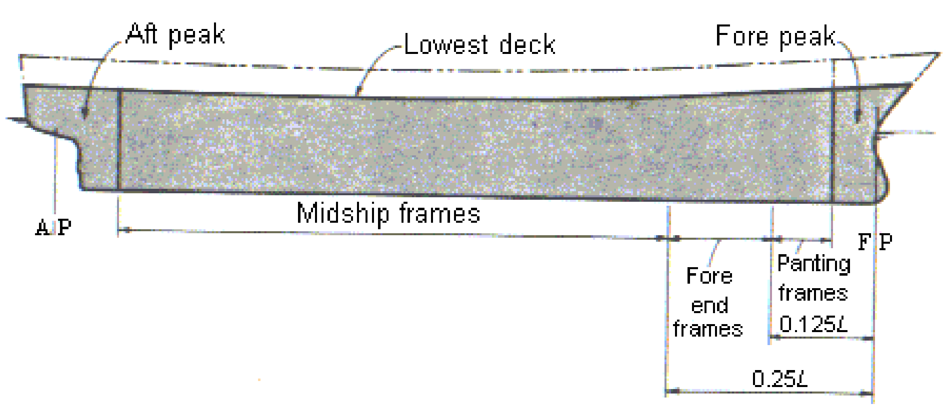


Figure 8.1 Zones of Framing

8.1.2 Holes in Frames: The calculated section modulus for frames is based upon the intact section being used. Where it is proposed to cut holes in the outstanding flanges or large openings in the webs of any frame, the net section is to be used in determining the section modulus for the frame, in association with the plating to which it is attached.

8.1.3 End Connections: At the ends of un-bracketed frames, both the web and the flange are to be welded to the supporting member. At bracketed end connections, continuity of strength it to be maintained at the connection to the bracket and at the connection of the bracket to the supporting member. Welding is to be in accordance with Table 30.1. Where longitudinal frames are not continuous at bulkheads, end connections are to effectively develop their sectional area and resistance to bending. Where a structural member is terminated, structural continuity is to be maintained by suitable back-up structure, fitted in way of the end connection of frames.

8.1.4 Frame Spacing: The standard frame spacing S amidships for ships with transverse framing may be obtained from the following equations. The spacing in the peaks and the distance from the stem to the first frame are not to exceed 610 mm or the standard frame spacing amidships, whichever is less; fore- end spacing is to be increased gradually to midship spacing. In ships of fine form or with straight lines, the requirements for closer spacing are to be suitably extended. The spacing of cant frames is not to exceed the standard frame spacing.

$S = 2.08L + 438$ mm for $L \leq 270$ m

$S = 1000$ mm for $270 < L \leq 427$ m

L = length of ship as defined in 1.1 in m.

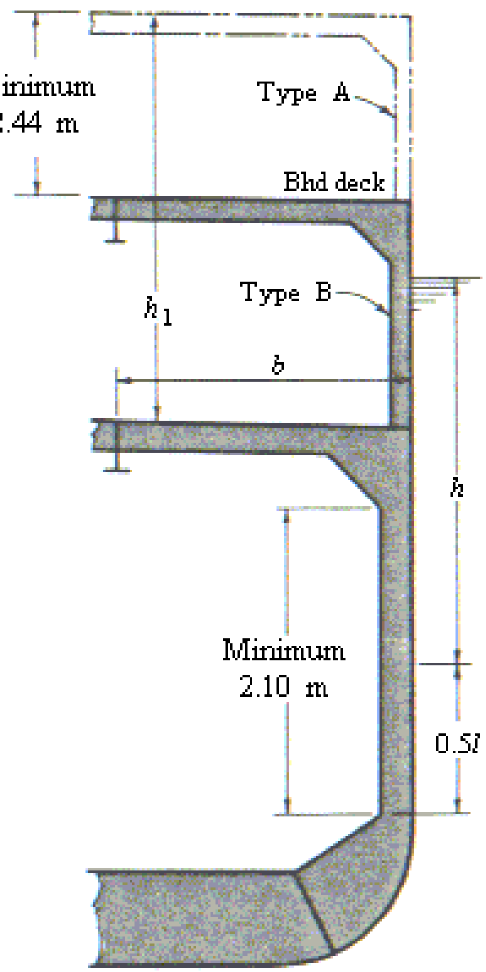


Figure 8.2 Hold Frames

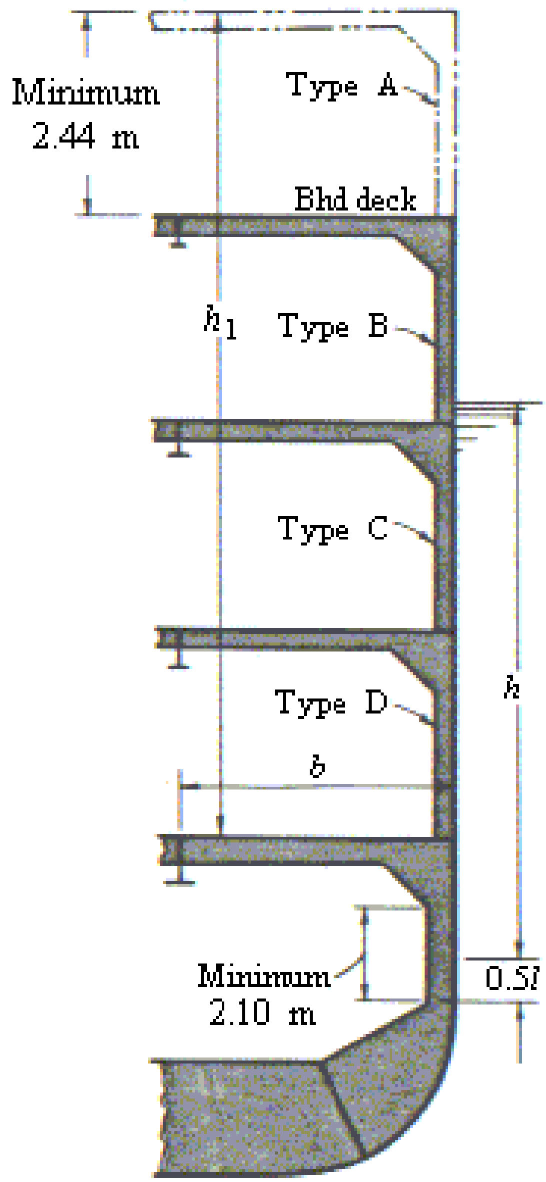


Figure 8.3 Hold Frames

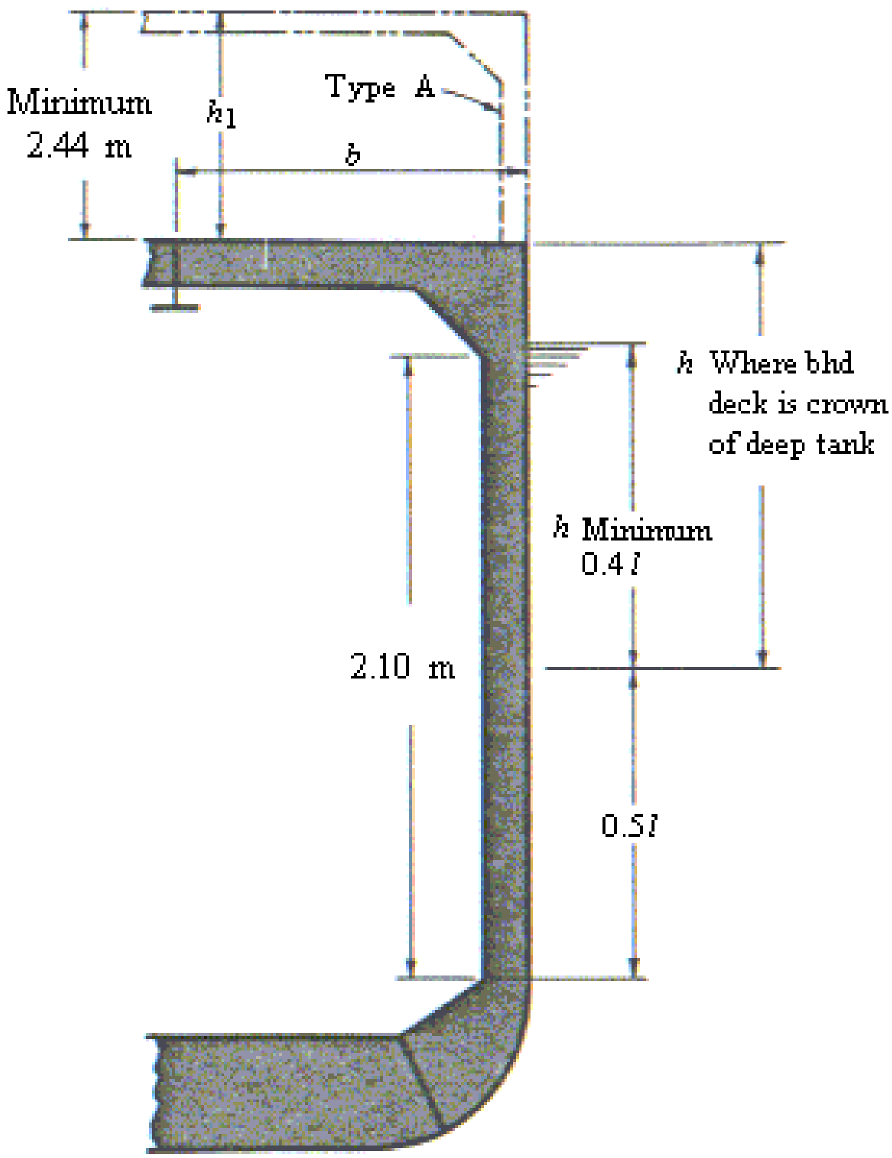


Figure 8.4 Hold Frames

8.2 HOLD FRAMES

8.2.1 Transverse Frames: The section modulus *SM* of each transverse frame amidships and aft below the lowest tier of beams is to be obtained from the following equation where *l* is the span inm as shown in Figures 8.2, 8.3 and 8.4 between the toes of brackets. Where beam knees are fitted on alternate frames, *l* is to be increased by one-half of the depth of the beam knee in m. The value of *l* for use with the equation is not to be less than 2.10 m.

a. Midship Frames

$SM = sl^2 (h + bh_{1/} 33) (7 + 45/l^{3)}$ cm^3

s = frame spacing in m

h = vertical distance in m from the middle of *l* to the load line or 0.4 *l*, whichever is the greater. In way of deep tanks, h is not to be less than the distance from the middle of *l* to the deck forming the top of tank.

b= horizontal distance in m from the outside of the frames to the first row of deck supports.

h_1 = vertical distance in m from the deck at the top of the frame to the bulkhead or freeboard deck plus the height of all cargo "tween-deck spaces and one-half the height of all passenger spaces above the bulkhead or freeboard deck, or plu 2.44 m if that is greater.

b. Deck Longitudinals with Deep Beams: Where the decks are supported by longitudinal beams in association with wide-spaced deep transverse beams, the value of h_1 for the normal frames between the deep beams may be taken as equal to zero; for the frames in way of the deep beams, the value of h_1 is to be multiplied by the number of frame spaces between the deep beams.

c. Sizes Increased for Heavy Load: Where a frame may be subject to special heavy loads, the section modulus is to be suitably increased in proportion to the extra load carried.

***d. Vessels below 91.5 m*.** Where the bulkhead deck is the lowest deck and *L* is less than 91.5 m, the section modulus obtained from 8.2.1 may be (SM) L / 91.5.

8.2.2 Raised Quarter Decks: In way of raised quarterdecks, *l* is to be the corresponding midship span in way of the freeboard deck plus one-half the height of the raised quarterdeck. The other factors are to be that obtained for midship frames in way of the freeboard deck.

8.2.3 Fore-end Frames: Each fore-end frame between the midship one-half and the midship three-quarters length is to have a section modulus obtained from 8.2.1, where *l* is to be the corresponding midship span plus one-half the sheer at 0.125 *L* from the stem; the other factors are to be those obtainedfor midship frames adjusted for spacing if required. Where there is no sheer, no increase in length is required. In deep tanks, the unsupported span of frames is not to exceed 3.66 m.

8.2.4 Panting Frames: Each panting frame between the midship three-quarters length and the forepeak bulkhead in ships which have effective panting arrangements as per subparagraph 8.2.7 is to have a section modulus as obtained from 8.2.1, where *l* is to be the corresponding midship span plus the sheerin m at 0.125*L* from the stem. In ships having normal sheer, the other factors in 8.2.1 are to be the same as those used for midship frames, adjusted for spacing if required. Where there is no sheer, the value of SM in 8.2.1 is to be at least 25% greater than obtained for corresponding midship frames, adjusted forspacing; where the sheer is less than normal, the increase is to be proportionate. Panting frames are to have depths not less than 1/20th of the actual span.

8.2.5 Side Stringers: Where stringers are fitted in accordance with this paragraph, the SM in 8.2.1, 8.2.2 and 8.2.3 above may be reduced 20% where *l* exceeds 2.74 m and the stringers are arranged so that there is not more than 2.10 m of unbroken span at any part of the girth of the hold framing. Stringers areto be at least as deep as the frames and are to have continuous faceplates.

8.2.6 Frames with Web Frames and Side Stringers: Where frames are supported by a system of web frames and side stringers of the sizes and arrangement obtained from Chapter 9, the section modulus is to be determined in accordance with 8.2.1, 8.2.2, and 8.2.3, but the length *l* may be taken as the distancefrom the toe of the bracket to the lowest stringer plus 0.15m; the value of *l* for use with the equations is not to be less than 2.10m.

8.2.7 Panting Webs and Stringers: Abaft the forepeak and forward of the after peak**,** panting arrangements are to be provided as may be required to meet the effects of sheer and flatness of form. Web frames are to be fitted at a gradually increasing spacing aft of the forepeak bulkhead and it is recommended that the first frame abaft the forepeak bulkhead be increased in size. Narrow stringers, similar to those described in 8.2.5, are to be fitted in this area in line with the stringers in the forepeak.At the after end, where owing to the shape of the ship, the frames have longer unsupported spans than the normal midship frames, stringers of increased size may be required.

8.3 FOREPEAK FRAMES

8.3.1 General: Forepeak frames are to be efficiently connected to deep floors of not less thickness than obtained from 6.2.4 for floors in engine space, but the thickness need not exceed 14.0 mm provided the stiffeners are not spaced more than 1.22 m. The floors are to extend as high as necessary to give lateral stiffness to the structure and are to be properly stiffened on their upper edges. Care is to be taken in arranging the framing and floors to assure no wide areas of unsupported plating adjacent to the stem.

Angle ties are to be fitted as required across the tops of the floors and across all tiers of beams or struts to prevent vertical or lateral movement. Breast hooks are to be arranged at regular intervals at and between the stringers above and below the waterline. In general, the frames above the lowest deck are to be as required by 8.4.2, but in ships having large flare or varying sheers on the different decks, stringers and webs above the lowest deck may be required.

8.3.2 Frame Scantlings: The section modulus SM of frames is to be obtained as follows for three different systems of construction:

a. Beams on Alternate Frames: In ships where beams are fitted in tiers on alternate frames, in conjunction with flanged stringer plates of the sizes given in 9.3.2, at intervals of not more than 2.10 m apart, and the distance from the lowest tier to the top of the floor is not more than 1.83 m, the section modulus SM of the peak frames are to be obtained from the following equation:

$SM = 3.7\,sL - 9.0$ cm^3 for $L \leq 427$ m

s = frame spacing in m

L = length of ship as defined in 1.1 in m

b. Beams or Struts on Every Frame: Where beams or struts are fitted on every frame (without stringer plates) in tiers 1.52 m apart, the section modulus SM of the frames is not to be less than obtained from the following equation where l is the length, in m, of the longest actual span of the peak frame from the toe of the lowest deck beam knee to the top of the floor.

$SM = (0.025L - 0.44)\,(7 + 45\square/l^3)\,l^2$ cm^3 for $L \leq 427$ m

L = length of ship as defined in 1.1 in m

c. No Beams or Struts Fitted: Where no beams or struts are fitted, the section modulus of frames is not to be less than that determined by the equation in 8.4.2a nor is the section modulus to be less than twice that obtained from the equation in 8.4.2b in association with a length l as defined in 8.4.2b.

d. Struts and Beams: Struts and beams, where fitted, are generally to be equivalent to channels having an area approximately the same as the forepeak frames.

8.4 AFTER-PEAK FRAMES

8.4.1 General: After-peak frames are to be efficiently connected to deep floors of not less thickness than obtained from 6.2.4 for floors in engine space but need not exceed 14.0 mm provided the floors are suitably stiffened. The floors are to extend as high as necessary to give lateral stiffness to the structure and are to be properly stiffened with flanges. Angle ties are to be fitted across the floors and tiers of beams or struts as required preventing vertical or lateral movement.

8.4.2 Frame Scantlings: The section modulus SM of each frame is to be obtained from the following equation, in association with deep floors or struts arranged so that there are not more than 2.44 m between supports at any part of the girth of the frame.

$SM = 2.79\ sL - 36\ cm^3$ for $L \leq 427$ m

s = frame spacing in m

L = length of ship as defined in 1.1 in m

8.4.3 Ships of High Power: For Ships of high power, a number of plate floors extending to the lowest deck and suitably supported longitudinally, web frames in the 'tween decks or other stiffening arrangements may be required in addition to the requirements of 8.4.1 and 8.4.2.

8.5 TWEEN-DECK FRAMES

8.5.1 General: The size of 'tween-deck framing is dependent on the standard of main framing, arrangement of bulkhead support, requirements of special loading, etc. In the design of the framing, consideration is to be given to the provision of continuity in the transverse framing from the bottom of the top of the hull. The standard is also contingent upon the maintenance of general transverse stiffness by means of efficient partial bulkheads in line with the main hold bulkheads. Care is to be taken that the strength and stiffness of the framing at the ends of the ship are proportioned to the actual unsupported length of the frame. Panting arrangements, comprised of webs and stringers, may be required in way of the forecastle side plating to meet the effects of flare.

8.5.2 Transverse Tween-deck Frames: The section modulus SM of each transverse tween-deck frame is to be obtained from the following equation.

$SM = (7 + 45 / l^3)\ sl^2\ K\ cm^3$

l = tween deck height or unsupported span along the frame length, whichever is

greater in ms = spacing of the frames in m

K = factor appropriate to the length of ship and type of tween decks, A, B, C, or D as shown in Figures 8.2,
8.3 and 8.4

Type A	K = 0.022L – 0.47	for	$L \leq 427$ m
Type B	K = 0.034L – 0.56	for	$L \leq 427$ m
Type C	K = 0.036L – 0.09	for	$L \leq 180$ m
	K = 0.031L + 0.83	for	$180 < L \leq 427$ m1
Type D	K = 0.029L + 1.78	for	$L \leq 427$ m

L = length of ship as defined in 1.1 but need not be taken as greater than 305 m

Tween-deck frames above the bulkhead deck forward of 0.125L from the stem are to be based on type B;below the bulkhead deck they are to be not less than required by the foregoing equations. In general, below the bulkhead deck and forward of the forepeak bulkhead tween-deck frames are also to be notless than required by 8.3.1.

8.5.3 Longitudinal Tween-deck Frames: Longitudinal tween-deck frames are to be in accordance with 8.13. Particular attention is to be given to the buckling strength of the longitudinal tween-deck frames adjacent to the strength deck where scantling reductions are being considered for the use of higher- strength steel.

8.5.4 Longitudinal Frames: The section modulus SM of each longitudinal side frame is to be not less than:

SM = 7.9 $chsl^2$ cm^3

s = spacing of longitudinal frames in mc = 0.95 clear of tanks

c = 1.00 in way of tanks

h = clear of tanks; above 0.5 D from the keel the vertical distance in m from the longitudinal frame to the bulkhead deck, but is not to be taken as less than 2.16 m. At and below 0.5D from the keel, 0.75 times the vertical distance in m from the longitudinal frame to the bulkhead deck but not less than 0.5D.

h = in way of tanks, the vertical distance in m from the longitudinal frame to two-thirds the distance from the top of the tank to the top of the overflow or to the distance given in column (e) of Table 10.1 above the top of the tank if that is greater.

l = the unsupported span in m

The section modulus of longitudinals in way of tanks is also not to be less than that obtained using c =
0.95 and h as required clear of tanks.

The section modulus of each longitudinal frame forward of 0.125L from the stem is to be not less than required by 8.5.2 for transverse frames in the same location, taking l as the unsupported span along the frame length.

8.6 MACHINERY SPACE

Care is to be taken to provide sufficient transverse strength and stiffness in the machinery space by means of webs and heavy pillars in way of deck openings and casings.

CHAPTER 9: WEB FRAMES AND SIDE STRINGERS.

9.1 GENERAL

Web frames and side stringers, Figure 9.1 where fitted in association with transverse frames of the sizes specifiedin 8.2.6, are to be of the sizes as required by this Chapter. It is recommended that the lowest stringer be not more than 2.10m above the top of the floors and that the distance between the stringers be not more than 2.44m. Webs and stringers are not to have less strength than would be required for similar members onwatertight bulkheads and in way of deep tanks they are to be at least as effective as would be required for similarmembers on deep-tank bulkheads.

9.2 WEB FRAMES

9.2.1 Hold Web Frames Amidships and Aft: Each hold web frame amidships and aft is to have a sectionmodulus SM not less than obtained from the following equation.

SM = 4.74 csl^2 (h + bh_1

/45K) cm^3c = 1.5

s = spacing of the web frames in m

l = span in m at amidships measured from the line of the inner bottom (extended to the side of the ship) to the deck at the top of the web frames. Where effective brackets are fitted, the length l may be modified as outlined in 9.2.3

h = vertical distance in m from the middle of l to the load line, but not less than 0.5 l.

h_1 = vertical distance in m from the deck at the head of the web frame to the bulkhead deck plus the height of all cargo tween-deck spaces and one-half the height of all passenger spaces above the bulkheaddeck or plus 2.44m if that be greater.

b = horizontal distance in m from the outside of the frame to the first row of deck supports.

K = 1.0, where the deck is longitudinally framed and a deck transverse is fitted in way of each web frame or

K = number of transverse frame spaces between web frames where the deck is transversely framed.

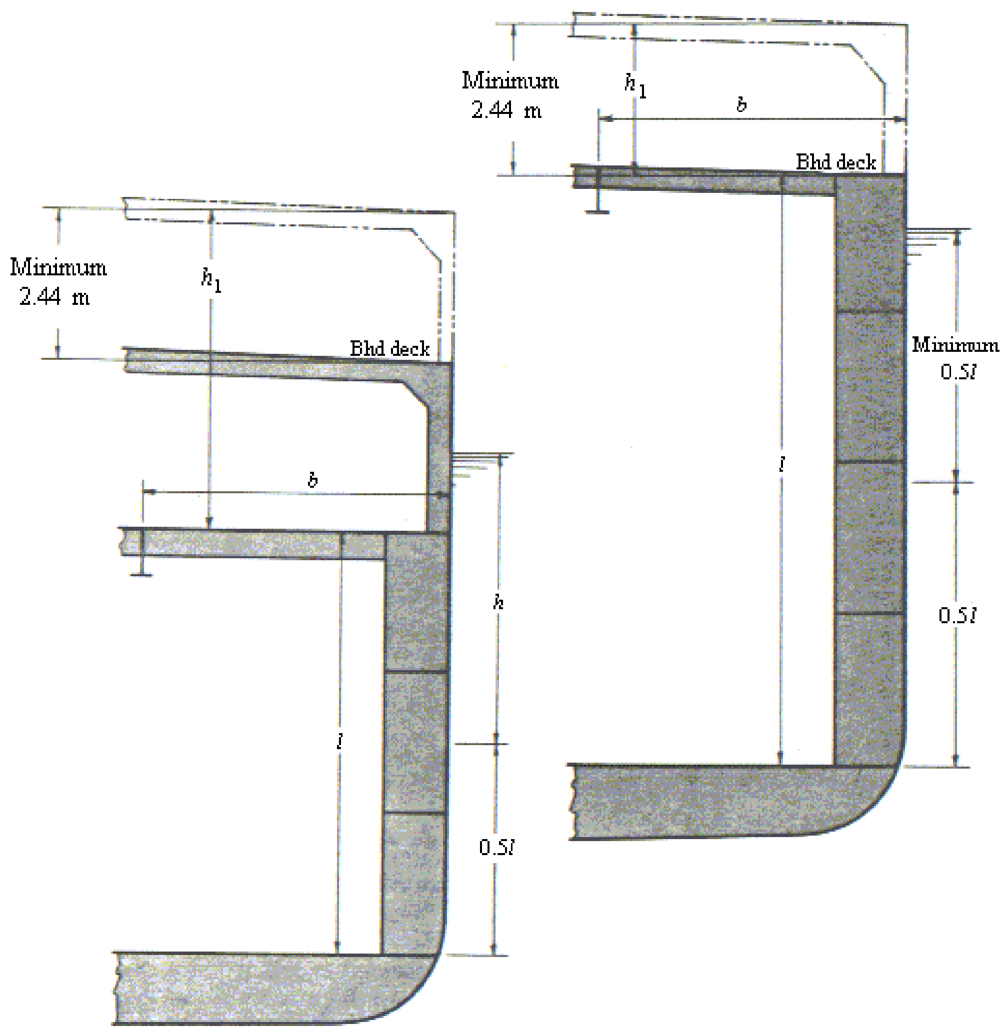


Figure 9.1 Hold Web-frame Arrangements

9.2.2 Hold Web Frames Forward of the Midship One-half Length: Hold web frames forward of the midship one-half length are to be obtained as described in 9.2.1, but the length *l* is to be increased in proportion to the increase in length due to sheer. Where the sheer is not less than normal, the other factors in 9.2.1 are to be the same as used for midship webs. Where there is no sheer, the value of SM forthe webs forward of the midship three-quarters length is to be increased 25%; where the sheer is less than normal, the increase is to be proportionate.

9.2.3 Brackets of Girders and Stringers: Where brackets are fitted having thickness not less than the girder or web plates, the value for *l* as defined in Chapters 9,11,12 and 13 may be modified in accordance with the following:

a. Where the face area on the bracket is not less than one-half that on the girder and the faceplate on thegirder is carried to the bulkhead, the length *l* may be measured to a point 150 mm on to the bracket.

b. Where the face area on the bracket is less than one-half that on the girder and the face plate or flange onthe girder is carried to the bulkhead, *l* may be measured to a point where the area of the bracket and its flange, outside the line of the girder, is equal to the flange area on the girder.

c. Where the faceplate of the girder is carried along the face of the bracket, *l* may be measured to the point of the bracket.

d. Brackets are not to be considered effective beyond the point where the arm on the girder is 1.5 times thelength of the arm on the bulkhead; in no case is the allowance in *l* at either end to exceed one-quarter of the over-all length of the girder.

9.2.4 Proportions: Hold webs are to have a depth of not less than 0.125 *l*; the thickness is not to be less than 1 mm per 100mm of depth plus 3.5 mm, but need not exceed 14 mm. Where the webs are in close proximity to boilers, the thickness of the webs, face bars, etc. are to be increased 1.5 mm above the normal requirements.

9.2.5 Tripping Brackets: Tripping brackets are to be fitted on deep webs as may be required; where the breadth of the flange on either side of the web exceeds 200 mm, the brackets are to be arranged to support the flanges at intervals of about 3m.

9.2.6 End Connections: Effective supporting members on the opposite side of bulkheads, tank tops, etc. should balance end connections of all girders and stringers, and their attachments are to be effectively welded.

9.3 SIDE STRINGERS

9.3.1 Hold Stringers

a. Strength Requirements: Each hold stringer, in association with web frames and transverse frames is tohave a section modulus SM not less than:

SM = 4.74

chsl^2 cm^{3}c=

1.50

h = vertical distance in m from the middle of s to the load line, or 1.8 m, whichever is

greatests = sum of the half lengths in m (on each side of the stringer) of the frames

supported

l = span in m between web frames; where brackets are fitted the length *l* may be modified.

b. **Proportions:** Hold stringers are to have a depth of not less than 0.125 *l* plus one-quarter of the depth of the slot for the frames, but need not exceed the depth of the web frames to which they are attached; in general, the depth if not to be less than 3 times the depth of the slots or the slots are to be fitted with filler plates; the thickness is not to be less than that determined by the equation in 9.3.2a. Where the stringers are in close proximity to boilers, the thickness of the stringer plates, face bars, etc. are to be increased 1.5 mm above the normal requirements.

9.3.2 Peak Stringers

a. Peak Stringer-plate Thickness: The peak stringer-plate thickness is not to be less than obtained fromthe following equation.

$t = 0.014 L + 7.2$ mm for $L \leq 200$ m

$t = 0.007 L + 8.6$ mm for $200 < L \leq 427$ m

t = plate thickness in mm

L = length of ship as defined in 1.1. in m.

b. Peak Stringer-plate Breadth: The peak stringer-plate breadth is not to be less than obtained from thefollowing equation.

b = 8.15L + 6 mm for $L \leq 100$m

b = 2.22L + 600 mm for $100 < L \leq 427$ m

b = breadth of peak stringer-plate in mm

L = length of ship as defined in 1.1 in m

Where beams are not fitted on every frame, the edge of the stringer is to be adequately stiffened by aflange.

9.3.3 Stiffeners and Tripping Brackets: Stiffeners are to extend for the full depth of the stringer on alternate frames and tripping brackets are to be fitted at intervals of about 3 m. Where the breadth of the flange on either side of the stringer exceeds 200 mm, the brackets are to be arranged to support the flange.

9.3.4 End Connections: End connections of side stringers are to be for the full depth of the web plate. Where the stringers are the same depth as the web frame, the standing flanges of the side stringers are to be attached.

9.4 TWEEN-DECK WEBS

Tween-deck webs are to be fitted below the bulkhead deck over the hold webs as may be required to providecontinuity of transverse strength above the main webs in the holds and machinery space.

9.5 BEAMS AT THE HEAD OF WEB FRAMES

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

CHAPTER 10: BEAMS AND CONNECTIONS

10.1 SPACING

Transverse beams are to be fitted on every frame at the freeboard deck in ships which exceed 4.57 m in depth and have no deck below the freeboard deck, also at the strength decks in all ships of 107 m in length and above, in way of all unsheathed decks where the frame spacing exceeds 760 mm and at all tank tops, and bulkhead recesses. Elsewhere they are not to be more than two frame spaces apart and those in different tiers are to be fitted on the same frames.

10.2 BEAMS

Each beam, in association with the plating to which it is attached, is to have a section modulus SM as obtained from.

$SM = 7.9\ chsl^2$ cm

c = 0.540 for half beams, for beams with centreline support only and for beams over tunnels.

c = 0.585 for beams between longitudinal deck girders, for longitudinal beams of platform decks and betweenhatches at all decks.

c = 0.90 for beams at deep-tank tops supported at one or both ends at the shell or on longitudinal

bulkheads.c = 1.000 for beams at deep-tank tops between longitudinal girders.

c = 1 / (1.709 – 0.651 k) for longitudinal beams of strength decks and of effective lower

decks.$k = SM_R Y/I_A$

SM_R = required hull-girder section modulus amidships in 5.2.1 in centimetres squared meters.

Y = distance, in m, from the neutral axis to the deck being considered, always to be taken

positive.I_A = hull-girder moment of inertia of the ship amidships in centimetres squared

meters squared.

The values of I_A and Y are to be those obtained using the area of the longitudinal beams given by the aboveequation.

s = spacing of beams in m

l = distance in m from the inner edge of the beam knee to the nearest line of girder support or between girder supports, whichever is greater. Normally *l* is not to be less than 0.2B. Under the top of deep tanks and in way of bulkhead recesses, the supports are to be arranged to limit the span to not over 4.57 m

h = height in m as follows.

h = is normally to be height measured at the side of the ship, of the cargo space wherever coal or cargo may be carried; h is to be suitably adjusted where cargo is to be suspended from the beams and where the cargo loads are greater or less than normal 715h Kg/m^2

h = Bulkhead recesses and tunnel flats is the height in m to the bulkhead deck at the centreline; where thatheight is less than 6.10 m, the value of h is to be taken as 0.8 times the actual height plus 1.22 m

h = deep-tank tops is not to be less than two-thirds of the distance from the top of the tank to the top of the overflow; it is not to be less than given in column (e) Table 10.1 or two thirds of the height to the bulkhead deck, whichever is greatest. The section modulus is not to be less than would be required for cargo beams.

Elsewhere, the value of h may be taken from the appropriate column of Table 10.1 as follows.

Weather deck and decks covered only by houses:	***COL***
Freeboard decks having no decks below	a
Freeboard decks having decks below	b
Forecastle decks (first above freeboard deck)- See Note 1	b
Bridge decks (first above freeboard deck)	c
Short bridges, not over 0.1L(first above freeboard deck)	d
Poop decks (first above freeboard deck)	d
Long superstructures (first above freeboard deck) forward of midship half-length	b
Long superstructures (first above freeboard deck) abaft midship Half-length forward and forward of midship 3/5 length aft	c
Long superstructures (first above freeboard deck) abaft midship 3/5 Length	d
Superstructure decks (second above freeboard deck)-See note 2	d
Superstructure decks, which contain only accommodation spaces	f

Lower decks and decks within superstructures:	***COL***
Decks below freeboard decks	c
Freeboard decks	c
Superstructure decks	d
Accommodation decks	f
Decks to which side shell plating does not extend, tops of Houses, etc.:	***COL***
First tier above freeboard deck	d
Second tier above freeboard deck- See Note 3	e
Third and higher tiers above freeboard deck- See Note 3	f

Notes

1. See also 16.5
2. Where superstructures above the first superstructure extend forward of the midship half length, the value of h may require to beincreased.
3. Where decks to which the side shell does not extend are generally used only as weather covering, the value of h may be reduced, but in no case is it to be less than in column (g).
4. Buckling strength of the plating and framing of decks is to be considered where they are part of the hull-girder.

Table 10.1 Values of h for Beams

Values of h for an intermediate length of ship are to be obtained by interpolation.

Meters							
L	**a**	**b**	**c**	**d**	**e**	**f**	**g**
61	1.98	1.68	1.22	0.91	0.76	0.61	0.46
70	2.16	1.86	1.31	1.00	0.85	0.70	0.46
80	2.36	2.06	1.41	1.10	0.95	0.80	0.46
90	2.56	2.26	1.51	1.20	1.05	0.90	0.46
100	2.76	2.29	1.69	1.30	1.15	0.91	0.46
110	2.90	2.29	1.90	1.44	1.15	0.91	0.46
120	2.90	2.29	1.98	1.64	1.27	0.91	0.46
122	2.90	2.29	1.98	1.68	1.30	0.91	0.46

10.3 HATCH-END BEAMS

Hatch-end beams, where not supported by pillars at the corners of the hatches, are to be designed in accordance with the requirements of 11.4.

10.4 SPECIAL HEAVY BEAMS

Special heavy beams are to be arranged where the beams may be required to carry special heavy concentrated loads such as at the ends of deckhouses, auxiliary machinery, etc.

10.5 END CONNECTIONS

At the ends of unbracketed longitudinals, or at the ends of unbracketed beams both the web and flange are to be welded to the supporting member. At bracketed end connections, continuity of strength of the beam or longitudinal is to be maintained at the connection to the bracket. Welding is to be in accordance with these regulations.

Deck longitudinals outside the line of openings are to be continuous or, at bulkheads, they are to have end connections that effectively develop their sectional area and resistance to bending.

Where beams or longitudinals are on the boundaries of tanks, structural continuity is to be maintained by suitable back-up structure in way of the end connection or the end connection is to be effectively extended by bracket to an adjacent stiffener.

10.6 CONTAINER LOADING

Where it is intended to carry containers, the exact locations of the container pads and the maximum total static load on the pads are to be indicated on the plans. Where the pads are not in line with the supporting structures, headers are to be provided to transmit the loads to these members.

Each member intended to support containers is to have a section modulus, SM, in cm^3 not less than obtained from the following equation:

$$SM = M/f$$

M = maximum bending moment due to maximum static container loading, in kg-cm

f = permissible maximum bending stress as given in the following table.

In determining the maximum bending moment, members may be considered fixed-ended provided the member is continuous over the adjacent spans or has end connections in accordance with 10.5. Where this is not the case the member is to be considered simply supported. Where weather deck containers are supported by pedestals, the section modulus required by 10.2, with h equal to the distance between the deck and the underside of the container (but not greater than 50% of the value given in Table 10.1), is to be added to the above required section modulus.

10.7 HIGHER-STRENGTH MATERIALS.

10.7.1 General: In general, applications of higher-strength materials for deck beams are to meet the requirements of this Chapter, but may be modified as permitted by the following paragraph. Calculations are to be submitted to show adequate provision against buckling.

Longitudinal members are to be of the same material as the plating they support.

Table 10.2 Values of *f* (Ordinary-strength Steel)

	kg/cm^2
Effective longitudinal members	1262

Transverse members and longitudinal	1420
members inside the line of openings	

The net sectional area of the web of the member in cm^2 including effective brackets where applicable is to be not less than obtained from the following equation.

$A = F / q$

F = shearing force at the point under consideration, in kg

q = allowable average shear stress in the web, not to exceed 1057 kg/cm^2

10.7.2 Beams of Higher-strength Materials: Each beam of higher-strength material, in association with the higher strength plating to which it is attached, is to have a section modulus SM_{hts} not less than obtained from the following equation.

$$SM_{hts} = 7.9\ chs l^2 Q\ cm^3$$

c,h,s and *l* are as defined in 10.2 and Q is as defined in 5.8.3

CHAPTER 11: PILLARS, GIRDERS AND HATCH-END BEAMS

11.1 GENERAL

The requirements of the present Chapter apply to members subjected to compressive axial stresses; deck pillars are to be fitted in line with the upper and lower pillars.

All tiers of beams are to be supported by pillars. Wide-spaced pillars are to be fitted in line with a keelson or intercostal double-bottom girder; the seating under them is to be of ample strength and is to provide effective distribution of the load. Lightening holes are to be omitted in floors and girders directly under wide-spaced hold pillars of large size. Special support is to be arranged at the ends of deckhouses, in machinery spaces under heavy concentrated weights. For forecastle decks see 16.5.

11.2 STANCHIONS AND PILLARS

11.2.1 Permissible Load: The permissible load W_a of a pillar is to be obtained from the following equation. Metric Tons

$W_a = (1.232 - 0.00452\ l / r)\ A$

l = unsupported span of the strut or pillar in cm

r = least radius of gyration in cm

A = area of strut or pillar in cm^2

11.2.2 Length: The length *l* for use in the equation is to be measured from the top of the inner bottom, or other structure on which the pillars are based, to the underside of the beam.

11.2.3 Calculated Load: The calculated load W for a specific pillar is to be obtained from the following equation:

Metric Tons

W = 0.715 bhs

b = mean breadth of the area supported, in m

h = height above the area supported as defined below, in m

s = mean length of the area supported, in m

For pillars spaced not more than two frame spaces the height h is to be taken as the distance from the deck supported to a point 3.80 m above the freeboard deck.

For wide-spaced pillars, the height h is to be taken as the distance from the deck supported to a point 2.44 m above the freeboard deck, except in the case of such pillars immediately below the freeboard deck in which case the value of h is given in Table 10.1, Column a. In measuring the distance from the deck supported to the specified height above the freeboard deck, the height for any tween decksdevoted to passenger or crew accommodation may be given in 10.2 for bridge-deck beams.

The height h for any pillar under the first superstructure above the freeboard deck is not to be less than 2.44m. The height h for any pillar is given in 10.2 for the beams at the top of the pillar plus the sum of the heights given in the same paragraph for the beams of all complete decks and one-half the heights given for all partial superstructures above.

The height h for pillars under bulkhead recesses is not to be less than the distance from the recess to the bulkhead deck at the centreline.

11.2.4 Special Pillars: Special pillars which are not directly in line with those above, but which support the loads from above, are to have the load W for use with the equation proportionate to the actual loads transmitted to the pillars through the system of girders with modifications to the design value of h as described in 11.2.3.

11.2.5 Pillars under the Tops of Deep Tanks: Pillars under the tops of deep tanks are not to be less than required by the foregoing. They are to be of solid sections and to have not less area than 1.015W cm^2, where W is obtained from the following equation.

W = 1.07 bhs metric tons.

b = breadth of the area of the top of the tank supported by the pillar, in m

s = length of the area of the top of the tank supported by the pillar, in m

h = height as required by Chapter 10 for the beams of the top of the tank, in m

11.2.6 Bulkhead Stiffening: Bulkheads which support girders and longitudinal bulkheads which are fitted in lieu of girders, are to be specially stiffened in such manner as to provide supports not less effective than required for stanchions.

11.2.7 Attachments: Wide- spaced tubular are to bear solidly at head and heel and are to be attached by welding, properly proportioned on the size of the pillar. The attachments of stanchions or pillars under bulkhead recesses or deep-tank tops, which may be subjected to tension loads, are to be specially developed to provide sufficient welding to withstand the tension load.

11.3 DECK GIRDERS

Girders of the sizes required by 11.4, 11.5 and 11.6 are to be fitted elsewhere as required to support the beams; in way of bulkhead recesses and the tops of tanks they are to be arranged so that the unsupported spans of the beams do not exceed 4.57m. Additional girders are to be fitted as required under masts or heavy concentrated loads. In way of deck girders or special deep beams the deck plating is to be of sufficient thickness to provide an effective part of the girder.

11.4 GIRDERS AND TRANSVERSES CLEAR OF TANKS

11.4.1 Deck Girders Clear of Tanks: Each deck girder clear of tanks, similar to that shown in Figure 11.1, is to have a section modulus SM as obtained from the following equation

$SM = 4.74\ cbhl^2\ cm^3$

c = 1.0

b = mean breadth of the area of deck supported in m

h = height as required by Chapter 10 for the beams supported, in m

l = span between centres of supporting pillars, or between pillar and bulkhead, in m. Where an effective bracket in accordance with 9.2.3 is fitted at the bulkhead, the length *l* may be modified.

11.4.2 Deck Transverses Clear of Tanks: Each deck transverse supporting a longitudinal deck beam is to have a section modulus SM as obtained from the equations in 11.4.1 where

c= 1.0

b= spacing of deck transverses in m

h= height as required by Chapter 10 for the beams supported, in m

l = span between supporting girders or bulkheads, in m. Where an effective bracket is fitted at the side frame, the length *l* may be modified. See 9.2.3

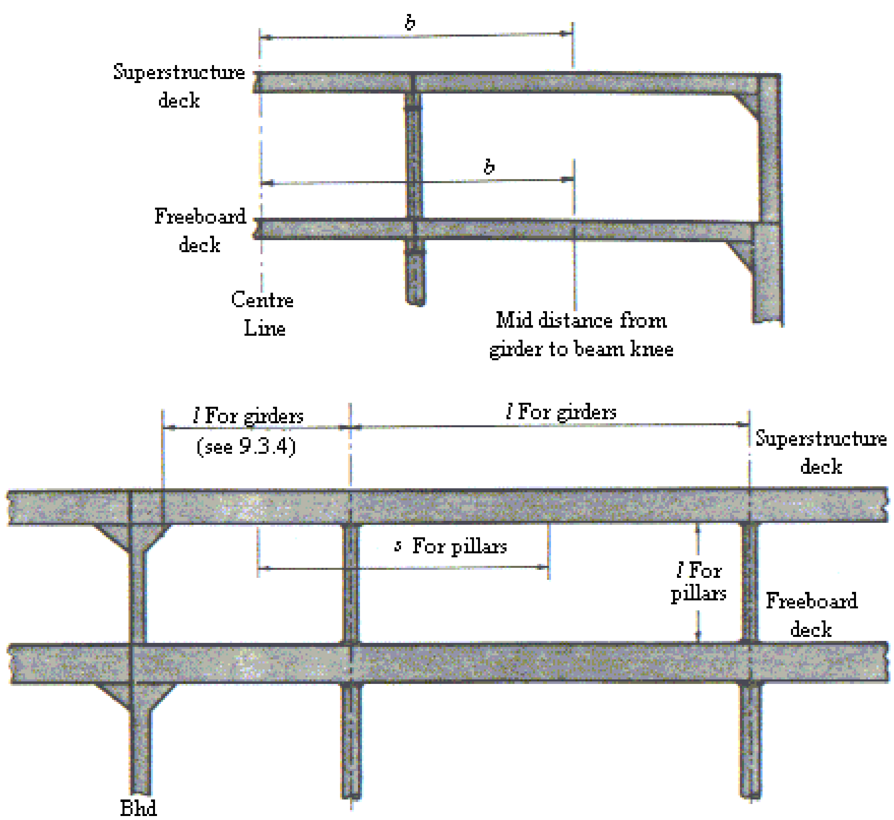


Figure 11.1 Deck Girders and Pillars

11.4.3 Proportions: Girders are to have a depth of not less than 0.0583 *l,* the thickness is not to be less than 1 mm per 100 mm of depth plus 4 mm, but is not to be less than 8.5 mm where the face area is 38 cm^2, 10 mm with 63 cm^2, 12.5 mm with 127 cm^2 and 15 mm with 190 cm^2.

11.4.4 Tripping Brackets: Tripping brackets arranged to support the flanges are to be fitted at every third frame where the breadth of the flanges on either side of the web exceeds 200 mm, at every secondframe where it exceeds 400 mm and at every frame where it exceeds 600 mm.

11.4.5 End Attachments: End attachments of deck girders are to be effectively attached by welding.

11.5 DECK GIRDERS AND TRANSVERSES IN TANKS

Deck girders and transverses in tanks are to be obtained in the same manner as given in 11.4.1 above, except the value of c is to be equal to 1.50 and the minimum depth of the girder is to be 0.0833 *l.* The minimum thickness and the sizes and arrangements of the stiffeners and end connections are to be the same as given in 11.4.3, 11.4.4 and 11.4.5.

11.6 HATCH SIDE GIRDERS

Scantlings for hatch side girders supporting athwart ship shifting beams or supporting hatch covers are to be obtained in the same manner as deck girders (11.4 and 11.5). Such girders along lower deck hatches under trunks in which covers are omitted are to be increased in proportion to the extra load, which may be required to be carried due to the loading up into the trunks. The structure on which the hatch covers are seated is to be effectively supported. Where deep coamings are fitted above decks, the girder below deck may be modified so as to obtain a section modulus in cm^3 (when taken in conjunction with the coaming up to the horizontal coaming stiffener), of not less than 35% more than the required girder value as derived from 11.4.1.

Where hatch side girders are not continuous under deck beyond the hatchways to the bulkheads, brackets extending for at least two frame spaces beyond the ends of the hatchways are to be fitted. Where hatch side girders are continuous beyond the hatchways, care is to be taken in proportioning their scantlings beyond the hatchway. Gusset plates are to be fitted at hatchway corners arranged so as to tie effectively the flanges of the side coamings and extension pieces both beyond and in the hatchway.

11.7 HATCH-END BEAMS

11.7.1 Hatch-end Beam Supports: Each hatch-end beam, similar to that shown in Figure 11.2, which is supported by a centreline pillar without a pillar at the corner of the hatchway, is to have a section modulus SM not less than obtained from:

a. Where Deck Hatch-side Girders are Fitted Fore and Aft Beyond the Hatchways

SM = K (AB + CD) h/ cm^3

b. **Where Girders are not Fitted on the Line of the Hatch Side Beyond the Hatchway**

SM = KABh/ cm^3

A = length of the hatchway, in m

B = distance from the centreline to the midpoint between the hatch side and the line of the toes of the beam knees, in m.

C = distance from a point midway between the centreline and the line of the hatch side to the midpoint between the hatch side and the line of the toes of the beam knees, in m; where no girder is fitted on the centerline beyond the hatchway C is equal to B.

D = distance from the hatch-end beam to the adjacent hold bulkhead, in m

h = height for the beams of the deck under consideration as given in Chapter 10, in m

l = distance from the toe of the beam knee to the centerline plus 0.305 m

K = 2.20 + 1.29 (F/N) when F/N $\leq$ 0.6

K = 4.28 – 2.17 (F/N) when F/N > 0.6

N = one-half the breadth of the ship in way of the hatch-end beam

F = distance from the side of the ship to the hatch side girder.

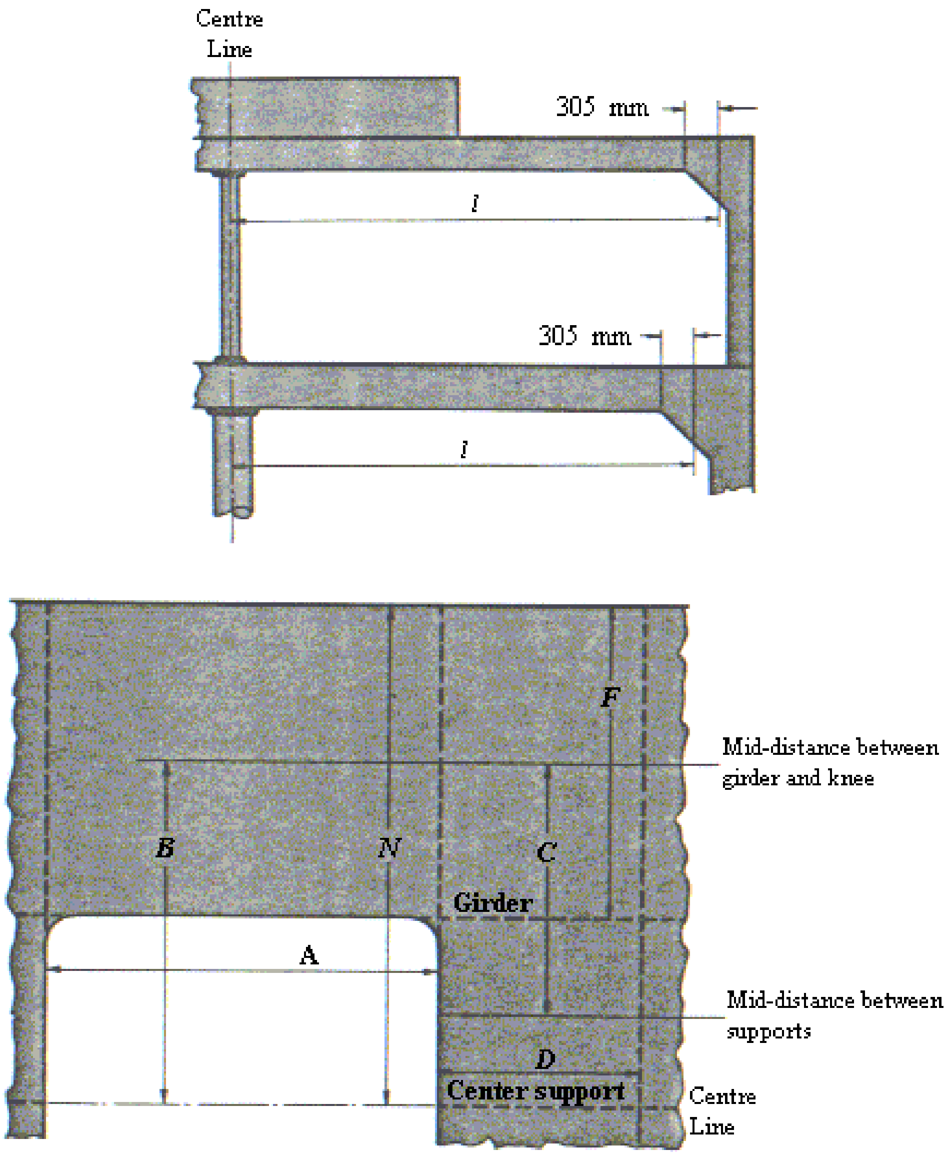


Figure 11.2 Hatch-end Beams

11.7.2 Weather-deck Hatch-end Beams: Weather-deck hatch-end beams which have deep coamings above deck for the width of the hatch may have the flange area reduced from a point well within the line of the hatch side girder to approximately 50% of the required area at the centerline; in such cases it is recommended that athwart ship brackets be fitted above deck at the ends of the hatch-end coaming.

11.7.3 Depth and Thickness: The depth and thickness of hatch-end beams are to be similar to those required for deck girders by 11.4.3.

11.7.4 Tripping Brackets: Tripping brackets arranged to support the flanges are to be located at intervals of about 3 m

11.7.5 Brackets: Brackets at the ends of hatch-end beams are to be as described in 9.2.3. Where brackets are not fitted, the length *l* is to be measured to the side of the ship and the faceplates or flanges on the beams are to be attached to the shell by heavy horizontal brackets extending to the adjacent frame.

11.8 CONTAINER LOADING

Where it is intended to carry containers, the structure is to comply with the requirements of these regulations.

11.9 HIGHER-STRENGTH MATERIALS

11.9.1 General: In general, applications of higher-strength materials for deck girders and deck transverses are to meet the requirements of this Chapter, but may be modified as permitted by the following paragraphs. Calculations are to be submitted to show adequate provision to resist buckling. Longitudinal members are to be of essentially the same material as the plating they support.

11.9.2 Girders and Deck Transverses: Each girder and deck transverse of higher-strength material, in association with the higher-strength plating to which they are attached, are to comply with the requirements of the appropriate preceding paragraphs of this Chapter and is to have a section modulus SM_{hts} not less than obtained from the following equation.

$SM_{hts} = SM\ (Q)$

SM = required section modulus in ordinary-strength material as determined elsewhere in this Chapter

Q = as defined in 5.8.3

CHAPTER 12: BULKHEAD REQUIREMENTS

12.1 GENERAL

All ships are to be provided with strength and watertight bulkheads in accordance with this Chapter. The plans submitted are to show the location and extent of the bulkheads.

All ships are to have a collision bulkhead, an after peak bulkhead and a watertight bulkhead at each end of the machinery space.

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 of web frames, increased framing, etc.

Proposals to dispense with one or more of these bulkheads will be considered, subject to suitable structural compensation.

Where applicable the number and disposition of bulkheads are to be arranged to suit the requirements for subdivision 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.

12.2 STRENGTH BULKHEADS

All ships are to have suitable arrangements to provide effective transverse strength and stiffness of hull. This may be accomplished by fitting transverse bulkheads extending to the strength deck. In Ships of special type, equivalent transverse strength may be obtained by fitting substantial partial bulkheads, deep webs, or combinations of these, so as to maintain effective transverse continuity of structure.

12.3 ARRANGEMENT OF WATERTIGHT BULKHEADS

12.3.1 Collision Bulkheads:

a. General: A collision bulkhead is to be fitted on all ships. It is to be without openings except as permitted. It is to extend in one plane, to the freeboard deck except in passenger ships where it is to extend to the bulkhead deck. In the case of ships having long superstructures at the fore end, it is to be extended weather tight to the superstructure deck. The extension need not be fitted directly over the bulkhead below, provided it be not less than the minima given in **b** or **c** abaft the forward perpendicular, and the part of the deck which forms the step is made weather tight.

b. Location in Passenger Ships: In passenger ships the collision bulkhead is to be located not less than $0.05L_{LL}$ nor more than $0.05L_{LL}$ plus 3.05 m, abaft the forward perpendicular at any point.

***c.* Location in All Other Ships:** In cargo ships the collision bulkhead may be located in accordance with 1 or 2 below.

1. In ships less than 200 m in length, L_{LL}, the collision bulkhead is to be not less than $0.05L_{LL}$, abaft the forward perpendicular at any point. Ships 200 m in length, L_{LL}, and above are to have a collision bulkhead located not less than 10 m abaft the forward perpendicular at any point. At no point on any ships, except as permitted in 2 below, is it to be further than $0.08L_{LL}$ from the forward perpendicular.

2. In the case of ships having bulbous bow the required distances given in 1 may be measured from a reference point located a distance forward of the forward perpendicular. This distance x is the lesser of half the distance between the forward perpendicular and the extreme forward end of the extension, p/2 (or $0.015L_{LL}$ for ships not exceeding 200 m in length and L_{LL}, and 3 m for ships of greater lengths). See Figure 12.1

L_{LL} = 96% of the total waterline length of ship on the waterline at 85% of least moulded depth, or, if greater, the length, on the same waterline, from the fore side of the stem to the centreline of the rudderstock.

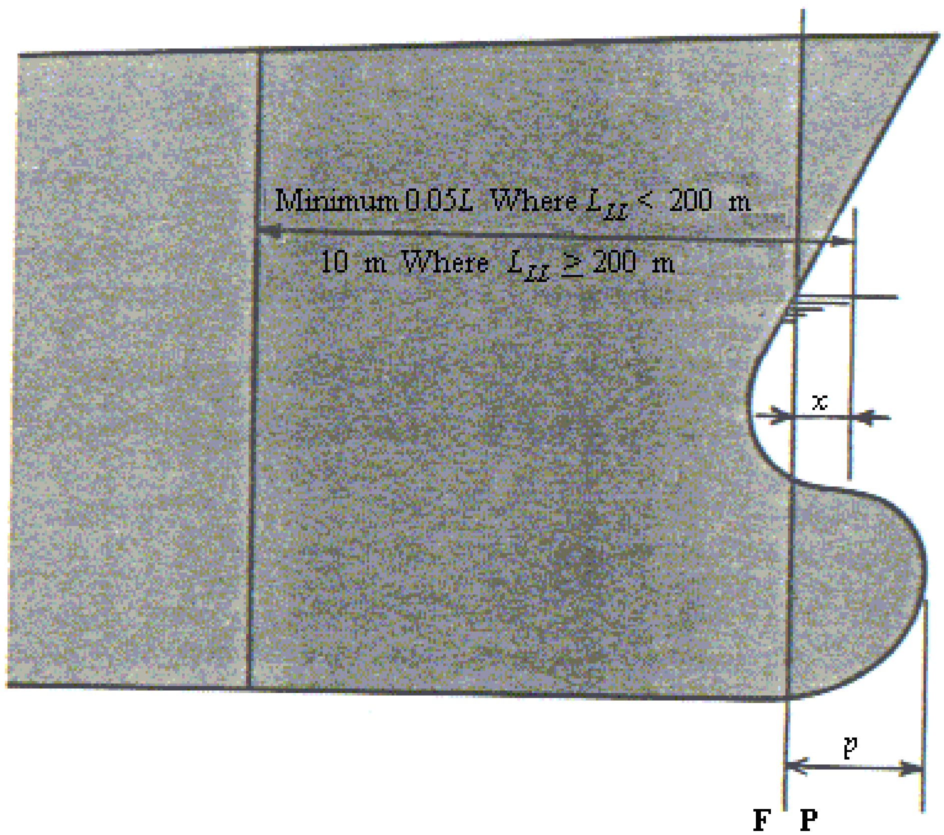


Figure 12.1 Collision Bulkhead Location With Bulbous Bow

12.3.2 After-peak Bulkheads: All ships are to have an after peak bulkhead generally enclosing the stern tube and rudder trunk in a watertight compartment. In twin-screw ships where the bossing ends forward of the after peak bulkhead, the stern tubes are to be enclosed in suitable watertight spaces inside or aft of the shaft tunnels. In passenger ships the stern tubes are to be enclosed in watertight spaces of moderate volume. The sterns gland is to be situated in a watertight shaft tunnel and of such volume that, if flooded 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).

12.3.3 Machinery Compartments: Machinery compartments are to be enclosed by watertight bulkheads, which extend to the freeboard deck. In those cases where the length of the machinery spaceis unusually large in association with a small freeboard, the attention of designers is called to the desirability of extending the bulkheads to a deck above the freeboard deck, or the inclusion of a watertight deck over the machinery space which might confine the amount of flooding in the event of damage in way of the machinery compartment.

12.3.4 Hold Bulkheads:

a. General: In addition to the foregoing required watertight bulkheads, the following arrangement of intermediate watertight bulkheads is recommended to provide a reasonable standard of subdivision for cargo ships. Where the bulkheads are spaced to provide protection against flooding, modified arrangements will be considered. It is recognized, however, that for certain types of cargo ships in special services it may be impracticable to adhere to the number and arrangement of hold bulkheads as recommended. In such cases, the Bureau is prepared to consider an alternative arrangement in order to meet the requirements of special trades.

b. Bulkhead Arrangements: In ships of 87 m length and above a watertight bulkhead, extending to the freeboard deck, is to be fitted between the forepeak bulkhead and the forward bulkhead of an amidships-machinery space. Two such bulkheads are to be fitted between the forepeak bulkhead and the forward bulkhead of an after-machinery space. These bulkheads are to be arranged to divide the hold into approximately equal lengths, but the forward bulkhead in each case is not to be more than 0.2L abaft the stem.

Ships of 102 m length and above are to have, in addition to the foregoing, a watertight bulkhead extending to the freeboard deck between the after-peak bulkhead and the after bulkhead of an amidships-machinery space; this bulkhead is to be about 0.2L to 0.25L forward of the after perpendicular.Where the machinery is aft, three watertight bulkheads are to be fitted between the forepeak bulkhead and the forward bulkhead of the machinery space.

Where the freeboard is less than 0.15d in ships of 102 m length and below or less than 0.2d in shipsabove 102 m length and above, the bulkheads are to extend to the superstructure deck.

Ships of 198 m length and above are to have, in addition to the foregoing, a second watertight bulkhead extending to the freeboard deck between the forepeak bulkhead and the forward bulkhead of a midship-machinery compartment. Where the machinery is aft, four watertight bulkheads are to be fitted between the forepeak bulkhead and the forward bulkhead of the machinery space. In each case the bulkheads are to be arranged to divide the holds into approximately equal lengths, but the first bulkhead abaft the forepeak is not to be more than 0.2*L* from the stem.

In ships having comparatively small sheer, the arrangement of the bulkheads is to be adjusted to provide no less effective subdivision than the above.

c. Carriage of Water Ballast in Cargo Holds: Where a cargo hold is intended to be used for the carriage of water ballast, the hold is to be completely filled and the scantlings of the inner bottom, side structure, hatch covers, etc. are to be in accordance with Chapter 13. The hatch cover and securing devices are to be suitable for the internal loading. See 17.5

Special consideration may be given to the scantlings of cargo holds partially filled with water ballast and full particulars are to be submitted.

12.3.5 Chain lockers: Chain lockers located abaft the collision bulkhead or those, which extend into a forepeak deep tank, are to be made watertight. The arrangements are to be such that accidental flooding of the chain locker cannot result in damage to auxiliaries necessary for the proper operation of the ship.

12.4 CONSTRUCTION OF WATERTIGHT BULKHEADS

12.4.1 Plating: Plating is to be of the thickness obtained from the following equations.

a. For h≤ 18m

$t = s\,[(h + 6.1)/1830] + 3.05$ mm

b. For h > 18m

$t = s\,[(h + 21.5)/3000] + 3.05$ mm

t =thickness in mm

h =distance from the lower edge of the plate to the bulkhead deck at centre, in m

s = spacing of stiffeners in mm

c. Collision and After peak Bulkheads: The plating of collision bulkheads is to be obtained from the above equations using a spacing of 152 mm greater than that actually adopted. The plating of after peak bulkheads below the lowest flat is not to be less than required for solid floors in the after-peak space. (See Chapter 8)

d. Cargo Hold Bulkheads: The lowest strake of plating is to be increased 1 mm in each case and it is to extend at least 915 mm above the top of the hold ceiling.

12.4.2 Stiffeners: Each stiffener, in association with the plating to which it is attached, is to have a section modulus SM not less than obtained from the following equation:

SM = 7.9 chsl^2 cm^3

c = 0.30 for stiffeners having efficient bracket attachments of both ends of their spans

c = 0.43 for stiffeners having efficient brackets at one end and supported by clip connections at the other end

c = 0.56 for stiffeners having clip connections at both ends and for stiffeners in the uppermost tween decks having no end attachments

c = 0.60 for stiffeners having no end attachments

s = spacing of the stiffeners in m

h = distance in m from the middle of *l* to the bulkhead deck at centre; where that distance is less than 6.10 m, h is to be taken as 0.8 times the distance in m plus 1.22

l = distance between the heels of the end attachments; where horizontal girders are fitted, *l* is the distance from the heel of the end attachment to the first girder, in m.

The value of SM for stiffeners on collision bulkheads is to be at least 25% greater than required above for stiffeners on watertight bulkheads. An effective bracket for the application of these values of c is to have the scantlings shown in Table 12.1 and is to extend onto the stiffener for a distance equal to one-eighth of the length *l* of the stiffener.

12.4.3 Corrugated Bulkheads:

a. Plating: The plating of corrugated bulkheads is to be of the thickness required by 12.4.1 with the following modification. The spacing to be used is the greater of dimensions a or c as indicated in Figure 12.2 where the angle ø is approximately 45 degrees or more. Where the angle ø is appreciably less than 45 degrees, the spacing to be used is to be the greater of the following:

$a + b/2$ or $c + a/2$

b. Stiffeners: The section modulus SM for a corrugated bulkhead is to be obtained from the following equation

SM = 7.9chsl^2 cm^3

l = distance between supporting members, in m

s = value determined using a + b (Figure 12.2)

c = 0.56

h =as defined in this chapter

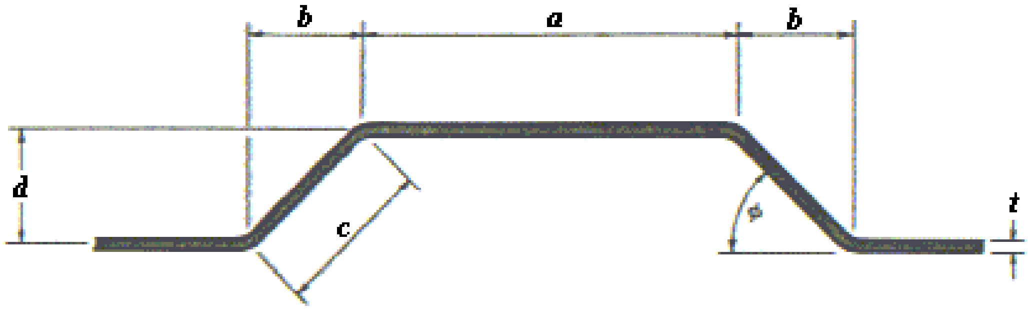


Figure 12.2 Corrugated Bulkhead

Table 12.1 Thickness and Flanges of Brackets and Knees

The thickness of brackets is to be suitably increased in cases where the depth at throat is less than two-thirds that of the knee.

Millimetres			
Thickness			
Depth of Longer Arm	Plain	Flange	Width of Flange
150	6.5		
175	7		
200	7	6.5	30
225	7.5	6.5	30
250	8	6.5	30

Millimetres			
Thickness			
Depth of Longer Arm	Plain	Flange	Width of Flange
275	8	7	35
300	8.5	7	35
325	9	7	40
350	9	7.5	40
375	9.5	7.5	45
400	10	7.5	45
425	10	8	45
450	10.5	8	50
475	11	8	50
500	11	8.5	85
525	11.5	8.5	55
550	12	8.5	55
600	12.5	9	60
650	13	9.5	65
700	14	9.5	70
750	14.5	10	75
800	10.5	80	
850	10.5	85	

Millimetres			
Thickness			
Depth of Longer Arm	Plain	Flange	Width of Flange
900	11	90	
950	11.5	90	
1000	11.5	95	
1050	12	100	
1100	12.5	105	
1150	12.5	110	
1200	13	110	

The developed section modulus SM may be obtained from the following equation, where a, t and d are asindicated in Figure 12.2

$SM = td^2 / 6 + (adt/2)$

Special consideration will be given where the angle ø is less than 40 degrees.

12.4.4 Girders and Webs:

a. Strength Requirements: Each girder and web, which supports bulkhead stiffeners are to have section modulus SM not less than obtained from the following equation where *l* is the span in m measured between the heels of the end attachments. Where brackets are fitted, the length *l* may be modified as indicated in 9.2.3.

$SM = 4.74\ chsl^2\ cm^3$

c = 1.0

h = vertical distance in m to the bulkhead deck at centre from the middle of s in the case of girders, and from the middle of *l* in the case of webs; where that distance is less than 6.10 m, the value of h is to be 0.8 times the distance in m plus 1.22

s = sum of half lengths (on each side of girder or web) of the stiffeners supported, in m.

The section modulus SM of each girder and web on the collision bulkheads is to be at least 25% greater than required for similar supporting members on watertight bulkheads.

b. Proportions: Girders and webs are to have depths not less than 0.0832*l* plus one-quarter of the depth of the slots for the stiffeners; the thickness is not to be less than 1mm per 100 mm of depth plus 3 mm but need not exceed 11.5 mm

c. Tripping Brackets: Tripping brackets are to be fitted at intervals of about 3 m and where the width of the face flange exceeds 200 mm on either side of the girder or web, these are to be arranged to support the flange.

12.4.5 Attachments: Lower brackets to inner bottoms are to extend over the floor adjacent to the bulkhead. Where stiffeners cross horizontal girders, they are to be effectively attached. Floor adjacent to the bulkhead. Where stiffeners cross horizontal girders, they are to be effectively attached.

12.5 DOORS

12.5.1 All access openings in end bulkheads of closed superstructures are to be fitted with doors.

The height of sills of the access openings is to be 380 mm. If a bridge or a poop cannot be considered as enclosed according paragraph 10(b), Regulation 3 of the International Convention on Load Lines, 1966, the height of sills of access openings is to be at least 600 mm in position 1 and 380 mm in position 2.

The sill height is to be measured from the upper surface of deck steel plating under the door opening.

Stresses in the door structural members caused by this pressure are not to exceed 0.8 times the yield stress of the material used.

When steel doors are stamping made the minimum thickness of their plating may be reduced by 1 mm. The minimum thickness of doors made of other materials will be specially considered in each particular case.

Doors are to be permanently attached to the bulkhead and fitted with quick acting means for their opening and closing operated from both sides.

The door closing appliances and exit ports are to be operable from both sides. Doors are to open as follows:

a. Doors of accommodation and service spaces leading to corridor – are to open inwards;

b. Doors of public spaces-outwards or to either side;

c. Outer doors in the end bulkheads of superstructures and in external transverse bulkheads of deckhouses – outwards in the direction of the nearest shipside;

d. Outer doors in the external longitudinal bulkheads of deckhouses -outwards in the forward direction.

In ships of 31 m in length and less, doors, specified in **a**, located at the end of a blind corridor are to open outwards (to the corridor).

In particular cases, the doors, mentioned in **c** and **d**, may be open inwards.

Sliding doors are not to be fitted at emergency exits and on escape routes.

Doors of accommodation spaces are to be provided in their lower part with detachable panels 0.4m x 0.5m in size, which may be easily knocked out. Panels in the doors of passenger cabins are to be provided with inscriptions: “Means of escape-knock out in case of emergency”.

Detachable panels need not be fitted where the spaces are provided with opening type side scuttles of at least 400 mm in inner diameter the smaller side of which is at least 400 mm, and on condition that persons are able to get to the corridor through the side scuttles.

Doors are to be weather tight when closed. The tightness is to be ensured by gaskets made of rubber or other suitable material.

The doors are to be of steel of other approved material.

12.6 SLUICE VALVES.

No valve for sluicing purposes is to be fitted on a collision bulkhead. They may be fitted only on other bulkheads under conditions where they are at all times accessible for examination; the control rods are to be workable from the bulkhead deck, and are to be provided with an index to show whether the valve is open or shut. The control rods are to be properly protected from injury and their weight is not to be supported by the valve.

CHAPTER 13: DEEP TANKS

13.1 GENERAL

Tanks for fresh water or fuel oil, which are not intended to be kept entirely filled in service, are to have divisions to minimize the dynamic stress on the structure. Longitudinal tight divisions, which are fitted for reasons of stability, in tanks which are to be entirely filled or empty in service, may be of the scantlings required for watertight bulkheads by Chapter 12; in such cases the tanks are to be provided with feed tanks, fitted with inspection plugs in order to ensure that they are kept full when in service. Tight divisions in all other cases, and the boundary bulkheads of all deep tanks in peaks or holds are to be constructed in accordance with the requirements of this Chapter. The arrangement of all deep tanks, together with their intended service and the height of the overflow pipes, are to be clearly indicated on the plans. Tanks forward of the collision bulkhead are not to be arranged for the carriage of oil or other liquid substances that are flammable.

13.2 CONSTRUCTION OF DEEP-TANK BULKHEADS

13.2.1 Plating: Plating is to be of the thickness obtained from the following equation.

$t = (s \sqrt{h} + 254) + 2.54$ mm

t = thickness in mm

s = stiffener spacing in mm

h = the greatest of the following distances, in m, from the lower edge of the plate to:

A point located above the top of the tank not less than given in column (e) of Table 10.1 appropriate to the ship's length or

A point representing the load line or

A point located at two-thirds of the distance to the bulkhead deck.

13.2.2 Stiffeners: Each stiffener is to have section modulus SM not less than obtained from the following equation.

$SM = 7.9\ chsl^2$ cm^3

c = 0.594 for stiffeners having efficient bracket attachments at both ends.

c = 0.747 for stiffeners having efficient bracket attachment at one end and supported by clip connections at the other end.

c = 0.900 for stiffeners having clip attachments to decks at both ends

c = 1.00 for stiffeners supported at both ends by horizontal girders.

s = spacing of the stiffeners in m

h = greatest of the following distances, in m from the middle of *l* to:

A point located above the top of the tank a distance not less than given in column (e) of Table 10.1, appropriate to the ship's length or

The load line or

A point located at two-thirds of the distance from the middle of *l* to the bulkhead deck.

l = distance in m between the heels of the end attachments; where horizontal girders are fitted, *l* is the distance from the heel of the end attachment to the first girder.

An effective bracket for the application of these values of c is to have the scantlings shown in Table 12.1 and is to extend onto the stiffener for a distance equal to one-eighth of the length *l* of the stiffener.

13.2.3 Corrugated Bulkheads: Where corrugated bulkheads are used as deep-tank boundaries, the scantlings may be developed from 12.4.3. The plating thickness t and values of h are to be as required by 13.2.1 and 13.2.2 respectively and c= 0.90.

13.2.4 Girders and Webs:

a. Strength Requirements: Each girder and web which support frames in deep tanks is to have section modulus SM as required by Chapters 9 and 11, whichever is the greater; those which support bulkhead stiffeners are to be as required by this paragraph. The section modulus SM is to be not less than obtained from the following equation.

$SM = 4.74chsl^2$ cm^3

c = 1.50

h = vertical distance in m from the middle of s in the case of girders and from the middle of *l* in the case of webs to the same heights to which h for the stiffeners is measured (see 13.2.2)

s = sum of half lengths (on each side of girder) of the frames or stiffeners supported, in m

l = span measured between the heels of the end of the attachments, in m. Where effective brackets are fitted, *l* may be modified as indicated in 9.2.3.

Where efficient struts are fitted across tanks connecting girders on each side of the tanks and spaced not over four times the depth of the girder, the value for the section modulus SM for each girder may be one-half that given above.

b. Proportions: Girders -except deck girders (see 11.5)- and webs are to have depths not less than 0.145*l* where no struts or ties are fitted, and 0.0833*l* where struts are fitted, plus one-quarter of the depth of the slots for the frames or stiffeners. In general, the depth is not to be less than 3 times the depth of the slots; the thickness is not to be less than 1 mm per 100 mm of depth plus 3 mm but need not exceed 11.5mm.

c. Tripping Brackets: Tripping brackets are to be fitted at intervals of about 3m and where the width of the face flange exceeds 200 mm on either side of the girder, these are to be arranged to support the flange.

13.3 TANK-TOP PLATING

Tops of tanks are to have plating 1 mm thicker than would be required for vertical plating at the same level; the thickness is not to be less than required for deck plating. Beams, and pillars are to be as required by Chapters 10 and 11.

13.4 HIGHER-STRENGTH MATERIALS

13.4.1 General: In general, applications of higher-strength materials for deep-tank plating are to meet the requirements of this Chapter, but may be modified as permitted by the following paragraphs. Calculations are to be submitted to show adequate provision to resist buckling.

13.4.2 Plating: Deep-tank plating of higher-strength material is to be of not less thickness than obtained from the following equation.

$t_{hts} = [t_{ms} – C] [(Q + 2 \sqrt{Q}) /3] + C$

t_{hts} = thickness of higher-strength material in mm

t_{ms} = thickness in mm of ordinary-strength steel, as required by preceding paragraphs of this

ChapterC = 3 mm

Q = as defined in 5.8.3

13.4.3 Stiffeners: Each stiffener of higher–strength material, in association with the higher-strength plating to which it is attached, is to have section modulus SM_{hts} not less than obtained from the following equation.

$SM_{hts} = 7.9\ chsl^2\ Q$ cm3

c,h,s, and *l* are as defined in 13.2.2 and Q is as defined in 5.8.3

13.5 DRAINAGE AND AIR ESCAPE

Limber and air holes are to be cut in all parts of the structure as required to ensure the free flow to the suction pipes and the escape of air to the vents. Efficient arrangements are to be made for draining the tops of deep tanks.

CHAPTER 14: CENTRAL DIVISION IN CARGO HOLDS.

14.1 GENERAL

14.1.1 Application: Where non-watertight central bulkheads are fitted in cargo holds and arranged to support the beams, they are to be in accordance with the requirements of this Chapter.

14.1.2 No Pillars Fitted at Hatchways Corners: Where pillars are not fitted at the corners of the hatchways and the centerline bulkheads support deep hatch-end beams, special sections are to be introduced under the beams, or the plating of the bulkheads is to be increased and additional stiffening provided to obtain supports not less effective than would be obtained with pillars of the sizes required by11.2.3.

14.2 SCANTLINGS

14.2.1 Plating: Plating is to have a thickness of not less than 6 mm where the spacing of the stiffeners does not exceed 760 mm and is to be increased at the rate of 0.5 mm for each additional 150 mm of spacing.

14.2.2 Stiffeners: The required load value W for each stiffener is to be obtained from the followingequation.

W = 0.715 bhs metric tons

b = 0.5*B* where no continuous side girders are fitted and 0.4*B* where continuous side girders are fitted.

B = breadth of ship as defined in 1.3, in m

h = height from the deck supported, in 3.81m above the freeboard deck, or the sum of the heights given in 10.2 for the decks supported.

s = spacing of the stiffeners in m.

The stiffener value W_s for the section selected is to be at least equal to the required load value W and isto be obtained from the following equation for rolled sections.

$W_s = (1.44 – 0.727\ l/r)$ A metric tons

l = distance in m from the heel connection to the underside of the deck beam

r = radius of gyration of the stiffener in cm taken about an axis parallel to the plane of the

bulkheadA = sectional area of the stiffener in cm^2

CHAPTER 15: DECKS

15.1 GENERAL

15.1.1 Application: The requirements of the present Chapter apply to deck and platform structures.

It is recommended that the weather portions of all strength decks be plated for at least the midship 0.4*L*; in ships of 76 m length and above this recommendation becomes a requirement. In ships of 91.5 m length and above, forecastle decks and strength decks for at least the midship 0.75*L* are to be plated, andin ships of 122m length and above at least one deck is to be completely plated. In all ships, portions of decks forming the crowns of machinery spaces, tops of tanks and steps in bulkheads are to be plated.

Weather portions of superstructure decks over accommodation, except relatively short deckhouse tops, are to be plated within the midship 0.4L in ships of 107 m length and above. In all other cases decks may be either completely plated or formed of stringers and tie plates having sufficient breadth and thickness to satisfy the requirements of 15.2. Where decks are completely plated for only a part of the length, the plating is to be gradually tapered to the stringer plates.

15.1.2 Frames: Frames are not to extend through the stringer plates of weather decks, tanks or watertight flats, unless watertight steel chocks are fitted. Where frames pass through other tight decks below the weather deck, welded chocks are to be fitted. Freeboard decks within open superstructures, and bulkhead decks in passenger ships are to be made tight in similar fashion.

15.1.3 Bulkhead deck: The bulkhead deck is to be not lower than the deck to which watertight bulkheads extend and are made effective, as required by 12.3.

15.2 HULL-GIRDER STRENGTH

15.2.1 Longitudinal Section Modulus Amidships: The required longitudinal hull-girder section modulus at amidships is obtained from the equations given in 6.2.

15.2.2 Strength Decks: For the definition of the strength deck for calculations see 6.3.1.

15.2.3 Longitudinally Framed Decks: Where the beams of the strength deck and other decks are fitted longitudinally in accordance with Chapter 10, the sectional area of effectively developed deck longitudinals may be included in the hull-girder section-modulus calculation.

15.2.4 Superstructure Decks: Superstructure decks, which are comparatively short strength deck, are to comply with the requirements.

15.2.5 Deck Transitions: Where the effective areas in the same deck change, e.g. partial superstructures,discontinuous decks, etc, care is to be taken to extend the heavier plating well into the section of the shipin which the lesser requirements apply. Partial decks within the hull are to be tapered off to the shell by means of long brackets. Where effective decks change in level, the change is to be accomplished by a gradually sloping section, in such manner as will compensate for the discontinuity of the structure. Atthe ends of partial superstructures the arrangements are to be as described in 7.6.

15.2.6 Deck Plating: Deck plating is to be of not less thickness than is required for purposes of longitudinal hull-girder strength. The thickness of the stringer plate is to be increased 25% in way of breaks of superstructures, but this increase need not exceed 6.5 mm. This requirement may be modified for set-in bridges and where the breaks of poop or forecastle are appreciably beyond the midship 0.5L. The required deck area is to be maintained throughout the midship 0.4L of the ship and is to be suitably extended into superstructures located at the midship 0.4L. From these locations to the ends of the ship, the deck area contributing to the hull-girder strength may be gradually reduced in accordance with 5.3.2.

Where bending moment envelope curves are used to determine the required hull girder section modulus the foregoing requirements for deck area may be modified in accordance with 5.3.2. Where so modified the strength deck area is to be maintained a suitable distance from superstructure breaks and is to be extended into the superstructure to provide adequate structural continuity. The thickness of the deck plating is also not to be less than given in 15.3.1 a.

15.3 STEEL-PLATED DECKS

15.3.1. Strength Deck Plating:

a. Plating Thickness Outside Line of Openings: The strength deck plating is to be of the thickness necessary to obtain the required hull-girder section modulus; and the thickness outside the line of the openings, is not to be less than obtained from the equations in 1 or 2, except within steel deckhouses where the plating may be 1 mm less. The requirements of equations 1b and 2b are to extend over 0.4*L* amidships, beyond which they may be gradually reduced in the manner permitted for strength deck area in 5.3.2. The extent of the requirement of 1b and 2b will be specially considered where bending moment envelope curves are used to determine the required hull-girder section modulus.

The requirements of 1a and 2a are to extend over the 0.8*L* amidships, beyond which the deck plating is tobe respectively not less than required for exposed forecastle and poop deck plating. In ships under 91.5m in length, where the depth is not less than *L*/12, the thickness of plating may be obtained from the equations in 2. In small ships where the required area is relatively small, it may be disposed in the stringer and alongside openings in plating of not less thickness than obtained from the equations in 1 or2; in such cases the remainder of the plating may be obtained from the equation in 5.

1. Thickness of Strength Decks with Transverse Beams in Ships Over 91.5 m up to 183 m in Length is to be not less than a or b below

a. $t = 0.01 s_b + 2.3$ mm for $s_b \le 760$ mm

$t = 0.0066 s_b + 4.9$ mm for $s_b > 760$ mm

b. $t = \frac{s_b (L + 45.73)}{25L + 6082}$ mm

2. Thickness of Strength Decks with Longitudinal Beams and of Forecastle Decks in Ships Over 122 m inLength is to be not less than a or b below. Thickness of Strength Decks with Transverse Beams in Ships 91.5 m or less is to be not less than 2a or 1b.

a. $t = 0.009 s_b + 2.4$ mm for $s_b \le 760$ mm

$t = 0.006 s_b + 4.7$ mm for $s_b > 760$ mm

b. $t = \frac{s_b (L + 48.76)}{26L + 8681}$ for $L \le 183$ m

$t = \frac{24.38 s_b}{1615.4 - 1.1 L}$ mm for $183 < L \le 427$ m

3. Thickness of Exposed Strength Decks within Line of Openings, Forecastle Decks in Ships of 122 m inLength or Less, exposed Poop Decks in Ships Over 100 m in Length

$t = 0.01\, s_b + 0.9$ mm for $s_b \leq 760$ mm

$t = 0.0067 s_b + 3.4$ mm for $s_b > 760$ mm

4. Thicknesses of Exposed Bridge Decks

$t = 0.01\, s_b + 0.25$ mm for $s_b \leq 760$ mm

$t = 0.0043\, s_b + 4.6$ mm for $s_b > 760$ mm

*5. Thickness of Exposed Poop Decks in Ships of 100m in Length or Less, Long Deckhouse Sides and Topsand Platform Decks in Enclosed Cargo Spaces. **

$t = 0.009\, s_b + 0.8$ mm for $s_b \leq 685$ mm

$t = 0.0039\, s_b + 4.3$ mm for $s_b > 685$ mm

**Where the tween deck height at side differs from 2.60 m, the thickness of plating in cargo spaces is to be not less than that indicated in equation 5 increased or reduced respectively at a rate of 0.83 mm for each m of greater or lesser tween deck height.*

Where the design cargo pressures are specified and differ from 715h Kg/m^2 the thickness is to be increased or reduced by 0.83 (p/715 - 2.6) mm; where p is the design cargo pressure in kg/m^2 and h is the tween deck height at side in m.

6. Thickness of Platform Decks in Enclosed Passenger Spaces

$t = 0.006\, s_b + 1.5$ mm for $s_b \leq 760$ mm

$t = 0.0055 s_b + 1.9$ mm for $s_b > 760$ mm

L = length of the ship as defined in 1.1 in ms_b = spacing of deck beams in mm

b. ***Plating within Line of Openings:*** Within the line of openings the thickness of exposed plating is to be not less than obtained from the equation in 3, amidships; at the forward and after ends it is to be as required for exposed forecastle and poop-deck plating. Within steel deckhouses, the plating may be of the thickness obtained from the equation in 5.

15.3.2 Effective Lower Decks: For use as an effective lower deck in calculating the hull-girder section modulus, the thickness of the plating is to be not less than obtained from 15.3.1, appropriate to thedepth $D_{s,}$ according to Table 15.1. In no case is plating to be less than obtained from the equation in
15.3.1 a5 or 15.3.1 a6. Stringer plates of effective decks are to be connected to the shell.

15.3.3 Reinforcement at Openings:

a. At Hatchways: At the corners of hatchways, generous radii are to be provided.

b. In Way of Machinery Space: In way of the machinery spaces, special attention is to be paid to the maintenance of lateral stiffness by means of through beams and plating and the provision of thoroughly effective deck support.

15.3.4 Platform Decks: Lower decks, which are not considered to be effective decks for longitudinal strength, are termed platform decks. The plating is not to be of less thickness than obtained from the equation in 15.3.1 a5 or 15.3.1 a6.

15.3.5 Superstructure Decks: See 16.1.2

15.3.6 Decks over Tanks: For decks over tanks see 13.3.

Table 15.1 Thickness Equation Location

Effective	**Ds**	**Minimum Thickness**
Lower Deck	Meters	Equation in
	Under 12.8	3
Second Deck	12.8 to 15.2	02:00 a.m.

	Over 15.2	01:00 a.m.
Third Deck	Under 9.8	4
	9.8 to 13.4	3
	13.4 to 17.7	02:00 a.m.
	Over 17.7	01:00 a.m.

15.3.7 Watertight Flats: Watertight flats over tunnels or steps in bulkheads are to be of not less thickness than required for the plating of ordinary bulkheads at the same level plus 1 mm.

15.3.8 Retractable Tween Decks: The thickness of the deck plating is to be not less than required by 15.3.1 a5 without correction for tween deck height. Where the uniform loading, p, exceeds 1859 kg/m^2 the thickness is to be increased 0.83 mm for each 715 kg/m^2 excess loading and may be reduced at the same rate for lesser loading. The edges of the deck panels are to be stiffened to provide the necessary rigidity.

The beams and girders in association with the plating to which they are attached are to have sectionmodulus, SM, not less than obtained from:

$SM = 7.9\ chsl^2\ cm^3$

c = 0.81 for the section modulus to the

flange or face barc = 1.00 for the section

modulus to the deck plating

h = p/715 m

p = uniform loading in kg/m^2

s = spacing of the beam of girder in m

l = unsupported length of the beam or girder in m

In general, the depth of the beam and girder is to be not less than 4% of the unsupported length.

When the retractable deck is intended for the operation or stowage of vehicles having rubber tires, the thickness of the deck plating is to be not less than required by 17.6.4. The retractable decks are to be secured against movement and effectively supported by the hull structure.

15.3.9 Wheel Loading: Where provision is to be made for the operation or stowage of vehicles having rubber tires, and after all other requirements are met, the thickness of an effective lower deck plating is to be not less than:

$t = 25.2\ Kn\ \sqrt{(CW)}$ mm

K = as given in Figure 15.1

n = 1.0 where *l*/s $\geq$2.0 and 0.85 where *l*/s = 1.0, for intermediate values of *l/s,* n is to be obtained by interpolation

C = 1.5 for wheel loads of vehicles stowed at sea and 1.1 for vehicles operating in Port.

W = static wheel load in metric tons

a = the wheel imprint dimension, in mm, parallel to the longer edge, *l*, of the plate panel, and in general the lesser wheel imprint dimension.

b = the wheel imprint dimension, in mm perpendicular to the longer edge, *l*, of the plate panel, and in general the lesser wheel imprint dimension.

s = the spacing of deck beams or deck longitudinals in mm

l = the length of the plate panel in mm

For wheel loading, the strength deck plating thickness is to be not less than 10% greater than required by the above equation, and platform deck plating thickness is to be not less than 90% of that required by theabove equation.

Where the wheels are close together special consideration will be given to the use of a combined imprint and load. Where the intended operation is such that only the larger dimension of the wheel imprint is perpendicular to the longer edge of the plate panel, b, above may be taken as the larger wheel imprint dimension, in which case, a, is to be the lesser one.

15.3.10 Corrosion Control: Where special protective coatings are to be applied to the exterior surfaces of weather decks as a means of corrosion control (see 2.2.2), after all minimum thickness and longitudinal hull-girder requirements have been satisfied, the thickness of the deck plating, including the stringer plate, may be reduced by 10% but not more than 3.5 mm. In no case is the thickness of exposed superstructure decks to be less than 6.5 mm, except where permitted by equations in 3, 4 or 5 in 15.3.1a.

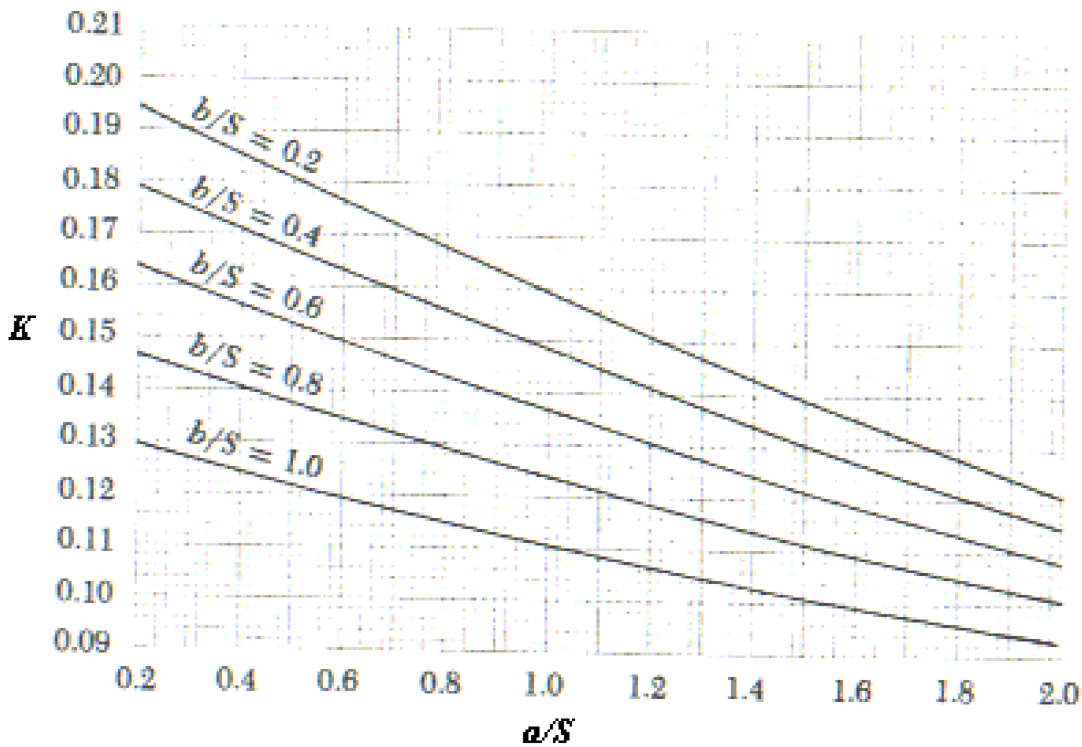


Figure 15.1 Wheel Loading Curves of "K"

15.4 DECKS OF HIGHER-STRENGTH MATERIAL

15.4.1 Thickness: In general, proposed applications of higher-strength material for decks are to be accompanied by submission of calculations in support of adequate strength against buckling. Care is to be exercised to avoid the adoption of reduced thickness of material such as might be subject to damage during normal operation. The thickness of deck plating, etc. where constructed of higher-strengthmaterial is to be not less than required for longitudinal strength, nor is it to be less than:

$t_{hts} = (t_{ms} – C)Q + C$

t_{hts} = thickness of higher-strength material

in mmt_{ms} = thickness of ordinary-strength

steel in mm C = 4.3 mm for exposed deck

plating

Q = is as defined in 5.8.3

The thickness t_{hts} is also to be determined from the above equation using the t_{ms} as obtained from 15.3.1a, equation 2b, or with a factor of 0.92/√Q in lieu of Q. The factor 0.92/√Q is not to be less than 1.00.

Where the deck plating is transversely framed, the thickness of the higher-strength material will bespecially considered, taking into consideration the size of the ship and the foregoing requirements.

15.4.2 Wheel Loading: Where decks are constructed of higher strength material and provision is made for the operation of vehicles having rubber tires, the thickness of plating is to be not less than obtained from:

$t_{hts} = t_{ms} \sqrt{(24/Y)}$ mm

t_{hts} = thickness of higher-strength material in mm

t_{ms} = thickness of ordinary-strength steel as obtained from

15.3.9.Y = as defined in 5.8.3

15.5 DECK COMPOSITIONS

Deck compositions are to be of material, which is not destructive to steel, or they are to be effectively insulated from the steel by a non-corrosive protective covering. The Surveyor may take samples from the composition while it is being laid, in which case the samples are to be subject to independent analysis at the manufacturer's expense. The steel plating is to be thoroughly cleaned with alkaline solution before the composition is laid.

Large areas of deck are to be divided by cabin sills, angles, etc., and unless otherwise approved, holdfasts are to be fitted no more than 915 mm apart. Deck coverings within accommodation spaces on the decks forming the crown of machinery and cargo spaces are to be of a type, which will not ignite readily.

CHAPTER 16: SUPERSTRUCTURES

16.1 SCANTLINGS

16.1.1 General: Side plating of superstructures within the midship 0.4*L* of the ship is to be obtained from7.2.

The requirements of the present Chapter apply to superstructure end bulkheads and deckhouse sidesand ends.

16.1.2 Decks of Superstructures: Decks of superstructures whose lengths are over 0.1*L* are to be considered as strength decks and are to comply with the requirements of 15.3. Where 0.1*L* or less in length, the stringer plate may be the thickness of the side plating and the remainder of the deck plating outboard of openings is to be adjusted to provide an effective area approximately 50% of that of the deckbelow in way of the superstructure. The thickness of the plating at the forward and aft ends is to be obtained from 15.3.1 for forecastle and poop deck plating.

16.1.3 Frames: Frames are to be of the sizes obtained from 8.5. Web frames are to be fitted over main bulkheads and elsewhere as may be required to give effective transverse rigidity to the structure.

16.1.4 Breaks in Continuity: Breaks in the continuity of superstructures are to be specially strengthened (see 7.6). The arrangements in this area are to be clearly shown on the plans submitted for approval.

16.2 EXPOSED BULKHEADS OF SUPERSTRUCTURES AND DECKHOUSES

16.2.1. General: The scantlings of the exposed bulkheads of superstructures are to be in accordance with the following paragraphs, except that the requirements for house side stiffeners need not exceed the requirements of Chapter 8 for the side frames directly below the deck on which the house is located. In general, the lowest tier is that on the freeboard deck.

Special consideration may be given to the bulkhead scantlings of deckhouses, which do not protect openings in the freeboard deck, or in the top of a lowest tier deckhouse.

Superstructures or deckhouses whose lengths are greater than 0.1*L* and which are located within the midship 0.4*L* are to have effective longitudinal scantlings to give a hull-girder section modulus through the superstructure or deckhouse equal to that of the main hull-girder. The superstructure scantlings are to be in accordance with 16.1 and the housetop and side plating of long deckhouses is to be not less than obtained from equation 5 in 15.3.1a.

Partial bulkheads, deep webs, etc., are to be fitted at the ends and sides of large superstructures or deckhouses to provide resistance to racking.

16.2.2 Stiffeners: Each stiffener is to have section modulus SM not less than:

$SM = 3.5 s l^2 h$ cm^3

s = spacing of stiffeners in m

l = tween deck height in m

h = a [(bf)- y]c, the design head in m. For unprotected front bulkheads on the lowest tier, h is to be taken as not less than 2.5+*L*/100m in which *L* need not be taken as greater than 250m. For all other bulkheads the minimum value of h is to be not less than one-half the minimum required for unprotected front bulkheads on the lowest tier.

a = coefficient given in Table 16.1

b = 1.0 + [(x/*L*)-0.45]/(C_b+0.2)^2 where x/*L* $\le$ 0.45

b = 1.0 + 1.5 [(x/L)–0.45]/(C_b+0.2)^2 where x/*L* > 0.45

C_b = block coefficient at summer load waterline, based on the ship's length *L* as defined in 1.1, not to be taken as less than 0.60 nor greater than 0.80. For aft end bulkheads forward of amidships, C_b need not be taken as less than 0.80

x = distance in m between the after perpendicular and the bulkhead being considered. Deckhouse side bulkheads are to be divided into equal parts of exceeding 0.15*L* in length and x is to be measured from the after perpendicular to the centre of each part considered.

Table 16.1 VALUES OF *a*

Bulkhead Location	***Metric Units***
Unprotected front, lowest tier	$2.0 + L_2/120$
Unprotected front, 2nd tier	$1.0 + L_2/120$
Unprotected front, 3rd tier	$0.5 + L_2/150$
Protected front, all tiers	$0.5 + L_2/150$
Sides, all tiers	$0.5 + L_2/150$
Aft ends, aft of amidships, all tiers	$0.7 + (L_2/1000) - 0.8x/L$
Aft ends, forward of amidships, all tiers	$0.5 + (L_2/1000) - 0.4x/L$

L, L_2 = length of ship in m, but L_2 need not be taken as greater than 300 m

f = coefficient given in Table 16.2

y = vertical distance in m from the summer load waterline to the midpoint of the stiffener span

c = $(0.3 + 0.7b_1/B_1)$ but is not to be taken as less than 1.0 for exposed machinery casing bulkheads. In no case is b_1/B_1 to be taken as less than 0.25

b_1 = breadth of deckhouse at the position being considered

B_1 = actual breadth of the ship at the freeboard deck at the position being considered.

16.2.3 Plating: The plating is to be not less in thickness than obtained from the following equation.

$t = 3s\sqrt{h}$ mm

S and h are as defined in these regulations; when determining h, y is to be measured to the middle of the plate.

In no case is the thickness for the lowest tier bulkheads to be less than 5.0 + L_2/100 mm for other tier bulkheads the thickness is to be not less than 4.0 + L_2/100 mm or 5.0 mm, where L_2 is defined in these regulations.

16.2.4 End Attachments: Both ends of the webs of lowest tier bulkhead stiffeners are to be effectively attached. The scantlings of stiffeners having other types of end connection are to be specially considered.

16.2.5 Raised-quarter-deck Bulkheads: Raised-quarter-deck bulkheads are to have plating of not less thickness than required for bridge-front bulkheads. The sizes of stiffeners are to be specially considered on the basis of the length of the ship and the arrangement of the structure.

16.2.6 Corrosion Control: Where special protective coatings are to be applied to exterior surfaces of exposed bulkheads as a means of corrosion control (see 2.2.2), the thickness of the plating may be reduced by 10%. In no case, however, is the reduction to be applied to bulkheads of which the required thickness is less than 7.5 mm.

16.3 ENCLOSED SUPERSTRUCTURES

16.3.1 Openings in Bulkheads: All openings in the bulkheads of enclosed superstructures are to be provided with efficient means of closing, so that in any sea conditions water will not penetrate the ship. Opening and closing appliances are to be framed and stiffened so that the whole structure is equivalent to the un-pierced bulkhead when closed.

16.3.2 Doors for Access Openings: Doors for access openings into enclosed superstructures are to be of steel permanently attached to the bulkhead. The doors are to be provided with gaskets and clamping devices, permanently attached to the bulkhead and the doors are to be so arranged that they can be operated from both sides of the bulkhead.

16.3.3 Sills of Access Openings: Except as otherwise provided in these Principles, the height of the sills of access openings in bulkheads at the ends of enclosed superstructures is to be at least 380 mm above the deck.

16.3.4 Port lights: Port lights in the end bulkheads of enclosed superstructures are to be of substantial construction and provided with efficient inside deadlights.

16.3.5 Bridges and Poops: A bridge or poop is not to be regarded as enclosed unless access is provided for the crew to reach machinery and other working spaces inside these superstructures by alternate means which are available at all times when bulkhead openings are closed.

16.4 OPEN SUPERSTRUCTURES

Superstructures with openings, which do not fully comply with 16.5, are to be considered as open superstructures.

16.5 STRENGTHENING AT ENDS AND SIDES OF ERECTIONS

16.5.1 Web frames are to be fitted within poops and bridges that have large deckhouses. Web frames are also to be arranged to support the sides and ends of large deckhouses.

16.5.2 These web frames should be spaced about 9 m apart and are to be arranged, in line withwatertight bulkheads below. Webs are also to be arranged in way of large openings and other points of high loading. 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 are to be fitted below and above doors. Housetops 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.

16.5.3 Adequate support under the ends of erections is to be provided in the form of webs 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 doublers should generally be fitted.

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 sheer strake. This plating is to be efficiently stiffened at the upper edge and supported by web plates not more than 1.5m from the end bulkhead. Proposals for alternative arrangements, including the use of higher tensile steel, will be individually considered.

Table 16.2 VALUES OF *f*

Intermediate values of *f* may be obtained by interpolation.

METRIC UNITS	
L, m	*f*
60	4.07
80	5.41
100	6.61
120	7.68
140	8.65
160	9.39
180	9.88
200	10.27
220	10.57
240	10.78
260	10.93
280	11.01
300 and greater	11.03

Note: The above table is based on the following equations.

Metric Units

L	***f***
$L \leq 150$ m	$(L/10)(e^{-L/300}) - [1 - (L/150)^2]$
$150 < L < 300$m	$(L/10)e^{-L/300})$
$L \geq 300$ m	11.03

CHAPTER 17: DECK OPENINGS

17.1 GENERAL

The width of openings of single cargo hatches is not to exceed 0.7 of the ship's breadth in way of the opening. Where the opening breadth is greater and in the case of double and triple hatches, the deck structure will be specially considered with particular attention paid to the hatch corners.

Openings in decks other than hatch openings are to comply with the following requirements:

- As far as possible, openings in the strength deck within $-0.3L \leq x \leq 0.3\,L$ and in ships with large hatchopenings in way of cargo holds are to be arranged between the hatches,
- Openings in strength deck between the ship's side and line of hatch openings are to be well clear of thehatch corners and side,
- Openings in the remaining areas and decks are to be sufficiently clear of the corners of hatch openingsand areas where increased stresses may occur.

17.2 POSITION OF DECK OPENINGS

For the purpose of the Principles, two positions of deck openings are defined as follows:

Position 1 Upon exposed freeboard and raised quarterdecks situated forward of a point located a quarter of the ship's length from the forward perpendicular.

Position 2 Upon exposed superstructure decks situated abaft a quarter of the ship's length from the forward
perpendicular.

17.3 HATCHWAY COAMINGS

17.3.1 Height of Coamings: The height of coamings of hatchways secured weather tight by tarpaulinsand battening devices is to be at least as follows.

600 mm if in Position 1

450 mm if in Position 2

Where hatch covers are made of steel and made tight by means of gaskets and clamping devices, theseheights may be reduced, provided that the safety of the ship is not thereby impaired in any sea condition.

17.3.2 Coaming Plates: Coaming plates are not to be less than 10 mm thick in ships of 61 m length and 11 mm thick in ships of 76 m length and above; the thickness at intermediate lengths are obtained by interpolation.

17.3.3 Coaming Stiffening: Horizontal stiffeners are to be fitted on coamings in Position 1; they are to be not more than 254 mm below the upper edge of the coaming; the breadth of the stiffeners is not to be less than 150 mm in ships 61 m in length, nor less than 175 mm in ships 76 m in length and above; the minimum breadths for ships of intermediate lengths are to be obtained by interpolation. Efficient brackets are to be fitted from the stiffeners to the deck at intervals of not more than 3 m. All exposed coamings other than Position 1, which are 760 mm or more in height, are to be similarly supported. Where the height of any exposed coaming exceeds 915 mm, the arrangement of the stiffeners and brackets is to be such as to provide equivalent support. Where end coamings are protected, the arrangement of the stiffeners and brackets may be modified.

17.3.4 Protection of Coamings: Heavy convex mouldings are to be fitted at the upper edges of all exposed coamings, and the lower edges are to be flanged.

17.3.5 Continuous Longitudinal Hatch Coamings: Where longitudinal bulkheads or deep girders effectively support strength deck longitudinal hatch coamings of length greater than 0.14*L*, as indicated in 5.7, they are to be longitudinally stiffened. The coaming thickness is to be not less than required by 15.3.1a, equation 2b and the longitudinal stiffeners not less than required by 10.2 for strength deck longitudinal beams; where s is the spacing of the stiffeners, *l* is the distance between coaming brackets and h is as given in column b of Table 10.1. Special consideration will be given to the coaming scantlings where adequate buckling strength is shown to be otherwise provided.

17.4 HATCHWAYS CLOSED BY PORTABLE COVERS AND SECURED WEATHER TIGHT BY TARPAULINS AND BATTENING DEVICES.

17.4.1 Bearing Surface: The width of each bearing surface for hatchway covers is to be at least 65 mm.

17.4.2 Wood Hatch Covers: Wood covers are to have a finished thickness of not less than 60mm in association with an unsupported span of 1.5m, and of not less than 82 mm with 2 m; the thickness for intermediate spans is to be obtained by linear interpolation. Where the tween deck height, h_H, 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. The ends of all wood hatch covers are to be protected by encircling galvanized steelbands, about 65 mm wide and 33 mm thick, efficiently secured.

17.4.3 Steel Hatch Covers:

a. Design Conditions: Where covers are made of steel, the strength is to be calculated with assumed loads not less than 1.75 metric tons per square meter on hatchways in Position 1, and not less than

1.30 metric tons per square meter on hatchways in Position 2, and the product of the maximum stress thus calculated is not to exceed the minimum ultimate strength of the material. They are to be so designed asto limit the deflection to not more than 0.0028 times the span under these loads.

b. Reduced Design Loads: The assumed loads on hatchways in Position 1 may be reduced to 1.36 metric ton per square meter for ships 61 m in length and are to be not less than 1.75 metric tons per square meter for ships 100 m in length. The corresponding loads on hatchways in Position 2 may be reduced to

1.02 metric tons per square meter and 1.30 metric tons per square meter respectively. In all cases valuesat intermediate lengths are to be obtained by interpolation.

17.4.4 Portable Beams: Where portable beams for supporting hatchway covers are made of steel, the strength is to be calculated with assumed loads not less than 1.75 metric tons per square meter on hatchways in Position 1, and not less than 1.30 metric tons per square meter on hatchways in Position 2; and the product of the maximum stress thus calculated is not to exceed the minimum ultimate strengthof the material. They are to be so designed as to limit the deflection to not more than 0.0022 times the span under these loads. For ships of not more than 100 m in length the reduced loads indicated in 17.4.3b may be used.

17.4.5 Pontoon Covers: Where pontoon covers used in place of portable beams and covers are made of steel, the strength is to be calculated with the assumed loads given in 17.4.3a and the product of the maximum stress thus calculated is not to exceed the minimum ultimate strength of the material. They are to be so designed as to limit the deflection to not more than 0.0022 times the span. Steel plating forming the tops of covers is not to be less in thickness than 1% of the spacing of stiffeners or 6 mm if that were greater. For ships of not more than 100 m in length the reduced loads indicated in 17.4.3b may be used.

17.4.6 Material Other than Steel: The strength and stiffness of covers made of materials other than steelare to be equivalent to those of steel.

17.4.7 Carriers: Carriers for portable beams are to be of substantial construction, and are to provide means for the efficient fitting and securing of the beams. Where rolling types of beams are used, the arrangements are to ensure that the beams remain properly in position when the hatchway is closed. The bearing surface is not to be less than 75 mm in width measured along the axis of the beam. Carriers for beams are to extend to the deck level or the coamings are to be fitted with stiffeners in way of each beam.

17.4.8 Cleats: Cleats are to be set to fit the taper of the wedges. They are to be at least 65 mm wide andspaced not more than 600 mm centre to centre; the cleats along each side or end are to be not morethan 150 mm from the hatch corners.

17.4.9 Wedges: Wedges are to be of tough wood; they are to have a taper of not more than 1 in 6 and are to be not less than 13.0 mm thick at the toes.

17.4.10 Battening Bars: Battening bars are to be provided for properly securing the tarpaulins; they are to have a width of 64 mm and a thickness of not less than 9.5 mm.

17.4.11 Tarpaulins: At least two tarpaulins thoroughly waterproofed and of ample strength are to be provided for each exposed hatchway. The material is to be guaranteed free from jute and is to be of an approved type. Synthetic fabrics, which have been demonstrated, to be equivalent will be specially approved.

17.4.12 Security of Hatchway Covers: For all hatchways in Position 1 or 2, steel bars are to be provided in order to secure efficiently and independently each section of hatchway covers after the tarpaulins are battened down. Hatchway covers of more than 1.5 m in length are to be secured by at least two such securing appliances.

17.5 HATCHWAYS CLOSED BY COVERS OF STEEL FITTED WITH GASKETS AND CLAMPING DEVICES.

17.5.1 Strength of Covers: Where weather tight covers are of steel, the strength is to be calculated with assumed loads not less than 1.75 metric tons per square meter on hatchways in Position 1, and not less than 1.30 metric tons per square meter on hatchways in Position 2, and the product of the maximum stress thus calculated is not to exceed the minimum ultimate strength of the material. They are to be so designed as to limit the deflection to not more than 0.0028 times the span under these loads. Steel plating forming the tops of covers is to be not less in thickness than 1% of the spacing of stiffeners or 6 mm if that were greater. For ships of not more than 100 m in length the reduced loads indicated in 17.4.3b may be used.

17.5.2 Other Materials: The strength and stiffness of covers made of materials other than steel is to be equivalent to those of steel.

17.5.3 Means for Securing Weather Tightness: The means for securing and maintaining weather tightness are to be such that the tightness can be maintained in any sea conditions. The covers are to be hose-tested in position under a water pressure of at least 2.1 kg/cm^2 at the time of construction and subsequent surveys.

17.5.4 Flush Hatch Covers: Where flush hatch covers are fitted on the freeboard deck within the forward one-fourth length, and the ship is assigned a freeboard less than Type-B under the International Convention on Load Lines 1966, the assumed loads on flush hatch covers are to be increased 15% over that indicated in 17.5.1.

17.5.5 Gasket Less Covers: Special consideration will be given to the omission of gaskets on covers on hatchways in decks located above Position 2 where it can be shown that the closing arrangements are weather tight.

17.6 HATCHWAYS IN LOWER DECKS

17.6.1 General: The following scantlings are intended for ocean-going ships and conventional type covers. Those for covers of special types are to be specially considered.

17.6.2 Beams and Wood Covers: Hatchways in lower decks are to be framed with beams of sufficient strength. Where such hatches are intended to carry a load of cargo, the hatch beams are to have a section modulus SM not less than:

SM = 7.9 $chsl^2$ cm^3c = 1.18

h = tween-deck height in m

s = spacing of hatch

beams in ml = length of

hatch beams in m

The wood covers are not to be less than 63.5 mm thick where the spacing of the beams does not exceed 1.52m. Where the height to which the cargo may be loaded on top of a hatch exceeds about 2.6 m, the thickness of the wood covers are to be suitably increased.

17.6.3 Steel Covers: Where steel covers are fitted, the thickness of the plating is to be not less than required for platform decks in enclosed cargo spaces as obtained from equation 5 in 15.3.1a. A stiffening bar is to be fitted around the edges as required to provide the necessary rigidity to permit the covers being handled without deformation. The effective depth of the framework is normally to be not less than 4% of its unsupported length. Each stiffener in association with the plating to which it is attached is to have section modulus SM not less than:

SM = 7.9 hsl^2 cm3

h = ‘tween-deck height in m

s = spacing of the stiffeners in m

l = length of the stiffener in m

17.6.4 Wheel Loading: Where provision is to be made for the operation of vehicles having rubber tires, the thickness of the hatch cover plating is to be not less than obtained from 15.3.9, except that the thickness of plate panels adjacent to the edges of the covers is to be 15% greater than obtained from 15.3.9.

17.7 HATCHWAYS WITHIN OPEN SUPERSTRUCTURES

Hatchways within open superstructures are to be considered as exposed.

17.8 HATCHWAYS WITHIN DECKHOUSES

Hatchways within deckhouses are to have coamings and closing arrangements as required in relation to the protection afforded by the deckhouse from the standpoint of its construction and the means provided for the closing of all openings into the house.

17.9 CONTAINER LOADING

Where it is intended to carry containers on steel hatch covers complying with 17.9, the exact locations of the container pads and the maximum total static load on the pads are to be indicated on the plans. Where the pads are not in line with supporting structures, headers are to be provided to transmit the loads to these members. Each member intended to support containers is to have a section modulus, SM, in cm^3, not less than:

$$SM = M/f$$

M = maximum bending moment due to maximum static container loading, in kg-cm

f = permissible maximum bending stress, not to exceed 1104 kg/cm^2

In determining the maximum bending moment, members are to be considered simply-supported.

The next sectional area of the web of the member, in cm^2, including effective brackets where applicable, is to be not less than obtained from the following equation:

A

= F/q F = shearing force at the point under

consideration in kg

q = allowable average shear stress in the web, not to exceed 810 kg/cm^2

17.10 MACHINERY CASINGS

17.10.1 Arrangement: Machinery-space openings in Position 1 or 2 are to be framed and efficiently enclosed by steel casings of ample strength, and, those in freeboard decks are to be within superstructures. Access opening in exposed casings are to be fitted with doors complying with the requirements of 16.3.2, the sills of which are to be at least 600mm above the deck if in Position 1, and at least 380 mm above the deck if in Position 2. Other openings in such casings are to be fitted with equivalent covers, permanently attached in their proper positions.

17.10.2 Fiddleys and Ventilators: Coamings of any fiddley or machinery-space ventilator in an exposed position on the freeboard or superstructure deck are to be as high above the deck as is reasonable. Fiddley openings are to be fitted with strong covers of steel permanently attached in their proper positions and capable of being secured weather tight.

17.10.3 Exposed Casings on Freeboard or Raised Quarter Decks: Exposed casings on freeboard or raised quarter decks are to have plating at least 7.0 mm thick with 8.5 mm coamings in ships 61 m in length, and
7.5 mm thick with 9.5 mm coamings in ships 91.5 m in length and above; intermediate thickness may be obtained by interpolation. Where coamings are not fitted, the thickness of the plating may be required to be increased. Stiffeners are to be spaced not over 760 mm apart and are to be at least as effective as those required for watertight bulkheads. Where the ends of the casings are not protected by other structures, the thickness of the plating and the sizes of the stiffeners are to be increased as may be required by the conditions.

17.10.4 Exposed Casings on Superstructure Decks: Exposed casings on superstructure decks are to have plating at least 5.5 mm thick with coamings 7.5 mm thick in ships 61 m and 7.5 mm thick with coamings
9.5 mm thick, in those 122 m in length and above, where the stiffeners are spaced not more than 760mm apart; intermediate thickness may be obtained by interpolation. Where coamings are not fitted, the thickness of the plating may be required to be increased. Each stiffener in association with the plating to which it is attached, is to have a section modulus SM as obtained from the following equation:

$$SM = 7.9\, csh l^{2} \text{ cm}^3$$

c = 0.25

s = spacing of

stiffeners in mh =

height of the casing in

m

l = length, between supports, of the stiffeners in m

Where the ends of the casings are not protected by other structures, the thickness of the plating and thesizes of the stiffeners are to be increased as may be required by the conditions.

17.10.5 Casings within Open Superstructures: Casings within open superstructures are to be of similar scantlings to those obtained from 17.10.4 for exposed casings on superstructure decks. Where there are no end bulkheads to the superstructures, the arrangements and scantlings are to be specially considered.

17.10.6 Casings within Enclosed Superstructures: Casings within enclosed superstructures where cargo is carried are to have plating at least 5.0 mm thick with coamings 7.5 mm thick in ships 61 m in length, and 6.5 mm thick with coamings 9.5 mm thick in those 122 m in length and above, where the stiffeners are spaced not more than 760 mm apart; intermediate thickness may be obtained by interpolation. Side plating of casings in accommodation space above the crown of the machinery space may be 4.5 mm thickwhere the spacing of the stiffeners is not more than 760 mm and suitable coamings are fitted. The plating thickness is to be increased at the rate of 0.5 mm, for each 75 mm greater spacing.

Where coamings are not fitted, the thickness of plating may need to be increased. Each stiffener is to be fitted in line with the beams and is to have section modulus SM as required for exposed casings by17.5.4, but the coefficient in the equation may be 0.14 instead of 0.25, and h is the tween-deck height.

17.10.7 Casings within Deckhouses: Casings within deckhouses are to have scantlings and closing arrangements to entrances as required in relation to the protection offered by the deckhouse from the standpoint of its construction and the means for closing all openings into the house.

17.8 MISCELLANEOUS OPENINGS IN FREEBOARD AND SUPERSTRUCTURE DECKS

17.8.1 Manholes and Scuttles: Manholes and flush scuttles in Position 1 or 2 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.

17.8.2 Other Openings: Openings in freeboard decks other than hatchways, machinery-space openings and flush scuttles are to be protected by an enclosed superstructure, or by a deckhouse of equivalent strength and weather tightness. Any such opening in an exposed superstructure deck, or in the top of a deckhouse on the freeboard deck which gives access to a space below the freeboard deck, is to be protected by an efficient deckhouse or companionway. Doorways in such deckhouses or companionways are to be fitted with doors complying with the requirements of 16.3.2.

17.8.3 Escape Openings: The closing appliances of escape openings are to be readily operable from each side.

17.8.4 Companionway Sills: In Position 1 the height above the deck of sills to the doorways in companionways is to be at least 600 mm. In Position 2 they are to be at least 380 mm.

17.9 MAST OPENINGS

Openings penetrating decks and other structures to accommodate masts, kingposts and similar members are to be reinforced by fitting doublings.

CHAPTER 18: MACHINERY COMPARTMENT

18.1 GENERAL

In view of the effect upon the structure of the necessary openings in the machinery space and of distributing the weight of the machinery, special attention is directed to the need for arranging, for the provision of plated through beams and pillar supports as are required to secure structural efficiency; careful attention to these features in design and construction is to be regarded as of the utmost importance. All parts of the machinery, shafting, etc., are to be efficiently supported and the adjacent structure is to be adequately stiffened. In twin- screw ships it will be necessary to make additions to the strength of the structure and the area of attachments, which are proportional to the weight and proportions of the machinery, more specially where the engines are relatively high in proportion to the width of the bed plate.

The height and approximate weight of engines are to be stated upon the bolting plan, which is to be approved before the bottom construction is commenced. A determination is to be made to assure that the foundations formain propulsion units and the structure supporting those foundations are adequate to maintain required alignment and rigidity under all anticipated conditions of loading. Consideration is to be given to the submittal ofplans of the foundations for main propulsion units and of the structure supporting those foundations to the machinery manufacturer for review.

18.2 ENGINE FOUNDATIONS

18.2.1 Single-bottom Ships: In ships with single bottoms the engines are to be seated on thick plates laidacross the top of deep floors. Intercostal plates are to be fitted between the floors beneath the lines of bolting to distribute the weight effectively through the bottom structure to the shell. Seat plates are to be of thickness and width appropriate to the holding-down bolts and are to be effectively attached to girders and intercostals.

18.2.2 Double-bottom ships: In ships with double bottoms the engines are to be seated directly upon thick inner-bottom plating arranged to distribute the weight effectively. Additional intercostal girders are to be fitted within the double bottom to ensure the satisfactory distribution of the weight and the rigidityof the structure.

18.3 BOILER FOUNDATIONS

Boilers are to be supported by deep saddle-type floors arranged to distribute the weight effectively. Where transverse saddles or girders support them, the floors in way of boilers are to be suitably increased in thickness and specially stiffened. Boilers are to be placed to ensure accessibility and proper ventilation; they are to be at least 457 mm clear of tank tops, bunker walls, etc.; the thickness of adjacent material is to be increased as maybe required where the clear space is unavoidably less; the available clearance is to be indicated on the plans submitted for approval.

18.4 THRUST FOUNDATIONS

Thrust blocks are to be bolted to efficient foundations extending well beyond the thrust blocks and arranged to distribute the loads effectively into the adjacent structure; extra intercostal girders, effectively attached, are to be fitted in way of the foundations as may be required.

18.5 SHAFT STOOLS AND AUXILIARY FOUNDATIONS

Shaft stools and auxiliary foundations are to be of ample strength and stiffness in proportion to the weight supported.

18.6 TUNNELS AND TUNNEL RECESSES

18.6.1 Plating: The plating of flat sides of shaft tunnels is to be of the thickness as obtained from 12.4.1 for watertight bulkheads; the lowest strake of the plating is to be increased 1 mm. Flat plating on the tops of tunnels is to be of the thickness required for watertight bulkhead plating at the same level; whereunsheathed in way of hatches, the thickness is to be increased 2 mm and where the top of the tunnel forms a part of a deck, the thickness is not to be less than required for the plating of watertightbulkheads at the same level plus 1 mm. Curved plating may be of the thickness required for watertight bulkhead plating at the same level in association with a stiffener spacing 150 mm less than that actually adopted. Crown plating in way of hatches is to be increased at least 2.5 mm.

18.6.2 Stiffeners: Stiffeners are not to be spaced more than 915 mm apart, and each stiffener in association with the plating to which it is attached is to have a section modulus SM as obtained from the equation:

$SM = 4.42\ hsl^2\ cm^3$

h = distance in m from the middle of *l* to the bulkhead deck

s = spacing of stiffeners in m

l = distance in m between the top and bottom supporting members without brackets.

The ends of stiffeners are to be welded to the top and bottom supporting members. Where masts, stanchions, etc., are stepped upon tunnels, local strengthening is to be provided proportional to the weight carried.

18.6.3 Beams and Girders: Beams and girders under the tops of tunnels are to be as required for similar members on bulkhead recesses.

18.6.4 Tunnels through Deep Tanks: Where tunnels pass through deep tanks, the thickness of the plating and the sizes of the stiffeners in way of the tanks are not to be less than required for deep-tank bulkheads. Tunnels of circular form are to have plating of not less thickness *t* than obtained from the following equation:

t = 0.1345 dh + 9 mm

d = diameter of the tunnel in m

h = distance in m from the bottom of the tunnel to the highest point of the following:

- Load line
- The highest level to which the tank contents may rise in service conditions
- A point located at a distance two-thirds *D*, as defined in 1.3 above the baseline
- A point located two-thirds of the test head above the top of the tank.

18.6.5 Testing of Tunnels: Requirements for testing are contained in Chapter 21.

CHAPTER 19: BULWARKS, PORTS AND VENTILATORS.

19.1 BULWARKS

19.1.1 General Requirements: The equipment mentioned in this Chapter is to comply with the following principles, which are considered complement of the relevant Load Lines 1966 regulations. In ships with length > 90 m, the design of the bulwark structure is to preclude it from taking part in the generalbending of the hull.

Where the bulwark is welded to the sheer strake, the smooth transition with a radius of at least 100 mm between the bulwark plating and the sheer strake is to be maintained. Sufficient provision is to be made for freeing the decks from water, particularly in areas where bulwarks and superstructures form wells.

The height of bulwarks on exposed parts of freeboard and superstructure decks is to be at least 1 m from the deck. Where this height would interfere with the normal operation of the ship, a lesser height may be approved.

No port light is to be fitted in a position with its sill below a line drawn parallel to the freeboard deck at side and having its lowest point 2.5% of the breadth of the ship above the load waterline, or 500 mm whichever is the greater distance.

19.1.2 Bulwark Strength: If the bulwarks are of Rule height, their thickness is not to be less than

$t = 0.065L + 1.75$, [mm] for $L \leq 60$m

$t = 0.025L + 4.00$, [mm] for $L \geq 60$ m

The thickness of bulwark plate is not to be less than 3 mm and need not be greater than 8 mm. The thickness of bulwark plates in superstructures in way of x□0.25 *L*, as well as of superstructures and deckhouses of the second tier and the tiers above may be decreased by 1 mm.

The bulwark is to be supported by stays spaced not more than 1.8 m. In the fore part of the ship for $x >$ 0.43 *L*, spacing between stays are to be decreased to 1.2 m. Where the flare is large and in ships intended for the carriage of timber on deck, spacing between stays will be specially considered. The stays are to be in line with beams or additional deck stiffeners.

Where the bulwark height is 1 m, the width of the lower end of a stay, measured along the connection with the deck, is not to be less than:

$b = (0.65L + 190)\sqrt{s}$, [mm]

but need not exceed 360 mm.

s - spacing between stays [m]; in ships carrying deck cargo and in the fore part of the ship. s = 1.8 m is to be taken for calculations.

Outside the bow region, where bulwark is welded to the sheer strake, b may be reduced by 20%. Where the height of the bulwark exceeds 1 m, the width b is to be increased in proportion to the bulwark height.The thickness of stays is to be 1 mm greater than that of the bulwark plating.

Stays are to have flanges welded to free edges. The width is not to be less than 60 mm, but it is not to exceed 90 mm. Flat bars strengthening the lower edge of the bulwark are not to be welded to the deck. The dimensions of lightening holes in stays are not to exceed half the stay width in any cross-section.

The thickness of stays in way of bulwark cut to form a gangway is to exceed the bulwark thickness by 25%. Additional strengthening of bulwark may be required in way of mooring pipes and eye plates for cargo gear. Stays are to be welded to rail and deck. The stay is to be welded to the deck with double continuous weld. Adequate openings are to be provided for freeing the deck of water.

19.1.3 Guard Rails: The upper edge of the bulwark is to end with a rail made of adequate firm section, the thickness of which is at least 1 mm greater than that of the bulwark plating.

The lower edge of the bulwark in way of a gap between the bulwark and the sheer strake is to be strengthened by a longitudinal stiffener.

19.2 FREEING PORTS

19.2.1 General: Except as provided in 19.2.2 and 19.2.3, the minimum freeing-port area A on each side of the ship for each well on the freeboard deck is to be obtained from the following equations in cases where the sheer in way of the well is standard or greater than standard (Standard sheer as defined in the International Convention on Load Lines, 1966). The minimum are for each well on superstructure decksis to be one-half of the area obtained from the following equation:

a. Where the Length of Bulwark l in the Well is 20 m or Less

$A = 0.7 + 0.035l \text{ m}^2$

b. Where l Exceeds 20 m

A = 0.07*l* m2

In no case need *l* be taken as greater than 0.7*L* where *L* is the length of the ship as defined in Chapter 1.If the bulwark is more than 1.2 m in average height, the required area is to be increased by 0.004m^2 per m of length of well for each 0.1 m difference in height. If the bulwark is less than 0.9 m in average height, the required area may be decreased by 0.004 m^2 per m of length of well for each 0.1 m difference inheight.

19.2.2 Ships with Less than Standard Sheer: In ships with no sheer, the calculated area is to be increasedby 50%. Where the sheer is less than the standard, the percentage is to be obtained by interpolation.

19.2.3 Trunks: Where a ship is fitted with a trunk, and open rails are not fitted on weather parts of the freeboard deck in way of the trunk for at least half their length, the minimum area of the freeing-port openings is to be calculated from the following table:

Breadth of hatchway	*Area of freeing ports*
Or trunk, in relation	*in relation to the total*
To the breadth of ship	*area of the bulwarks*
40% or less	20%
75% or more	10%

The area of freeing ports at intermediate breadths is to be obtained by linear interpolation.

19.2.4 Open Superstructures: In ships having superstructures, which are open at ends, adequate provision for freeing the space within such superstructures is to be provided.

19.2.5 Specific Details: The lower edges of the freeing ports are to be as near the deck as practicable. Two-thirds of the freeing-port area required is to be provided in the half of the well nearest the lowest point of the sheer curve. All such openings in the bulwarks are to be protected by rails spaced approximately 230 mm apart. If shutters are fitted to freeing ports, ample clearance is to be provided to prevent jamming. Hinges are to have pins of no corrodible material and are to be located at the top ofthe shutters. If shutters are fitted with securing appliances, these are to be approved.

19.3 CARGO AND FUELLING PORTS

19.3.1 Construction: Cargo and fuelling ports in the sides of ships are to be strongly constructed and capable of being made thoroughly watertight; where frames are cut in way of such ports, web frames are to be fitted on each side of the opening and suitable arrangements are to be provided for the support of the beams over the opening. Shell doublings are to be fitted as required to compensate for the openingsand the corners of the openings are to be well rounded. Waterway angles and scuppers are to be provided on the deck in way of openings in cargo spaces below the freeboard deck or in cargo spaces within enclosed superstructures to prevent the spread of any leakage water over the deck.

19.3.2 Location: Unless especially approved, the lower edge of cargo and fuelling port openings is not to be below a line drawn parallel to the freeboard deck at side, which has at its lowest point the upper edge of the uppermost load line.

19.4 PORTHOLES

19.4.1 Construction: Portholes to spaces below the freeboard deck or to spaces within enclosed superstructures are to be fitted with efficient inside deadlights arranged so that they can be effectively closed and secured watertight. They are to have strong frames and opening-type portholes are to have non-corrosive hinge pins.

19.4.2 Location: No porthole is to be fitted in a position with its sill below a line drawn parallel to the freeboard deck at side and having its lowest point 2.5% of the breadth of the ship above the load waterline, or 500 mm whichever is the greater distance.

19.5 VENTILATORS

19.5.1 Construction of Coamings: Ventilator on exposed freeboard or superstructure decks to spaces below the freeboard deck or decks of enclosed superstructures are to have coamings of steel or other equivalent material. Coaming-plate thickness is not to be less than 7.5 mm for ventilators up to 200 mm diameter, and 10 mm for diameters of 457 mm and above; the thickness for intermediate diameters may be obtained by interpolation.

Coamings are to be effectively secured to properly stiffened deck plating of sufficient thickness. Coamings which are more than 900 mm high, and which are not supported by adjacent structures are to have additional strength and attachment. Ventilators passing through superstructures other than enclosed superstructures are to have substantially constructed coamings of steel at the freeboard deck.

19.5.2 Height of Coamings: Ventilators in Position 1 are to have coamings at least 900 mm above the deck; ventilators in Position 2 are to have coamings at least 760 mm above the deck. In exposed positions, the height of coamings may be required to be increased.

19.5.3 Means for Closing Openings in Ventilators: Except as provided below, ventilator openings are to be provided with efficient closing appliances. Ventilators in Position 1, the coamings of which extend to more than 4.5 m above the deck, and in Position 2, the coamings of which extend to more than 2.3 m above the deck, need not be fitted with closing arrangements unless unusual features of the design makeit necessary.

CHAPTER 20: PLANKING AND PROTECTION OF STEEL

20.1 CLOSE CEILING

Close ceiling in ships with single bottoms is to be fitted on the floors and up to the upper turn of the bilge; the ceiling is not to be less than 57 mm in ships 61 to 76 m in length, nor less than 63 mm in ships of greater length. The ceiling is to be laid in portable sections on the flat of floors, for easy removal when required for cleaning, or inspection of the bottom. In ships with double bottoms, where close ceiling is fitted, it is to be laid from the margin plate to the upper part of the bilge, so arranged as to be readily removable for inspection of the limbers. Where the margin plate is horizontal, this requirement may be modified.

Ceiling is to be laid under all hatchways or the thickness of the inner bottom is to be increased 2 mm, except that neither is required for ships intended for the exclusive carriage of containers on the inner bottom. Ceiling, wherefitted on top of inner-bottom plating, is to be laid on battens, for drainage purposes.

20.2 SPARRING

Sparring is to be fitted to the sides above the bilge ceiling, in all cargo spaces where it is intended to carry generalcargo; the sparring is not to be less than 40 mm thick, finished, nor is it to provide less protection to the framing than is obtained from battens at least 140 mm wide and spaced 380 mm centre to centre. Sparring is to be bolted, fitted in cleats, or in portable frames for convenience in removal. Sparring may be obtained in ships engaged in the carriage of coal, and similar cargoes.

20.3 PROTECTION OF STEEL WORK

Unless otherwise approved, all steel work is to be suitably coated with paint. Tanks or holds intended for water ballast are to have a corrosion resistant coating on all internal surfaces. Other effective methods of corrosion protection will be specially considered. Tanks intended for oil or the holds of combination carriers intended for the carriage of dry bulk cargoes and oil cargoes need not be coated.

CHAPTER 21: TESTING AND TRIALS – HULL

21.1 TANK AND RUDDER TESTING

21.1.1 General: After all hatches and watertight doors are installed, penetrations, including pipe connections, are to be fitted before cement work or ceiling is applied over joints; all tanks and watertight bulkheads are to be tested and proven tight. Refer to Table 21.1 for specific test requirements. Close visual examination combined with non-destructive testing may be accepted in certain areas where specially approved, as an alternative to hose testing.

21.1.2 Hydrostatic Testing: Unless air testing has been approved as an alternative, tanks are to be testedwith a head of water to the overflow. This may be carried out before or after the ship is launched. Special coatings may be applied before hydrostatic testing provided all welding at joints and penetrationsis visually examined to the satisfaction of the Surveyor before special coating is applied.

21.1.3 Air Tests: Where permitted in Table 21.1, air testing or other approved procedure may be accepted at the discretion of the Surveyor, as an alternative to hydrostatic testing. Where air testing is adopted, all boundary welds, and penetrations including pipe connections are to be examined under the approved test procedure with a suitable leak indicator solution prior to the application of special coatings. Air test pressure differential should normally be 0.14 kg/cm^2. Means are to be provided to prevent accidental over pressuring of tanks during testing. Air-pressure drop testing, i.e., checking for leaks by monitoring drop in pressure, is not an acceptable substitute for required hydrostatic testing.

21.1.4 Hose Testing: Hose testing is to be carried out under simultaneous inspection of both sides of thejoint. The pressure in the hose is not to be less than 2.1 kg/cm^2.

Table 21.1 Initial tank and rudder tightness test requirements

Item	***Test Method***
Double Bottom Tanks	Hydro Test
Deep Tanks	Hydro Test
Forepeak & After peak Tanks	Hydro Test
Ballast Tanks, Dry cargo Ships	Hydro Test
Forepeak Dry Space	Hose Test
Duct Keels	Hydro Test
Shaft Tunnels (clear of deep tanks)	Hose Test
Chain Lockers (aft of fore peak Bulkhead)	To be filled with water
Hawse Pipes	Hose Test
Weather tight Hatch covers & Closing Appliances	Hose Test
Watertight Bulkheads, Flats & Closing Appliances	Hose Test
Oil Cargo Tanks, Tanker or Combination Carrier	Hydro Test
Ballast Tanks, Tanker or Combination Carrier	
- Within cargo tank section	Hydro Test
- Outside of cargo tank section	Hydro Test
Chemical Cargo Tanks	Hydro Test
Bulkheads at Ends of Cargo Tank Section	Hydro Test

Boundaries of Tanker Segregated Cargoes	Hydro Test
Void Space Boundaries Required to be Watertight	Hose Test
Double Plate Rudders	Hydro Test

Item	***Test Method***
Gas Carriers: □ Pressurized Gas Tanks (Type B and C) (MARVS 2.1 kg/cm^2 and over)	Hydro Test
□ Integral Tanks (Types A & B) (MARVS under 2.1 kg/cm^2	Hydro Test to simulate design stresses in accordance with
□ Membrane Tanks	Testing subject to special approval
□ Ballast or Fuel Oil Tanks Adjacent to Cargo Tank Hold Spaces	Hydro Test
□ Initial Service Tests, All Gas Carriers	

21.2 TANK TESTS FOR STRUCTURAL ADEQUACY

In order to demonstrate the structural adequacy, representative hydrostatic testing of tanks may be required in connection with the approval of the design. This would include at least one tank of each type of new tank design.

21.3 ANCHOR WINDLASS

Each anchor windlass is to be tested under normal working conditions to demonstrate satisfactory operation. Each required anchor handling unit is to be tested for braking, clutch functioning, power lowering, hoisting, and proper riding of the chain through the hawse pipe, over the wildcat (chain wheel), through the chain pipe, and stowing in the chain locker. Also, it is to be demonstrated that the windlass is capable of lifting each anchor with

82.5 m length of chain submerged and hanging free. Where the available water depth is insufficient, the proposed test method will be specially considered.

21.4 BILGE SYSTEM TRIALS

All elements of the bilge system are to be tested to demonstrate satisfactory pumping operation, including emergency suctions. Upon completion of the trials, the bilge strainers are to be opened, cleaned and closed up in good order.

21.5 STEERING TRIALS

Refer to 4.9 for technical details of the steering trials.

21.6 CONSTRUCTION WELDING AND FABRICATION

For surveys of hull construction welding and fabrication. Recognized and approved procedures for Non-destructive Inspection of Hull Welds may be accepted at the discretion of the Surveyor.

21.7 HULL CASTINGS AND FORGINGS

For surveys in connection with the manufacture of hull castings and forgings.

21.8 HULL PIPING

For surveys in connection with the manufacture of hull piping.

HISTORY

REV. No.	DATE	COMMENTS
00	DEC/11/2013	New Rule
01	NOV/12/2014	Annual revision of the class rule
02	DEC/07/2015	Annual revision of the class rule
03	DEC/14/2016	Annual revision of the class rule
04	OCT/22/2017	Annual revision of the class rule
05	DEC/28/2018	Annual revision of the class rule
06	DEC/16/2019	Annual revision of the class rule
07	DEC/05/2020	Annual revision of the class rule
08	MAY/07/2022	Total revision of the document

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