ACS (Asia Classification Society)

Rules for

Classification of Vessels

(2014)

Part 3

Hull Construction and Equipment

Rules for Classification of Vessels

Contents

Part 3 Hull Construction and Equipment

Chapter 1 General

Section 1 Definitions

1 Application

The following definitions are used in the Rules.

1.1 Length

1.1.1 Scantling Length (L)

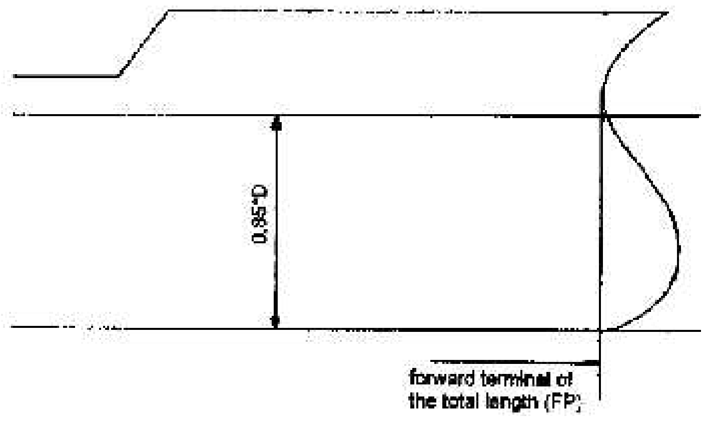
L is the distance in meters on the summer load line from the fore side of the stem to the centerline of the rudder stock. L is not to be less than 96% and need not be greater than 97% of the length on the summer load line. The forward end of L is to coincide with the fore side of the stem on the waterline on which L is measured.

1.1.2 Freeboard Length (L_f)

L_f is the distance in meters on a waterline at 85% of the least molded depth measured from the top of the keel from the fore side of the stem to the centerline of the rudder stock or 96% of the length on that waterline, whichever is greater.

Where the stem contour is concave above the waterline at 85% of the least molded depth, both the forward terminal of the total length and the fore-side of the stem respectively shall be taken at the vertical projection to that waterline of the aftermost point of the stem contour (above that waterline) (see figure 1.1).

Figure 1.1



1.2 Breadth (B)

Unless expressly provided otherwise, the breadth (B) in meter is the maximum breadth of the ship, measured amidships to the molded line of the frame in a ship with a metal shell and to the outer surface of the hull in a ship with a shell of any other material.

1.3 Depth

1.3.1 Molded Depth (D)

The molded depth D in meter is the vertical distance measured from the top of the keel to the top of the freeboard deck beam at side. In wood and composite ships the distance is measured from the lower edge of the keel rabbet. Where the form at the lower part of the midship section is of a hollow character, or where thick garboards are fitted, the distance is measured from the point where the line of the flat of the bottom continued inwards cuts the side of the keel. In ships having rounded gunwales, the molded depth shall be measured to the point of intersection of the molded lines of deck and sides, the lines extending as though the gunwale were of angular design.

Where the freeboard deck is stepped and the raised part of the deck extends over the point at which the molded depth is to be determined, the molded depth shall be measured to a line of reference extending from the lower part of the deck along a line parallel with the raised part.

1.3.2 Scantling Depth (D_s)

The scantling depth D_s, is the distance in meters from the molded base line to the strength deck.

1.3.3 Depth for freeboard

The depth for freeboard is the molded depth amidships, plus the freeboard deck thickness at side. The depth for freeboard in a ship having a rounded gunwale with a radius greater than 4% of the breadth or having topsides of unusual form is the depth for freeboard of a ship having a midship section with vertical topsides and with the same round of beam and area of topside section equal to that provided by the actual midship section.

1.4 Draft (d)

d is the molded draft, and is the distance in meters from the molded base line to the summer load line.

1.5 Molded Displacement (Δ)

Δ is the molded displacement of the vessel in metric tons, excluding appendages, taken at the summer load line.

1.6 Block Coefficient (C_b)

The block coefficient (C_b) is given by:

$C_b = \Delta /(1.025\ L\ B\ d)$;

where Δ is the molded displacement of the ship; L is the scantling length; B is the greatest molded breadth at the summer load line ;and d is the molded draft .

When calculating the block coefficient of a multi- hull craft, the full breadth is to be used and not the breadth of a single hull.

1.7 Decks

1.7.1 Freeboard Deck

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

At the option of the owner and subject to the approval of the Administration, a lower deck may be designated as the freeboard deck provided it is a complete and permanent deck continuous in a fore and aft direction at least between the machinery space and peak bulkheads and continuous athwartships.

1.7.2 Bulkhead Deck

The bulkhead deck is the highest deck to which the watertight bulkheads extend and are made effective.

1.7.3 Strength Deck

The strength deck is the deck that forms the top of the effective hull girder at any part of its length.

1.8 Superstructure

A superstructure is a decked structure on the freeboard deck, extending from side to side of the ship or with the side plating not being inboard of the shell plating more than 4% of the breadth (B).

The height of a superstructure is the least vertical height measured at side from the top of the superstructure deck beams to the top of the freeboard deck beams.

The length of a superstructure (S) is the mean length of the part of the superstructure which lies within the length (L).

1.8.1 Superstructure deck.

A superstructure deck is a deck forming the upper boundary of a superstructure and 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 Rules refers to the first such deck above the freeboard deck.

1.8.2 Bridge. A bridge is a superstructure which does not extend to either the forward or after perpendicular.

1.8.3 Poop. A poop is a superstructure which extends from the after perpendicular forward to a point which is aft of the forward perpendicular. The poop may originate from a point aft of the aft perpendicular.

1.8.4 Forecastle. A forecastle is a superstructure which extends from the forward perpendicular aft to a point which is forward of the after perpendicular. The forecastle may originate from a point forward of the forward perpendicular.

1.8.5 Full superstructure. A full superstructure is a superstructure which, as a minimum, extends from the forward to the after perpendicular.

1.8.6 Raised quarterdeck. A raised quarterdeck is a superstructure which extends forward from the after perpendicular, generally has a height less than a normal superstructure, and has an intact front bulkhead (side scuttles of the non-opening type fitted with efficient deadlights and bolted man hole covers). Where the forward bulkhead is not intact due to doors and access openings, the superstructure is then to be considered as a poop.

1.9 Deadweight (DWT) and Lightship Weight

For the purpose of these Rules, deadweight, DWT, is the difference in metric tons between the displacement of the vessel at its summer load line in water having a specific gravity of 1.025 and the lightship weight. For the purpose of these Rules, lightship weight is the displacement of the vessel in metric tons with no cargo, fuel, lubricating oil, ballast water, fresh water nor feed water in tanks, no consumable stores, and no passengers or crew nor their effects.

1.10 Units

These Rules are written in SI units.

1.11 Freeboard

The freeboard assigned is the distance measured vertically downwards amidships from the upper edge of the deck line to the upper edge of the related load line.

1.12 Flush deck ship

A flush deck ship is one which has no superstructure on the freeboard deck.

1.13 Weathertight

Weathertight means that in any sea conditions water will not penetrate into the ship.

1.14 Watertight

Watertight means capable of preventing the passage of water through the structure in either direction with a proper margin of resistance under the pressure due to the maximum head of water which it might have to sustain.

1.15 Well

A well is any area on the deck exposed to the weather, where water may be entrapped. Wells are considered to be deck areas bounded on two or more sides by deck structures.

1.16 Positions

The hatchways are classified according to their position as follows:

Position 1: Upon exposed freeboard and raised quarterdecks, and upon exposed superstructure decks situated forward of a point located a quarter of ship's length from forward perpendicular.

Position 2: Upon exposed superstructure decks situated abaft a quarter of the ship's length from the forward perpendicular and located at least one standard height of the superstructure above the freeboard deck.

Upon exposed superstructure decks situated forward of a point located a quarter of the ship's length from the forward perpendicular and located at least two standard height of the superstructure above the freeboard deck.

1.17 Type A and Type B ships

1.17.1 Type A ship

A Type A ship is one which:

- is designed to carry only liquid cargoes in bulk;

- has a high integrity of the exposed deck with only small access openings to cargo compartments, closed by watertight gasketed covers of steel or equivalent material;

  and

- has low permeability of loaded cargo compartments.

A Type A ship is to be assigned a freeboard following the requirements reported in the International Load Line Convention 1966, as amended.

1.17.2 Type B ship

All ships which do not come within the provisions regarding Type A ships stated in 1.17.1 are to be considered as Type B ships.

A Type B ship is to be assigned a freeboard following the requirements reported in the International Load Line Convention 1966, as amended.

1.17.3 Type B-60 ship

A Type B-60 ship is any Type B ship of over 100 metres in length which is assigned with a value of tabular freeboard which can be reduced up to 60 per cent of the difference between the “B” and “A” tabular values for the appropriate ship lengths.

1.17.4 Type B-100 ships

A Type B-100 ship is any Type B ship of over 100 metres in length which is assigned with a value of tabular freeboard which can be reduced up to 100 per cent of the difference between the “B” and “A” tabular values for the appropriate ship lengths.

Section 2 General Requirements

1 Material and Fabrication

1.1 Material

1.1.1 Steel

These Rules are intended for vessels of welded construction using steels complying with the requirements of Part 2, Chapter 3. Use of steels other than those in Part 2, Chapter 3 and the vessels' corresponding scantlings will be specially considered.

1.1.2 Aluminum Alloys

The use of aluminum alloys in hull structures will be considered upon submission of a specification of the proposed alloys and their proposed method of fabrication.

1.1.3 Design Consideration

Where scantlings are reduced in association with the use of higher-strength steel or where aluminum alloys are used, adequate buckling strength is to be provided. Where it is intended to use material of cold flanging quality for important longitudinal strength members, this steel is to be indicated on the plans.

1.1.4 Guidance for Repair

Where a special welding procedure is required for special steels used in the construction, including any low temperature steel and those materials not encompassed in Part 2 Chapter 3, a set of plans showing the following information for each steel is to be placed aboard the vessel:

- Material Specification
- Welding procedure
- Location and extent of application

These plans are in addition to those normally placed aboard the vessel, and are to show all material applications.

1.2 Application

The requirements of the Rules apply to steel vessels of all welded construction. Riveted hull construction, where used, will be considered on case by case basis.

2 Application of Steel Materials

2.1 Selection of Material Grade

Steel materials for particular locations are not to be of lower grades than those required by Table 2.1 for the material class given in Table 2.2.

When fatigue loading is present, the effective strength of higher-strength steel in welded construction may not be greater than that of ordinary-strength steel. Precautions against corrosion fatigue may also be necessary.

Table 2.1: Material Grades

Class	I		II		III	
Thickness in mm	MS	HT	MS	HT	MS	HT
t ≤ 15	A	AH	A	AH	A	AH
15 < t ≤ 20	A	AH	A	AH	B	AH
20 < t ≤ 25	A	AH	B	AH	D	DH
25 < t ≤ 30	A	AH	D	DH	D	DH
30 < t ≤ 35	B	AH	D	DH	E	EH
35 <t ≤ 40	B	AH	D	DH	E	EH
40 < t ≤ 50	D	DH	E	EH	E	EH

Table 2.2: Material Class or Grade of Structural Members

	Material class	
Structural member category	Within0.4L amidships	Outside0.4L amidships
SECONDARY: A1. Longitudinal bulkhead strakes, other than that belonging to the Primary category A2. Deck Plating exposed to weather, other than that belonging to the Primary or Special category A3. Side plating	I	A/AH
PRIMARY: B1. Bottom plating, including keel plate B2. Strength deck plating, excluding that belonging to the Special category B3. Continuous longitudinal members above strength deck, excluding hatch coamings B4. Uppermost strake in longitudinal bulkhead B5. Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank	II	A/AH
SPECIAL: C1. Sheer strake at strength deck [1], [8] C2. Stringer plate in strength deck [1], [8] C3. Deck strake at longitudinal bulkhead [2], [8] C4. Strength deck plating at outboard corners of cargo hatch openings in container carriers and other ships with similar hatch openings configuration [3] C5. Strength deck plating at corners of cargo hatch openings in bulk carriers, ore carriers, combination carriers and other ships with similar hatch openings configuration [4] C6. Bilge strake [5], [6], [8] C7. Longitudinal hatch coamings of length greater than 0.15 L. [7] C8. End brackets and deck house transition of longitudinal cargo hatch coamings [7]	III	II (I outside 0.6L amidships)

Notes:

[1] Not to be less than grade E/EH within 0.4L amidships in ships with length exceeding 250 metres.

[2] Excluding deck plating in way of inner-skin bulkhead of double hull ships.

[3] Not to be less than class III within the length of the cargo region.

[4] Not to be less than class III within 0.6L amidships and class II within the remaining length of the cargo region.

[5] May be of class II in ships with a double bottom over the full breadth and with length less than 150 metres.

[6] Not to be less than grade D/DH within 0.4L amidships in ships with length exceeding 250 metres.

[7] Not to be less than grade D/DH.

[8] Single strakes required to be of class III or of grade E/EH and within 0.4L amidships are to have breadths not less than 800+5xL mm, need not be greater than 1800 mm, unless limited by the geometry of the ship's design.

2.2 Structures exposed to low air temperatures

For ships intended to operate in areas with low air temperatures (below and including - 20ºC), e.g. regular service during winter seasons to Arctic or Antartic waters, the materials in exposed structures are to be selected based on the design temperature t_D, to be taken as defined in 2.3.

Materials in the various strength members above the lowest ballast water line (BWL) exposed to air are not to be of lower grades than those corresponding to classes I, II and III, as given in Table 2.3, depending on the categories of structural members (SECONDARY, PRIMARY and SPECIAL). For non-exposed structures and structures below the lowest ballast water line, see 2.1.

Table 2.3: Application of Material Classes and Grades - Structures Exposed at Low Temperatures

	Material class	
Structural member category	Within 0.4L amidships	Outside 0.4L amidships
SECONDARY: Deck Plating exposed to weather, in general Side plating above BWL Transversebulkheads above BWL	I	I
PRIMARY: Strength deck plating [1] Continuous longitudinal members above strength deck, excluding hatch coamings Longitudinal bulkhead above BWL Top wing tank bulkhead above BWL	II	I
SPECIAL: Sheer strake at strength deck [2] Stringer plate in strength deck [2] Deck strake at longitudinal bulkhead [3] Continuous longitudinal hatch coamings [4]	III	II (I outside 0.6L amidships)

Notes:

[1] Plating at corners of large hatch openings to be specially considered. Class III or grade E/EH to be applied in positions where high local stresses may occur.

[2] Not to be less than grade E/EH within 0,4 L amidships in ships with length exceeding 250 metres.

[3] In ships with breadth exceeding 70 metres at least three deck strakes to be class III.

[4] Not to be less than grade D/DH.

The material grade requirements for hull members of each class depending on thickness and design temperature are defined in Table 2.4. For design temperatures tD < -55ºC, materials are to be specially considered by ACS.

Table 2.4 - Material Grade Requirements for Classes, I, II and III at Low Temperatures

(N.A. = Not Applicable)

Class I

Thickness in mm	-20/-25 ^{O}C		-26/-35 ^{O}C		-36/-45 ^{O}C		-46/-55 ^{O}C	
	MS	HT	MS	HT	MS	HT	MS	HT
t ≤ 10	A	AH	B	AH	D	DH	D	DH
10 < t ≤ 15	B	AH	D	DH	D	DH	D	DH
15 < t ≤ 20	B	AH	D	DH	D	DH	E	EH
20 < t ≤ 25	D	DH	D	DH	D	DH	E	EH
25 < t ≤ 30	D	DH	D	DH	E	EH	E	EH
30 < t ≤ 35	D	DH	D	DH	E	EH	E	EH
35 <t ≤ 45	D	DH	E	EH	E	EH	N.A.	FH
45 < t ≤ 50	E	EH	E	EH	N.A.	FH	N.A.	FH

Class II

Thickness in mm	-20/-25 ^{O}C		-26/-35 ^{O}C		-36/-45 ^{O}C		-46/-55 ^{O}C	
	MS	HT	MS	HT	MS	HT	MS	HT
t ≤ 10	B	AH	D	DH	D	DH	E	EH
10 < t ≤ 20	D	DH	D	DH	E	EH	E	EH
20 < t ≤ 30	D	DH	E	EH	E	EH	N.A.	FH
30 < t ≤ 40	E	EH	E	EH	N.A.	FH	N.A.	FH
40 <t ≤ 45	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.
45 < t ≤ 50	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.

Class III

Thickness in mm	-20/-25 ^{O}C		-26/-35 ^{O}C		-36/-45 ^{O}C		-46/-55 ^{O}C	
	MS	HT	MS	HT	MS	HT	MS	HT
t ≤ 10	D	DH	D	DH	E	EH	E	EH
10 < t ≤ 20	D	DH	E	EH	E	EH	N.A.	FH
20 < t ≤ 25	E	EH	E	EH	N.A.	FH	N.A.	FH
25 < t ≤ 30	E	EH	E	EH	N.A.	FH	N.A.	FH
30 < t ≤ 35	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.
35 <t ≤ 40	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.
40 < t ≤ 50	N.A.	FH	N.A.	FH	N.A.	N.A.	N.A.	N.A.

Single strakes required to be of class III or of grade E/EH or FH are to have breadths not less than 800+5L mm, maximum 1800 mm.

Plating materials for sternframes, rudder horns, rudders and shaft brackets are not to be of lower grades than those corresponding to the material classes given in 2.1.

2.3 Design temperature t_D

The design temperature t_D is to be taken as the lowest mean daily average air temperature in the area of operation.

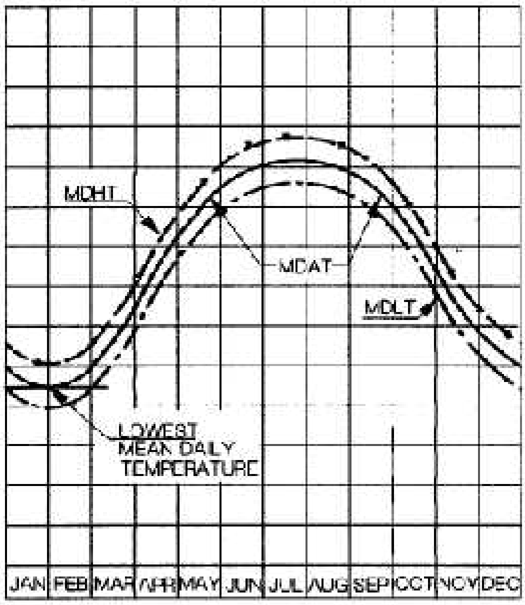
Mean: Statistical mean over observation period (at least 20 years).

Average: Average during one day and night.

Lowest: Lowest during year.

For seasonally restricted service the lowest value within the period of operation applies.

Fig2.1 illustrates the temperature definition.



MDHT = Mean Daily High (or maximum) Temperature.
MDAT = Mean Daily Average Temperature.
MDLT = Mean Daily Low (or Minimum) Temperature.

3 Scantlings

3.1 General

The midship scantlings specified in the Rules are to apply throughout the midship 0.4L. End scantlings are not to extend for more than 0.1L from each end of the vessel. Reduction in scantlings from the midship to the end scantlings is to be effected in as gradual a manner as practicable. Sections having appropriate section moduli or areas, 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 vessel’s structure.

3.2 Reduced Scantlings with Protective Coatings

Where deemed necessary, to suit a particular type and/or service of a vessel or a space, a reduction in scantlings in association with protective coatings may be considered. In such instances, a justification for the reduction is to be submitted for review, together with particulars of the coating. A program for maintenance is to be submitted. The plans are to show the required scantlings and the proposed 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.

3.3 Dynamic Loading Approach

The dynamic loading approach may be considered for vessels. The review is based upon an acceptable load and structural analysis procedure, taking into consideration the dynamic load components acting on the vessel.

The dynamic load components considered are to include the external hydrodynamic pressure loads, dynamic loads from cargoes and inertial loads of the hull structure. The magnitude of the load components and their combinations are to be determined from appropriate ship motion response calculations for loading conditions which represent the envelope of maximum dynamically induced stresses in the vessel.

The adequacy of the hull structure for all combinations of the dynamic loadings is to be evaluated using an acceptable finite element analysis method.

In no case are the structural scantlings to be less than those obtained from other requirements in the Rules.

4 Proportions

In general, these Rules are valid for all vessels with following dimensional ratios:

$$\mathrm{L} \leq 500\,\mathrm{m},\ B \leq L/5,\ B \leq 2.5 D_S$$

Where D_s is the depth to strength deck.

Vessels beyond these proportions will be specially considered.

5 Workmanship

All workmanship is to be of commercial marine quality and acceptable to the Surveyor. Welding is to be in accordance with the requirements of Part 2 of the rule.

6 Drydocking

Consideration is to be given to drydocking of the vessel within twelve months after delivery. For vessels 228.5 m in length, L, and over, information indicating docking arrangements is to be prepared and furnished onboard the vessel for guidance.

7 Structural Sections

7.1 General

The scantling requirements of these Rules are applicable to structural angles, channels, bars, and rolled or built-up sections.

7.2 Deep Supporting Members

The required section modulus of members such as girders, webs, etc., supporting frames, beams 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 of the sum of the 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 of the spacing or 16.5% of the unsupported span l, whichever is less, is to be used.

7.3 Frames, Beams and Stiffeners

7.3.1 Section Modulus

The required section modulus is to be provided by the stiffener and a maximum of one frame space of the plating to which it is attached.

7.3.2 Web Thickness

The depth to thickness ratio of the web portion of members is not to exceed the following:

Members with flange $50C_1C_2$

Members without flange $15\ C_1C_2$

where

C_1 = 0.95 (horizontal web within a tank)

= 1.0 (all other cases)

C_2 = 1.0 (ordinary strength steel)

= 0.92 (AH32)

= 0.90 (AH36)

8 Structural Design Details

8.1 General

The designer is to give consideration to the following:

i) The thickness of internals in locations susceptible to rapid corrosion.

ii) The proportions of built-up members for compliance with established standards for structural stability.

iii) The design of structural details, such as noted below, against the harmful effects of stress concentrations and notches:

- Details of the ends, at the intersections of members and associated brackets.
- Shape and location of air, drainage, and/or lightening holes.
- Shape and reinforcement of slots or cut-outs for internals.
- Elimination or closing of weld scallops in way of butts, “softening” of bracket toes, reducing abrupt changes of section or structural discontinuities.

iv) 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 considerations is to be submitted for review and comment.

8.2 Termination of Structural Members

Unless permitted elsewhere in the Rules, structural members are to be effectively connected to adjacent structures in such a manner as to avoid hard spots, notches and other harmful stress concentrations.

Where load-bearing members are not required to be attached at their ends, special attention is to be given to the end taper, by using a sniped end of not more than 30°.

Where the member has a face bar or flange, it is to be sniped and tapered not more than 30°.

The end brackets of large primary load-bearing members are to be soft-toed. Where any end bracket has a face bar it is to be sniped and tapered not more than 30°.

Bracket toes and sniped end members are to be kept within 25 mm of the adjacent member, unless the bracket or member is supported by another member on the opposite side of the plating. The depth of toe or sniped end is generally not to exceed 15 mm.

Where a strength deck or shell longitudinal terminates without an end attachment, the longitudinal is to extend into the adjacent transversely framed structure, or stop at a local transverse member fitted at about one transverse frame space (see Ch2. Sec.5 1.3) beyond the last floor or web that supports the longitudinal.

The end attachments of non-load bearing members may, in general, be snipe ended. The sniped end is to be not more than 30° and is to be kept generally within 40 mm of the adjacent member unless it is supported by a member on the opposite side of the plating. The depth of the toe is generally not to exceed 15 mm.

8.3 Fabrication

Structural fabrication is to be carried out in accordance with a recognized standard to the satisfaction of the attending Surveyor. If a recognized national standard or an appropriate shipbuilding and repair standard is not available, the latest version of IACS Recommendation No. 47 “Shipbuilding and Repair Quality Standard” may be used.

Chapter 2 Hull Structures and Arrangements

Section 1 Longitudinal Strength

1 Application

This requirement applies to steel ships in unrestricted service. For ships having one or more of the following characteristics, special additional considerations will be given by ACS.

(i) Proportion $L/B \leq 5$, $B/D \geq 2.5$

(ii) Length $L \geq 500$ m

(iii) Block coefficient $C_b < 0.6$

(iv) Large deck opening

(v) Ships with large flare

(vi) Carriage of heated cargoes

(vii) Unusual type or design

2 Longitudinal Hull Girder Strength

2.1 Sign Convention of Bending Moment and Shear Force

The sign convention for bending moment and shear force is shown in Figure 2.1.

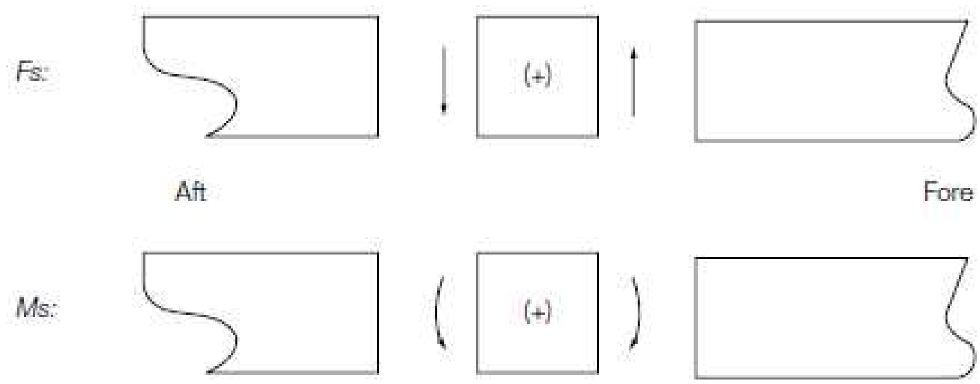


Figure 2.1: sign convention for bending moment and shear force

2.2 Still-water Bending Moment and Shear Force

2.2.1 General

If the design still water bending moments are not defined, at a preliminary design stage, at any hull transverse section, the longitudinal distributions shown in Fig 2.2 may be considered.

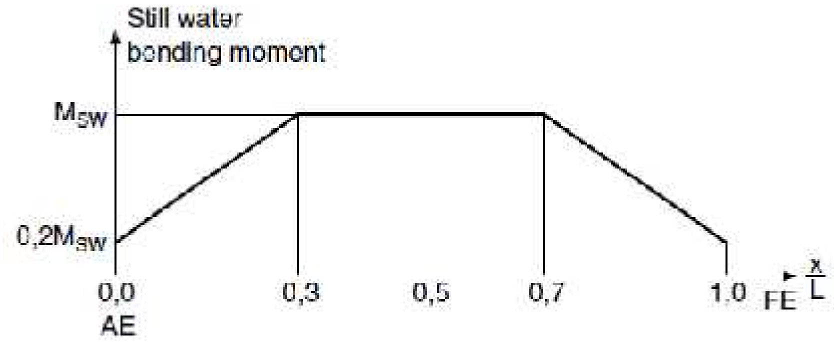


Figure 2.2: Preliminary still water bending moment distribution

Still water bending moments, Ms (kN-m), and still water shear forces, Fs (kN), are to be calculated at each section along the ship length for design cargo and ballast loading conditions as specified in the following subsections.

The still water bending moment amidship, Mswm,in hogging or sagging conditions, whose absolute values are not to be taken less than those obtained, in KN.m, by the following formulae:

- Hogging Condition: $Mswm = 175 \; C \, L^2 \, B(Cb + 0,7) \, 10^{-3} - Mwh$ (kN - m)
- Sagging Condition: $Mswm = 175 \; C \, L^2 \, B(Cb + 0,7) \, 10^{-3} + Mws$ (kN - m)

For these calculations, downward loads are assumed to be taken as positive values, and are to be integrated in the forward direction from the aft end of L. The sign conventions of Ms and Fs are as shown in Fig. 2.1.

2.2.2 Design loading Conditions

In general, the following design cargo and ballast loading conditions, based on amount of bunker, fresh water and stores at departure and arrival, are to be considered for the Ms and Fs calculations. Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted in addition to those for departure and arrival conditions. Also, where any ballasting and/or deballasting is intended during voyage, calculations of the intermediate condition just before and just after ballasting and/or deballasting any ballast tank are to be submitted and where approved included in the loading manual for guidance.

General cargo ships, container ships, roll-on/roll-off and refrigerated cargo carriers, bulk carriers, ore carriers:

- Homogeneous loading conditions at maximum draught
- Ballast conditions
- Special loading conditions e.g., container or light load conditions at less than the maximum draught, heavy cargo, empty holds or non-homogeneous cargo conditions, deck cargo conditions, etc., where applicable.
- All loading conditions specified in UR S25 Section 4 for bulk carriers with notation BC-A, BC-B or BC-C, as applicable.

Oil tankers:

- Homogeneous loading conditions (excluding dry and clean ballast tanks) and ballast or part loaded conditions
- Any specified non-uniform distribution of loading
- Mid-voyage conditions relating to tank cleaning or other operations where these differ significantly from the ballast conditions.

Chemical tankers:

- Conditions as specified for oil tankers
- Conditions for high density or segregated cargo.

Liquefied gas carriers:

- Homogeneous loading conditions for all approved cargoes
- Ballast conditions
- Cargo conditions where one or more tanks are empty or partially filled or where more than one type of cargo having significantly different densities are carried.

Combination Carriers:

- Conditions as specified for oil tankers and cargo ships.

2.2.3 Partially filled ballast tanks in ballast loading conditions

Ballast loading conditions involving partially filled peak and/or other ballast tanks at departure, arrival or during intermediate conditions are not permitted to be used as design conditions unless:

- design stress limits are satisfied for all filling levels between empty and full, and
- for bulk carriers, UR S17, as applicable, is complied with for all filling levels between empty and full.

To demonstrate compliance with all filling levels between empty and full, it will be acceptable if, in each condition at departure, arrival and where required by 2.2.2 any intermediate condition, the tanks intended to be partially filled are assumed to be:

- empty
- full
- partially filled at intended level

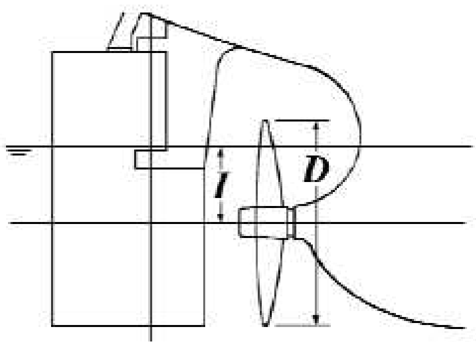
Where multiple tanks are intended to be partially filled, all combinations of empty, full or partially filled at intended level for those tanks are to be investigated.

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

- trim by stern of 3% of the ship's length, or
- trim by bow of 1.5% of ship's length, or
- any trim that cannot maintain propeller immersion (I/D) not less than 25%, where;

I = the distance from propeller centerline to the waterline

D = propeller diameter (see the following figure)



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

2.2.4 Partially filled ballast tanks in cargo loading conditions

In cargo loading conditions, the requirement in 2.2.3 applies to the peak tanks only.

2.2.5 Sequential ballast water exchange

Requirements of 2.2.3 and 2.2.4 are not applicable to ballast water exchange using the sequential method.

2.3 Wave loads

2.3.1 Wave bending moment

The wave bending moments, Mw, at each section along the ship length are given by the following formulae:

M_{wh} (+)= + 190 M C L^2 B C_b x 10^{-3} (kN - m) ... For positive moment

M_{ws} (-) = - 110 M C L^2 B (C_b + 0.7) x 10^{-3} (kN - m) ... For negative moment

Where:

M = Distribution factor given in Fig. 2.3

$C = 0.0707\ L \qquad L<90$

$= 10.75 - \left(\frac{300-L}{100}\right)^{1.5} \qquad 90 \le L \le 300$

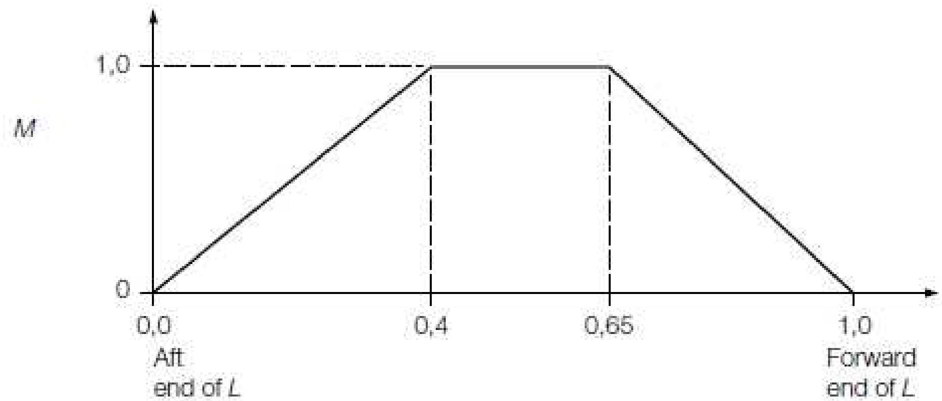
$= 10.75 \qquad 300 \le L \le 350$

$= 10.75 - \left(\frac{L-350}{150}\right)^{1.5} \qquad 350 \le L \le 500$

L = Length of the ships in metres

B = Greatest molded breadth in metres

C_b = Block coefficient,but not to be taken less than 0.6



Distance from the aft end of L in terms of L

Figure 2.3 Distribution Factor M

2.3.2 Envelope Curve of Wave Bending Moment

The wave bending moment along the length, L, of the vessel may be obtained by multiplying the midship value by the distribution factor M, given by Figure 2.3.

2.3.3 Wave Shear Force

The wave shear forces, Fw, at each section along the length of the ship are given by the following formulae:

$F_w\ (+) = +\ 30\ F_1\ C\ L\ B\ (C_b + 0.7) \times 10^{-2}$ (kN) For positive shear force

$F_w\ (–) = –\ 30\ F_2\ C\ L\ B(C_b + 0.7) \times 10^{-2}$ (kN) For negative shear force

F_{wp}, F_{wn} = maximum shearing force induced by wave, in kN

C = as defined in 2.3.1

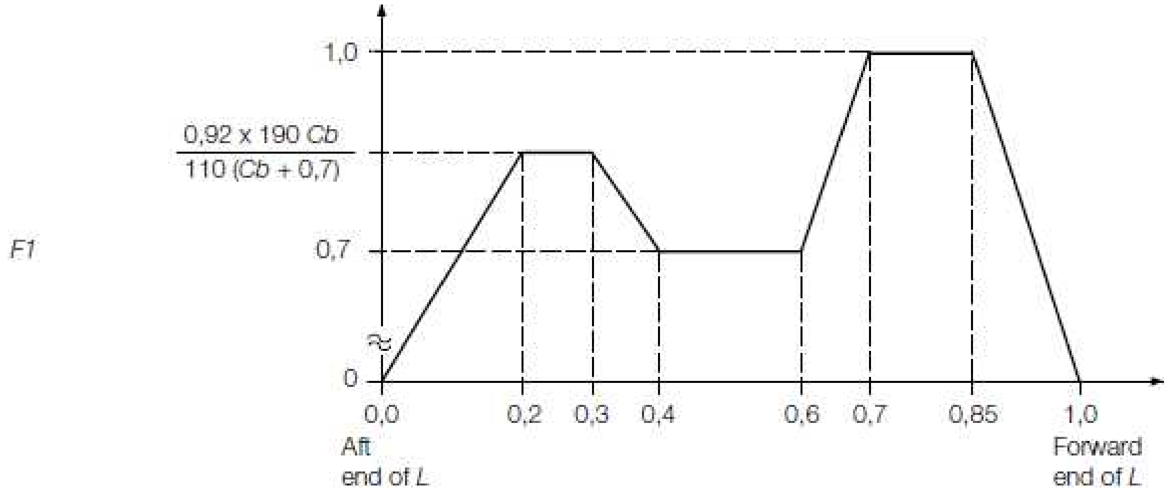
L = length of vessel, in m

B = breadth of vessel, in m

C_b = block coefficient, but not to be taken less than 0.6

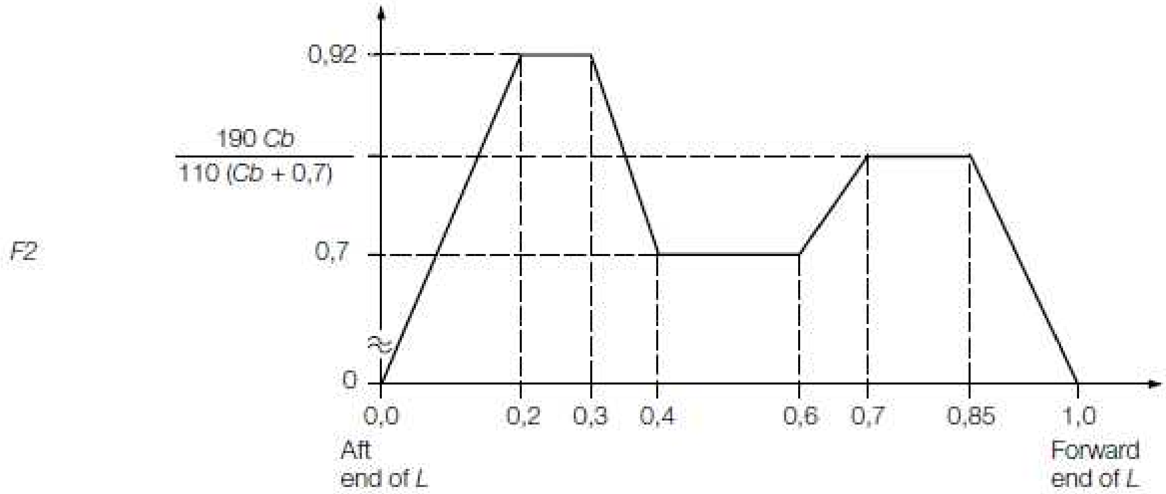
F_1 = distribution factor, as shown in Figure 2.4

F_2 = distribution factor, as shown in Figure 2.5



Distance from the aft end of L in terms of L

Figure 2.4 Distribution Factor F1



Distance from the aft end of L in terms of L

Figure 2.5 Distribution Factor F2

2.4 Bending Strength Standard

2.4.1 Hull Girder Section Modulus

2.4.1 (a) Hull Section Modulus. Hull section modulus is not to be less than the values given by the following formula in way of 0.4 L midships for the still water bending moments Msw and the wave bending moments Mw.

$SM = (M_{sw} + M_w) / \sigma_p \ \ m^3$

where

M_{sw} = still-water bending moment in KN-m

M_w = maximum wave-induced bending moment in KN-m

σ_p = nominal permissible bending stress = 175 x 10^3 in KN/m^2

The total bending moment, M_t, is to be considered as the maximum algebraic sum (see sign convention in 2.1) of still-water bending moment and wave-induced bending moment, as follows:

$M_t = (M_{sw} + M_w)$

2.4.1 (b) Minimum Section Modulus. The minimum hull girder section modulus amidships is not to be less than obtained from the following equation:

SM = 0.01 CL^2B (C_b + 0.7) cm^2-m

Where C, L (Length in m), B (breadth in m), C_b (block coefficient not to be taken less than 0.6) as defined in 2.3.1.

2.4.1 (c) Extension of Midship Section Modulus. In general, where the still-water bending moment envelope curve is not submitted or where 2.4.1(b) governs, scantlings of all continuous longitudinal members of the hull girder are to be maintained throughout 0.4L amidships and then may be gradually tapered beyond.

Where the scantlings are based on the still-water bending moment envelope curves, 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.

2.4.2 Hull Girder Moment of Inertia

The hull girder moment of inertia, I, amidships, is to be not less than:

I = L SM/33.3 cm^2- m^2

where

L = length of vessel, in m

SM = required hull girder section modulus, in cm^2-m. See 2.4.1.

2.4.3 Hull Girder Strength Outside of 0.4L Amidships

The strength of the hull girder is to be checked at sections outside of 0.4L amidships. The required section modulus for the regions outside 0.4L amidships is to be obtained based on the total bending moment at the section considered and applying the permissible bending stress as given in 2.4.1(a). As a minimum hull girder bending strength checks are to be carried out at the following locations:

- In way of the forward end of the engine room.
- In way of the forward end of the foremost cargo hold.
- At any locations where there are significant changes in the hull cross-section.
- At any locations where there are changes in the framing system.

Continuity of structure is to be maintained throughout the length of the ship. Where significant changes in the structural arrangement occur adequate transitional structure is to be provided.

For ships with large deck openings, such as containerships, sections at or near to the aft and forward quarter length positions are to be checked. For such ships with cargo holds aft of the superstructure, deckhouse or engine room, strength checks of sections in way of the aft end of the aft-most holds, and the aft end of the deckhouse or engine room are to be performed.

Buckling strength of members contributing to longitudinal strength and subjected to compressive and shear stresses is to be checked in accordance with subsection 10, in particular in regions where changes in the framing system or significant changes in the hull cross-section occur.

2.5 Shearing Strength

2.5.1 General

In calculating the nominal total shear stress, f_s, due to still-water and wave-induced loads, the maximum algebraic sum of the shearing force in still-water F_{sw} and that induced by wave F_w at the station examined is to be used. The thickness of the side shell, and where fitted, the longitudinal bulkhead, is to be such that the nominal total shear stress f_s, as obtained from 2.5.2 or 2.5.4, are not greater than 11.0 kN/cm^2 .

2.5.2 Shearing Strength for Vessels without Effective Longitudinal Bulkheads

For vessels without continuous longitudinal bulkheads, the nominal total shear stress ,f_s, in the side shell plating may be obtained from the following equation:

$f_s = (F_{sw} + F_w)\, m/(2\, t_s\, I)$

where

I = moment of inertia of the hull girder at the section under consideration, in cm^4

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

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

F_{sw} = hull girder shearing force in still-water, in kN

$F_w = F_{wp}$ or F_{wn}, as specified by 2.3.3, in kN, depending upon loading

2.5.3 Modification of Hull girder Shearing Force Peaks

The hull girder shearing force in still water, F_{sw}, to be used for calculating shear stresses in the side shell plating may be modified to account for the loads transmitted through the double bottom structure to the side shell through the transverse bulkhead. For this modification, unless a detailed calculation is performed, the following equation may be used as guidance to determine the shear force carried by the side shell at the transverse bulkhead (Figure 2.6), provided that the girders in the double bottom are arranged in accordance with rules, as appropriate.

$F_s = F_{sw} - F_B$ in kN

Where

F_{sw} = hull girder shearing force in still water as obtained by the conventional direct integration method, in kN.

$F_B = F_{BA}$ or F_{BF} , whichever is the lesser

$F_{BA} = (0.45 – 0.2\ l_A / b_A)\ W_A\ b_A /B$

$F_{BF} = (0.45 – 0.2\ l_F / b_F)\ W_F\ b_F /B$

W_A, W_F = total load (net weight or net buoyancy) in the hold immediately abaft or forward of the bulkhead in question, in kN

l_A, l_F = length of the adjacent holds, respectively, containing W_A and W_F, in m

b_A, b_F = breadth of the double bottom structure in the holds immediately abaft and forward of the bulkhead in question, respectively, in m. For vessels having lower wing tanks with sloping tops, making an angle of about 45 degrees with the horizontal, the breadth may be measured between the midpoints of the sloping plating. For vessels having double skins with flat inner bottom, it may be measured to the inner skins.

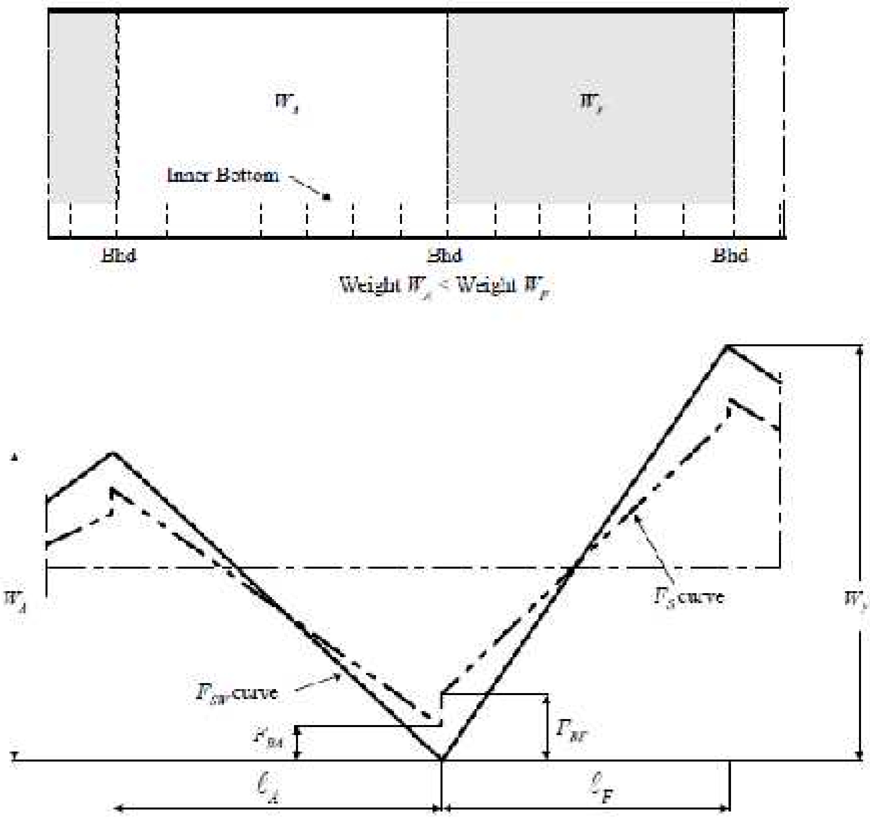
B = breadth of vessel, in m

2.5.4 Shearing Strength for Vessels with Two or Three Longitudinal Bulkheads

For vessels having continuous longitudinal bulkheads, the total shear stresses in the side shell and the longitudinal bulkheads are to be calculated by an acceptable method. In determining the Stillwater shear force, consideration is to be given to the effects of non-uniform athwartship distribution of loads. The method described in Appendix 1 may be used as a guide in calculating the nominal total shear stress f_s, related to the shear flow in the side shell or longitudinal bulkhead plating.

Alternative methods of calculation may also be considered.

Figure 2.6 Shear Force Distribution



3 Longitudinal Strength with Higher-Strength Materials

3.1 General

Vessels where 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 steel, are to have longitudinal strength generally in accordance with the preceding paragraphs of this section, but the value of the hull girder section modulus and permissible shear stress may be modified as permitted by 3.3 and 3.4. Application of higher-strength material is to be continuous over the length of the vessel to locations where the stress levels will be suitable for the adjacent 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 continuous throughout the required extent of higher-strength steel.

3.2 Hull Girder Moment of Inertia

The hull girder moment of inertia is to be not less than required by 2.4.2 using the mild steel section modulus obtained from 2.4.1.

3.3 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 2.4, may be reduced by the factor Q.

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

where

SM = section modulus as obtained from 2.4

Q = 0.78 for AH32 strength steel

Q = 0.72 for AH36 strength steel

Q = 0.68 for AH40 strength steel

A32, A36, A40 = as specified in Part 2 Chapter 3.

Q factor for steels having other yield points or yield strengths will be specially considered.

3.4 Hull girder Shearing Force

Where the side shell or longitudinal bulkhead is constructed of higher strength material, the permissible shear stresses indicated in 2.5 may be increased by the factor 1/Q. For plate panel stability, see 10.

4 Loading Guidance

4.1 Loading Manual and Loading Instrument

All vessels contracted for construction on or after 1 July 1998, are to be provided with a loading manual and, where required, a loading instrument in accordance with Appendix 2.

In addition, bulk carriers, ore carriers and combination carriers 150 m or more in length (Lf) are to comply with the requirements in Appendix 3.

4.2 Allowable Stresses

4.2.1 At Sea

See 2.4.1 for bending stress and 2.5.1 for shear stress for vessels with ordinary strength steel material. For higher-strength steel, the allowable stress may be increased by a factor of 1/Q where Q is as defined in 3.3.

4.2.2 In Port

The allowable still water in-port stress is 131.3 N/mm^2 for bending and 100 N/mm^2 for shear. For higher-strength steel, the allowable stress may be increased by a factor of 1/Q where Q is as defined in 3.3.

5 Section Modulus Calculation

5.1 Items Included in the Calculation

In general, the following items may be included in the calculation of the hull girder section modulus, provided that they are continuous or effectively developed:

• Deck plating (strength deck and other effective decks)

- Shell and inner bottom plating
- Deck and bottom girders
- Plating and longitudinal stiffeners of longitudinal bulkheads
- All longitudinals of deck, side, bottom and inner bottom
- Continuous longitudinal hatch coamings. see sub-section 7.

5.2 Effective Areas Included in the Calculation

In general, all openings are to be deducted from the sectional areas of longitudinal strength members to be used in the hull girder section modulus calculation, except that small isolated openings need not be deducted, provided that these openings and the shadow area breadths of other openings in any one transverse section do not reduce the hull girder section modulus by more than 3%. The breadth or depth of such openings is not to be greater than 1200 mm or 25% of the breadth or depth of the member in which it is located, whichever is less, with a maximum of 75 mm for scallops. The length of small isolated openings, which are not required to be deducted, is generally not to be greater than 2500 mm. The shadow area of an opening is the area forward and aft of the opening enclosed by lines drawn tangential to the corners of the opening and intersecting each other to form an included angle of 30 degrees. See Figure 3.1.

5.3 Section Modulus to the Deck or Bottom

The section modulus to the deck, or bottom, is obtained by dividing the moment of inertia I by the distance from the neutral axis to the molded deck line at side or to the base line, respectively.

5.4 Section Modulus to the Top of Hatch Coamings

For continuous longitudinal hatch coamings, in accordance with 7, the section modulus to the top of the coaming is to be obtained by dividing the moment of inertia I by the distance from the neutral axis to the deck at side plus the coaming height. This distance need not exceed yt as given by the following equation, provided that yt is not less than the distance to the molded deck line at side.

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

where

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

x = distance, in m, at the top of the hatch coaming from the outboard edge of the continuous coaming web plate to the centerline of the vessel

B = breadth of vessel, in m

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

Section modulus to the top of longitudinal hatch coamings between multi-hatchways will be subject to special considerations.

6 Strength Decks

6.1 Definition

The uppermost deck to which the side shell plating extends is to be considered the strength deck for that portion of the length, except in way of short superstructures, wherein the modified requirements for the side shell and superstructure deck are adopted. In way of such superstructures, the deck on which the superstructures are located is to be considered the strength deck.

6.2 Tapering of Deck Sectional Areas

In general, the tapering of deck sectional areas beyond the amidship 0.4L is to be in accordance with 2.4.1(c). The deck sectional area at 0.15L from the ends may be one-half of the amidships deck area. In way of a superstructure beyond the amidship 0.4L, the strength deck area may be reduced to approximately 70% of the deck area required at that location if there were no superstructure.

7 Continuous Longitudinal Hatch Coamings and Above Deck Girders

Where strength deck longitudinal hatch coamings of length greater than 0.14L are effectively supported under by longitudinal bulkheads or deep longitudinal girders, the coamings are to be longitudinally stiffened in accordance with 3.2.15 / 3.5. The hull girder section modulus amidships to the top of the coamings is to be as required by 2.4.1, 2.4.2 and 5.4, but the section modulus to the deck at side, excluding the coamings, need not be determined in way of such coamings.

Continuous longitudinal girders on top of the strength deck are to be considered similarly. Their scantlings are also to be in accordance with 3.2.8

8 Effective Lower Decks

To be considered effective, and in order to be included in calculating the hull girder section modulus, the thickness of the stringer plate and the deck plating is to comply with the rule requirements of 3.2.3/3. The sectional areas of lower decks used in calculating the section modulus are to be obtained as described in 5.2, but should exclude the cutout in the stringer plate in way of through frames. In general, where the still-water bending moment envelope curve is not submitted, or where 2.4.1(b) governs, these areas are to be maintained throughout the midship 0.4L and may be gradually reduced to one-half their midship value at 0.15L 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.

9 Longitudinal Deck Structures Inboard of Lines of Openings

9.1 General

Where deck structures are arranged with two or more large openings abreast, the degree of effectiveness of that portion of the longitudinal structure located between the openings is to be determined in accordance with the following:

Plating and stiffening members forming these structures may be included in the hull girder section modulus calculation, 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.

9.2 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 section modulus. Longitudinal deck structures, not supported by longitudinal bulkheads, but of 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. The effective area, obtained as the product of the net sectional area of the longitudinal deck structure inboard of lines of hatch openings and the factor H_0, as given below, may be used in the hull girder section modulus calculations.

$$H_0 = \frac{0.62}{1 + 0.38(A_0 / A + Z^2 A_0 / I)}$$

where

A = cross sectional area of hull girder amidships, port and starboard, excluding longitudinal deck structures inside the lines of outermost hatch openings, in cm^2

I = moment of inertia of hull girder amidships, port and starboard, about the horizontal neutral axis, excluding longitudinal deck structures inside the lines of outermost hatch openings, in cm^2-m^2

Z = distance between the horizontal neutral axis of area A, and the centroid of area A_0 , in m

A_0 = total cross sectional area of the longitudinal deck structures inside the lines of outermost hatch openings, including plating, longitudinal stiffeners, and girders, port and starboard, in cm^2.

An efficiency factor obtained by other methods of engineering analysis will be subject to special consideration.

10 Buckling Strength

Where the various strength members are subjected to compressive or shear stresses due to longitudinal bending, the stability of the local plate panels and the supporting members is to be checked against buckling.

Calculations, in accordance with Appendix 4, are to be submitted for review.

Where still water bending moments are positive (hogging) in all operating conditions, the total bending moment, Mt , is to be taken as not less than 0.9Mws for the purpose of evaluating the structural stability of the hull girder upper flange. Where it can be shown that all possible conditions of loading between lightship and full load draft result in positive (hogging) still water bending moments, such as with passenger vessels, the above specified minimum total bending moment may be specially considered. A statistical analysis of wave induced bending moment is to be carried out in such instances, taking into account the effect of the hull form including bow flare.

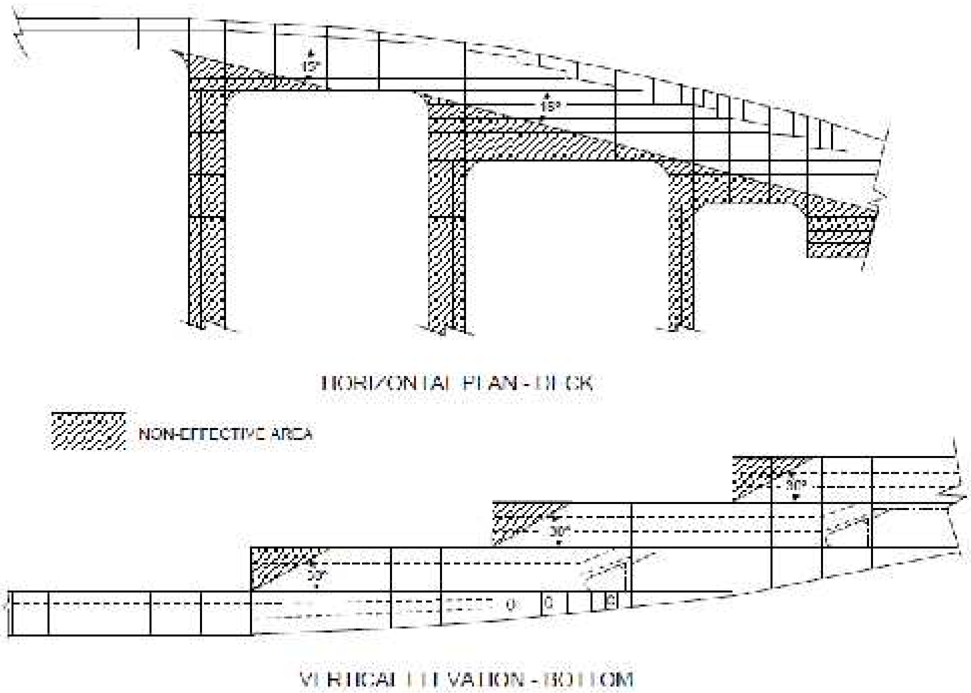


Figure 3.1 Effective Area of Hull Girder Members

Section 2 Shell Plating

1 Application

Shell plating is to be of not less thickness than is required for purposes of longitudinal hull girder strength; nor is it to be less than is required by this section. In general, the shell plating is not to be less in thickness than required by section 10/2.1 for deep tanks. For bottom shell plating bounding tanks having normal tank/air vent configurations in order to avoid accidental overpressure, the head “h” need not be greater than the distance from the plate under consideration to the deck at side. In the case of unusual configurations, or where the tanks are intended to carry liquids having a specific gravity equal to or greater than 1.05, “*h*” should be in accordance with section 10/2.1.

2 Shell Plating Amidships

2.1 Vessels with no Partial Superstructures above Uppermost Continuous Deck

In vessels that 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 molded depth, in m, measured to the uppermost continuous deck.

2.2 Superstructures Fitted above Uppermost Continuous Deck (Side Plating Extended)

Where superstructures are fitted above the uppermost continuous deck to which the side plating extends throughout the amidship 0.4L, the thickness of the bottom and side plating is to be obtained from the appropriate equations where D_s is the molded depth, in m, measured to the superstructure deck. In such cases, the sheer strake beyond the superstructure is to be proportioned from the thickness as required for the sheer strake amidships, where D_s is measured to the uppermost continuous deck.

2.3 Superstructures Fitted above Uppermost Continuous Deck (Side Plating Not Extended)

Where superstructures are fitted above the uppermost continuous deck, to which the side plating does not extend throughout the amidship 0.4L, the thickness of the bottom and side plating is to be obtained from the appropriate equations where D_s is the molded depth, in m, measured to the uppermost continuous deck.

2.4 In way of Comparatively Short Superstructures

In way of comparatively short superstructure decks, or where the superstructure deck is not designed as the strength deck, the thickness of the bottom and side plating is to be obtained from the appropriate equations where D_s is the molded depth, in m, measured to the uppermost continuous deck. In such cases, the thickness of the side plating above the uppermost continuous deck is to be specially considered, but in no case is the thickness to be less than that obtained from equations 1a and 1b in Sec.3/Table 3.2, but substituting the frame spacing, in mm, for s_b in lieu of the deck beam spacing.

2.5 Side Shell Plating

The minimum thickness, t, of the side shell plating throughout the amidship 0.4L, for vessels having lengths not exceeding 427 m, is to be obtained from the following equations:

$t = (s\sqrt{h}/268) + 2.5$ mm for $L \le 90$ m

$t = (s/645)\sqrt{(L-15.2)(d/D_S)} + 2.5$ mm for $90 < L \le 305$ m

$t = (s/828)\sqrt{(L+175)(d/D_S)} + 2.5$ mm for $305 < L \le 427$ m

where

s = spacing of transverse frames or longitudinals, in mm

L = length of vessel, as defined in Ch.1 Sec.1/1.1, in m

h = depth, as defined in Ch.1 Sec.1/1.4, in m

d = molded draft, as defined in Ch.1 Sec.1/1.4, in m

D_s = molded depth, in m, as defined in Ch.1 Sec.1/1.3 in m

The actual ratio of d/D_S is to be used in the above equations, except that the ratio is not to be taken less than 0.0433 L/D_S.

The side shell thickness amidships is to be not less than the thickness obtained by 3.1 using 610 mm as the frame spacing.

2.6 Sheer Strake

The minimum width, b, of the sheer strake throughout the amidship 0.4L is to be obtained from the following equations:

b = 5L + 800 mm for L < 200 m

b = 1800 mm for 200 ≤ L ≤ 427 m

where

L = length of vessel, as defined in Ch..1 Sec..1/1.1, in m

b = width of sheer strake, in mm

In general, the thickness of the sheer strake is not to be less than the thickness of the adjacent side shell plating, nor is it to be less than required by equation 1b or 2b in Sec.3/Table 3.2, as appropriate, from Decks-A of Sec.3/Table 3.1. The thickness of the sheer strake is to be increased 25% in way of breaks of superstructures, but this increase need not exceed 6.5 mm. Where breaks in way of the forecastle or poop are appreciably beyond the amidship 0.5L, this requirement may be modified.

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

2.7 Bottom Shell Plating Amidships

2.7.1 Extent of Bottom Plating Amidships

The term “bottom plating amidships” refers to the bottom shell plating from the keel to the upper turn of the bilge, extending over the amidships 0.4L.

2.7.2 Bottom Shell Plating

The thickness, t, of the bottom plating amidships is not to be less than obtained from the following equations or the thickness determined by 2.9, whichever is greater.

2.7.2 (a) For Vessels with Transversely-framed Bottoms

$$t = (s/519)\sqrt{(L-19.8)(d/D_S)} + 2.5 \quad \text{mm} \qquad \text{for } L \le 183 \text{ m}$$

2.7.2 (b) For Vessels with Longitudinally-framed Bottoms

$$t = (s/671)\sqrt{(L-18.3)(d/D_S)} + 2.5 \quad \text{mm} \qquad \text{for } L \le 122 \text{ m}$$

$$t = (s/508)\sqrt{(L-62.5)(d/D_S)} + 2.5 \quad \text{mm} \qquad \text{for } 122 < L \le 305 \text{ m}$$

$$t = (s/661)\sqrt{(L-105)(d/D_S)} + 2.5 \quad \text{mm} \qquad \text{for } 305 < L \le 427 \text{ m}$$

where L, d, s, and D_s are as defined in 2.5.

The actual ratio of d/D_s is to be used in the above equations, but the ratio is not to be taken less than 0.0433 L/D_s.

After all corrections have been made, the bottom shell thickness amidships is not to be less than the thickness obtained by 3.1 using 610 mm as the frame spacing.

Where the actual bottom hull girder section modulus SM_A is greater than required by Ch.2 Sec.1/ 2.4.1, 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 defined as follows:

$$R_n = \sqrt{\frac{1}{(f_p/\pm_t)(1 - SM_R/SM_A) + 1}}$$ but is not to be taken less than 0.85 ($d/D_s \ge$ 0.65)

= 1.0 ($d/D_s \le 0.0433L/D_s$)

= by linear interpolation ($0.0433L/D_s < d/D_s < 0.65$)

where

f_p = nominal permissible bending stress, in kN/cm^2, as given in Ch.2 Sec.1/2.4.1

$\sigma_t = K P_t (s/t)^2$, in kN/cm^2

K = 0.5 for transverse framing and 0.34 for longitudinal framing

$P_t = 1.005\,(0.638H + d)\,10^{-3}$ kN/cm^2

SM_R = hull girder section modulus required by Ch.2 Sec.1/2.4.1, in cm^2-m

SM_A = bottom hull girder section modulus, in cm^2-m, of the vessel with the greater of the bottom shell plating thickness obtained when applying R_n or R_b

t = bottom shell plating thickness required by 2.7.2(a) or 2.7.2(b), in mm

H = wave parameter, in m

= 0.0172L + 3.653 m $L \le 150$ m

$= 0.0181L + 3.516$ m	$150 < L \le 220$ m
$= [4.50L - 0.0071L^2 + 103]10^{-2}$ m	$220 < L \le 305$ m
$= 8.151$ m	$305 < L \le 427$ m

L, d and D_s are as defined in 2.5.

R_b is defined in 2.9.2.

SM_R/SM_A is not to be taken as less than 0.70

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

2.8 Flat Plate Keel

The thickness of the flat plate keel is to be 1.5 mm greater than that required for the bottom shell plating at the location under consideration. This 1.5 mm increase in thickness is not required where the submitted docking plan specifies that all docking blocks are to be arranged clear of the flat plate keel. See Ch.1 Sec.2/6 and sub-section 4.

2.9 Minimum Thickness

After all other requirements are met, the thickness, t_{min}, of the shell plating amidships below the upper turn of bilge is not to be less than obtained from the following equations:

2.9.1 Transverse Framing

$t_{min} = s\,(L + 45.73)/(25L + 6082)$ mm for $L \le 183$ m

where

s = frame spacing, in mm, but is not to be less than that given in Ch.2 Sec.5/1.4

L = length of vessel, as defined in Ch.1 Sec.1/1.1, in m

2.9.2 Longitudinal Framing

$t_{min} = s(L - 18.3)/(42L + 1070)$ mm for $L \le 427$ m

where

s = frame spacing, in mm, but is not to be less than 88% of that given in Ch.2 Sec.5/1.4 or 813 mm, whichever is less

L = length of vessel, as defined in Ch.1 Sec.1/1.1, in m

Where the bottom hull girder section modulus SM_A is greater than required by Ch.2 Sec.1/2.4.1, and still-water bending moment calculations are submitted, the thickness of bottom shell plating amidships, obtained from the above equations, may be multiplied by the factor, R_b.

$R_b = (SM_R / SM_A)^{0.5}$ but is not to be taken less than 0.85	$(d/D_s \ge 0.65)$
$= 1.0$	$(d/D_s \le 0.0433L/D_s)$
= by linear interpolation	$(0.0433L/D_s < d/D_s < 0.65)$

where SM_R and SM_A are as defined in 2.7.2.

For transverse framing, R_b is to be not less than $1.2285 - L/533.55$, where L is as defined above, but is not to be taken as less than 122 m.

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

3 Shell Plating at Ends

3.1 Minimum Shell Plating Thickness

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

$t = 0.0463 L + 0.009 s$ mm for $L \le 90$ m

$t = 0.035 (L + 29) + 0.009 s$ mm for $90 < L \le 305$ m

$t = (11.70 + 0.009s) (D /35)^{0.5}$ mm for $305 < L \le 427$ m

where

s = fore or aft peak frame spacing, in mm

L = length of vessel, as defined in Ch.1 Sec.1/1.1, in m

D = molded depth, in m, as defined in Ch.1 Sec.1/1.3 or 35 m, whichever is greater

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.

3.2 Immersed Bow Plating

The thickness t of the plating below the load waterline forward of 0.16L 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.

$t = 0.06 L + 0.009s$ mm for $L \le 90$ m

$t = 0.05(L + 20) + 0.009s$ mm for $90 < L \le 305$ m

$t = (16.25 + 0.009s) (D / 35)^{0.5}$ mm for $305 < L \le 427$ m

where

s = fore peak frame spacing, in mm

L = length of vessel, as defined in Ch.1 Sec.1/1.1, in m

D = molded depth, in m, as defined in Ch.1 Sec.1/1.3 or 35 m, whichever is greater

3.3 Bottom Forward

Where the forward draft of the vessel in the ballast loading condition to be used while the vessel is in heavy weather (heavy ballast draft forward) is less than 0.04L m, the plating on the flat of bottom forward, forward of the location given in Ch.2 Sec.4/Table 7.1 is to be not less than required by the following equation:

$$t = 0.0046 s \sqrt{(0.005 L_1^2 - 1.3 d_f^2) / d_f} \quad \text{mm}$$

where

s = frame spacing, in mm

L_1 = length of vessel, as defined in Ch.1 Sec.1/1.1, in m, but need not be taken greater than 214 m

L = length of vessel, as defined in Ch.1 Sec.1/1.1, in m

d_f = heavy 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 2.7, 3.1 and 3.3, as appropriate.

3.4 Forecastle Side Plating

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

$t = 0.038(L + 30.8) + 0.006\,s$	mm	$L \le 90$ m
$t = 0.05(L + 76) + 0.006(s - S)$	mm	$90 < L \le 106.5$ m
$t = 0.035(L + 154) + 0.006(s - S)$	mm	$106.5 < L$ m

where

s = spacing of longitudinal or transverse frames, in mm

S = standard frame spacing, in mm, given by the equation in Ch.2 Sec. 5/1.4 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 vessel, as defined in Ch.1 Sec.1/1.1, in m, but need not be taken more than 305 m

3.5 Poop Side Plating

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

$t = 0.0296(L + 39.5) + 0.006\,s$	mm	$L \le 90$ m
$t = 0.0315(L + 150) + 0.006(s - S)$	mm.	$90 < L$ m

where

s = spacing of longitudinal or transverse frames, in mm

S = standard frame spacing, in mm, given by the equation in Ch.2 Sec.5/1.4 with an upper limit of 1070 mm, except that in way of the aft peak, the standard frame spacing is not to exceed 610 mm

L = length of vessel, as defined in Ch.1 Sec.1/1.1, in m, but need not be taken more than 305 m

3.6 Bow and Stern Thruster Tunnels

The thickness of the tunnel plating is not to be less than required by 3.1, where *s* is to be taken as the standard frame spacing given by the equation in Ch.2 Sec.5/1.4, nor is the thickness to be less than obtained from the following equation:

$t = 0.008d + 3.3$ mm

where

d = inside diameter of the tunnel, in mm, or 968 mm, whichever is greater

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

3.7 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 vessels 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.

3.7.1 Spectacle Bossing

$t = 0.088(L - 23) + 0.009s$ mm for $L \le 427$ m

where

L = length of vessel, as defined in Ch.1 Sec.1/1.1, in m

s = frame spacing, in mm

3.7.2 Other Plates on Stern Frame

$t = 0.094(L - 16) + 0.009s$ mm for $L \le 427$ m

where

L = length of vessel, as defined in Ch.1 Sec.1/1.1, in m

s = frame spacing, in mm

3.7.3 Boss and Heel Plates

The thickness of the boss and heel plating is to be at least 20% greater than the thickness of spectacle bossing obtained in 3.7.1.

4 Bottom Shell Plating for Special Docking Arrangement

Where it is not intended to use keel blocks when drydocking the vessel, the increase to the keel plate thickness in 2.8 will not be required. However, the thickness of the bottom shell plating strakes in way of the docking blocks to be used in lieu of keel blocks when drydocking the vessel is to be increased by 1.5 mm. In such instances, the recommended docking arrangement is to be indicated on the structural plans submitted for approval and also on the docking plan to be furnished to the vessel.

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, fueling 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 is proposed to fit port-lights in the shell plating, the locations and sizes are to be clearly indicated on the midship-section drawing when first submitted for approval.

6 Breaks

Vessels having partial superstructures are to be specially strengthened in way of breaks to limit the local increase in stresses at these locations. The stringer plate thickness and the sheer strake thickness at the lower level is to be doubled or increased in thickness well beyond the break in both directions. The thickness increase is to be 25% in way of breaks in the superstructures, but the increase need not exceed 6.5 mm. The side plating of the superstructure is to be increased in thickness in way of the break.

The side shell plating below the sheer strake and in way of the break is to be increased appropriately and is to extend well beyond the end of the superstructure in such a fashion as to provide a long gradual taper.

Where the breaks of the forecastle or poop are appreciably beyond the amidship 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 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 Bilge Keels

Bilge keels where fitted, are to be attached to the shell by a doubler. In general, both the bilge keel and the doubler are to be continuous. The connections 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, and doubler butts are to be flush in way of the bilge keel. In general, scallops and cutouts are not to be used. Where desired, a drilled crack arresting hole, at least 25 mm in diameter, may be provided in the bilge keel butt weld as close as practicable to the doubler.

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.

8 Higher-strength Materials

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 Ch.2 Sec.1/3.1. 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 the bottom and side shell plating, where constructed of higher strength materials, is to be not less than required for the purpose of longitudinal hull girder strength; nor is the thickness to be less than required by the foregoing paragraphs of this section when modified as indicated in 8.2 and 8.3.

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:

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

where

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

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

The requirements t_{min} given in 2.9 are to be used in the above equation with the factor $0.92/\sqrt{Q}$ substituted for Q. The value of $0.92/\sqrt{Q}$ is not to be less than 1.00.

C = 4.3 mm

Q = as defined in Ch.2 Sec.1/3.3

Where the bottom shell plating is transversely framed, the thickness will be specially considered.

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 8.2

Where the side-shell plating is transversely framed, the thickness will be specially considered.

8.4 End Plating

End-plating thickness, including immersed bow plating and plating on the flat of bottom forward, where constructed of higher-strength materials, will be subject to special consideration.

Section 3 Decks

1 General

1.1 Extent of Plating

All exposed decks, portions of decks forming the crowns of machinery spaces, and the boundaries of tanks or steps in bulkheads are to be plated. Decks in other locations are to be plated, as necessary, for strength or water tightness.

2 Hull Girder Strength

2.1 Longitudinal Section Modulus Amidships

The required longitudinal hull girder section modulus amidships is obtained from the equations given in Ch.2 Sec.1/2.4.1 and 3.3

2.2 Strength Deck

For the definition of the strength deck for calculation purposes, see Ch.2 Sec.1/6.1.

2.3 Longitudinally Framed Decks

Where the beams of the strength deck and other decks are fitted longitudinally in accordance with Section Ch.2 Sec.7, the sectional area of effectively developed deck longitudinals may be included in the hull girder section-modulus calculation.

2.4 Superstructure Decks

Superstructure decks which are comparatively short or which are not designed as the strength deck (see Ch.2 Sec.2/2.4 and 2.2) are to comply with the requirements of Ch.2 Sec.11/1.2.

2.5 Deck Transitions

Where the effective areas in the same deck change, as in way of partial superstructures or over discontinuous decks, care is to be taken to extend the heavier plating well into the section of the vessel in which the lesser requirements apply, to obtain a good transition from one arrangement to the other. 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 or the deck material at each level is to be effectively overlapped and thoroughly tied together by diaphragms, webs, brackets, etc., in such manner as will compensate for the discontinuity of the structure. At the ends of partial superstructures, the arrangements are to be as described in Ch. 2 Sec.2/6.

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 where the breaks of poop or forecastle are appreciably beyond the midship 0.5L. The required deck area is to be maintained throughout the amidship 0.4L of the vessel and is to be suitably extended into superstructures located at or near the amidship 0.4L. From these locations to the ends of the vessel, the deck area contributing to the hull girder strength may be gradually reduced in accordance with Ch.2 Sec.1/6.2. 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 Ch.2 Sec.1/6.2. 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 3.1.

3 Deck Plating

3.1 Thickness

The thickness of deck plating is to be not less than obtained from the equations specified in Table 3.1.

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 3.1, appropriate to the depth DS, according to Table 3.1.

In no case is the plating to be less than obtained from I or J in Table 3.1, as appropriate. Stringer plates of effective decks are to be connected to the shell.

3.3 Reinforcement at Openings

3.3.1 Openings in Strength Decks

Unless otherwise specifically required, openings in the strength deck are, in general, to have a minimum corner radius of 0.125 times the width of the opening, but need not exceed a radius of 600 mm. In other decks, the radius is to be 0.09375 times the width of the opening, but need not exceed a radius of 450 mm. Additionally, the minimum radius in way of narrow deck transverse ligaments between adjacent hatch openings having the same width is not to be less than 150 mm.

3.3.2 Openings in Effective Decks

At the corners of hatchways or other openings in effective decks, generous radii are to be provided.

3.3.3 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 webs and heavy pillars in way of deck opening and casings.

3.4 Platform Decks

Lower decks, which are not considered to be effective decks for longitudinal strength, are termed platform decks. The plating thickness is not to be less than obtained from Decks I or J of Table 3.1, as appropriate.

3.5 Superstructure Decks

See Ch.2 Sec.11/1.2.

3.6 Decks Over Tanks

For decks over tanks see Ch.2 Sec.10/2.3.

3.7 Watertight Flats

The thickness of watertight flats over tunnels, or watertight flats forming recesses or steps in bulkheads, is to be not less than the thickness required for the plating of ordinary bulkheads at the same level, plus 1 mm.

3.8 Retractable Tween Decks

The thickness of retractable tween deck plating is not to be less than required by equation 6 of Table 3.2.

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 section modulus, SM, not less than obtained from the following equation.

$SM = 7.8\ chsl^2$ cm^3

where

c = 0.81 for the section modulus to the flange or face bar

= 1.00 for the section modulus to the deck plating

h = p /7.04 m

p = uniform loading, in kN/m^2

s = spacing of the beam or girder, in m

l = unsupported length of the beam or girder, in m

In general, the depth of beams and girders is not to be less than 4% of the unsupported length.

When retractable decks are 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 Ch.2 Sec.15/7.4. The retractable decks are to be secured against movement and effectively supported by the hull structure.

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 the plating of an effective lower deck (see 3.2) is not to be less than obtained from the following equation:

$t = 8.05Kn\sqrt{CW}$ mm

where

K = as obtained from Figure 3.1

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 kN

a = the wheel imprint dimension, in mm, parallel to the longer edge, l, of the plate panel

b = the wheel imprint dimension, in mm, perpendicular to the longer edge, l, of the plate panel

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 not to be less than 110% of that required by the above equation, and platform deck plating thickness is not to be less than 90% of that required by the above 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, then b above may be taken as the larger wheel imprint dimension, in which case a is to be the lesser dimension.

Table 3.1: Applicable Thickness Equations

Decks	Minimum Thickness Equation in Table 3.2
A. Strength Deck Outside Line of Openings 1. With Transverse Beams 2. With Longitudinal Beams	 1a and 1b (note 1) 2a and 2b (note 1)
B. Exposed Strength Deck within Line of Openings	3 (note 2)
C. Enclosed Strength Deck within Line of Openings	5
D. Effective Lower Decks 1. Second Deck: a. $D_S > 15.2$ m b. 15.2 m $\geq D_S \geq$ 12.8 m c. $D_S < 12.8$ m 2. Third Deck: a. $D_S > 17.7$ m b. 17.7 m $\geq D_S \geq$ 13.4 m c. 13.4 m $\geq D_S \geq$ 9.8 m d. $D_S < 9.8$ m	 1a 2a 3 1a 2a 3 4
E. Exposed Forecastle Decks 1. L > 122 m 2. L ≤ 122 m	 2a 3
F. Exposed Poop Decks 1. L > 100 m 2. L ≤ 100 m	 3 5
G. Exposed Bridge Deck	4
H. Long Deckhouse Top	5
I. Platform Decks in Enclosed Cargo Spaces	6 (note 3)
J. Platform Decks in Enclosed Accommodation Spaces	7 (note 3)

Notes:

1) In small vessels 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 1a and 1b; in such cases the remainder of the plating may be obtained from the equation in 5.

2) Equation 3 applies amidships. At the forward and aft ends, plating is to be as required for exposed forecastle and poop deck.

3) Where the platform decks are subjected to hull girder bending, special consideration is to be given to the structural stability of deck supporting members.

Table 3.2: Minimum Thickness Equations

Equation Number	Equation	
1a (notes 1,2)	$t = 0.01s_b + 2.3$ mm $t = 0.0066s_b + 4.9$ mm	for $s_b \le 760$ mm for $s_b > 760$ mm
1b (notes 1,3)	$t = s_b\ (L+45.73)/(25L+ 6082)$ mm	
2a (notes 1,2)	$t = 0.009s_b + 2.4$ mm $t = 0.006s_b + 4.7$ mm	for $s_b \le 760$ mm for $s_b > 760$ mm
2b (notes 1,3)	$t = s_b\ (L+48.76)/(26L+ 8681)$ mm $t =24.83\ s_b/\ (1615.4-1.1L)$ mm	for $L \le 183$ m for $183 < L \le 427$m
3	$t = 0.01s_b + 0.9$ mm $t = 0.0067s_b + 3.4$ mm	for $s_b \le 760$ mm for $s_b > 760$ mm
4	$t = 0.01s_b + 0.25$ mm $t = 0.0043s_b + 4.6$ mm	for $s_b \le 760$ mm for $s_b > 760$ mm
5	$t = 0.009s_b + 0.8$ mm $t = 0.0039s_b + 4.3$ mm	for $s_b \le 760$ mm for $s_b > 760$ mm
6	$t = 0.00394s_b \sqrt{h} + 1.5$ but not less than 5.0 mm h = tween deck height in m When a design load is specified, h is to be taken as p/n where p is the specified design load in kN/m^2 and n is defined as 7.05	
7	$t = 0.0058s_b + 1.0$ mm but not less than 4.5 mm	

L = scantling length of the vessel as defined in Ch.1 Sec.1/1.1 in m

s_b = spacing of deck beams, in mm

Notes:

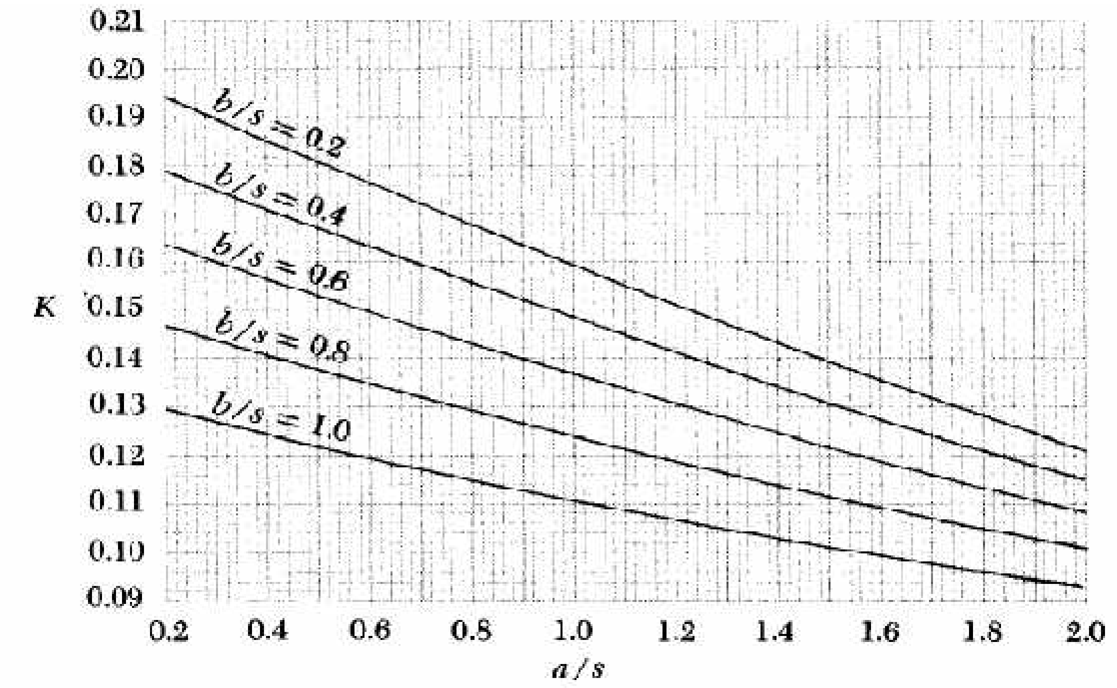
1) Within steel superstructures or deckhouse, the plating thickness may be reduced by 1 mm.

2) To extend over 0.8L amidships, beyond which the thickness forward and aft is not to be less than required for forecastle and poop deck plating respectively.

3) To extend over 0.4L amidships and tapered beyond in a manner the same as in Ch.2 Sec.1/6.2.

Vessels designed on still water bending moment envelope curves will be specially considered.

FIGURE 3.1: Wheel Loading Curves of "K"



4 Higher-strength Material

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 for longitudinally framed decks, where constructed of higher-strength material, is to be not less than required for longitudinal strength, nor is it to be less than obtained from the following equation.

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

where

t_{ms} = thickness of ordinary-strength steel, in mm, as required by the Rules

C = 4.3 mm for exposed deck plating

Q = is as defined in Ch.2 Sec.1/3.3

The thickness t_{hts} is also to be determined from the above equation using the t_{ms} as obtained from Table 3.2, equation 2b with a factor of $0.92/\sqrt{Q}$ in lieu of Q. The factor $0.92/\sqrt{Q}$ is not to be less than 1.00.

Where the deck plating is transversely framed, or where the Rules do not provide a specific thickness for the deck plating, the thickness of the higher-strength material will be specially considered, taking into consideration the size of the vessel, intended service and the foregoing Rule requirements.

4.2 Wheel Loading

Where decks or flats are constructed of higher-strength material and provision is made for the operation or stowage of vehicles having rubber tires, the thickness of plating is to be not less than obtained from the following equation:

$t_{hts} = t_{ms} \sqrt{235/Y}$ mm

where

t_{ms} = thickness of ordinary-strength steel, as obtained from 3.8

Y = as defined in Ch.2 Sec.9/3.1

5 Deck Covering Compositions

Deck covering compositions are to be of materials which are not destructive to steel, or they are to be effectively insulated from the steel by a noncorrosive protective covering. Samples may be taken by the Surveyor 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 not 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 that will not ignite readily.

Section 4 Bottom Structures

1 Double Bottoms

1.1 General

Double bottoms are to be fitted fore and aft between the peaks, or as near thereto as practicable, in vessels of ordinary design other than tankers. Where, for special reasons, it may be desired to omit the inner bottom, the arrangements are to be clearly indicated on the plans when first submitted for approval. A double bottom need not be fitted in way of deep tanks, provided the safety of the vessel in the event of bottom damage is not thereby impaired. It is recommended that the double bottom be arranged to protect the bilges as much as possible and that it be extended to the sides of the vessel.

Shell longitudinals and frames in way of deep tanks are to have not less strength than is required by Ch.2 Sec.10/2.2 for stiffeners on deep tank bulkheads. For bottom shell longitudinals bounding tanks having normal tank/air vent configurations in order to avoid accidental overpressure, the head "h" need not be greater than the distance from the longitudinal under consideration to the deck at side. In the case of unusual configurations or where the tanks are intended to carry liquids having a specific gravity equal to or greater than 1.05, "h" should be in accordance with Ch.2 Sec.10/2.2.

1.2 Testing

Requirements for testing are contained in Part 3, Chapter 7.

2 Center and Side Girders

2.1 Center Girders

A center girder is to extend as far forward and aft as practicable. The plates are to be continuous within the amidship 0.75L; elsewhere, they may be intercostal between the floors. Manholes may be cut in every frame space outside the amidship 0.75L. Elsewhere, the minimum practical number of manholes for adequate access and ventilation may be provided, but the depth of the manholes is not to exceed one-third the depth of the center girder. Compensation for the manholes within the amidship 0.75L is to be provided.

2.1.1 General

Center girder plates are to be of the thickness and depths given by the following equations, between the peak bulkheads. In peaks, the center girder plates are to be of the thickness of the peak floors.

Where longitudinal framing is adopted, the center girder plate is to be suitably stiffened between floors, and docking brackets are to be provided in accordance with 2.4.

Where special arrangements, such as double skins or lower wing tanks, effectively reduce the unsupported breadth of the double bottom, the depth of the center girder may be reduced by substituting for B, the distance between the sloping plating of wing tanks at the inner bottom plating level, or the distance between the inner skins. Where the distance is less than 0.9B, an engineering analysis of the double bottom structure may be required. Where the length of the cargo hold is greater than 1.2B, or where the vessel is intended to carry heavy cargoes, particularly in alternate holds, the thickness and depth of center girder plates are to be specially considered.

2.1.1 (a) Thickness Amidships

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

2.1.1 (b) Thickness at Ends

85% of the thickness required amidships

2.1.1 (c) Depth

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

where

t = thickness of plating, in mm

L = length of vessel, as defined in Ch.1 Sec.1/1.1, in m

d_{DB} = depth of double bottom, in mm

d = molded draft of vessel, as defined Ch.1 Sec.1/1.4, in m

B = breadth of vessel, as defined in Ch.1 Sec.1/1.2, in m

2.2 Pipe Tunnels (Note: An alternative arrangement of center girders)

A pipe tunnel, or tunnels, may be substituted for the center girder provided that the thickness of the sides of the pipe tunnel(s) is not less than is required for tank-end floors. The construction arrangement and details of pipe tunnels are to be clearly shown on the plans submitted for approval.

2.3 Docking Brackets (Note: Not only for center girder but also for side girders)

Docking brackets are to be provided on the center girder where the spacing of the floors exceeds 2.28 m, unless calculations are submitted to verify that the girder provides sufficient stiffness and strength for docking loads. Where the docking arrangement is such that the side girders or bulkheads are subject to docking loads, such arrangement is to be indicated on the submitted structural plan, and docking brackets are to be fitted on those members where the spacing of floors exceeds the foregoing limit.

2.4 Side Girders

Amidships and aft, side girders of the thickness obtained from the equation of 3 are to be so arranged that the distance from the center girder to the first side girder, the distance between the girders, and the distance from the outboard girder to the center of the margin plate does not exceed 4.57 m. At the fore end, they are to be arranged as required by 7.3 or 7.4, as appropriate. 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.

3 Solid Floors

3.1 General

Solid floors (see Figure 3.1) of the thickness obtained from the following equations (and 3.3, where applicable), are to be fitted on every frame under machinery and transverse boiler bearers, under the outer ends of bulkhead stiffener brackets and at the forward end (see 7.3 or 7.4, as appropriate).

Elsewhere, they may have a maximum spacing of 3.66 m in association with intermediate open floors (see 4), or longitudinal framing of the bottom or inner bottom plating. With the latter, the floors are to have stiffeners at each longitudinal, or an equivalent arrangement is to be provided. Where floors are fitted on every frame, the thickness need not exceed 14.0 mm, provided the buckling strength is proven adequate,where tn = 12.5 mm in FOT or 12.0 mm for others. Where boilers are mounted on the tank top, the floors and intercostals in way of the boilers are to have an additional 1.5 mm added to their thickness after all other requirements have been satisfied.

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

where

t = thickness, in mm

L = length of vessel, as defined in Ch.1 Sec.1/1.1, in m

c = 1.5 mm for floors where the bottom shell and inner bottom are longitudinally framed

= 0 mm for side girders and brackets, and for floors where the bottom shell and inner bottom are transversely framed

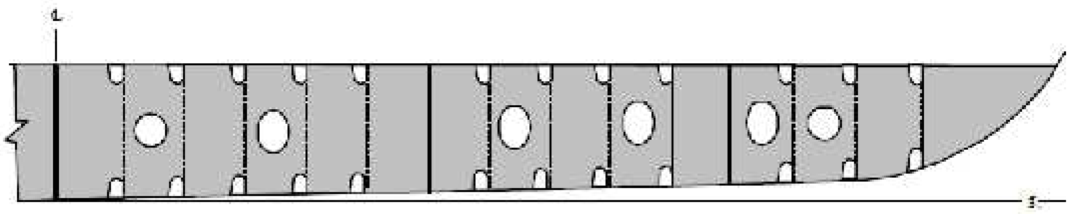
3.2 Tank-end Floors

Tank-end floor thickness is to be not less than required for deep tank bulkhead plating or 3.1, whichever is greater.

3.3 Floor Stiffeners

Stiffeners spaced not more than 1.53 m apart are to be fitted on every solid floor. Where the depth of the double bottom exceeds 0.915 m, 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 3.1.

FIGURE 3.1: Double-bottom Solid Floors



4 Open Floors

4.1 General

Where solid floors are not fitted on every frame, as permitted 3.1, open floors are to be fitted at each frame between the solid floors.

4.2 Frames and Reverse Frames

Each frame and reverse frame similar to that shown in Figure 4.1, in association with the plating to which it is attached, is to have a section modulus SM as obtained from the following equation:

SM = $7.8chsl^2$ cm^3

where

s = spacing of frames, in m

c = 1.0 without struts

= 0.5 with struts in accordance with 4.4

h = distance, in m, from the keel to the summer load line (d as defined in Ch.1 Sec.1/1.4), or two-thirds of the distance from the keel to the bulkhead or freeboard deck (0.66D), whichever is greater. In the case of reverse frames without struts, the distance may be measured from the top of the double bottom.

l= the greatest distance, in m, between the connecting brackets or intercostals, as shown in Figure 4.1. Where effective struts are fitted and the tank top is intended to be uniformly loaded with cargo, l may be taken as 85% of the distance between supports, as determined above.

4.3 Center and Side Brackets

Center and side brackets are to overlap the frames and reverse frames for a distance equal to 0.05B (see Figure 4.1); they are to be of the thickness required for solid floors in the same location and are to be flanged or stiffened on their outer edges.

4.4 Struts

The permissible load W_a for struts is to be determined in accordance with Ch.2 Sec.8/2.1. The calculated load W is to be determined by:

W = $10.5phs$ kN

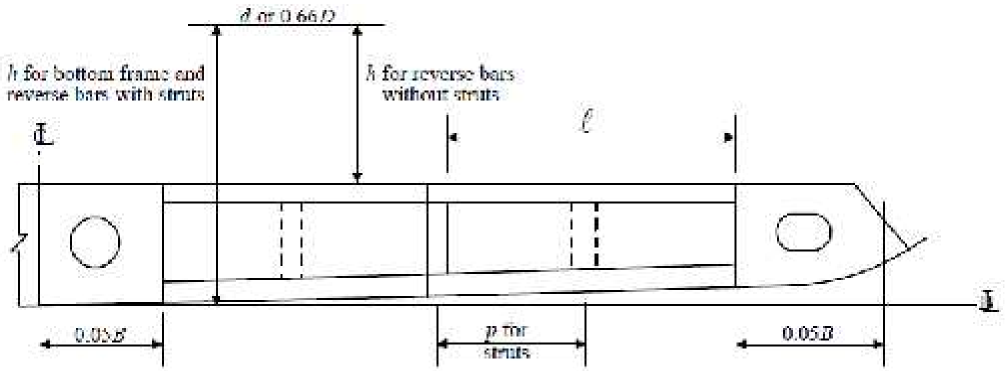
where

p = distance, in m, between center of the struts.

s, h are as defined in 4.2.

Struts are to be positioned so as to divide the span into approximately equal intervals.

FIGURE 4.1 Double-bottom Open Floors



5 Inner-bottom Plating

5.1 Inner-bottom Plating Thickness

Inner-bottom plating thickness is not to be less than obtained from the following equation or as required by Ch.2 Sec.10/2.3, or by Ch.2 Sec.1/10, whichever is the greatest:

$t = 0.037L + 0.009s - c$ mm for $L \le 427$ m

where

L = scantling length of vessel, as defined in Ch.1 Sec.1/1.1, in m

s = frame spacing, in mm

c = 0.5 mm with transverse framing

= 1.5 mm with longitudinal framing

Where close ceiling, as defined in Ch.2 Sec.18/1, is not fitted on the inner bottom in way of hatchways, the thickness t, as determined above, is to be increased by 2.0 mm, except in holds designated exclusively for the carriage of containers on the inner bottom.

5.2 Center Strakes

Center strakes are to have a thickness determined from 5.1; in way of pipe tunnels, the thickness may require to be suitably increased.

5.3 Under Boilers

Under boilers, there is to be a clear space of at least 460 mm. Where the clear space is necessarily less, the thickness of the plating is to be increased as may be required.

5.4 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 thickness of the inner bottom plating is to be at least 19.0 mm. This thickness may be required to be increased according to the size and power of the engine(s). Holding-down bolts are to pass through angle flanges of sufficient breadth to take the nuts.

5.5 Margin Plates

Where margin plates are approximately vertical, the plates amidships are to extend for the full depth of the double bottom with a thickness not less than obtained from the equation in 5.1 plus 2.0 mm.

Where approximately horizontal, margin plates may be of the thickness required for tank-top plating at that location.

5.6 Recommendations Where Cargo is Handled by Grabs

For vessels regularly engaged in trades where the cargo is handled by grabs, or similar mechanical appliances, it is recommended that flush inner-bottom plating be adopted throughout the cargo space, and that the plating requirements of 5.1 be suitably increased, but the increase need not exceed 5.0 mm. It is also recommended that the minimum thickness be not less than 12.5 mm with 610 mm frame spacing and 19.0 mm with 915 mm frame spacing, and the thickness for intermediate frame spacing is to be obtained by linear interpolation.

5.7 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 Ch.2 Sec.3/3.8.

6 Bottom and Inner-bottom Longitudinals

6.1 General

Bottom and inner-bottom longitudinals are to be continuous or attached at their ends to effectively develop their sectional area and their resistance to bending.

6.2 Bottom Longitudinals

Each bottom longitudinal frame similar to that shown in Figure 3.1, in association with the plating to which it is attached, is to have a section modulus SM not less than that obtained from the following equation:

$SM = 7.8chsl^2$ cm^3

where

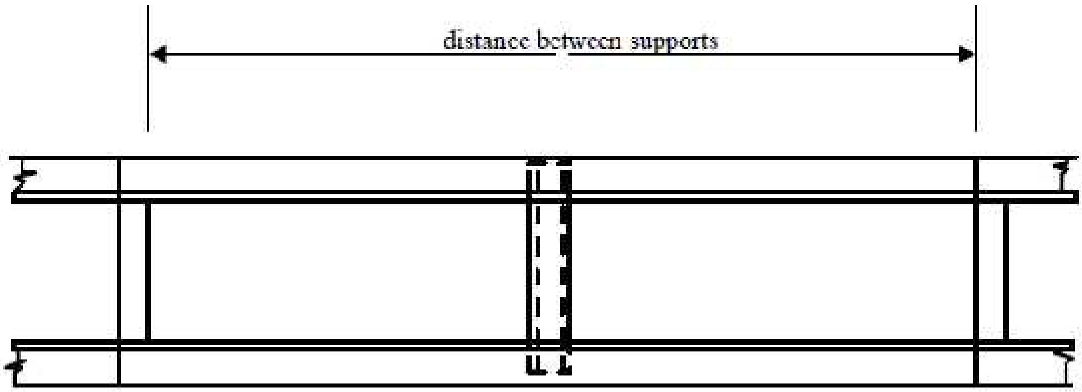
c = 1.3 without struts

= 0.715 with effective struts

h = distance, in m, from the keel to the load line, or two-thirds of the distance to the bulkhead or freeboard deck, whichever is the greater.

s = spacing of longitudinals, in m

l = distance, in m, between the supports, but is not to be taken as less than 1.83 m without struts or 2.44 m with struts. Where effective struts are fitted and the tank top is intended to be uniformly loaded with cargo, l may be taken as 81% of the distance between supports subject to above minimum.



The section modulus SM of the bottom longitudinals may be obtained from the above equations multiplied by the factor R_l where,

i) The bottom hull girder section modulus SM_A is greater than required by Ch.2 Sec.1/2.4.1, at least throughout 0.4L amidships,

ii) Still-water bending moment calculations are submitted, and

iii) Adequate buckling strength is maintained.

$R_l = n/[n + f_p(1 - SM_R/SM_A)]$ but is not to be taken less than 0.69

where

n = 8.278

f_p = nominal permissible bending stress, as given in Ch.2 Sec.1/2.4.1

SM_R = hull girder section modulus required by Ch.2 Sec.1/2.4.1, in cm^2-m

SM_A = bottom hull girder section modulus, in cm^2-m, with the longitudinals modified as permitted above.

Bottom longitudinals, with this modified section modulus are to meet all other Rule requirements including side longitudinals in Ch.2 Sec.5/2.9.

6.3 Inner-bottom Longitudinals

Inner-bottom longitudinals are to have values of SM at least 85% of that required for the bottom longitudinals.

7 Fore-end Strengthening

7.1 General

Where forward draft of the vessel in the ballast condition to be used while the vessel is in heavy weather (heavy ballast draft forward) is less than 0.04L m, strengthening of the flat of bottom forward is to be in accordance with 7.2, 7.3, 7.4 and Ch.2 Sec.2/3.3. Information on the heavy ballast draft forward used for the required fore-end strengthening is to be furnished to the master for guidance. The heavy ballast draft is also to be indicated on the shell expansion plan.

7.2 Extent of Strengthening

The flat of bottom forward is forward of the locations indicated in Table 7.1. For intermediate values of C_b, 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 7.1.

7.3 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 7.1 is to be not less than required by the following equation, nor less than required by 6.2.

$$SM = 8.47(0.005L_1^2 - 1.3d_f^2)sl^2 / d_f \quad \text{cm}^3$$

where

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

= d_f × 214/L m, where L > 214 m

L_1 = length of vessel, as defined in Ch.1 Sec.1/1.1, in m, but need not be taken greater than 214 m

L = length of vessel, as defined in Ch.1 Sec.1/1.1, in m

s = spacing of longitudinals, in m

l = distance between floors, in m

The spacing of floors in the forward 0.25L is not to be greater than that given in Table 7.2 nor greater than the spacing amidships.

7.4 Transverse Framing

Where the heavy ballast draft forward is less than 0.04L m, solid floors are to be fitted on every frame, and 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 7.1 does not exceed 2.13 m and that the spacing of alternating half and full-depth girders forward of the location in Table 7.1 does not exceed 1.07 m. Where the heavy ballast draft forward is 0.04L m or more, the arrangement of solid floors and side girders may be in accordance with 2.4 and 3.

Table 7.1

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

C_b is the block coefficient as defined in Ch.1 Sec.1/1.6.

Table 7.2: Spacing of Floors

d_f (1, 3)	C_b	From 0.25L to 0.3L from amidships	Forward of 0.3L from amidships
0.02L and less	0.60 or less greater than 0.60	3s (2) 3s (2)	2s (2) 3s (2)
0.035L	all values	3s (2)	3s (2)
0.04L and more	all values	As required elsewhere in the Rules	

1) d_f is the heavy ballast draft, in m, at the forward perpendicular and C_b is the block coefficient at the summer load waterline, based on L, as defined in Ch.1 Sec.1/1.1.

2) s is the spacing of transverse side frames, in m, or S in Ch.2 Sec.5/1.4, where side shell is longitudinally framed.

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

8 Higher-strength Materials

8.1 General

In general, applications of higher-strength materials for bottom structures are to meet the requirements of this section, but may be modified as permitted by the following paragraphs. Care is to be exercised to avoid the adoption of a 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 they support.

8.2 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 by 5.1 or Ch.2 Sec.10/2.3, as modified by the following equation.

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

where

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

t_{ms} = thickness of mild steel, as required by 5.1 or Ch.2 Sec.10/2.3, in mm, increased where required by 5.1 for no ceiling

C = 3 mm

= 5 mm where the plating is required by 5.1 to be increased for no ceiling

Q = as defined in Ch.2 Sec.1/3.3

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

Where cargo is handled by grabs, or similar mechanical appliances, the recommendations of 5.6 are applicable to this.

8.3 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-strength plating to which they are attached, is to be determined as indicated in 6.2 and 6.3, except that the value may be reduced by the factor Q, as defined in Ch.2 Sec.1/3.3.

8.4 Center Girders, Side Girders, and Floors

Center girders, side girders, and floors, where constructed of higher-strength materials, generally are to comply with the requirements of 2 or 3, but may be modified, as permitted, by the following equation.

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

where t_{hts}, t_{ms}, and C are as defined in 8.2.

Q is as defined in Ch.2 Sec.1/3.3.

9 Structural Arrangements and Details

9.1 Structural Sea Chests

In addition to the requirements of 1 and 5, where the inner-bottom or the double-bottom structure form part of a sea chest, the thickness of the plating is to be not less than required by Ch.2 Sec.2/3.1 for the shell at 0.1L, where s is the maximum unsupported width of plating. The thickness need not exceed that required in Ch.2 Sec.2/2 for side or bottom shell, as appropriate.

9.2 Drainage

Efficient arrangements are to be provided for draining water that may gather on the inner bottom. Where wells are fitted for such purpose, it is recommended that, with the exception of the after tunnel well, such wells are not to extend for more than one-half the depth of the double bottom nor to less than 460 mm from the shell or from the inner edge of the margin plate and are to be so arranged as to comply with requirements. Plating forming drain wells is to be at least 2.5 mm greater than is otherwise required at that location. This requirement may be modified where corrosion-resistant material is used or special protective coatings are applied. Thick steel plates or other approved arrangements are to be provided in way of sounding pipes to prevent damage by the sounding rods.

9.3 Manholes and Lightening Holes

Manholes and lightening holes are to be cut in all non-tight members, except in way of widely spaced pillars, to ensure accessibility and ventilation; the proposed locations and sizes 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 material, and where no ceiling is fitted in the cargo holds, they are to be effectively protected from damage by the cargo.

9.4 Air and Drainage Holes

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

10 Single Bottoms with Floors and Keelsons

10.1 General

Where double bottom construction is not required by 1.1 or is not applied, single bottom construction is to be in accordance with requirements in 10 and 11, as may be applicable.

10.2 Center Keelsons

Single-bottom vessels are to have center keelsons formed of continuous or intercostal center girder plates with horizontal top plates. The thickness of the keelson and the area of the horizontal top plate are to be not less than that obtained from the following equations. Vessels less than 30.5 m in length will be subject to special consideration. Tapering of the horizontal top plate area at the ends is not normally considered for vessels less than 30.5 m in length. The keelsons are to extend as far forward and aft as practicable.

10.2.1 Center-girder Plate Thickness Amidships

$t = 0.063L + 5$ mm

10.2.2 Center-girder Plates Thickness at Ends

t = 85% of center keelson thickness amidships

10.2.3 Horizontal Top-plate Area Amidships

$A = 0.168L^{3/2} - 8$ cm^2

10.2.4 Horizontal Top-Plate Area at Ends [$L \geq 30.5$ m]

$A = 0.127L^{3/2} - 1$ cm^2

where

t = thickness of center-girder plate, in mm

L = length of vessel, as defined in Ch.1 Sec.1/1.1, in m

A = area of horizontal top plate, in cm^2

10.3 Side Keelsons

Side keelsons are to be arranged so that there are not more than 2.13 m from the center 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 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 center girder plates. The scantlings of the side keelsons are to be obtained from the following equations but need not exceed 10.2, if that be less.

10.3.1 Side Keelson and Intercostal Thickness Amidships

$t = 0.063L + 4$ mm

10.3.2 Side Keelson and Intercostal Thickness at Ends

t = 85% of center thickness amidships

10.3.3 Side Keelson and Intercostal, Horizontal Top Plate Area Amidships

$A = 0.038L^{3/2} + 17$ cm^2

10.3.4 Side Keelson and Intercostal, Horizontal Top Plate Area at Ends

$A = 0.025L^{3/2} + 20$ cm^2

t, L and A are as defined in 10.2.

10.4 Floors

10.4.1 Section Modulus

With transverse framing, a floor as shown in Figure 10.1 is to be fitted on every frame and is to be of the scantlings necessary to obtain a section modulus, SM, not less than that obtained from the following equation:

$SM = 7.8chsl^2$ cm^3

where

$c = 0.55$

h = draft, d, in m, as defined in Ch.1 Sec.1/1.4, but not to be less than 0.66D or 0.066L, whichever is greater.

s = floor spacing, in m

l = span, in m.

Where brackets are fitted and supported by bulkheads, inner bottom or side shell, the length, l, may be measured as permitted therein.

The section modulus may be calculated at the centerline of the vessel, provided the rise of floor is such that the depth at the toe of brackets is not less than one-half of the depth at the centerline.

The above requirements are limited to cargo holds where cargoes of specific gravity 0.715 or less are uniformly loaded. In way of engine room and in the forward 0.2L, the floor face bar area is to be doubled.

10.4.2 Depth

The minimum depth of floors at centerline is not be less than that obtained from the following

equation:

$h_f = 62.5l$ mm

where

h_f = floor depth, in mm

l = unsupported span of floors, in m. Where brackets are fitted, the length, *l*, may be measured as permitted therein.

10.4.3 Thickness

The minimum thickness of floors is not to be less than that obtained from the following equation:

$t = 0.01h_f + 3$ mm

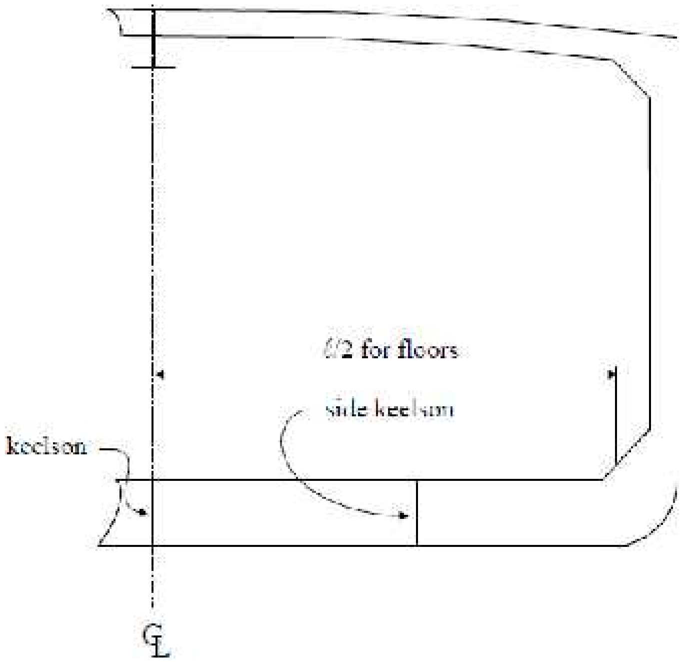
where

t = floor thickness, in mm

h_f = floor depth, in mm

Floors under engine girders are to be not less in thickness than the thickness required for keelsons.

Figure 10.1: Plate Floors



11 Single Bottoms with Longitudinal or Transverse Frames

11.1 General

Where longitudinal frames supported by bottom transverses or transverse frames supported by longitudinal girders and bottom transverses are proposed in lieu of keelsons referred to in subsection 10, the construction is to be in accordance with this subsection. Frames are not to have less strength than is required for watertight bulkhead stiffeners or girders in the same location in association with head to the bulkhead deck. In way of deep tanks, frames are not to have less strength than is required for stiffeners or girders on deep tank bulkheads. See Figures 11.1, 11.2 and 11.3.

Figure 11.1: Round Bottom Floors with Deadrise

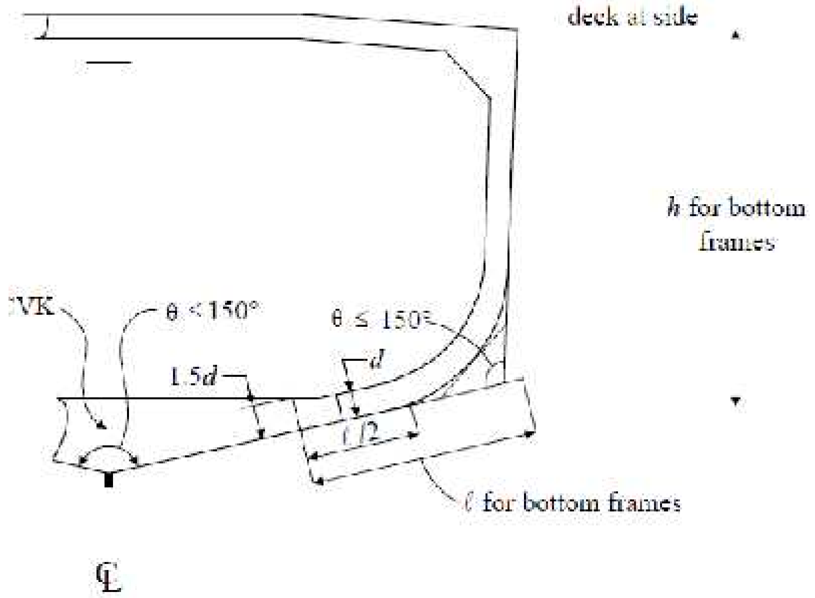


Figure 11.2: Transverse Bottom Frames with Longitudinal Side Girders

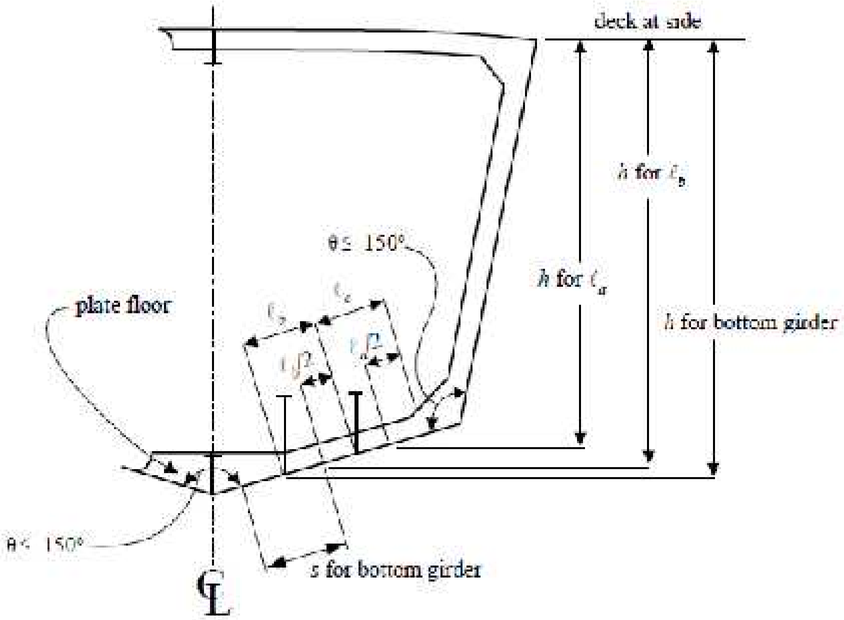
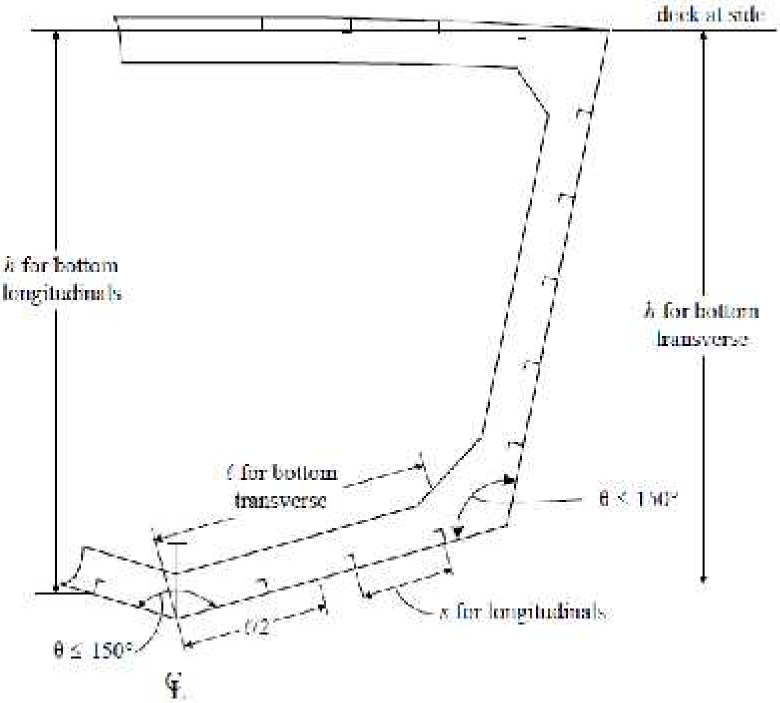


Figure 11.3: Longitudinal Frames with Transverse Webs



11.2 Bottom Girders and Transverses

11.2.1 Section Modulus

The section modulus, SM, of each bottom girder and transverse, where intended as a primary

supporting member, in association with the plating to which it is attached, is not to be less than that obtained from the following equation:

SM = $7.8chsl^2$ cm^3

where

c = 0.915

h = vertical distance, in m, from the center of area supported to the deck at side

s = spacing, in m

l = unsupported span, in m.

Where brackets are fitted and are supported by bulkheads, inner bottom or side shell, the length, l, may be measured as permitted therein.

Tripping brackets are to be fitted at intervals of about 3 m and stiffeners are to be fitted as

may be required.

11.2.2 Depth

The minimum depth of the girder or transverse is to be not less than 2.5 times the depth of the cutouts for bottom frames, unless effective compensation for cutouts is provided, nor less than that obtained from the following equation:

$h_w = 145l$ mm

where

h_w = girder or transverse depth, in mm

l is defined in 11.2.1.

11.2.3 Thickness

The minimum thickness of the web is to be not less than that obtained from the following equation:

$t = 0.01h_w + 3$ mm

where

t = floor thickness, in mm

h_w is as given in 11.2.2.

11.2.4 Non-prismatic Members

Where the cross sectional properties of the member is not constant throughout the length of the girders or transverses, the above requirements will be specially considered with particular attention being paid to the shearing forces at the ends.

11.3 Center Girder

In general, a center girder is to be fitted, complying with 11.2; however, alternative arrangements that provide suitable support for docking will be considered.

11.4 Frames

The section modulus, SM, of each bottom frame to the chine or upper turn of bilge, in association with the plating to which it is attached, is not to be less than that obtained from the following equation:

$SM = 7.8chsl^2$ cm^3

where

c = 0.80 for transverse frames clear of tanks

= 1.00 for longitudinal frames clear of tanks, and in way of tanks

= 1.00 for transverse frames in way of tanks

s = frame spacing in, m

l = unsupported span, in m, Where brackets are fitted and supported by bulkheads, inner bottom or side shell, the length, l, may be measured as permitted therein.

h = vertical distance, in m, from the middle of l to the deck at side. In way of a deep tank, h is the greatest of the distances, in m, from the middle of l to a point located at two-thirds of the distance from the top of the tank to the top of the overflow, a point located above the top of the tank not less than 0.01L + 0.15 m or 0.46 m, whichever is greatest.

L is as defined in Ch.1 Sec.1/1.1.

Section 5 Frames

1 General

1.1 Basic Considerations

The required sizes and arrangements of frames are to be in accordance with this section and as shown in Figure 1.1. The equations apply to vessels which have well-rounded lines, normal sheer and bulkhead support not less effective than that specified in Ch.2 Sec.9. Additional stiffness will be required where bulkhead support is less effective, where sheer is excessive or where flat surface areas are abnormally large. Frames are not to have less strength than is required for bulkhead stiffeners in the same location in association with heads to the bulkhead deck, and 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.

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.

1.3 End Connections

At the ends of unbracketed frames, both the web and the flange are to be welded to the supporting member.

At bracketed end connections, continuity of strength is 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 Ch.2 Sec.19/Table 2.1. 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 a suitable back-up structure, fitted in way of the end connection of frames, or the end connection is to be effectively extended by a bracket or flat bar to an adjacent beam, stiffener, etc.

1.4 Standard and Cant Frame Spacing

The standard frame spacing, S, amidships for vessels with transverse framing, may be obtained from the following equations. In vessels of fine form or high power, a closer spacing is to be considered within and adjacent to the peaks. The spacing of cant frames is not to exceed the standard frame spacing.

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

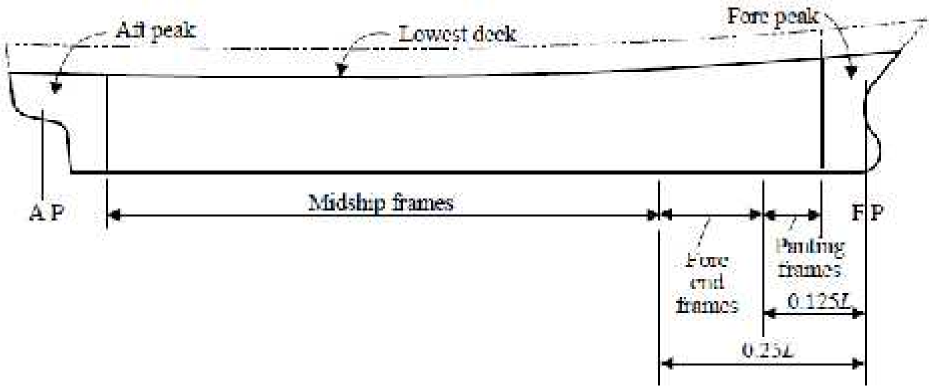
$S = 1000$ mm for $270 < L \leq 427$ m

where

S = standard frame spacing, in mm

L = scantling length of vessel, as defined in Ch.1 Sec.1/1.1, in m

Figure 1.1: Zones of Framing



2 Hold Frames

2.1 Transverse Frames

2.1.1 Strength Requirement

The section modulus SM of each transverse frame amidships and aft below the lowest deck is to be obtained from the following equation, where *l* is the span in m as shown in Figures 2.1, 2.2 and 2.3 between the toes of brackets. The value of *l* for use with the equation is not to be less than 2.10 m.

$SM = s\, l^2 (h + bh_1/30)\,(7 + 45/l^3)$ cm^3

where

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.

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 plus 2.44 m, if that be greater. Where the cargo load differs from 7.04 kN/m^3 multiplied by the tweendeck height in m, the height of that tween-deck is to be proportionately adjusted in calculating h_1.

2.1.2 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.

2.1.3 Sizes Increased for Heavy Load

Where a frame may be subject to special heavy loads, such as may occur at the ends of deep transverse girders which in turn carry longitudinal deck girders, the section modulus is to be suitably increased in proportion to the extra load carried.

Figure 2.1: Hold Frames

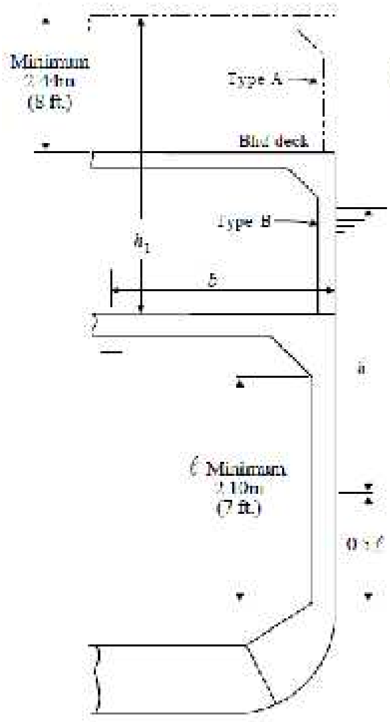


Figure 2.2: Hold Frames

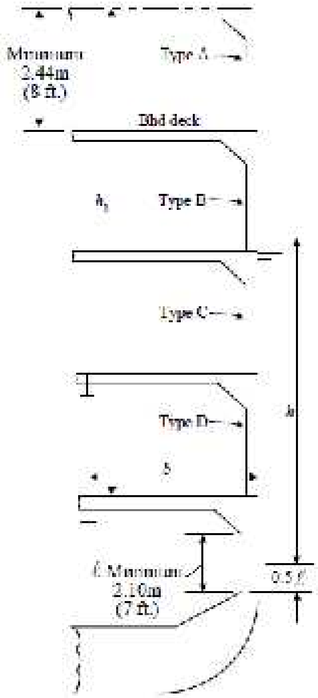
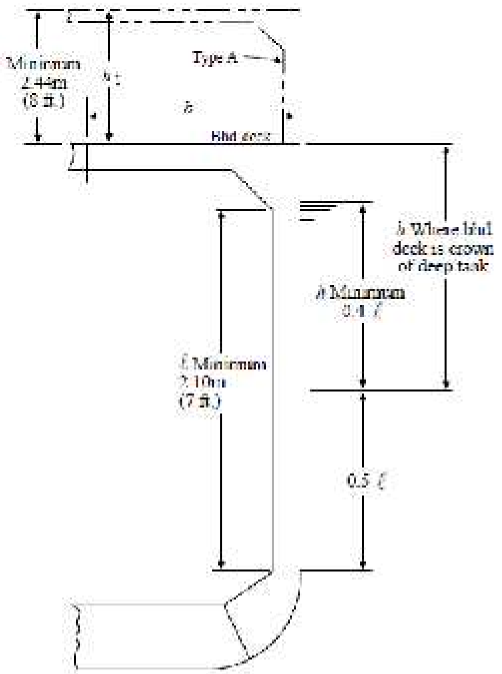


Figure 2.3: Hold Frames



2.2 Raised Quarter Decks

In way of raised quarter decks, *l* is to be the corresponding midship span in way of the freeboard deck plus one-half the height of the raised quarter deck, and the other factors are to be those obtained for midship frames in way of the freeboard deck.

2.3 Fore-end Frames

Each fore-end frame between the amidship 0.5L and the amidship 0.75L is to have a section modulus obtained from 2.1, where *l* is to be the corresponding midship span plus one-half the sheer at 0.125L from the stem; the other factors are to be those obtained for 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.

2.4 Panting Frames

Each panting frame between the midship three-quarters length and the forepeak bulkhead in vessels which have effective panting arrangements as per 2.7 is to have a section modulus as obtained from 2.1, where *l* is to be the corresponding midship span plus the sheer in m at 0.125L from the stem.

In vessels having normal sheer, the other factors in 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 2.1 is to be at least 25% greater than obtained for corresponding midship frames, adjusted for spacing; 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.

2.5 Side Stringers

Where stringers are fitted in accordance with this paragraph, the SM in 2.1, 2.2, and 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 are to be at least as deep as the frames and are to have continuous face plates.

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 Ch.2 Sec.6, the section modulus is to be determined in accordance with 2.1, 2.3, and 2.4, but the length l may be taken as the distance from the toe of the bracket to the lowest stringer plus 0.15 m. The value of l for use with the equations is not to be less than 2.10 m.

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 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 vessel, the frames have longer unsupported spans than the normal midship frames, stringers or frames of increased size may be required.

2.8 Hold Frame Brackets

Brackets connecting hold frames to margin plates are to be flanged (edge stiffened) and of not less thickness than the frame web thickness plus 2 mm. The thickness is also not to be less than required by Ch.2 Sec.9/Table 3.1. Where the double bottom is longitudinally framed, flanged brackets are to be fitted inside the double bottom in line with the hold frame brackets and extending to the outboard inner bottom and shell longitudinals.

2.9 Longitudinal Frames

The section modulus SM of each longitudinal side frame is to be not less than obtained from the following equation:

$SM = 7.8\ chsl^2 \qquad cm^3$

where

s = spacing of longitudinal frames, in m

c = 0.95

h = above 0.5D from the keel, the vertical distance, in m, from the longitudinal frame to the bulkhead or freeboard deck, but is not to be taken as less than 2.13 m.

= at and below 0.5D from the keel, 0.75 times the vertical distance, in m, from the longitudinal frame to the bulkhead or freeboard deck, but not less than 0.5D.

l = the unsupported span, in m

2.10 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.

3 Tween-deck Frames

3.1 General

The size of tween-deck framing is dependent upon 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 framing from the bottom to 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, or by the extension of deep frames at regular intervals to the tops of superstructures. Care is to be taken that the strength and stiffness of the framing at the ends of the vessel 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.

3.2 Transverse Tween-deck Frames

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

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

where

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

s = spacing of the frames, in m

K = factor appropriate to the length of vessel and type of tween decks, A, B, C, or D, as shown in Figure 2.1, 2.2, and 2.3.

L = length of vessel, as defined in Ch.1 Sec.1/1.1, but need not be taken as greater than 305 m

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 $180 < L \leq 427$ m
Type D	$K = 0.029L + 1.78$	for $L \leq 427$ 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 not less than required by 4.1.

3.3 Longitudinal Tween-deck Frames

Longitudinal tween-deck frames are to be in accordance with 2.9. The section modulus of each longitudinal tween-deck frame forward of 0.125L from the stem is to be not less than required by 3.2 for transverse frames in the same location, taking l as the unsupported span along the frame length.

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. See also Ch.2 Sec.1/10 and Ch.2 Appendix A4.

4 Forepeak Frames

4.1 General

Forepeak frames are to be efficiently connected to deep floors of not less thickness than that obtained from Ch.2 Sec.4/3.1 for floors with transverse framing, 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 4.2, but in vessels having large flare or varying sheers on the different decks, with unusually long frames, stringers and webs above the lowest deck or suitably increased frames may be required.

4.2 Frame Scantlings

The section modulus SM of frames is to be obtained, as follows, for three different systems of construction.

4.2.1 Beams on Alternate Frames

In vessels where beams are fitted on alternate frames, in conjunction with flanged stringer plates of the sizes given in Ch.2 Sec.6/5, are fitted in tiers 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.

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

where

s = frame spacing, in m

L = length of vessel, as defined in Ch.1 Sec.1/1.1, in m

4.2.2 Beams or Struts on Every Frame

Where beams or struts are fitted on every frame (but without stringer plates) in tiers 1.52 m apart, the section modulus SM of the frames is not to be less than determined by the above equation, nor is the section modulus 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.

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

where

L = length of vessel, as defined in Ch.1 Sec.1/1.1, in m

4.2.3 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 4.2.1, nor is the section modulus to be less than twice that obtained from the equation in 4.2.2 in association with a length l, as defined in 4.2.2.

4.2.4 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.

5 After-peak Frames

5.1 General

After-peak frames are to be efficiently connected to deep floors of not less thickness than obtained from Ch.2 Sec.4/3.1 for floors with transverse framing, 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 to prevent vertical or lateral movement.

5.2 Frame Scantlings

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

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

where

s = frame spacing, in m

L = length of vessel, as defined in Ch.1 Sec.1/1.1, in m

5.3 Vessels of High Power or Fine Form

For vessels of high power or fine form, a number of plate floors extending to the lowest deck or flat and suitably supported longitudinally, web frames in the tween decks or other stiffening arrangements may be required in addition to the requirements of 5.1 and 5.2.

Section 6 Web Frames and Side Stringers

1 General

Web frames and, in the case of transverse framing, side stringers, similar to those shown in Figure 2.1, where fitted in association with transverse or longitudinal frames of the sizes specified in Ch.2 Sec.5/2.6 or 2.9, are to be of the sizes as required by this section. It is recommended that webs and stringers be spaced not more than approximately 3 m apart. Webs and stringers are not to have less strength than would be required for similar members on watertight bulkheads, and in way of deep tanks, they are to be at least as effective as would be required for similar members on deep-tank bulkheads. For webs in machinery spaces, see also 2.10.

2 Web Frames

2.1 Hold Web Frames Amidships and Aft

Each hold web frame amidships and aft is to have a section modulus SM not less than obtained from the following equation:

$SM = 4.74cs l^2(h + bh_1/45K)$ cm^3

where

$c = 1.5$

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 vessel) to the deck at the top of the web frames. Where effective brackets are fitted, the length l may be modified as outlined in 4.1

h = vertical distance, in m, from the middle of l to the load line; the value of h is not to be less than $0.5l$

h_1 = vertical distance, in m, from the deck at the top of the web 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 plus 2.44 m, if that be greater. Where the cargo load differs from 7.04 kN/m^3 multiplied by the tween-deck height in m, the height of that tween-deck is to be proportionately adjusted in calculating h_1

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

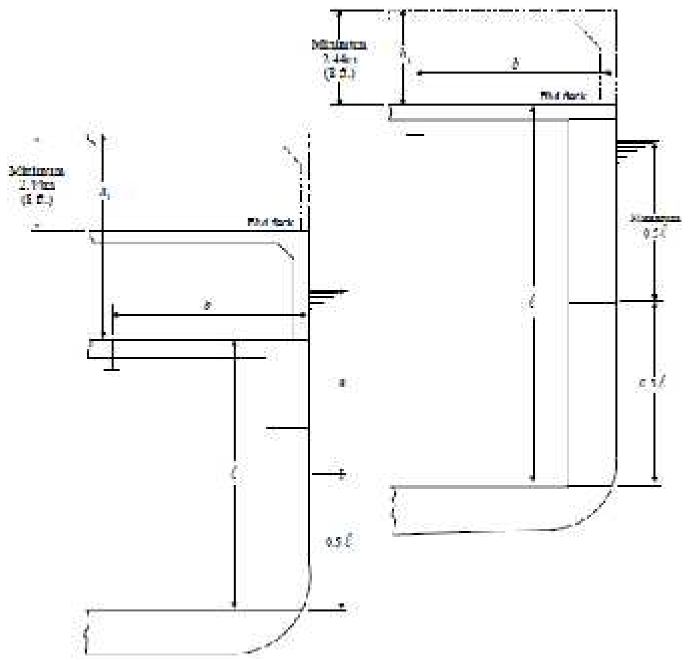
K = 1.0, where the deck is longitudinally framed and a deck transverse is fitted in way of each web frame

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

2.2 Hold Web Frames Forward

Hold web frames forward of the midship one-half length are to be obtained as described in 2.1, but the length l is to be increased in length due to sheer. Where the sheer is not less than normal, the other factors in 2.1 are to be the same as used for midship webs. Where there is no sheer, the value of SM for the 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.

Figure 2.1: Hold Web-frame Arrangements



2.3 Proportions

Hold webs are to have a depth of not less than 0.125*l*; the thickness is not to be less than 1mm per 100 mm 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, flanges, etc. are to be increased 1.5 mm above the normal requirements.

2.4 Stiffeners

Where the shell is longitudinally framed, stiffeners attached to the longitudinal frames and extending to the full depth of the web frame are to be fitted at least at alternate longitudinal frames. Other stiffening arrangements may be considered based on the structural stability of the web plates.

2.5 Tripping Bracket

Tripping brackets are to be fitted at intervals of about 3 m and near the change of section. Where the breadth of the flanges on either side of the web exceeds 200 mm, tripping brackets are to be arranged to support the flange.

2.6 Tween-deck Webs

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

3 Side Stringers

3.1 Hold Stringers

Each hold stringer, in association with web frames and transverse frames, is to have a section modulus SM not less than obtained from the following equation:

$SM = 4.74chsl^2$ cm^3

where

c = 1.50

h = vertical distance, in m, from the middle of s to the load line, or to two-thirds of the distance from the keel to the bulkhead deck, or 1.8 m, whichever is greatest

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

l = span, in m, between web frames, or between web frame and bulkhead; where brackets are fitted, the length *l* may be modified

3.2 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 is 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 5.1. Where the stringers are in close proximity to boilers, the thickness of the stringer plates, face bars, flanges, etc. are to be increased 1.5 mm above the normal requirements.

3.3 Stiffeners

Stiffeners attached to the frame and extending to the full depth of the stringer are to be fitted on alternate transverse frames. Other stiffening arrangement may be considered based on the structural stability of the web plates.

3.4 Tripping Brackets

The arrangement of tripping brackets is to be in accordance with 2.5.

4 Structural Arrangements and Details

4.1 Brackets of Girders, Webs, and Stringers

Where brackets are fitted having thickness not less than the girder or web plates, the value for *l*, as defined in this Section, Ch. 2 Sec.8, Sec.9, and Sec.10, may be modified in accordance with the following.

i) Where the face area on the bracket is not less than one-half that on the girder or web and the face plate or flange on the girder or web is carried to the bulkhead or base, the length *l* may be measured to a point 150 mm on to the bracket.

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

iii) Where the face plate or flange area of the girder or web is carried along the face of the bracket, which may be curved for the purpose, *l* may be measured to the point of the bracket.

iv) Brackets are not to be considered effective beyond the point where the arm on the girder or web is 1.5 times the length of the arm on the bulkhead or base; in no case is the allowance in *l* at either end to exceed one-quarter of the overall length of the girder or web.

4.2 End Connections

End connections of all girders, webs and stringers should be balanced by effective supporting members on the opposite side of bulkheads, tank tops, etc., and their attachments are to be effectively welded.

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.

5 Peak Stringers

5.1 Peak Stringer-plate Thickness

The peak stringer-plate thickness is not to be less than that obtained from the following equation.

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

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

where

t = plate thickness, in mm.

L = length of vessel, as defined in Ch.1 Sec.1/1.1, in m

5.2 Peak Stringer-plate Breadth

The peak stringer-plate breadth is not to be less than that obtained from the following equation.

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

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

where

b = breadth of peak stringer-plate, in mm

L = length of vessel, as defined in Ch.1 Sec.1/1.1, in m

Where beams or struts are not fitted on every frame, the edge of the stringer is to be adequately stiffened by a flange or face bar.

Section 7 Beams

1 General

1.1 Arrangement

Transverse beams are to be fitted on every frame. Beams, transverses and girders are to have adequate structural stability.

1.2 Design Head

Where decks are designed to scantling heads less than those specified in this Section, a notation indicating the restricted deck loading will be entered in the Record.

2 Beams

2.1 Strength Requirement

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

$SM = 7.8chsl^2$ cm^3

where

c = 0.540 for half beams, for beams with centerline support only, for beams between longitudinal bulkheads, and for beams over tunnels or tunnel recesses

= 0.585 for beams between longitudinal deck girders. For longitudinal beams of platform decks and between hatches at all decks

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

= 1.00 for beams at deep-tank tops between longitudinal girders

= 1/(1.709 − 0.651k) 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 Ch.2 Sec.1/2.4.1 or 3.3, whichever is applicable, in cm^2-m

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 vessel amidships, in cm^2-m^2

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

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

= is normally to be the height measured at the side of the vessel, of the cargo space wherever stores or cargo may be carried. Where the cargo load differs from 7.04 kN/m^3 multiplied by the tween-deck height, in m, the height is to be proportionately adjusted.

= for bulkhead recesses and tunnel flats is the height, in m, to the bulkhead deck at the centerline; where that height 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.

= for 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) of Ch.2 Sec.7/Table 2.1, appropriate to the length of the vessel, the height to the load line or two-thirds of the height to the bulkhead or freeboard 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 Ch.2 Sec.7/Table 2.1, as follows.

Weather deck and decks covered only by houses:	*Column*
Freeboard decks having no decks below	a
Freeboard decks having decks below	b
Forecastle decks (first above freeboard deck) See Note 1	c
Bridge decks (first above freeboard deck)	c
Short bridges, not over 0.1*L* (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 (third and higher above freeboard deck) which contain only accommodation spaces	f
Lower decks and decks within superstructures:	
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.:	
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 Ch.2 Sec.11/5.

2) Where superstructures above the first superstructure extend forward of the amidship 0.5L, the value of h may be required to be increased.

3) Where decks to which the side shell does not extend and 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 all decks is to be considered where they are part of the hull girder.

Table 2.1: Values of h for Beams in Meters

L	a	b	c	d	e	f	g
≤ 90	0.02L+0.76	0.02L+0.46	0.01L+0.61	0.01L+0.3	0.01L+0.15	0.01L	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

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

2.2 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, in way of masts, winches, auxiliary machinery, etc.

2.3 Beams at the Head of Web Frames

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

2.4 End Connections

At the ends of unbracketed longitudinals, inside the line of openings or on platform decks, or at the ends of unbracketed beams, both the web and flange are to be welded to the supporting member. At beam knees or at other bracketed end connections, continuity of strength of the beam or longitudinal is 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 Ch.2 Sec.19/Table 2.1.

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, or terminate on, the boundaries of tanks or watertight compartments, structural continuity is to be maintained by a suitable back-up structure in way of the end connection, or the end connection is to be effectively extended by bracket or flat bar to an adjacent stiffener, etc.

3 Deck Fittings

3.1 General

The strength of supporting hull structures used for mooring operations and/or normal towing operations at bow, sides and stern are to comply with the requirements of this section.

Deck fittings for mooring and/or towing are to be located on longitudinals, beams and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the mooring and/or towing load. The same attention is to be paid to recessed bitts, if fitted, of their structural arrangements and strength of supporting structures.

3.2 Design Loads

Unless greater safe working load (SWL) of deck fittings is specified by the applicant, the minimum design load to be used is the greater values obtained from 3.2.1 or 3.2.2, whichever is applicable:

3.2.1 Mooring Operations

The minimum design load for deck fittings for mooring operations is the applicable value obtained from 3.2.1(a) or 3.2.1(b):

3.2.1 (a) Mooring Line Force. 1.25 times the breaking strength of the mooring line according to Ch. 5 /Table 5.2 for each equipment number (EN). EN is the corresponding value used for determination of the vessel's equipment. (See Note)

Notes:

1 Side projected area including maximum stacks of deck cargoes is to be taken into account for assessment of lateral wind forces, arrangements of tug boats and selection of mooring lines.

2 Where the tabular breaking strength exceeds 490 kN, the breaking strength of individual mooring line may be reduced with corresponding increase of number of the mooring lines, provided that the total breaking load of all lines aboard the vessel is not less than the total loads as specified in Ch.5 Table5. 2. The number of mooring lines is not less than 6 and no one line is to have a strength less than 490 kN.

3.2.1 (b) Mooring Winch Force. The design load applied to supporting hull structures for winches, etc. is to be 1.25 times the intended maximum brake holding load and, for capstans, 1.25 times the maximum hauling-in force.

3.2.2 Towing Operations

The minimum design load for deck fittings for towing operations is the applicable value obtained from 3.2.2(a) or 3.2.2(b):

3.2.2 (a) Normal towing operations (e.g., harbor/maneuvering). 1.25 times the intended maximum towing load (e.g., static bollard pull) as indicated on the towing and mooring arrangements plan.

3.2.2 (b) Other towing service (e.g., escort). The nominal breaking strength of the tow line according to the Ch.5 Table 5.2 for each equipment number (EN). EN is the corresponding value used for determination of the vessel's equipment. (See Note)

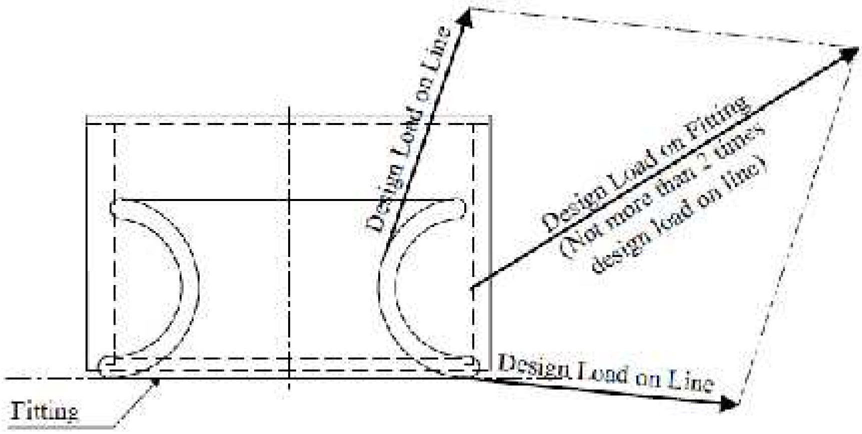
Note: Side projected area including maximum stacks of deck cargoes is to be taken into account for assessment of lateral wind forces, arrangements of tug boats and selection of mooring lines.

3.2.3 Application of Design Loads

The design load is to be applied through the mooring line or tow line, whichever is applicable, according to the arrangement shown on the mooring and towing arrangements plan.

The method of application of the design load to the supporting hull structures is to be taken into account such that the total load need not be more than twice the design load specified in 3.2.2 above, i.e., no more than one turn of one line (Figure 3.1 below).

Figure 3.1: Application of Design Loads



When a specific SWL is applied for a deck fitting at the request of the applicant, by which the design load will be greater than the above minimum values, the strength of the supporting hull structures is to be designed using this specific design load.

3.3 Supporting Structures

3.3.1 Arrangement

The reinforced structural members (e.g., carling) are to be arranged beneath the deck where deck fittings are located and effectively distribute the loads from deck fittings for any variation of direction (horizontally and vertically).

3.3.2 Line Forces

The acting point of the mooring and/or towing force on deck fittings is to be taken at the attachment point of a mooring line or a towing line, as applicable.

3.3.3 Allowable stresses

Allowable stresses under the design load conditions as specified in 3.2 are as follows:

• Normal stress: 100% of the specified minimum yield point of the material;

• Shearing stress: 60% of the specified minimum yield point of the material.

No stress concentration factors being taken into account. Normal stress is the sum of bending stress and axial stress with the corresponding shearing stress acting perpendicular to the normal stress.

3.4 Scantlings

3.4.1 Net Scantlings

The net minimum scantlings of the supporting hull structure are to comply with the requirements given in 3.3. The net thicknesses, t_{net}, are the member thicknesses necessary to obtain the above required minimum net scantlings. The required gross thicknesses are obtained by adding the total corrosion additions, t_c, given in 3.4.2, to t_{net}.

3.4.2 Corrosion Addition

The total corrosion addition, t_c, in mm, for both sides of the hull supporting structure is not to be less than the following values:

- Ships covered by Common Structural Rules (CSR) for bulk carriers and CSR for double hull oil tankers: Total corrosion additions defined in these rules
- Other ships: 2.0

4 Container Loading

4.1 General

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.

4.2 Strength Requirements

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

$SM = M/f$

where

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

f = permissible maximum bending stress, as given in Table 5.1

In determining the maximum bending moment, members may be considered fixed-ended, provided that the member is continuous over the adjacent spans or is effectively attached to a bulkhead stiffener or frame or has end connections in accordance with 2.4. 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 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 2.1, is to be added to the above required section modulus.

5 Higher-strength Materials

5.1 General

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

5.2 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.

$SM_{hts} = 7.8chsl^2Q \quad cm^3$

where c, h, s and *l* are as defined in 2 and Q is as defined in Ch.2 Sec.1/3.3.

Table 5.1: Values of f (Ordinary-strength Steel)

	kN/cm^2
Effective longitudinal members	12.36
Transverse members and longitudinal members inside the line of openings	13.90

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 kN

q = allowable average shear stress in the web, not to exceed 10.35 kN/cm_2

Section 8 Pillars, Deck Girders and Transverses

1 General

1.1 Arrangements – General

Tween-deck pillars are to be arranged directly above those in the holds, or effective means are to be provided for transmitting their loads to the supports below. Pillars are to be fitted in line with a double bottom girder or floor, or as close thereto as practicable. 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 hold pillars.

Where longitudinal beams are used on more than one deck, transverses on the uppermost continuous deck and decks below, and on long superstructures and deck houses are to be fitted at the same vertical plane.

Special support is to be arranged at the ends and corners of deckhouses, in machinery spaces, at ends of partial superstructures and under heavy concentrated weights. For forecastle decks, see also Ch.2 Sec.11/5.

1.2 Container Loading

Where it is intended to carry containers, the structure is to comply with Ch.2 Sec.7/3.

2 Pillars

2.1 Permissible Load

The permissible load W_a of a pillar or strut is to be obtained from the following equation which will, in all cases, be equal to or greater than the calculated load W as determined in accordance with Ch.2 Sec.4/4.4, 2.2, 2.3 or 2.4, as appropriate.

$W_a = (k - nl/r)A$ kN

where

k = 12.09 ordinary strength steel

= 16.11 HT32 strength steel

= 18.12 HT36 strength steel

l = unsupported span of the pillar or strut, in m, measured from the top of the inner bottom, deck or other structure on which the pillar is based to the underside of the beam or girder supported.

r = least radius of gyration, in cm

A = cross sectional area of strut, in cm^2

n = 4.44 ordinary strength steel

= 7.47 HT32 strength steel

= 9.00 HT36 strength steel

2.2 Calculated Load

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

W = nbhs kN

where

n = 7.04

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 widely-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 not to be less than given in Ch.2 Sec.7/Table 2.1, Column a. In measuring the distance from the deck supported to the specified height above the freeboard deck, the height for any tween decks devoted to passenger or crew accommodation may be taken as the height given in Ch.2 Sec.7/2 for bridge deck beams.

The height h for any pillar under the first superstructure above the freeboard deck is not to be less than 2.44 m. The height h for any pillar is not to be less than the height given in Ch.2 Sec.7/2 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 or the tops of tunnels is not to be less than the distance from the recess or tunnel top to the bulkhead deck at the centerline.

2.3 Special Pillars

Special pillars which are not directly in line with those above, or which are not on the lines of the girders, but which support the loads from above or the deck girders through a system of supplementary fore and aft or transverse girders, such as at hatch ends where the pillars are fitted only on the centerline, 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 2.2.

2.4 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 cW cm^2 where W and c are obtained as follows:

W = nbhs kN

where

n = 10.5

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 Ch.2 Sec.7/2.1, for beams at the top of tanks, in m

c = 0.1035 ordinary strength steel

= 0.0776 HT32 strength steel

= 0.069 HT36 strength steel

2.5 Bulkhead Stiffening

Bulkheads which support girders, or pillars 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 or pillars.

2.6 Attachments

Widely-spaced tubular or solid pillars 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, tunnel tops 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.

3 Deck Girders and Transverses

3.1 General

Girders and transverses of the sizes required by 3.2 through 3.8 are to be fitted, 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 4.57 m. Additional girders are to be fitted, as required under masts, king posts, deck machinery or other heavy concentrated loads. In way of deck girders or special deep beams, the deck plating is to be of sufficient thickness and suitably stiffened to provide an effective part of the girder.

3.2 Deck Girders Clear of Tanks

Each deck girder clear of tanks, similar to that shown in Figure 3.1, is to have a section modulus SM as

obtained from the following equation:

$SM = 4.74cbhl^2$ cm^3

where

c = 1.0

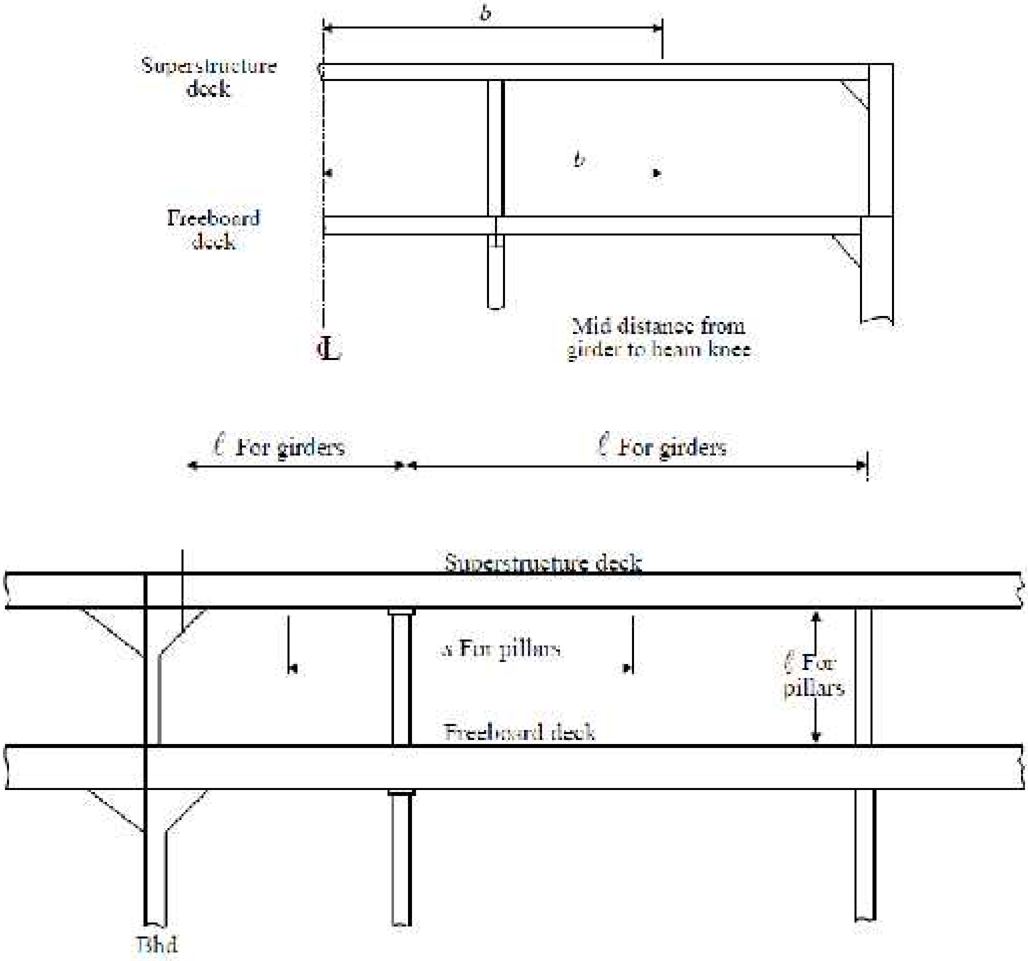
b = mean breadth of the area of deck supported, in m

h = height, as required by Ch.2 Sec.7/2.1, for the beams supported, in m

l = span between centers of supporting pillars, or between pillar and bulkhead, in m.

Where an effective bracket, in accordance with Ch.2 Sec.6/4.1, is fitted at the bulkhead, the length *l* may be modified.

Figure 3.1: Deck Girders and Pillars



3.3 Deck Transverses Clear of Tanks

Each deck transverse supporting longitudinal deck beams is to have a section modulus SM, as obtained from the equations in 3.2, where:

c = 1.0

b = spacing of deck transverses, in m

h = height, as required by Ch.2 Sec.7/2.1, for the beams supported, in m

l = span between supporting girders or bulkheads, or between girder and side frame, in m. Where an effective bracket is fitted at the side frame or bulkhead, the length *l* may be modified. See Ch.2 Sec.6/4.1.

3.4 Proportions

Girders and transverses 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 or less, 10 mm with 63 cm^2,12.5 mm with 127 cm^2 and 15 mm with 190 cm^2 or over. The thickness for intermediate area may be obtained by interpolation.

3.5 Tripping Brackets

Tripping brackets are to be fitted at intervals of about 3 m and near the change of section. Where the breadth of the flanges on either side of the web exceeds 200 mm, tripping brackets are to be arranged to support the flange. Additional supports are to be provided for the flanges where their breadth exceeds 400 mm.

3.6 End Attachments

The ends of deck girders and transverses are to be effectively attached by welding.

3.7 Deck Girders and Transverses in Tanks

Deck girders and transverses in tanks are to be obtained in the same manner as given in 3.2, except that the value of c is to be equal to 1.50 and the minimum depth of the girder is to be $0.0833l$. The minimum thickness, sizes and arrangements of the stiffeners, tripping brackets and end connections are to be the same as given in 3.4, 3.5, and 3.6.

3.8 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 (3.2 through 3.7). 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 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, such as at weather decks, the girder below deck may be modified so as to obtain a section modulus, when taken in conjunction with the coaming up to and including the horizontal coaming stiffener, of not less than 35% more than required by 3.2.

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. Where the hatch side coaming is extended beyond the hatchway, it is not to be connected to the end bulkheads of superstructures or deckhouses, except where it is shown to be appropriate by detailed analysis.

Gusset plates are to be fitted at hatchway corners, arranged so as to effectively tie the flanges of the side coamings and extension pieces or continuous girders and the hatch-end beam flanges both beyond and in the hatchway.

4 Hatch-end Beams

4.1 Hatch-end Beam Supports

Each hatch-end beam, similar to that shown in Figure 4.2, which is supported by a centerline pillar without a pillar at the corner of the hatchway, is to have a section modulus SM not less than obtained from the following equations:

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

$$SM = K\,(AB + CD)\,hl \quad \text{cm}^3$$

4.1.2 Where Girders are not Fitted on the Line of the Hatch Side Beyond the Hatchway

SM = KABhl cm^3

where

A = length of the hatchway, in m

B = distance from the centerline 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 centerline 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 Ch.2 Sec.7/2.1, in m

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

K = 2.20 + 1.29(F/N) when F/N ≤ 0.6

= 4.28 − 2.17(F/N) when F/N > 0.6

N = one-half the breadth of the vessel in way of the hatch-end beam, in m

F = distance from the side of the vessel to the hatch side girder, in m

4.2 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 athwartship brackets be fitted above deck at the ends of the hatch-end coaming.

4.3 Depth and Thickness

The depth and thickness of hatch-end beams are to be similar to those required for deck girders by 3.4.

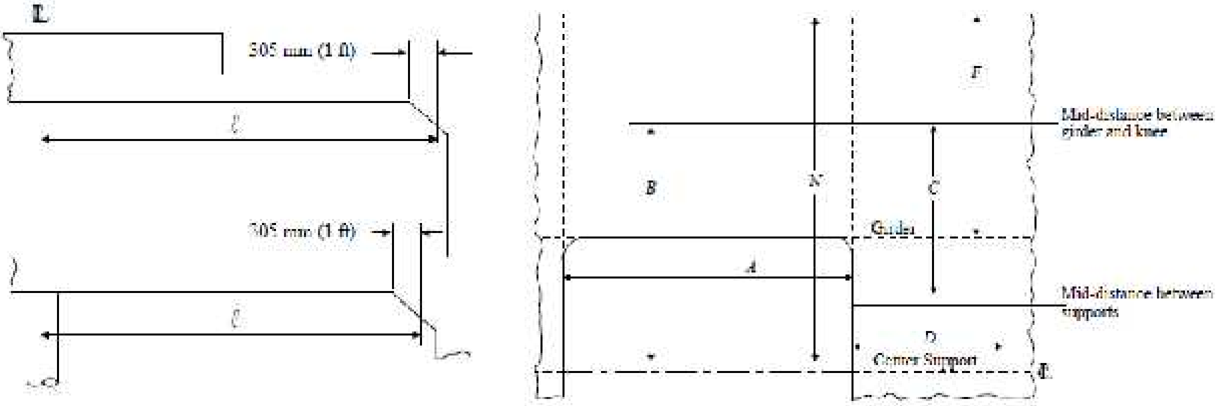
4.4 Tripping Brackets

The arrangement of tripping brackets is to be in accordance with 3.5.

4.5 Brackets

Brackets at the ends of hatch-end beams are to be generally as described in Ch.2 Sec.6/4.1. Where brackets are not fitted, the length l is to be measured to the side of the vessel and the face plates or flanges on the beams are to be attached to the shell by heavy horizontal brackets extending to the adjacent frame.

Figure 4.2: Hatch-end Beams



5 Higher-strength Materials

5.1 General

In general, applications of higher-strength materials for deck girders and deck transverses are to meet the requirements of this section, but may be modified as permitted by the following paragraphs. Calculations are to be submitted to show adequate provision to resist buckling.

5.2 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 generally to comply with the requirements of the appropriate preceding paragraphs of this section and is to have a section modulus SM_{hts} not less than obtained from the following equation:

$SM_{hts} = SM(Q)$

where

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

Q = as defined in Ch.2 Sec.1/3.3

Section 9 Watertight Bulkheads And Doors

1 General

1.1 Application

All vessels are to be provided with strength and watertight bulkheads in accordance with this section. In vessels of special type, alternative arrangements are to be specially approved. In all cases, the plans submitted are to clearly show the location and extent of the bulkheads. Watertight bulkheads constructed in accordance with the Rules will be recorded in the Record as WT (watertight), the symbols being prefixed in each case by the number of such bulkheads.

1.2 Openings and Penetrations

The number of openings in watertight subdivisions is to be kept to a minimum, compatible with the design and proper working of the vessel. Where penetrations of watertight bulkheads and internal decks (see Ch.2 Sec.15/9.2) are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity. Relaxation in the watertightness of openings above the freeboard deck may be considered, provided it is demonstrated that any progressive flooding can be easily controlled and that the safety of the vessel is not impaired.

Ventilation penetrations through watertight subdivision bulkheads are to be avoided. Where penetrations are unavoidable, the ventilation ducting is to satisfy watertight bulkhead requirements or watertight closing appliances are to be installed at the bulkhead penetrations. For ventilation penetrations below the bulkhead deck or below damage equilibrium waterlines, the closing appliances are to be operable from the bridge.

Where the penetration is located above the bulkhead deck and damage waterline, local manual controls may be provided at the closing appliances, on one or both sides of the bulkhead, so that the controls will be accessible in the prescribed flooded conditions.

1.3 Sluice Valves and Cocks

No valve or cock for sluicing purposes is to be fitted on a collision bulkhead. Where fitted on other watertight bulkheads, sluice valves or cocks are to comply with the requirements.

1.4 Strength Bulkheads

All vessels are to have suitable arrangements to provide effective transverse strength and stiffness of the hull. This may be accomplished by fitting transverse bulkheads extending to the strength deck. In vessels 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.

1.5 Testing

Requirements for testing are contained in Part 3, Chapter 7.

2 Arrangement of Watertight Bulkheads

2.1 Collision Bulkhead

2.1.1 General

A collision bulkhead is to be fitted on all vessels. It is to be intact, that is, without openings except as permitted in exceptional cases. It is to extend, preferably in one plane, to the freeboard deck. In the case of vessels having long superstructures at the fore end, it is to be extended weathertight to the superstructure deck. The extension need not be fitted directly over the bulkhead below, provided that the location of the extension meets the following requirements and the part of the deck which forms the step is made effectively weathertight.

On vessels with bow-doors, that part of their sloping loading ramps that form part of the extension of a collision bulkhead, and are more than 2.3 m above the freeboard deck, may extend forward of the limit below. See Figure 2.1.

2.1.2 Location

The collision bulkhead is to be located at any point not less than $0.05L_r$ or 10 m, whichever is less, abaft the reference point. At no point on any vessel, except as specially permitted, is it to be further than $0.08L_r$ or $0.05L_r + 3$ m, whichever is greater, from the reference point.

2.1.3 Definitions

The reference point in determining the location of the collision bulkhead is the forward end of L_r except that in the case of vessels having any part of the underwater body, such as bulbous bow, extending forward of the forward end of L_r, the required distances are to be measured from a reference point located a distance forward of the forward end of L_r. This distance x is the least of the following:

i) Half the distance between the forward end of L_r and the extreme forward end of the extension, p/2

ii) $0.015L_r$ or

iii) 3 m. See Figure 2.2.

L_r = (for passenger vessels) length between perpendiculars at the deepest subdivision load line.

The forward end of L_r is to coincide with the fore side of stem on the waterline on which L_r is measured.

L_r = (for other vessels) L_f as defined in Ch.1 Sec.1/1.

2.2 After-peak Bulkhead

An after-peak bulkhead is to be fitted in all screw vessels arranged to enclose the shaft tubes in a watertight compartment. The bulkhead is to extend to the strength deck, or efficient partial bulkheads are to extend thereto. The requirements of enclosing the shaft tube in a watertight compartment may be specially considered where such an arrangement is impracticable.

Figure 2.1: Collision Bulkhead in Vessels with Bow Door

$y_1 = 0.05L_r$ or 10m whichever is less

$y_2 = 0.08L_r$ or $0.05L_r$ + 3m whichever is greater

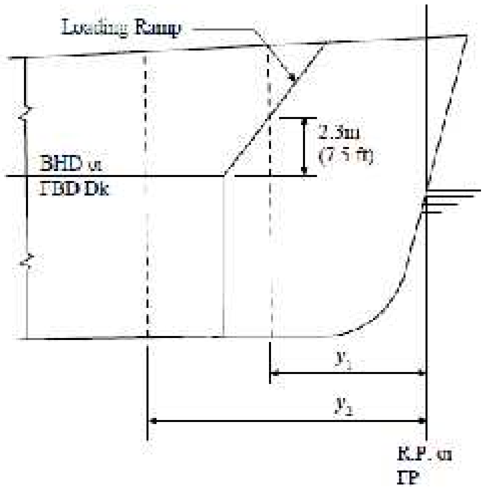
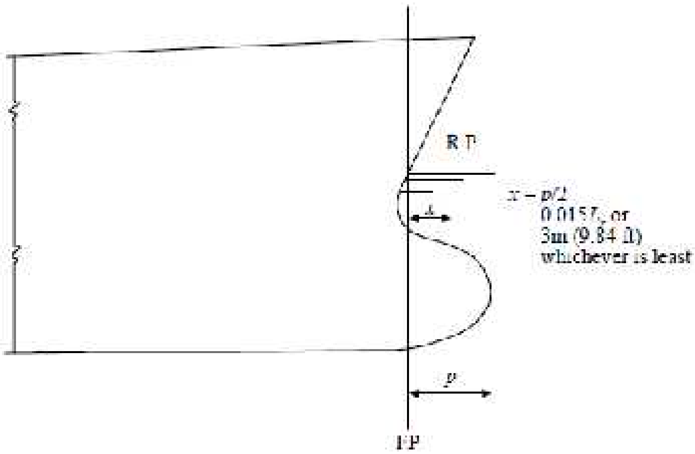


Figure 2.2: Reference Point for Vessels with Bulbous Bow



2.3 Machinery Spaces

Machinery spaces are to be enclosed by watertight bulkheads which extend to the freeboard deck. In those cases where the length of the machinery space is 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, the fitting of an intermediate bulkhead, or the inclusion of a watertight deck over the machinery space which, in association with tight casings, might confine the amount of flooding in the event of damage in way of the machinery space.

2.4 Hold Bulkheads

2.4.1 General

In addition to the foregoing required watertight bulkheads, the number and arrangement of hold bulkheads are to satisfy the subdivision and damage stability requirements.

2.4.2 Carriage of Water Ballast in Cargo Holds

Where a cargo hold is intended to be used for the carriage of water ballast or liquid cargoes, the hold is in general to be completely filled and the scantlings of the inner bottom, side structure, transverse bulkheads, deck and hatch covers are also to be in accordance with Ch. 2 Sec.10. The hatch cover and securing devices are to be suitable for the internal loading. .

Special consideration may be given to the scantlings of cargo holds partially filled with water ballast or liquid cargoes. Full particulars are to be submitted.

2.5 Chain Lockers

Chain lockers and chain pipes are to be made watertight up to the weather deck. The arrangements are to be such that accidental flooding of the chain locker cannot result in damage to auxiliaries or equipment necessary for the proper operation of the vessel nor in successive flooding into other spaces. Bulkheads between separate chain lockers not forming a part of subdivision bulkhead (see Figure 2.3A below), or bulkheads which form a common boundary of chain lockers (see Figure 2.3B below), need not be watertight.

Where means of access into chain lockers are provided, they are to be closed by a substantial cover secured by closely spaced bolts. Doors are not permitted.

Where a means of access to chain lockers is located below the weather deck, the access cover and its securing arrangements are to be in accordance with recognized standards (such as ISO 5894-1999), or equivalent for watertight manhole covers. Butterfly nuts and/or hinged bolts are prohibited as the securing mechanism for the access cover.

For closure of chain pipes, see Ch.2 Sec.15/12.6.

The arrangements on vessels that are not subject to the International Convention on Load Lines or its Protocol may be specially considered.

Figure 2.3A

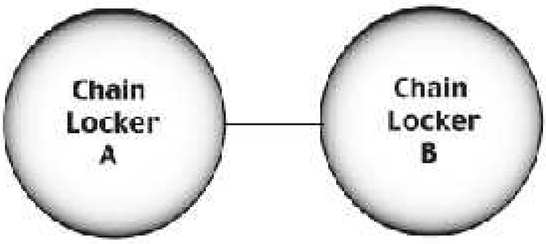
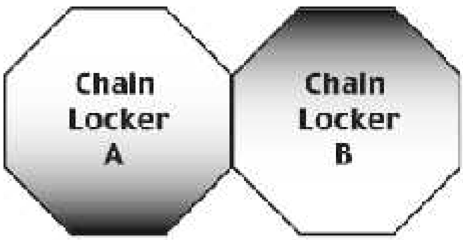


Figure 2.3B



3 Construction of Watertight Bulkheads

3.1 Plating

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

$t = sk\sqrt{qh}/c + 1.5$ mm but not less than 6 mm or

$s/200 + 2.5$ mm, whichever is greater

where

t = thickness, in mm

s = spacing of stiffeners, in mm

k = (3.075 $\sqrt{\sim}$ − 2.077)/(α + 0.272) where 1 ≤ α ≤ 2

= 1.0 where α > 2

α = aspect ratio of the panel (longer edge/shorter edge)

q = 235/Y N/mm^2

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

h = distance from the lower edge of the plate to the deepest equilibrium waterline in the one compartment damaged condition, in m.

- For passenger vessels, *h* is to be taken as not less than the distance to the margin line.
- For cargo vessels, *h* is to be not less than the distance to the bulkhead deck at center unless a deck lower than the uppermost continuous deck is designated as the freeboard deck, as allowed in Ch.1 Sec.1/7.1. In such case, *h* is to be not less than the distance to the designated freeboard deck at center.

c = 254 for collision bulkhead

= 290 for other watertight bulkhead

The plating of afterpeak bulkheads below the lowest flat is not to be less than required for solid floors in the after peak space. See Ch.2 Sec.5/5.

3.2 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 = 7.8chsl^2 cm^3

where

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

= 0.43 for stiffeners having effective brackets at one end and supported by clip connections or by horizontal girders at the other end

= 0.56 for stiffeners having clip connections at both ends, or clip connections at one end and supported by horizontal girders at the other end, and for stiffeners in the uppermost tween decks having no end attachments

= 0.60 for other stiffeners having no end attachments and for stiffeners between horizontal girders

s = spacing of the stiffeners, in m

h = distance, in m, from the middle of *l* to the deepest equilibrium waterline in the one compartment damaged condition.

- For passenger vessels, *h* is to be taken as not less than the distance to the margin line.
- For cargo vessels, *h* is to be not less than the distance to the bulkhead deck at center unless a deck lower than the uppermost continuous deck is designated as the freeboard deck, as allowed in Ch.1 Sec.1/7.1. In such case, h is to be not less than the distance to the designated freeboard deck at center.
- For all vessels, where the distance indicated above is less than 6.10 m, *h* is to be taken as 0.8 times the distance plus 1.22 m.

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, or the distance between the horizontal girders, 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 the above values of c, is to have the scantlings not less effective than shown in Table 3.1 and is to extend onto the stiffener for a distance at least one-eighth of the length *l* of the stiffener.

3.3 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.

Table 3.1: Thickness and Flanges of Brackets and Knees

Millimeters			
Depth of Longer Arm	Thickness		Width of Flange
	Plain	Flanged	
150	6.5		
175	7.0		
200	7.0	6.5	30
225	7.5	6.5	30
250	8.0	6.5	30
275	8.0	7.0	35
300	8.5	7.0	35
325	9.0	7.0	40
350	9.0	7.5	40
375	9.5	7.5	45
400	10.0	7.5	45
425	10.0	8.0	45
450	10.5	8.0	50
475	11.0	8.0	50
500	11.0	8.5	55
525	11.5	8.5	55
550	12.0	8.5	55
600	12.5	9.0	60
650	13.0	9.5	65
700	14.0	9.5	70
750	14.5	10.0	75
800		10.5	80
850		10.5	85
900		11.0	90
950		11.5	90
1000		11.5	95
1050		12.0	100
1100		12.5	105
1150		12.5	110
1200		13.0	110

Note: 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.

3.4 Girders and Webs

3.4.1 Strength Requirements

Each girder and web which supports bulkhead stiffeners is to have section modulus SM not less than obtained from the following equation:

$SM = 4.74chsl^2$ cm^3

where

c = 1.0

h = vertical distance, in m, to the deepest equilibrium waterline in the one compartment damaged condition from the middle of *s* in the case of girders and from the middle of *l* in the case of webs.

• For passenger vessels, *h* is to be taken as not less than the distance to the margin line.

• For cargo vessels, *h* is to be not less than the distance to the bulkhead deck at center unless a deck lower than the uppermost continuous deck is designated as the freeboard deck, as allowed in Ch.1 Sec.1/7.1, in which case

h is to be not less than the distance to the designated freeboard deck at center.

• For all vessels, where the distance indicated above is less than 6.10 m, the value of *h* is to be 0.8 times the distance plus 1.22 m.

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

l = span measured between the heels of the end attachments, in m. Where brackets are fitted, the length l may be modified as indicated in Ch.2 Sec.6/4.1.

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.

3.4.2 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 1 mm per 100 mm of depth plus 3 mm but need not exceed 11.5 mm.

3.4.3 Tripping Brackets

Tripping brackets are to be fitted at intervals of about 3 m, and near the change of section.

Where the width of the face flange exceeds 200 mm on either side of the girder or web, tripping brackets are to be arranged to support the flange.

4 Construction of Corrugated Bulkheads

4.1 Plating

The plating of corrugated bulkheads is to be of the thickness required by 3.1 with the following modification. The spacing to be used is the greater of dimensions a or c, as indicated in Figure 4.1. The angle φ is to be 45 degrees or more.

4.2 Stiffeners

The section modulus SM for a corrugated bulkhead is to be not less than obtained from the following equation:

$SM = 7.8chsl^2$ cm^3

where

l = distance between supporting members, in m. Where applicable, the distance l may be measured between the upper and lower stools, except that the credit for upper stools of rectangular cross section is not to exceed twice the width of the cross section (“2 × b” in Figure 4.3-2) and trapezoidal cross section is not to exceed twice the width of the mid-segment (“b′ + b” in Figure 4.3-4)

s = value determined using a + b (See Figure 4.1)

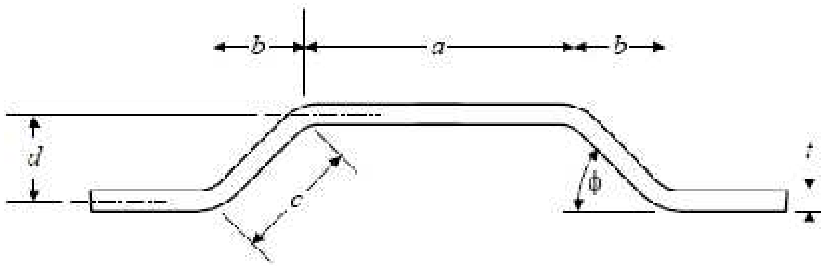
c = 0.56

h = as defined in 3.2

The developed section modulus SM may be obtained from the following equation, where a, t and d are as indicated in Figure 4.1.

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

Figure 4.1: Corrugated Bulkhead



4.3 End Connections

The structural arrangements and size of welding at the ends of corrugations are to be designed to develop the required strength of corrugated stiffeners. Joints within 10% of the depth of corrugation from the outer surface of corrugation, d_1, are to have double continuous welds with fillet size w not less than 0.7 times the thickness of bulkhead plating or penetration welds of equal strength. See Figure 4.2 and Ch.2 Sec.19/8.

Figure 4.2: Corrugated Bulkhead End Connections

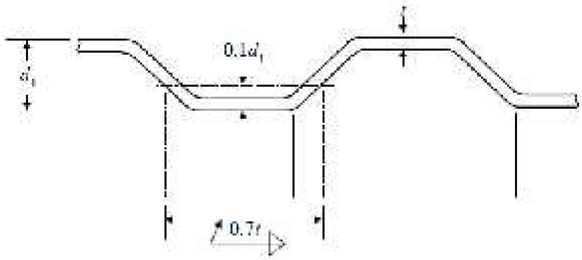
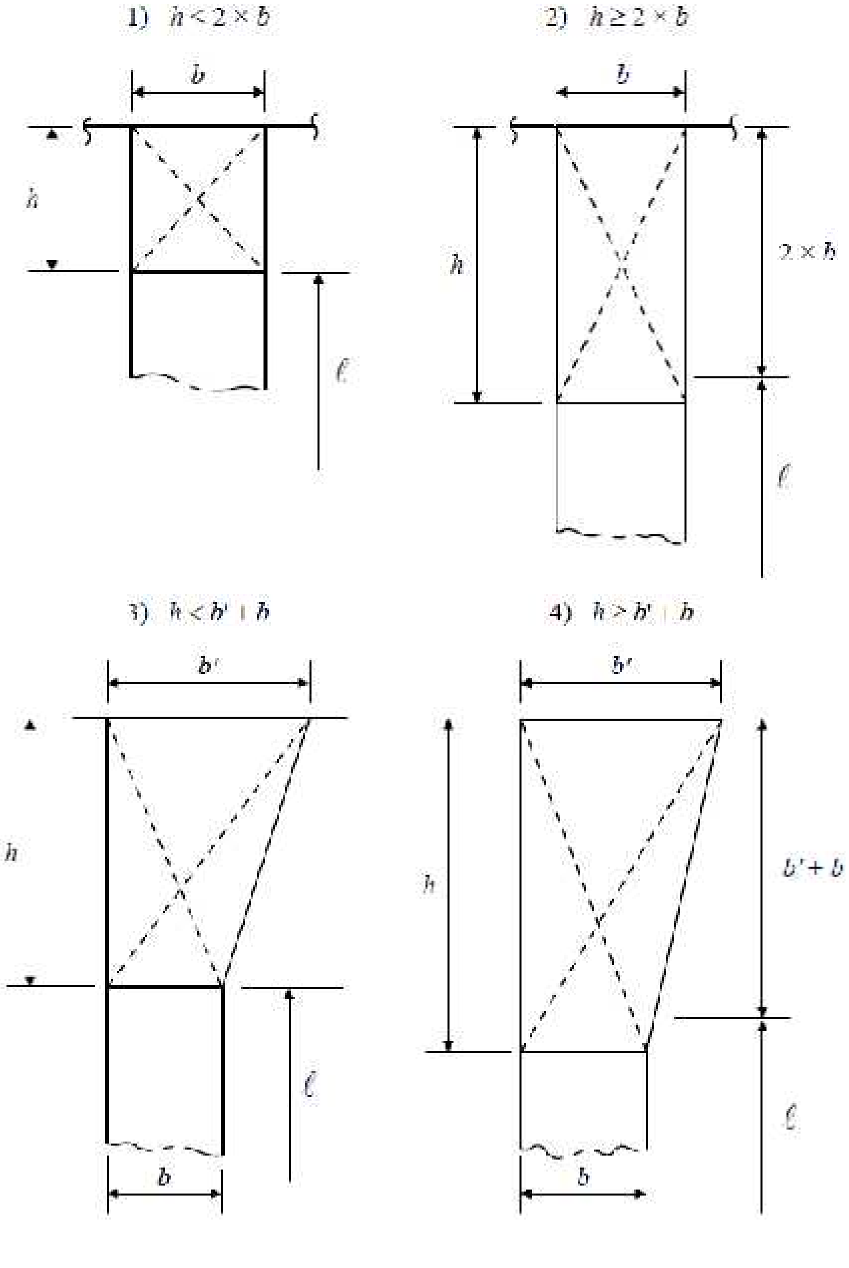


Figure 4.3: Corrugated Bulkhead Upper Stool Credit



5 Watertight Doors

5.1 Doors Used While at Sea

Doors that are used while at sea are to be sliding watertight doors capable of being remotely closed from the bridge and are also to be operable locally from each side of the bulkhead. Indicators are to be provided at the control position showing whether the doors are open or closed, and an audible alarm is to be provided which is to sound whenever the door is closed remotely by power. The power operated doors, control systems and indicators are to be functional in the event of main power failure. Particular attention is to be paid to minimize the effect of control system failure. Each power operated sliding watertight door is to be provided with an individual hand-operated mechanism. It is to be possible to open and close the door by hand at the door itself from each side.

5.2 Access Doors Normally Closed at Sea

Access doors and access hatch covers (see Ch.2 Sec.15/10.2) normally closed at sea may be substantially constructed hinged type fitted with gaskets and dogs spaced and designed to ensure that the opening may be closed thoroughly watertight. These closing appliances are to be provided with means of indicating locally and on the bridge whether they are open or closed. A notice is to be affixed to each closing appliance to the effect that it is not to be left open.

Additionally, where a vessel is a Type A ship over 150 m in length or a Type B ship over 100 m in length, with a freeboard less than that based on Table B in Regulation 28 of the International Convention on Load Lines, 1966, the final waterline after flooding, taking into account sinkage, heel and trim, is to be below the lower edge of openings of those doors through which progressive down flooding may take place, unless the doors are remotely operated. Doors separating a main machinery space from the steering gear compartment may be hinged, quick acting type (e.g., all door dogs are in closed/opened position simultaneously by a manually-operated single handle or equivalent), provided that the sill of such doors is above the summer load waterline.

5.3 Doors or Ramps Dividing Large Cargo Spaces

Watertight doors or ramps (see Ch.2 Sec.15/10.2) of satisfactory construction may be fitted to internally subdivide large cargo spaces, provided it is demonstrated to ACS that such doors or ramps are essential.

These doors or ramps may be hinged, rolling or sliding doors or ramps, but are not to be remotely controlled.

Such doors or ramps may be approved on condition that the shipboard personnel close them before the voyage commences and are kept closed during navigation. The time of opening such doors or ramps in port and of closing them before the vessel leaves port is to be recorded and entered in the logbook.

Doors or ramps accessible during the voyage are to be fitted with a device, which prevents unauthorized opening.

5.4 Other Openings Closed at Sea

Closing appliances which are to be kept permanently closed at sea, to ensure the watertight integrity of internal openings in watertight bulkheads and decks (see Ch.2 Sec.15/10.2), that are not fitted with a device which prevents unauthorized opening are to be provided with a notice affixed to each such closing appliance to the effect that it is to be kept closed while the vessel is at sea. Manholes fitted with closely bolted covers need not be so marked.

5.5 Construction

Watertight doors are to be of ample strength for the water pressure to which they may be subjected.

Doorframes are to be carefully fitted to the bulkheads; where liners are required, the material is to be not readily injured by heat or by deterioration. Sliding doors are to be carefully fitted to the frames.

Where stiffeners are cut in way of watertight doors, the openings are to be framed and bracketed to maintain the full strength of the bulkheads without taking the strength of the doorframes into consideration.

5.6 Testing at Sliding Door Manufacturer

Sliding doors are to be tested for operation at the manufacturer's plant. Hydrostatic testing of sliding doors is also to be carried out at the manufacturer's plant, with a head of water equivalent to the height to the bulkhead deck or freeboard deck at center.

Section 10 Deep Tanks

1 General

1.1 Application

This Section applies to all deep tanks where the requirements in this Section exceed those of Ch.2 Sec.9.

1.2 Arrangement

The arrangement of all deep tanks, together with their intended service and the height of the overflow pipes, is to be clearly indicated on the plans submitted for approval.

Tanks for fresh water or fuel oil or those that are not intended to be kept entirely filled in service, are to have divisions or deep swashes as may be required to minimize the dynamic stress on the structure. Oil or other liquid substances that are flammable are not to be carried in tanks forward of the collision bulkhead.

1.3 Construction

The boundary bulkheads of all deep tanks are to be constructed in accordance with the requirements of this Section.

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 Ch.2 Sec.9. In such cases, the tanks are to be provided with feed tanks or deep hatches, fitted with inspection plugs in order to ensure that the tanks on both sides of the bulkhead so designed are kept full when in service.

1.4 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 spaces above deep tanks.

1.5 Testing

Requirements for testing are contained in Ch. 7.

2 Construction of Deep Tank Bulkheads

Where the specific gravity of the liquid exceeds 1.05, the design head, *h*, in this section is to be increased by the ratio of the specific gravity of the liquid to be carried, to 1.05.

2.1 Plating

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

$t = (sk\sqrt{qh}\ /254) + 2.5$ mm but not less than 6.5 mm or

s /150 + 2.5 mm, whichever is greater.

where

t = thickness, in mm

s = stiffener spacing, in mm

$k = (3.075 \sqrt{\sim} - 2.077)/(\alpha + 0.272)$ where $1 \le \alpha \le 2$

= 1.0 where $\alpha > 2$

α = aspect ratio of the panel (longer edge/shorter edge)

q = 235/Y N/mm^2

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

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

- a point located two-thirds of the distance from the top of the tank to the top of the overflow
- a point located above the top of the tank at a distance not less than given in column (e) of Ch.2 Sec.7/Table 2.1, appropriate to the vessel's length
- the load line
- a point located at two-thirds of the distance to the bulkhead or freeboard deck

2.2 Stiffeners

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

$SM = 7.8chsl^2$ cm^3

where

c = 0.594 for stiffeners having effective bracket attachments at both ends

= 0.747 for stiffeners having effective bracket attachment at one end and supported by clip connections or by horizontal girders at the other end

c = 0.900 for stiffeners having clip attachments to decks or flats at both ends or having such attachments at one end with the other end supported by horizontal girders

= 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 at two-thirds of the distance from the top of the tank to the top of the overflow
- a point located above the top of the tank a distance not less than given in column (e) of Ch.2 Sec.7/Table 2.1, appropriate to the vessel's length
- the load line
- a point located at two-thirds of the distance to the bulkhead or freeboard 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 or the distance between the horizontal girders.

An effective bracket for the application of these values of *c* is to have the scantlings not less effective than shown in Ch.2 Sec.9 Table 3.1 and is to extend onto the stiffener for a distance at least one-eighth of the length *l* of the stiffener.

2.3 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, girders and pillars are to be as required by Ch.2 Sec.7 and Ch.2 Sec.8.

2.4 Girders and Webs

2.4.1 Strength Requirements

Each girder and web which support frames or beams in deep tanks is to have section modulus SM as required by Ch.2 Sec.6 and Ch.2 Sec.8 or as required by this paragraph, 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.

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

where

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 2.2)

s = sum of half lengths (on each side of girder or web) 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 Ch.2 Sec.6/4.1.

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

2.4.2 Proportions

Girders, except deck girders (see Ch.2 Sec.8/3.7), 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% of the depth plus 3 mm but need not exceed 11.5 mm.

2.4.3 Tripping Brackets

Tripping brackets are to be fitted at intervals of about 3 m and near the change of section.

Where the width of the face flange exceeds 200 mm on either side of the girder or web, tripping brackets are to be arranged to support the flange.

2.5 Corrugated Bulkheads

Where corrugated bulkheads are used as deep-tank boundaries, the scantlings may be developed from Ch.2 Sec.9/4.

The plating thickness t and value of SM are to be as required by 2.1 and 2.2, respectively,

with c = 0.90.

3 Higher-strength Materials

3.1 General

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

3.2 Plating

Deep-tank plating of higher-strength material is to be of not less thickness than obtained by 2.1.

3.3 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:

$SMhts = 7.8chsl^2Q$ cm^3

where c, h, s and l are as defined in 2.2 and Q is as defined in Ch.2 Sec.1/3.3.

Section 11 Superstructures, Deckhouses and Helicopter Decks

1 General Scantlings of Superstructures and Deckhouses

1.1 Side Plating

Side plating of superstructures within the amidship 0.4L of the vessel is to be obtained from Ch.2 Sec.2/2. At the forward and after ends, the plating for 0.1L from each end may be of the thickness obtained from Ch.2 Sec.2/3.4 and Ch.2 Sec.2/3.5 for forecastle and poop side plating respectively; beyond 0.1L from each end, the thickness of the plating is to be gradually increased to that required within the amidship 0.4L length.

1.2 Decks

1.2.1 Superstructures

Decks of superstructures having lengths greater than 0.1L are to be considered as strength decks and are to comply with the requirements of Ch.2 Sec.3/3. Where 0.1L or less in length, the stringer plate may be the thickness of the side plating and the remainder of the deck plating is to meet the hull girder section modulus requirements of Section Ch.2 Sec.1 if located within the 0.4L amidships. The thickness of the plating at the forward and aft ends is to be obtained from Ch.2 Sec.3/Table 3.1 for forecastle and poop deck plating.

1.2.2 Deckhouses

The top plating of long deckhouses is to be as required by Ch.2 Sec.3/Table 3.1 line H. In addition, deckhouses located within 0.4L amidships and having lengths over 0.1L are to have plating meeting the hull girder requirements of Section Ch.2 Sec.1.

1.3 Frames

Frames are to be of the sizes obtained from Ch.2 Sec.5/3. Web frames or partial bulkheads are to be fitted over main bulkheads and elsewhere as may be required to give effective transverse rigidity to the structure.

1.4 Breaks in Continuity

Breaks in the continuity of superstructures are to be specially strengthened (see Ch.2 Sec.2/6). The arrangements in this area are to be clearly shown on the plans submitted for approval.

2 Exposed Bulkheads

2.1 General

The scantlings of the exposed bulkheads of superstructures and deckhouses are to be in accordance with the following paragraphs, except that the requirements for house side stiffeners need not exceed the requirements of Ch.2 Sec.5 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, superstructure deck or in the top of a lowest tier deckhouse, or which do not protect machinery casings, provided they do not contain accommodation, or do not protect equipment essential to the operation of the vessel.

Superstructures or deckhouses located within the amidship 0.4L and having lengths greater than 0.1L 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 Ch.2 Sec.11/1 and the house top and side plating of long deckhouses is to be not less than obtained from equation 5 in Ch.2 Sec.3/Table 3.2.

Partial bulkheads, deep webs, etc. are to be fitted at the ends and sides of large superstructures or deckhouses to provide resistance to racking.

2.2 Plating

The plating is to be not less in thickness than obtained from the following equation:

$t = 3s\sqrt{h}$ mm

where *s* and *h* are as defined in 2.3; 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 not to be less than

$4.0 + L_2/100$ mm or 5.0 mm, whichever is greater

where L_2 is defined in 2.3.

2.3 Stiffeners

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

$SM = 3.5sl^2h$ cm^3

where

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 not to be taken less than 2.5+L/100 m, in which L need not be taken as greater than 250 m.

• 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 2.1.

$$b = 1.0 + \left[\frac{(x/L) - 0.45}{C_b + 0.2}\right]^2 \quad \text{where } x/L \le 0.45$$

$$= 1.0 + 1.5\left[\frac{(x/L) - 0.45}{C_b + 0.2}\right]^2 \quad \text{where } x/L > 0.45$$

C_b = block coefficient, as defined in Ch.1 Sec.1/1.6, not to be taken as less than 0.60 nor greater than 0.80. For aft end bulkheads forward of amidships, C_b may be taken as 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 not exceeding 0.15L in length and x is to be measured from the after perpendicular to the center of each part considered.

L, L_2 = length of vessel, in m, but L_2 need not be taken as greater than 300 m

f = value determined from Table 2.2, in m.

y = vertical distance, in m, from the summer load waterline to the midpoint of the stiffener span

c = $(0.3 + 0.7\, b_1/B_1)$ 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, in m

B_1 = actual breadth of the vessel at the freeboard deck at the position being considered, in m

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.

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 vessel, the actual height of the raised quarter deck and the arrangement of the structure.

Table 2.1: Values of a

Bulkhead Location	a
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	$0.5 + (L_2/1000) - 0.4x/L$

Table 2: Values of f

Intermediate values of f may be obtained by interpolation

L, m	*f, m*
24	1.24
40	2.57
60	4.07
80	5.41
90	6.00
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:

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

3 Enclosed Superstructures

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 condition water will not penetrate the vessel. Opening and closing appliances are to be framed and stiffened so that the whole structure is equivalent to the unpierced bulkhead when closed.

3.2 Doors for Access Openings

Doors for access openings into enclosed superstructures are to be of steel or other equivalent material, permanently and strongly attached to the bulkhead. The doors are to be provided with gaskets and clamping devices, or other equivalent arrangements, permanently attached to the bulkhead or to the doors themselves, and the doors are to be so arranged that they can be operated from both sides of the bulkhead.

3.3 Sills of Access Openings

Except as otherwise provided in these Rules, 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. For companionway sills, see Ch.2 Sec.15/12.4.

3.4 Portlights

Portlights in the end bulkheads of enclosed superstructures are to be of substantial construction and provided with efficient inside deadlights. Also see Ch.2 Sec.17/4.

3.5 Bridges and Poops

A bridge or poop is not regarded as enclosed unless an alternate means of access is provided for the crew from any point on the exposed portion of the uppermost continuous deck to reach the machinery space or other working spaces within these superstructures when the bulkhead openings are closed.

4 Open Superstructures

Superstructures with openings which do not fully comply with Ch.2 Sec.11/3 are to be considered as open superstructures.

5 Forecastle Structures

Forecastle structures on vessels with minimum freeboard are to be supported by girders in association with deep beams and web frames, preferably arranged in complete transverse belts and supported by lines of pillars extending continuously down into the structure below. Beams and girders are to be arranged, where practicable, to limit the spans to about 3 m. Pillars are to be provided as required by Ch.2 Sec.8/2.1, except that generally the diameter of pillars is not to be less than 200 mm for vessels possibly subjected to green water on the deck. Main structural intersections are to be carefully developed with special attention given to pillar head and heel connections, and to the avoidance of stress concentrations.

6 Helicopter Decks

6.1 General

Helicopter decks, where provided, are to meet the following structural and safety requirements. The attention of Owners, builders and designers is directed to various international and governmental regulations and guides regarding the operational and other design requirements for helicopters landing on ships.

Plans showing the arrangement, scantlings and details of the helicopter deck are to be submitted. The arrangement plan is to show the overall size of the helicopter deck and the designated landing area. If the arrangement provides for the securing of a helicopter or helicopters to the deck, the predetermined position(s) selected to accommodate the secured helicopter, in addition to the locations of deck fittings for securing the helicopter, are to be shown. The type of helicopter to be considered is to be specified and calculations for appropriate loading conditions are to be submitted.

6.2 Structure

Scantlings of helicopter decks and supporting structure are to be determined on the basis of the following loading conditions, whichever is greater, in association with the allowable factors of safety shown in Ch.2 Sec.11/Table 6.1. Plastic design considerations may be applied for deck plating and stiffeners.

6.2.1 Overall Distributed Loading

A minimum distributed loading of 2.01 kN/m^2 is to be taken over the entire helicopter deck.

6.2.2 Helicopter Landing Impact Loading

A load of not less than 75% of the helicopter maximum take-off weight is to be taken on each of two square areas, 0.3 m × 0.3 m. Alternatively, the manufacturer's recommended wheel impact loading will be considered. The deck is to be considered for helicopter landings at any location within the designated landing area. The structural weight of the helicopter deck is to be added to the helicopter impact loading when considering girders, stanchions, truss supports, etc. Where the upper deck of a superstructure or deckhouse is used as a helicopter deck and the spaces below are normally manned (quarters, bridge, control room, etc.), the impact loading is to be multiplied by a factor of 1.15.

6.2.3 Stowed Helicopter Loading

If provisions are made to accommodate helicopters secured to the deck in a predetermined position, the structure is to be considered for a local loading equal to the manufacturer's recommended wheel loading at maximum take-off weight, multiplied by a dynamic amplification factor based on the predicted motions of the vessel for this condition, as may be applicable for the vessel under consideration.

In addition to the helicopter load, a uniformly distributed loading of 490 N/m^2, representing wet snow or ice, is to be considered, if applicable. For the girders, stanchions, truss supports, etc., the structural weight of the helicopter deck is also to be considered.

6.2.4 Loading due to Motions of Vessel

The structure supporting helicopter decks is to withstand the loads resulting from the motions of the vessel.

6.2.5 Special Landing Gear

Helicopters fitted with landing gear other than wheels will be specially considered.

6.2.6 Environmental Loading

Calculations are to consider anticipated wind and wave impact loading on helicopter decks and their supporting structures.

Table 6.1: Allowable Factors of Safety Based on Y for Helicopter Decks

Y = specified minimum yield point or yield strength of the material

	Plating	Beams	Girders, Stanchions, russ Supports, etc.(See Note 3)
Overall Distributed Loading	1.67	1.67	1.67
Helicopter Landing Impact Landing	(See Note 1) (See Note 2)	1.00	1.10
Stowed Helicopter Loading	1.00	1.10	1.25

Notes:

1) The minimum plate thickness t is generally not to be less than obtained from the following:

Beam spacing	T
460 mm	4.0 mm
610 mm	5.0 mm
760 mm	6.0 mm

2) An allowable stress that exceeds Y may be considered provided the rationale of the submitted analysis is sufficiently conservative.

3) For members subjected to axial compression, the factor of safety is to be based on the yield stress or critical buckling stress, whichever is less.

Note: The minimum plate thickness for materials other than steel will be specially considered.

6.3 Safety Net

The unprotected perimeter of the helicopter landing deck is to be provided with safety netting or equivalent.

6.4 Material

In general, the construction of helicopter decks is to be of steel or other material with equivalent ability to retain structural capacity in a fire. If the helicopter deck forms the deckhead of a deckhouse or superstructure, it is to be insulated to A-60 class standard.

Aluminum alloys may be used for helicopter decks above deckhouses, provided the following conditions are complied with:

i) There are to be no openings in the exterior bulkheads directly below the helicopter deck

ii) All windows in the lower exterior bulkheads are to be fitted with steel shutters.

6.5 Means of Escape and Access

The helicopter deck is to be provided with both a main and an emergency means of escape and access for fire fighting and rescue personnel. These means are to be located as far apart from each other as is practicable and preferably on opposite sides of the helicopter deck.

Section 12 Machinery Space and Tunnel

1 General

1.1 Arrangement

In view of the effect upon the structure of the necessary openings in the machinery space, the difficulty of securing adequate support for the decks, of maintaining the stiffness of sides and bottom and of distributing the weight of the machinery, special attention is directed to the need for arranging, in the early stages of design, for the provision of plated through beams and such casing 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 vessels, and in other vessels of high power, it will be necessary to make additions to the strength of the structure and the area of attachments, which are proportional to the weight, power and proportions of the machinery, more especially 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 for main propulsion units, reduction gears, shaft and thrust bearings, 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 of plans of the foundations for main propulsion units, reduction gears, and thrust bearings and of the structure supporting those foundations to the machinery manufacturer for review.

1.2 Testing of Tunnels

Requirements for testing are contained in Ch. 7.

2 Engine Foundations

2.1 Engine Foundations in Double-bottom Vessels

In vessels with double bottoms, the engines are to be seated directly upon thick inner-bottom plating or upon thick seat plates on top of heavy foundations 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 rigidity of the structure.

2.2 Boiler Foundations

Boilers are to be supported by deep saddle-type floors or by transverse or fore-and-aft girders arranged to distribute the weight effectively. Where they are supported by transverse saddles or girders, 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 460 mm clear of tank tops, bunker walls, etc. The thickness of adjacent material is to be increased as may be required where the clear space is unavoidably less. The available clearance is to be indicated on the plans submitted for approval.

2.3 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.

2.4 Shaft Stools and Auxiliary Foundations

Shaft stools and auxiliary foundations are to be of ample strength and stiffness in proportion to the weight supported.

3 Tunnels and Tunnel Recesses

3.1 Plating

The plating of flat sides of shaft or other watertight tunnels is to be of the thickness as obtained from Ch.2 Sec./3.1 for watertight bulkheads; but the lowest strake of the plating is to be increased 1 mm.

Flat plating on the tops of tunnels or tunnel recesses is to be of the thickness required for watertight bulkhead plating at the same level, where unsheathed in way of hatches, the thickness is to be increased 2 mm. Where the top of the tunnel or recess forms a part of a deck, the thickness is not to be less than required for the plating of watertight bulkheads at the same level plus 1 mm, nor than would be required for the deck plating. 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 or is to be protected by wood sheathing not less than 50 mm thick.

3.2 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 not less than obtained from the following equation:

$SM = 4.42\, hs l^2 \quad cm^3$

where

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.

3.3 Beams, Pillars and Girders

Beams, pillars and girders under the tops of tunnels, or tunnel recesses are to be as required for similar members on bulkhead recesses.

3.4 Tunnels Through Deep Tanks

Where tunnels pass through deep tanks, the thickness of the plating and the size of the stiffeners in way of the tanks is 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

where

d = diameter of the tunnel, in m

h = distance, in m, from the bottom of the tunnel to the highest point of the following:

- the 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 Ch.1 Sec.1/1.3, above the baseline
- a point located two-thirds of the test head above the top of the tank

Section 13 Stems, Stern Frames, Rudder Horns, and Propeller Nozzles

1 Stems

1.1 Plate Stems

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

t = 1.46 + L/12 mm   L ≤ 245 m

t = 22 mm   245 < L ≤ 427 m

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

1.2 Cast-steel Stems

Cast-steel stems of special shape are to be proportioned to provide a strength at least equivalent to that of a plate stem, and all joints and connections are to be at least that effective.

2 Stern Frames

2.1 General

Stern frames may be fabricated from steel plates or made of cast steel. For applicable material specifications and steel grades, see Ch.1 Sec.2/1 and Table 2.2. The scantlings are to comply with 2.3 and 2.4. Stern frames of other material or construction will be specially considered.

2.2 Rudder Gudgeons

Rudder gudgeons are to be an integral part of the stern frame. The bearing length of the pintle is to be between 1.0 and 1.2 times the pintle diameter. The thickness of the pintle housing is not to be less than 25% of the pintle diameter.

2.3 Scantlings Below the Propeller Boss

Except as modified in 2.4, the scantlings of stern frames of single screw vessels are to be in accordance with the following, as applicable:

2.3.1 Fabricated Stern Frame

The thickness t, width w and $tw^2\sqrt{1+(2l/w)^2}$ for fabricated stern frames are to be not less than those given by the following equations:

$$t = 0.225\sqrt{L} \text{ cm}$$

$$w = 45 \text{ cm}$$

$$tw^2\sqrt{1+(2l/w)^2} = C_f L^{1.5}$$

where

t = thickness of side plating (See Figure 2.1)

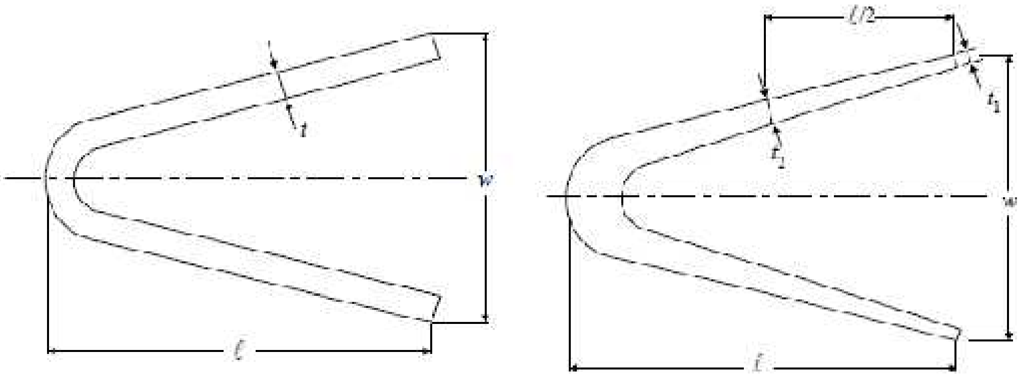
w = width of stern frame (See Figure 2.1)

l = length of stern frame, in cm (See Figure 2.1)

L = length of vessel, as defined in Ch.1 Sec.1/1.1

C_f = 9.6

Figure 2.1: Stern Frame



a Fabricated b Cast

2.3.2 Cast Stern Frame

The thicknesses t_1, t_2 and $0.5(t_1+t_2)w^2\sqrt{1+(2l/w)^2}$ for cast stern frames are to be not less than given by the following equations:

$t_1 = 0.3\sqrt{L}$ cm but not less than 2.5 cm

$t_2 = 1.25t_1$

$$0.5(t_1+t_2)w^2\sqrt{1+(2l/w)^2} = C_c L^{1.5}$$

where

w, l, L = as defined in 2.3.1.

t_1 = thickness of casting at end. (See Figure 2.1)

t_2 = thickness of casting at mid-length (See Figure 2.1)

C_c = 8.4

The thickness in way of butt welding to shell plating may be tapered below t_1. The length of taper is to be at least three times the offset.

The castings are to be cored out to avoid large masses of thick material likely to contain defects and to maintain a relatively uniform section throughout. Suitable radii are to be provided in way of changes in section.

2.4 Stern Frames with Shoe Piece

The scantlings below the boss of stern frames with shoe pieces are to be gradually increased to provide strength and stiffness in proportion to those of shoe pieces.

2.5 Scantlings Above the Propeller Boss

Above the propeller boss, the scantlings are to be in accordance with 2.3, except that in the upper part of the propeller aperture, where the hull form is full and centerline supports are provided, the thickness may be reduced to 80% of the requirements in 2.3, subject to the same minimum for a cast steel stern frame.

2.6 Secondary Members

Where round bars are used at the after edge of stern frames, their scantlings and connection details are to be such as will accomplish acceptable welding.

Ribs or horizontal brackets of thickness not less than 0.8t or $0.8t_1$ are to be provided at suitable intervals.

Where t or t_1 is reduced in accordance with 2.5, a proportionate reduction in the thickness of ribs or horizontal brackets may be made.

2.7 Shoe Pieces

The equivalent stress σe, in the shoe piece at any section is not to exceed 115/Kg N/mm^2 and is to be obtained from the following equation:

$$\sigma_e = n\sqrt{\sigma_b^2 + 3\tau^2} \quad \text{N/mm}^2$$

where

n = 1000

K_g = K as defined in Ch.2 Sec.14/1.3 for castings and forgings

= 1.0 for ordinary strength hull steel plate

= Q as defined in Ch.2 Sec.1/3.3 for higher strength steel plate

σ_b= bending stress = $0.5C_R l/Z_v$

C_R = rudder force, as defined in Ch.2 Sec.14/2

l = horizontal distance between centerline of rudder stock and the particular section of the stern frame shoe piece, in m (see Figure 2.2)

Z_v = section modulus of shoe piece about the vertical axis at the particular section under consideration, in cm^3

τ = shear stress = $0.5C_R / A_s$.

A_s = effective shear area in the transverse direction at the section of the shoe piece under consideration in, mm^2

In addition, shoe piece width is to be approximately twice the depth, and vertical and horizontal section modulus and sectional area are in no case to be less than required by the following equations.

$Z_z = k_z C_R l K_g$ cm^3

$Z_y = 0.5Z_z$ cm^3

$A_s = k_a C_R K_g$ mm^2

where

Z_z = minimum required section modulus of shoe piece about the vertical axis at the particular section under consideration

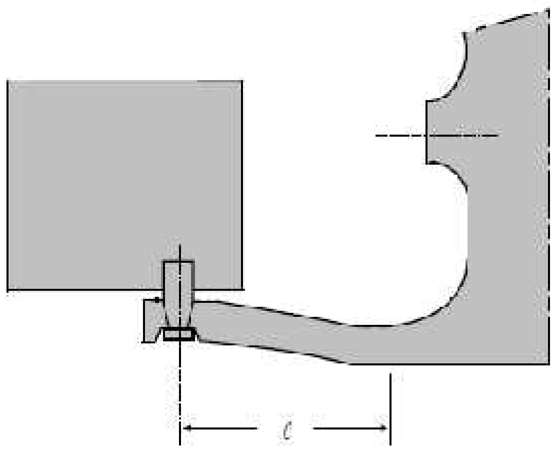
Z_y = minimum required section modulus of shoe piece about the transverse horizontal axis at the particular section under consideration

A_s = effective shear area in the transverse direction at the section of the shoe piece under consideration, in mm^2

$k_z = 6.25$

$k_a = 10.4$

Figure 2.2: Shoe Piece



3 Rudder Horns

3.1 Scantlings – Single Pintle Rudders

The strength of the rudder horn is to be based on the most critical location at any point up to and in way of the connection into the hull. At no section is the equivalent stress σ_e in the rudder horn to exceed 120/K_h N/mm^2 where σ_e is obtained from the following equation:

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

where

$n = 1000$

σ_b = bending stress = $C_R\, l_a l_v/(l_p \mathrm{SM})$

τ = shear stress due to bending = $C_R\, l_a/(l_p A_h)$

τ_T = shear stress due to torque = $0.5 C_R\, l_a l_h/(l_p a t)$

C_R = rudder force, as defined in Ch.2 Sec.14/2

l_a = vertical distance, in m, from the center of the neck bearing to the centroid of A (see Figure 3.1-a)

l_p = vertical distance, in m, from the center of the neck bearing to the center of the pintle bearing (see Figure 3.1-a)

l_v = vertical distance, in m, from the center of the pintle bearing to the section of the rudder horn being considered (see Figure 3.1-a)

l_h = horizontal distance in, mm, from the center of the pintle bearing to the center of area of the horizontal plane of the rudder horn at the section of the rudder horn being considered (see Figure 3.1-a)

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

A_h = effective shear area of the rudder horn in the transverse direction at the section being considered, in mm^2

a = area, in mm^2, enclosed by the outside lines of the rudder horn at the section of the rudder horn being considered

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

K_h = K as defined in Ch.2 Sec.14/1.3 for castings and forgings

= 1.0 for ordinary strength hull steel plate

= Q as defined in Ch.2 Sec.1/3.3 for higher strength steel plate

In addition to meeting the above maximum equivalent stress criteria, the shear stress is not to be greater than τ indicated in the following equation.

$\tau = 48/Kh \quad N/mm^2$

Also, the section modulus about the longitudinal horizontal axis is not to be less than given in the following equation:

$SM = n_z C_R (l_a / l_p) l_v K_h \quad cm^3$

$n_z = 14.9$

Webs extending down into the horn as far as practicable are to be fitted and effectively connected to the plate 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.

3.2 Scantlings – Two Pintle Rudders

The strength of the rudder horn is to meet the requirements for single pintle horns given in 3.1 above, with the following modified definitions of lever arm and component stresses.

l_a = vertical distance, in m, from the center of the upper pintle to the centroid of A (see Figure 3.1-b)

l_p = vertical distance, in m, from the center of the upper pintle bearing to the center of the lower pintle bearing (see Figure 3.1-b)

l_v = vertical distance, in m, from the center of the lower pintle bearing to the section of the rudder horn being considered up to the entry of the horn into the shell plating (see Figure 3.1-b)

l_h = horizontal distance, in mm, from the center of the lower gudgeon to the center of area of the horizontal plane of the rudder horn at the section of the rudder horn being considered (see Figure 3.1-b)

σ_b= bending stress

= $C_R\, l_a l_v /(l_p SM)$ between the upper and lower pintle gudgeons

= $C_R\, (l_v + l_a - l_p)/SM$, above the upper pintle gudgeon

τ = shear stress due to bending = $C_R l_a /(l_p A_h)$ between the upper and lower pintle gudgeons

= C_R /A_h above the upper gudgeon

τ_T =shear stress due to torque = $0.5 C_R l_a l_h /(l_p\, at)$ between the upper and lower pintle gudgeons

= $0.5 C_R l_h/(at)$ above the upper gudgeon

3.3 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 3.1 and 3.2. They may be required to be carried up to the first deck or flat.

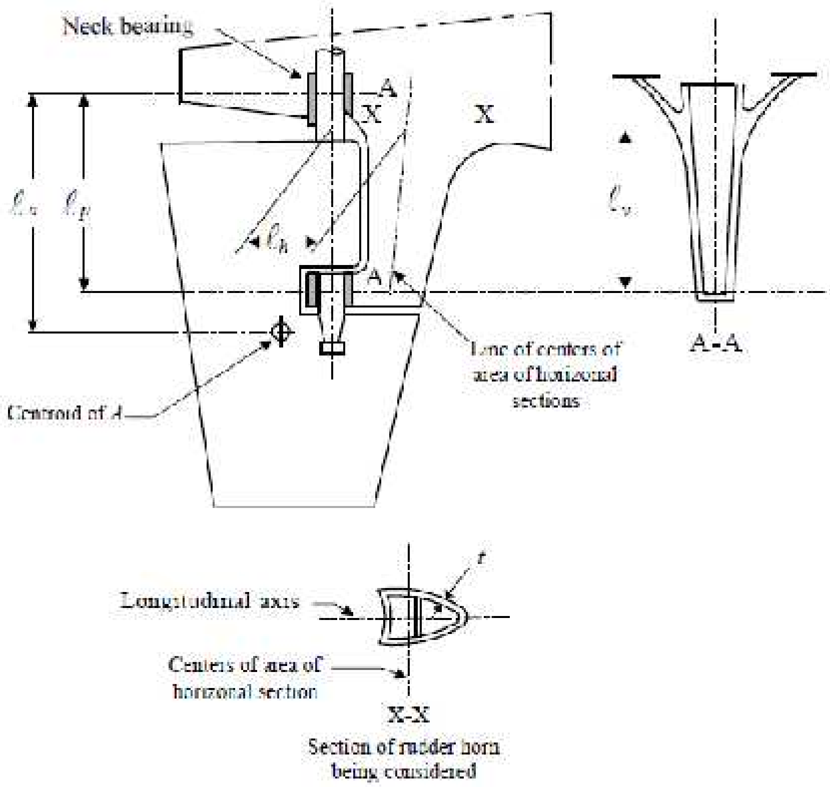
3.4 Shell Plating

Heavy shell plates are to be fitted in way of the heavy plate floors required by 3.3. Above the heavy floors, the heavy shell plates may be reduced in thickness in as gradual a manner as practicable.

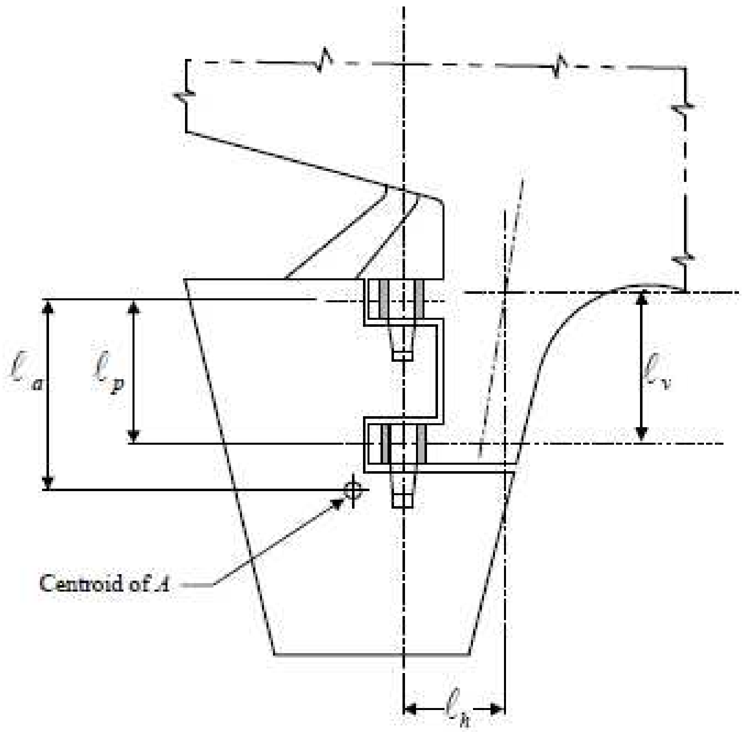
3.5 Water Exclusion

Rudder horns are to be provided with means for draining water, except where rudder horns are filled with an approved waterproof material, or equivalent.

Figure 3.1: Rudder Horn



a) Single Pintle



b) Two Pintles

4 Propeller Nozzles

4.1 Application

The requirements in this section are applicable for propeller nozzles with inner diameter *d* of 5 meters or less. Nozzles of larger inner diameter are subject to special consideration with all supporting documents and calculations submitted for review.

4.2 Design Pressure

The design pressure of the nozzle is to be obtained from the following:

$p_d = 10^{-6}\ c\ \varepsilon(N/A_P)$ N/mm^2

where

c = coefficient as indicated in Table 4.1

$\varepsilon = 21 - 2\times10^{-2}\ (N/A_P)$, but not to be taken less than 10

N = maximum shaft power, in kW

A_p = propeller disc area = $D^2\pi/4$ in m^2

D = propeller diameter, in m

Table 4.1: Coefficient c

Propeller Zone (see Figure 4.1)	c
2	10.0
1 & 3	5.0
4	3.5

4.3 Nozzle Cylinder

4.3.1 Shell Plate Thickness

The thickness of the nozzle shell plating, in mm, is not to be less than:

$t = t_o + t_c$, but not to be taken less than 7.5 mm

where

t_o = thickness obtained from the following formula:

$= c_n\ S_p\ \sqrt{p_d}$ mm

$c_n = 1.58 \times 10^{-1}$

S_p = spacing of ring webs, in mm

p_d = nozzle design pressure, in N/mm^2, as defined in 4.2

t_c = corrosion allowance determined by Table 4.2

K_n = nozzle material factor as defined in Ch.2 Sec.14/1.3

Table 4.2: Corrosion Allowance tc

Value of t_o	t_c mm
If $t_o \le 10.0$	1.5
If $t_o > 10.0$	the lesser of b_1, b_2

where

$b_1 = 3.0$ mm

$$b_2 = \left(t_o / \sqrt{K_n} + 5\right) \times 10^{-1} \quad \text{mm}$$

4.3.2 Internal Diaphragm Thickness

Thickness of nozzle internal ring web is not to be less than the required nozzle shell plating for Zone 3.

4.4 Nozzle Section Modulus

The minimum requirement for nozzle section modulus is obtained from the following formula:

$$SM = d^2 b V_d^{\,2} Q n \quad \text{cm}^3$$

where

d = nozzle inner diameter, in m

b = nozzle length, in m

V_d = design speed in ahead condition, in knots, as defined in Ch.2 Sec.14/2

Q = reduction factor conditional on material type

= 1.0 for ordinary strength steel

= 0.78 for H32 strength steel

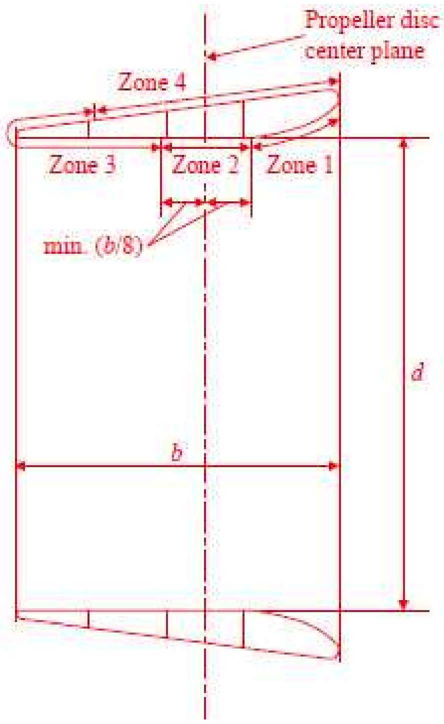
= 0.72 for H36 strength steel

= 0.68 for H40 strength steel

Q factor for steel having yield strength other than above is to be specially considered.

n = nozzle type coefficient taken equal to 0.7 for fixed nozzles

Figure 4.1: Propeller Nozzle Section View



b = nozzle length

d = nozzle inner diameter

Zone 1: zone of nozzle inner skin from nozzle leading edge to the fore end of Zone 2

Zone 2: zone of nozzle inner skin in way of propeller tips with two ring webs within the zone; the length on each side of the propeller center plane is not to be less than 1/8 of the nozzle length b

Zone 3: zone of nozzle inner and outer skin covering the tail vicinity, from aft end of Zones 2 to the aft end of Zone 4

Zone 4: zone of nozzle outer skin from the leading edge to the fore end of Zone 3

4.5 Welding Requirement

The inner and outer nozzle shell plating is to be welded to the internal stiffening ring webs with double continuous welds as far as practicable. Plug/slot welding is prohibited for the inner shell, but may be accepted for the outer shell plating, provided that the nozzle ring web spacing is not greater than 350 mm.

5 Inspection of Castings

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

Section 14 Rudders and Steering Equipment

1 General

1.1 Application

Requirements specified in this Section are applicable to:

i) Ordinary profile rudders described in Table 1.1A with rudder operating angle range from -35° to +35°.

ii) High-lift rudders described in Table 1.1B, the rudder operating angle of which might be

exceeding 35° on each side at maximum design speed.

Rudders not covered in Table 1.1A nor in Table 1.1B are subject to special consideration, provided that all the required calculations are prepared and submitted for review in full compliance with the requirements in this section.

Rudders provided on Ice Classed vessels are subject to additional requirements, as applicable.

Table 1.1A: Coefficient kc for Ordinary Rudders

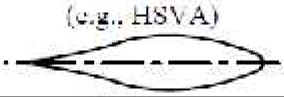
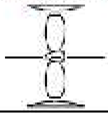
	Profile Type	k_c *Ahead Condition*	k_c *Astern Condition*
1	Single plate 	1.0	1.0
2	NACA-OO GÖttingen 	1.1	0.80
3	Flat side 	1.1	0.90
4	Mixed (e.g., HSVA) 	1.21	0.90
5	Hollow 	1.35	0.90

Table 1.1B: Coefficient kc for High-Lift/Performance Rudders

	Profile Type	k_c	
		Ahead Condition	*Astern Condition*
1	Fish tail (e.g. Schilling high-lift rudder) 	1.4	0.8
2	Flap rudder 	1.7	1.3
3	Rudder with steering nozzle 	1.9	1.5

1.2 Rudder and Rudder Stock Materials

Rudder stocks, pintles, coupling bolts, and keys are to be of steel, in accordance with the requirements of Part 2, Ch. 1. The Surveyor need not witness material tests for coupling bolts and keys. The surfaces of rudder stocks in way of exposed bearings are to be of noncorrosive material.

Material factors of castings and forgings used for the shoe piece (K_g), horn (K_h), stock (K_s), bolts (K_b), coupling flange (K_f), pintles (K_p), and nozzles (K_n) are to be obtained for their respective material from the following equation:

$K = (235/Y)^e$

where

Y = specified minimum yield strength of the material, in N/mm^2 , but is not to be taken as greater than 0.7U or 450 N/mm^2, whichever is less

U = minimum tensile strength of material used, in N/mm^2

e = 1.0 for $Y \leq 235$ N/mm^2

= 0.75 for $Y > 235$ N/mm^2

1.3 Expected Torque

The torque considered necessary to operate the rudder is to be indicated on the submitted rudder or steering gear plan. See 3.4.

Note that this expected torque is not the design torque for rudder scantlings.

1.4 Rudder Stops

Strong and effective structural rudder stops are to be fitted. Where adequate positive mechanical stops are provided within the steering gear, structural stops will not be required.

2 Rudder Design Force

2.1 Rudder Blades without Cutouts

The rudder force, C_R, upon which rudder scantlings are to be based is to be obtained from the following equation:

$C_R = 0.132\, k_R k_c k_l A V_R^2$ kN

where

$k_R = (b^2/A_t + 2)/3$ but not taken more than 1.33

b = mean height of rudder area, in m, as determined from Figure 2.1

A_t = sum of rudder blade area, A, and the area of rudder post or rudder horn within the extension of rudder profile, in m^2

A = total projected area of rudder blade, as illustrated in Figure 2.1 in m^2

For steering nozzles, A is not to be taken less than 1.35 times the projected area of the nozzle.

k_c = coefficient depending on rudder cross section as indicated in Table 1.1A and 1.1B.

For cross section differing from those in Table 1.1A and 1.1B, kc is subject to special consideration.

k_l = coefficient as specified in Table 2.1

V_R = vessel speed, in knots

= for ahead condition V_R equals V_d or $V_{\min}$, whichever is greater

= for astern condition V_R equals V_a, or $0.5V_d$, or $0.5V_{\min}$, whichever is greater

V_d = design speed, in knots, with vessel running ahead at the maximum continuous rated shaft rpm and at the summer load waterline

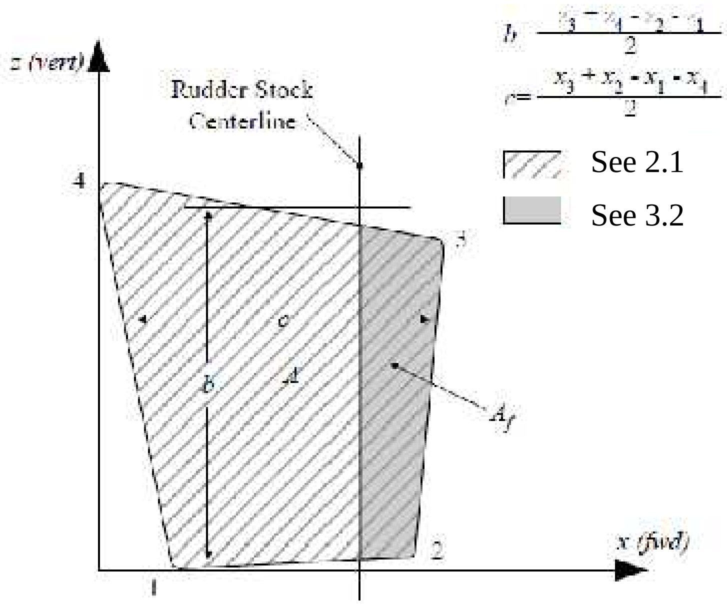
V_a = maximum astern speed, in knots

$V_{\min} = (V_{\mathrm{d}} + 20)/3$

Table 2.1: Coefficient k_l

Rudder/Propeller Layout	k_l
Rudders outside propeller jet	0.8
Rudders behind a fixed propeller nozzle	1.15
Steering nozzles and azimuthing thrusters	1.15
All others	1.0

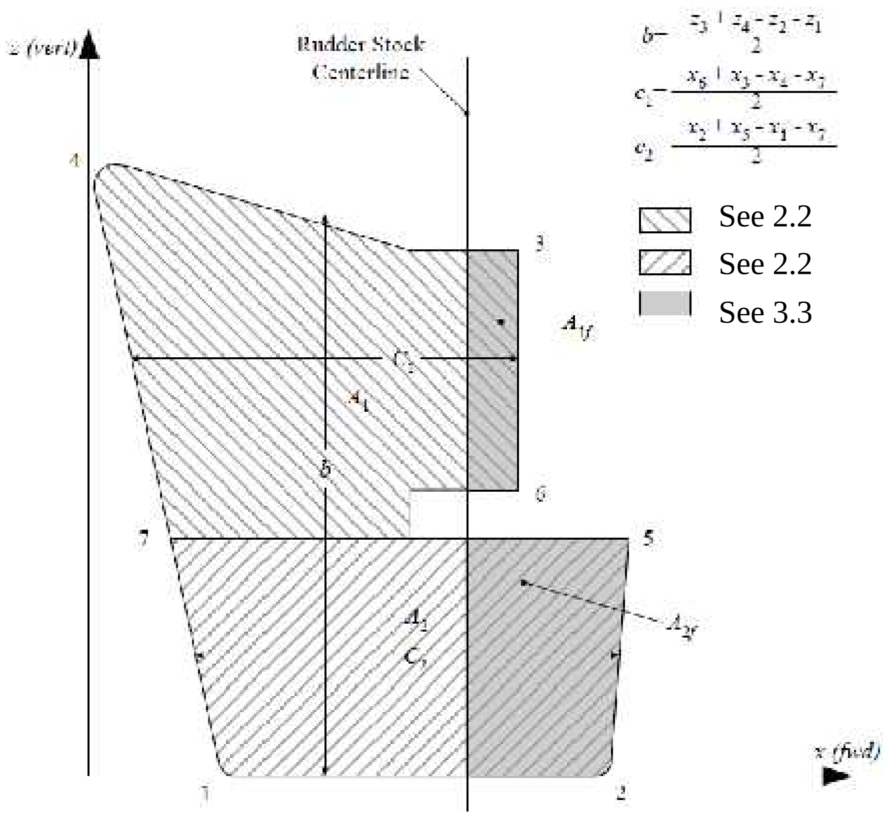
Figure 2.1: Rudder Blade without Cutouts



2.2 Rudders Blades with Cutouts

This paragraph applies to rudders with cutouts (semi-spade rudders), such that the whole blade area cannot be adequately defined by a single quadrilateral. See Figure 2.2. Equations derived in this paragraph are based on a cutout blade with two quadrilaterals. Where more quadrilaterals are needed to define the rudder shape, similar rules apply.

Figure 2.2: Rudder Blade with Cutouts



The total rudder force described in 2.1 is applicable for rudders with cutout(s), with A being the summation of sub-quadrilaterals that make up the whole area of the rudder blade. Rudder force distribution over each quadrilateral is to be obtained from the following equations:

$CR_1 = C_R A_1 / A$ kN

$CR_2 = C_R A_2 / A$ kN

where

C_R and A are as defined in 2.1.

A_1 and A_2 are as described in Figure 2.2.

3 Rudder Design Torque

3.1 General

The rudder design torque, Q_R, for rudder scantling calculations, is to be in accordance with 3.2 or 3.3 as applicable.

3.2 Rudders without Cutouts

Rudder torque, Q_R, is to be determined from the following equation for both ahead and astern conditions:

$Q_R = C_R\, r$ kN-m

where

C_R = rudder force as calculated in 2.1

$r = c(\alpha - k)$ but not less than $0.1c$ for ahead condition

c = mean breadth of rudder area as shown in Figure 2.1, in m

α = coefficient as indicated in Table 3.1

$k = A_f / A$

A_f = area of rudder blade situated forward of the rudder stock centerline, in m^2, as

shown in Figure 2.1

A = whole rudder area as described in 2.1

Table 3.1;Coefficient α

Rudder Position or High-lift	α	
	Ahead Condition	*Astern Condition*
Located behind a fixed structure, such as a rudder horn	0.25	0.55
Located where no fixed structure forward of it	0.33	0.66
High-Lift Rudders (see Table 1.1B)	Special consideration (0.40 if unknown)	Special consideration

3.3 Rudders Blades with Cutouts

This paragraph refers to rudder blades with cutouts (semi-spade rudders) as defined in 2.2. Equations derived in this paragraph are based on a cutout blade with two quadrilaterals. Where more quadrilaterals are needed to define the rudder shape, similar rules apply.

Total rudder torque, Q_R, in ahead and astern conditions is to be obtained from the following equation:

$Q_R = C_{R1}\, r_1 + C_{R2}\, r_2$ kN-m

but not to be taken less than $Q_{R\min}$ in the ahead condition

where

$Q_{R\min} = 0.1 C_R\, (A_1 c_1 + A_2 c_2)/A$

$r_1 = c_1(\alpha - k_1)$ m

$r_2 = c_2(\alpha - k_2)$ m

c_1, c_2 = mean breadth of partial area A_1, A_2, from Figure 2.2.

α = coefficient as indicated in Table 3.1.

k_1, k_2 = A_{1f}/A_1, A_{2f}/A_2 where A_{1f}, A_{2f} = area of rudder blade situated forward of the centerline of the rudder stock for each part of the rudder, as shown in Figure 2.2.

C_R, C_{R1}, C_{R2}, A_1, A_2 are as defined in 2.2.

3.4 Trial Conditions

Above equations for Q_R are intended for the design of rudders and should not be directly compared with the torque expected during the trial (see 1.3) or the rated torque of steering gear.

4 Rudder Stocks

4.1 Upper Rudder Stocks

The upper stock is that part of the rudder stock above the neck bearing or above the top pintle, as applicable.

At the upper bearing or tiller, the upper stock diameter is not to be less than obtained from the following equation:

$S = N_u \sqrt[3]{Q_R K_s}$ mm

where

$N_u = 42.0$

Q_R = total rudder torque, as defined in 3, in kN-m

K_s = material factor for upper rudder stock, as defined in 1.2

4.2 Lower Rudder Stocks

In determining lower rudder stock scantlings, values of rudder design force and torque calculated in 2 and 3 are to be used. Bending moments and shear forces, as well as the reaction forces are to be determined by direct calculation and are to be submitted for review. For rudders supported by shoe pieces or rudder horns, these structures are to be included in the calculation model to account for support of the rudder body. Guidance for calculation of these values is given in Ch. 2 Appendix A5.

The lower rudder stock diameter is not to be less than obtained from the following equation:

$$S_l = S\sqrt[6]{1 + 4/3 \times \left(M / Q_R\right)^2} \quad \text{mm}$$

where

S = upper stock required diameter from 4.1, in mm

M = bending moment at the section of the rudder stock considered, in kN-m

Q_R = rudder torque from 3, in kN-m

Above the neck bearing, a gradual transition is to be provided where there is a change in the diameter of the rudder stock.

The equivalent stress of bending and torsion, σ_c to be assessed from the aforementioned direct calculation in the transition is not to exceed 118 /K N/mm^2.

$$\sigma_c = K\sqrt{\sigma_b^2 + 3\tau_t^2} \quad \text{N/mm}^2$$

where

K = material factor as defined in 1.2.

$$\sigma_b = 10.2M / S_l^3$$

$$\tau_t = 5.1Q_R / S_l^3$$

4.3 Rudder Stock Sealing

i) In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier.

ii) Where the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided.

5 Flange Couplings

5.1 General

Rudder flange couplings are to comply with the following requirements:

i) Couplings are to be supported by an ample body of metal worked out from the rudder stock.

ii) The smallest distance from the edge of the bolt holes to the edge of the flange is not to be less than two-thirds of the bolt diameter.

iii) Coupling bolts are to be fitted bolts.

iv) Suitable means are to be provided for locking the nuts in place.

In addition to the above, rudder flange couplings are to meet the type-specific requirements in 5.2 (horizontal couplings) or 5.3 (vertical couplings) as applicable.

5.2 Horizontal Couplings

5.2.1 Coupling Bolts

There are to be at least six coupling bolts in horizontal couplings, and the diameter, d_b, of each bolt is not to be less than obtained by the following equation:

$$d_b = 0.62\sqrt{d_s^3 K_b /(nrK_s)} \quad \text{mm}$$

where

d_s = required rudder stock diameter, S (see 4.1) or S_l (see 4.2) as applicable, in way of the coupling

n = total number of bolts in the horizontal coupling

r = mean distance, in mm, of the bolt axes from the center of the bolt system

K_b = material factor for bolts, as defined in 1.2

Ks = material factor for stock, as defined in 1.2

5.2.2 Coupling Flange

Coupling flange thickness is not to be less than the greater of the following equations:

$$t_f = 0.9 d_{bt}\sqrt{K_f / K_b} \quad \text{mm}$$

$$t_f = 0.9 d_{bt} \quad \text{mm}$$

where

d_{bt} = calculated bolt diameter as per 5.2.1 based on a number of bolts not exceeding 8

K_f = material factor for flange, as defined in 1.2

K_b = material factor of bolts, as defined in 1.2

5.3 Vertical Couplings

5.3.1 Coupling Bolts

There are to be at least eight coupling bolts in vertical couplings and the diameter of each bolt is not to be less than obtained from the following equation:

$$d_b = 0.81 d_s \sqrt{K_b /(nK_s)} \text{ mm}$$

where

n = total number of bolts in the vertical coupling

d_s, K_b, K_s as defined in 5.2.

In addition, the first moment of area, m, of the bolts about the center of the coupling is not to be less than given by the following equation:

$$m = 0.00043 d_s^3 \quad \text{mm}^3$$

where

d_s = diameter, in mm, as defined in 5.2

5.3.2 Coupling Flange

Coupling flange thickness, t_f, is not to be less than d_b as defined in 5.3.1.

6 Tapered Stock Couplings

6.1 Coupling Taper

Tapered stock couplings are to comply with the following general requirements in addition to type-specific requirements given in 6.2 or 6.3 as applicable:

i) Tapered stocks, as shown in Figure 6.1, are to be effectively secured to the rudder casting by a nut on the end.

ii) Taper length (l) in the casting is generally not to be less than 1.5 times the stock diameter (d_o) at the top of the rudder.

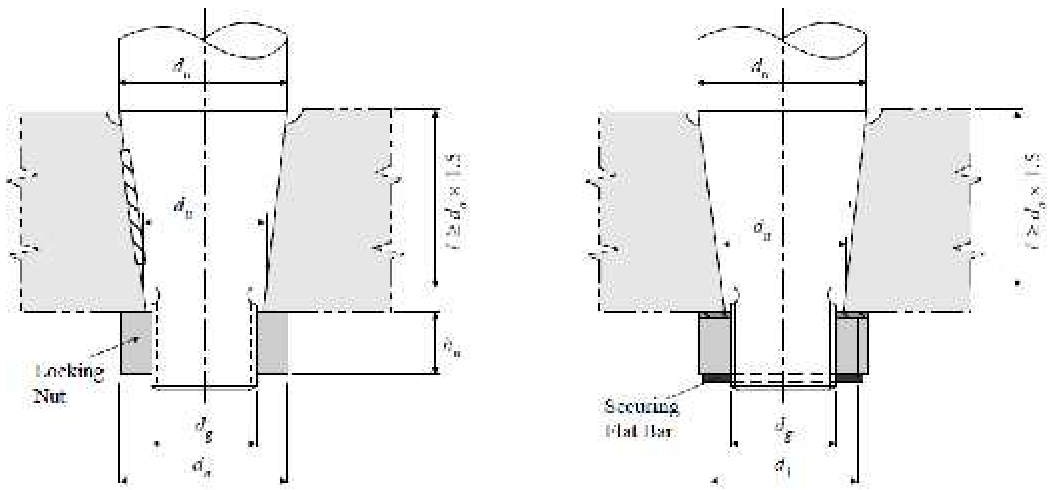
iii) The taper on diameter (c) is to be 1/12 to 1/8 for keyed taper couplings and 1/20 to 1/12 for couplings with hydraulic mounting/dismounting arrangements, as shown in the following table.

iv) Where mounting with an oil injection and hydraulic nut, the push-up oil pressure and the push-up length are to be specially considered upon submission of calculations.

v) Means of effective sealing are to be provided to protect against sea water ingress.

Type of Coupling Assembly	$c = (d_o - d_u)/ l$
Without hydraulic mounting/dismounting	$1/12 \le c \le 1/8$
With hydraulic mounting/dismounting	$1/20 \le c \le 1/12$

Figure 6.1: Tapered Couplings



a) Keyed Fitting b) Keyless Fitting

6.2 Keyed Fitting

Where the stock is keyed, the key is to be fitted in accordance with the following:

i) The top of the keyway is to be located well below the top of the rudder.

ii) Torsional strength of the key equivalent to that of the required upper stock is to be provided.

iii) The effective shear area* of the key is not to be less than A_k, given below.

$$A_k = S^3 Y_S / (5.1 r_{md} Y_K)$$

where

A_k = shear area of key; mm^2

S = required upper stock diameter; mm; as determined by 4.1

r_{md} = offered radius of tapered stock at mid length of the bearing surface of the key; mm

Y_S = specified minimum yield strength of keyway material; N/mm^2

Y_K = specified minimum yield strength of key material; N/mm^2

iv) In general, the key material is to be at least of equal strength to the keyway material. For keys of higher strength materials, shear and bearing areas of keys and keyways may be based on the respective material properties of the keys and the keyways, provided that compatibilities in mechanical properties of both components are fully considered. In no case, is the bearing stress of the key on the keyway to exceed 90% of the specified minimum yield strength of the keyway material.

** Note:* The effective area is to be the gross area reduced by any area removed by saw cuts, set screw holes, chamfer, etc., and is to exclude the portion of the key in way of spooning of the key way.

6.3 Keyless Fitting

Hydraulic and shrink fit keyless couplings are to be fitted in accordance with the following:

i) Hydraulic pressure is to be specially considered upon submittal of detailed preloading stress calculations and fitting instructions;

ii) The calculated torsional holding capacity is to be at least 2.0 times the transmitted torque based on the steering gear relief valve setting;

iii) Preload stress is not to exceed 70% of the minimum yield strength of either the stock or the bore;

iv) Prior to applying hydraulic pressure, at least 75% of theoretical contact area of rudder stock and rudder bore is to be achieved in an evenly distributed manner;

iv) The upper edge of the upper main piece bore is to have a slight radius;

v) The locking nut is to be fitted in accordance with 6.4.

6.4 Locking Nut

Dimensions of the securing nut, as shown in Figure 6.1, are to be proportioned in accordance with the following and the nut is to be fitted with an effective locking device.

Height $h_n \geq 0.6d_g$

Outer diameter of nut $d_n \geq 1.2d_u$ or $1.5d_g$ whichever is greater

External thread diameter $d_g \geq 0.65d_o$

In the case of a hydraulic pressure secured nut, a securing device such as a securing flat bar is to be provided. Calculations proving the effectiveness of the securing device are to be submitted.

7 Pintles

7.1 General

Pintles are to have a conical attachment to the gudgeons with a taper on diameter of:

1/12 to 1/8 for keyed and other manually assembled pintles with locking nut.

1/20 to 1/12 for pintle mounted with oil injection and hydraulic nut.

The diameter of the pintles is not to be less than obtained from the following equation.

$$d_P = k_1\sqrt{BK_p} \quad \text{mm}$$

where

$k_1 = 11.1$

B = bearing force, in kN, from submitted direct calculation but not to be taken less than $B_{\min}$ as specified in Table 7.1.

Table 7.1: Minimum Bearing Force $B_{\min}$

Pintle Type		$B_{\min}$
Conventional two pintle rudder		$0.5\ C_R$
Ch. 2 App5, Figure 3.1	lower pintle	$0.5\ C_R$
Ch. 2 App 5, Figure 5.1	main pintle	$C_R\, l_a / l_p{}^*$
Ch. 2 App 5,Figure 5.1	main pintle	$C_R\, l_a / l_p{}^*$
Ch.2 Sec.13, Figure 3.1	upper pintle	$0.25\ C_R$

* $B_{\min} = C_R$ where $l_a/l_p \geq 1$

l_a, l_p as described in Figure 6.1

K_p = material factor for the pintle, as defined in 1.2

Threads and nuts are to be in accordance with 6.4.

The depth of the pintle boss is not to be less than d_p. In addition, the bearing length of the pintle is to be between 1.0 and 1.2 times the pintle diameter. The bearing pressure is to be in accordance with 8.1.

For rudders on horns with two pintles, as shown in Ch.2 Sec.13/Figure 3.1b, calculations are to include pintle bearing forces with the vessel running ahead at the maximum continuous rated shaft rpm and at the lightest operating draft.

8 Supporting and Anti-Lifting Arrangements

8.1 Bearings

8.1.1 Bearing Surfaces

Bearing surfaces for rudder stocks, shafts and pintles are to meet the following requirements:

i) The length/diameter ratio (l_b/d_l) of the bearing surface is not to be greater than 1.2*

ii) The projected area of the bearing surface ($A_b = d_l\, l_b$) is not to be less than $Ab_{\min}$,

where

d_l = outer diameter of the liner, in mm

l_b = bearing length, in mm

$A_{b\min}$ =1000P/p_a mm^2

P = bearing reaction force, in kN, as specified in Table 8.1

p_a = allowable surface pressure, as indicated in Table 8.2 depending on bearing material, in N/mm^2

* Request for bearing arrangement of length/diameter ratio greater than 1.2 is subject to special consideration provided that calculations are submitted to show acceptable clearance at both ends of the bearing.

8.1.2 Bearing Clearance

i) The clearance for metal bearings is not to be less than d_i /1000 + 1.0 mm on the diameter, where d_i is the inner diameter of the bushing, in mm.

ii) The clearance for non-metallic bearings is to be specially determined considering the

material's swelling and thermal expansion properties. This clearance in general is not to be

taken less than 1.5 mm on diameter*.

* Request of clearance less than 1.5 mm for non-metallic bearings is subject to special

considerations provided that documented evidence, such as manufacturer's recommendation on acceptable clearance, expansion allowance and satisfactory service history with reduced clearances, are submitted for review.

8.1.3 Bearing Pressure

Bearing pressure is to be accordance with Table 8.2.

8.1.4 Bearing Material

Where stainless steel or wear-resistant steel is used for liners or bearings, the material properties including chemical composition of both components are to be submitted for review for an approved combination.

8.2 Rudder Carrier

i) The weight of the rudder assembly is to be supported by a rudder carrier mounted on the hull structure designed for that purpose.

ii) At least half of the rudder carrier's holding-down bolts are to be fitted bolts. Alternative means of preventing horizontal movement of the rudder carrier may be considered.

iii) Rudder carrier bearings are to comply with the requirements in 8.1.

iv) Hull structures in way of the rudder carrier are to be suitably strengthened.

8.3 Anti-lifting Devices

Means are to be provided to prevent accidental unshipping or undue movement of the rudder which may cause damage to the steering gear. There are to be at least two bolts in the joint of the anti-lifting ring.

Table 8.1: Bearing Reaction Force

Bearing Type	*P, Bearing Reaction Force kN*
Pintle bearings	$P = B$ as defined in 7
Other bearings	Calculation of P is to be submitted. Guidelines for calculation can be found in Appendix A5

Table 8.2: Allowable Bearing Surface Pressure

Bearing Material	*pa † N/mm²*
lignum vitae	*2.5*
white metal, oil lubricated	*4.5*
synthetic material with hardness between 60 and 70 Shore D *	*5.5*
steel § and bronze and hot-pressed bronze-graphite materials	*7.0*

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

† Higher values than given in the table may be taken if they are verified by tests.

* Indentation hardness test at 23°C and with 50% moisture, according to a

recognized standard. Synthetic bearing materials to be of approved type.

9 Double Plate Rudder

9.1 Strength

Rudder section modulus and web area are to be such that stresses indicated in the following Subparagraphs are not exceeded.

In calculating the section modulus of the rudder, the effective width of side plating is to be taken as not greater than twice the athwartship dimension of the rudder. Welded or bolted cover plates on access openings to pintles are not to be considered effective in determining the section modulus of the rudder.

Generous radii are to be provided at abrupt changes in section where there are stress concentrations, including in way of openings and cover plates.

Moments, shear forces and reaction forces are to be obtained by direct calculation, which is to be submitted.

Guidance for calculation of these values is given in Appendix A5.

9.1.1 Clear of Cutouts

Allowable stresses for determining the rudder strength clear of cutouts are as follows:

Bending stress $\sigma_b = K_\sigma / Q$ N/mm^2

Shear stress $\tau = K_\tau / Q$ N/mm^2

Equivalent stress $\sigma_e = K\sqrt{\sigma_b^2 + 3\tau_t^2} = K_e / Q$ N/mm^2

where

K_σ = 110, K_τ = 50, K_e = 120

Q = 1.0 for ordinary strength hull steel

= as defined in Ch.2 Sec.1/3.3 for higher strength steel plate

9.1.2 In way of Cutouts

Allowable stresses for determining the rudder strength in way of cutouts (see Figure 9.1) are

as follows:

Bending stress $\sigma_b = K_\sigma / Q$ N/mm^2

Shear stress $\tau = K_\tau / Q$ N/mm^2

Equivalent stress $\sigma_e = K\sqrt{\sigma_b^2 + 3\tau_t^2} = K_e / Q$ N/mm^2

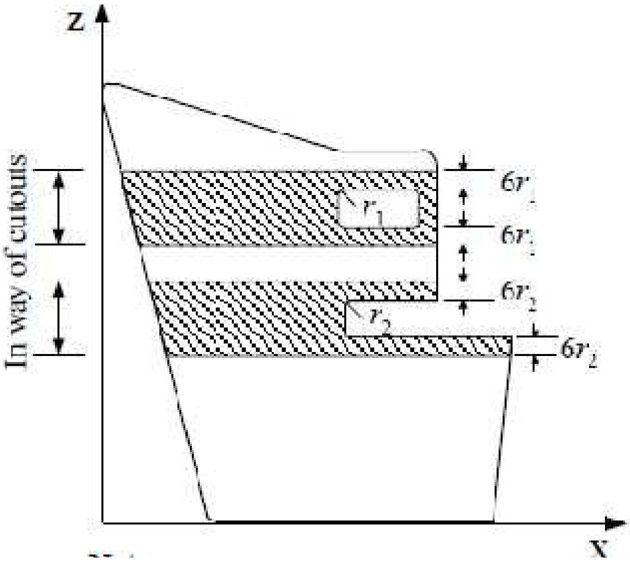
where

K_σ = 75, K_τ = 50, K_e = 100

Q = 1.0 for ordinary strength hull steel

= as defined in Ch.2 Sec.1/3.3 for higher strength steel plate

Figure 9.1



Note:

r_1 = corner radius of rudder plate in way of portable bolted inspection hole

r_2 = corner radius of rudder plate

For spade rudders and rudders with horns, the section modulus at the bottom of the rudder is not to be less than one-third the required section modulus of the rudder at the top of the rudder or at the center of the lowest pintle.

Where rudders have an unsymmetrical foil section (e.g., reaction rudder) details of the rudder are to be submitted.

Special attention is to be paid in design and construction of rudders with slender foil sections in the vicinity of their trailing edge (e.g., hollow foil sections, fishtail foil sections). Where the width of the rudder blade at the aftermost vertical diaphragm is equal or less than 1/6 of the trailing edge length measured between the diaphragm and the trailing edge, vibration analysis of the rudder blade is also to be submitted for review.

9.2 Side, Top and Bottom Plating

The plating thickness is not to be less than obtained from the following equation:

$$t = 0.0055s \sqrt{d + (0.1C_R / A)} \cdot \sqrt{Q} + 2.5$$

where

Q = 1.0 for ordinary strength hull steel

= as defined in Ch.2 Sec.1/3.3 for higher strength steel plate

d = summer loadline draft of the vessel, in m

C_R = rudder force according to 2, in kN

A = rudder area, in m^2

$= \sqrt{1.1 - 0.5(s/b)^2}$ maximum 1.0 for $b/s \geq 2.5$

s = smaller unsupported dimension of plating, in mm

b = greater unsupported dimension of plating, in mm

The thickness of the rudder side or bottom plating is to be at least 2 mm greater than that

required by Ch.2 Sec.10/2.1 for deep tank plating in association with a head *h* measured to the summer load line.

9.3 Diaphragm Plates

Vertical and horizontal diaphragms are to be fitted within the rudder, effectively attached to each other and to the side plating. Vertical diaphragms are to be spaced approximately 1.5 times the spacing of horizontal diaphragms.

The thickness of diaphragm plates is not to be less than 70% of the required rudder side plate thickness or 8 mm, whichever is greater. Openings in diaphragms are not to exceed one half their depth.

Welding is to be in accordance with Ch.2 Sec.19. Where inaccessible for welding inside the rudder, it is recommended that diaphragms be fitted with flat bars and the side plating be connected to these flat bars by continuous welds or by 75 mm slot welds spaced at 150 mm centers. The slots are to be fillet welded around the edges and filled with a suitable compound.

9.4 Watertightness

The rudder is to be watertight and is to be tested in accordance with Ch.3 Sec.7/Table 2.1.

10 Single Plate Rudders

10.1 Mainpiece Diameter

The mainpiece diameter is calculated according to 4.2. For spade rudders, the lower third may be tapered down to 0.75 times stock diameter at the bottom of the rudder.

10.2 Blade Thickness

The blade thickness is not to be less than obtained from the following equation:

$t_b = 0.0015sV_R + 2.5$ mm

where

s = spacing of stiffening arms, in mm, not to exceed 1000 mm

V_R = speed, as defined in 2

10.3 Arms

The thickness of the arms is not to be less than the blade thickness obtained in 10.2. The section modulus of each set of arms about the axis of the rudder stock is not to be less than obtained from the following equation:

$$SM = 0.0005sC_1^2V_R^2Q \qquad \text{cm}^3$$

where

C_1 = horizontal distance from the aft edge of the rudder to the centerline of the rudder stock, in m

Q = 1.0 for ordinary strength hull steel

= as defined in Ch.2 Sec.1/3.3 for higher strength steel plate

s, V_R are as defined in section 11.2.

11 Steering Nozzles

11.1 Application Scope

Requirements in this Subsection are applicable to conventional steering nozzles, as illustrated in Figure 11.1, with the following restrictions:

i) The inner diameter of 5 meters or less, and

ii) The operating angle ranging not more than –35° to +35° port and starboard

iii) Nozzles of above features but provided on the vessels for Ice Class are subject to additional requirements specified in rules, as applicable

Steering nozzles outside of the application scope are subject to special consideration with all supporting documents and calculations submitted to ACS for review. The submitted documents and calculations are to include, but not limited to, the items listed in the following:

i) *The drawings and plans of steering nozzle with indications of design operating angles and the torque considered necessary to operate the steering nozzle at the design operating angle*

ii) *The calculated steering nozzle section modulus*

iii) *The calculated maximum water induced pressure of the nozzle under design speed (both ahead and astern conditions) and at the design operating angle, and*

iv) *The calculated maximum shear and bending of nozzle support structure under design speed (both ahead and astern conditions) and at the design operating angle*

11.2 Design Force

The design force, C_R, for steering nozzles is to be obtained from the following equation:

$$C_R = n k_R k_c k_l A V_R^2 \qquad \text{KN}$$

where

$k_R = (d_m^2 / A_t + 2)/3$ but not taken more than 2

d_m = mean external diameter of the nozzle, in m

= $0.5(d_f + d_a)$

d_f , d_a = fore and aft nozzle external diameters as shown in Figure 11.1, in m

$A_t = A_{eq} + A_{po} + A_{mf}$, in m^2

A_{eq} = nominal projected area of nozzle cylinder, not to be taken less than $1.35 d_m b$

b = nozzle length in m

A_{po} = projected area of nozzle post or horn within the extension of nozzle profile as applicable

A_{mf} = projected area of movable flap if present

$= d_a\, b_{mf}$

$A = A_{eq} + A_{mf}$, in m^2

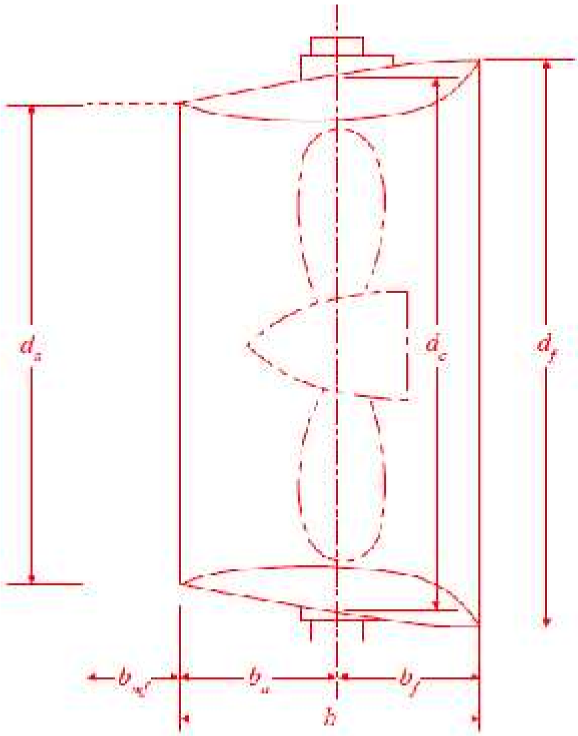
k_c = 1.9 for ahead condition

= 1.5 for astern condition

k_l = 1.15, as specified in Table 2.1

n, VR are as defined in 2.1.

Figure 11.1: Nozzle Geometry



11.3 Design Torque

Design torque, Q_R, for steering nozzle is to be determined from the following equation for both ahead and astern conditions:

$Q_R = C_R\, r$ kN-m

where

$r = (\alpha - k)l$, but not less than 0.1 l for ahead condition

$l = b$ without flap, in m

$= b + b_{mf}$ if flap present

$k = A_f / A$

$A_f = A_{eq}\, b_f / l$, in m^2

d_c = nozzle diameter at the section intersecting with nozzle stock axis;

α is as defined in Table 3.1.

A, *CR* are as defined in 11.2.

11.4 Nozzle Stock

11.4.1 Upper Stock

The upper stock is that part of the nozzle stock above the neck bearing.

At the upper bearing or tiller, the upper stock diameter is not to be less than obtained from the

following equation:

$$S = N_u \sqrt[3]{Q_R K_s} \quad \text{mm}$$

where

N_u = 42.0

Q_R = as defined in 11.3.

K_s = material factor for nozzle stock, as defined in 1.2

11.4.2 Lower Stock

In determining lower stock diameters, values of nozzle design force and torque calculated in

11.2 and 11.3 are to be used. Bending moments and shear forces, as well as the reaction forces are to be determined by direct calculation and are to be submitted for review. For

nozzles supported by shoe pieces, these structures are to be included in the calculation.

Calculation guidance for these values is given in Appendix A5.

The lower nozzle stock diameter is not to be less than obtained from the following equation:

$$S_l = S \sqrt[6]{1 + 4/3(M/Q_R)^2} \quad \text{mm}$$

where

S = required upper stock diameter from 11.4.1, in mm

M = bending moment at the cross section of the nozzle stock considered, in kN-m

Q_R = design torque obtained from 11.3, in kN-m

Where there is a change in stock diameter above the neck bearing, a gradual transition is to be provided.

11.5 Design Pressure

The design pressure of the nozzle is to be obtained from the following:

$p = p_d + p_s$ N/mm^2

where

$p_s = 0.001\ C_R/A$

C_R, A as defined in 11.2

p_d as defined in Ch.2 Sec.13/4.2

11.6 Plate Thickness

11.6.1 Nozzle Shell

The thickness of the nozzle shell plating, in mm, is not to be less than:

$t = t_o + t_c$ mm, but not to be taken less than 7.5 mm

where

t_o = thickness obtained from the following formula:

$$= c_n S_p \sqrt{pK_n} \quad \text{mm}$$

c_n = coefficient as indicated in Ch.2 Sec.13/Table 4.1

S_p = spacing of ring webs, in mm

p = design pressure, in N/mm^2, as defined in 11.5

t_c = corrosion allowance determined by Ch.2 Sec.13/Table 4.2

K_n = nozzle material factor as defined in 1.2

11.6.2 Internal Diaphragm

Thickness of nozzle internal ring web is not to be less than the required nozzle shell plating for Zone 3 as illustrated in Ch.2 Sec.13/Figure 4.1.

11.6.3 Movable Flap

Nozzle movable flap plate thickness, if present, is to comply with the following:

i) For double-plate movable flap, requirements in 9 are to be satisfied as applicable;

ii) For single-plate movable flap, requirements in 10 are to be satisfied as applicable;

11.7 Section Modulus

Steering nozzle is to have a section modulus at least equal to that specified in Ch.2 Sec.13/4.4, where n is replaced by 1.0.

11.8 Locking Device

A mechanical locking device is to be provided:

i) To prevent the steering nozzle from rotating beyond the maximum operating angle at design speed

ii) To prevent steering nozzle from rotating toward undesired directions in the event of accident or damage

11.9 Welding Requirement

Steering nozzle welding procedures are to comply with Ch.2 Sec.13/4.5.

Section 15 Protection of Deck Openings

1 General

All openings in decks are to be framed to provide efficient support and attachment to the ends of the half beams. The following Rules relate to vessels having minimum freeboards. Where the draft is less than that corresponding to the minimum freeboard, or for decks above the first deck above the freeboard deck, the heights of the coamings and the effectiveness of the closing arrangements may be modified. The proposed arrangements and details for all hatchways are to be submitted for approval.

2 Positions and Design Pressures

2.1 Positions of Deck Openings

For the purpose of the Rules, two positions of deck openings are defined as in Ch.1 Sec.1, 1.16

2.2 Design Pressures

The design pressures are not to be taken as less than the following. Values at intermediate lengths are to be determined by interpolation.

2.2.1 Cargo Hatch Covers in Position 1

For ships of 100 m in length and above:

$p = 34.3 + (p_{FP} – p_0)(0.25 – x/L_f)/0.25$ kN/m^2

For ships less than 100 m in length:

$p = 15.8 + (L_f/3)[1 – (5/3)(x/L_f)] – 3.6x/L_f$ kN/m^2

For a position 1 hatchway located at least one superstructure standard height higher than the freeboard deck:

$p = 3.5– 1.5x\ (100 − L_{f1})/76$ kN/m^2

where

p_{FP} = pressure at the forward perpendicular

= $49.0 + a(L_f – 100)$ kN/m^2 for L_f in meters

a = 0.0726 kN/m^2 for type B freeboard ships

= 0.356 kN/m^2 for ships with reduced freeboard

L_f = freeboard length, in m, as defined in Ch.1 Sec.1/1.1, but is not to be taken as greater than 340 m

L_{f1} = freeboard length, in m, as defined in Ch.1 Sec.1/1.1, but is not to be taken as greater than 150 m and less than 90 m

x = distance, in m, from the mid length of the hatch cover under examination to the forward end of L_f, or $0.25L_f$, whichever is less.

2.2.2 Cargo Hatch Covers in Position 2

Where a position 2 hatchway is located at least one superstructure standard height higher than the freeboard deck, the pressure p may be 25.5 kN/m^2 for vessel's L_f 100 m and greater. Where vessel's L_f is less than 100 m the design pressures are as follows:

$p = 25.5 - 0.142(100 - L_f)$ kN/m^2

3 Hatchway Coamings

3.1 Height of Coamings

The height of coamings of hatchways secured weathertight by tarpaulins and 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 or other equivalent material and made tight by means of gaskets and clamping devices, these heights may be reduced, or the coamings omitted entirely, provided that the safety of the vessel is not thereby impaired in any sea condition.

3.2 Coaming Plates

Coaming plates are not to be less than 11 mm thick.

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 175 mm.

Effective brackets or stays 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 or stays is to be such as to provide equivalent support. Where end coamings are protected, the arrangement of the stiffeners and brackets or stays may be modified.

Where chocks are provided on the coaming to limit the horizontal movement of the hatch cover, the strength of the coaming and deck structure is to be adequate to withstand the load on these chocks. Similar consideration is to be given to pads supporting the weight from hatch covers.

3.4 Protection of Coaming Edges

Heavy convex moldings are to be fitted at the upper edges of all exposed coamings of hatches sealed by tarpaulins and battens, as protection against chafing as well as damage to the coaming. The lower edge of the coaming is to be flanged or provided with other suitable protection against damage unless the spaces served by the hatchway are intended exclusively for specialized cargoes such as containers.

3.5 Continuous Longitudinal Hatch Coamings

Where strength deck longitudinal hatch coamings of length greater than 0.14L are effectively supported by longitudinal bulkheads or deep girders, as indicated in Ch.2 Sec.1/7, they are in general to be longitudinally stiffened. The coaming thickness is to be not less than required by Ch.2 Sec.3/Table 3.2, equation 2b, and the longitudinal stiffeners not less than required by Ch.2 Sec.7/2.1 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 Ch.2 Sec.7/Table 2.1. Special consideration will be given to the coaming scantlings where adequate buckling strength is shown to be otherwise provided.

4 Hatchways Closed by Portable Covers and Secured Weathertight by Tarpaulins and Battening Devices

4.1 Pontoon Covers

4.1.1 Scantlings

Where steel pontoon covers are used in place of portable beams and covers, the maximum allowable stress and deflection under the design pressures in 2.2, and the minimum required top plate thickness are as follows.

Maximum allowable stress	0.68Y
Maximum allowable deflection	0.0044 times the span
Top plate thickness	0.01s, but not less than 6 mm

where

Y = specified minimum upper yield point strength of the materials, in N/mm^2

s = stiffener spacing

Covers are to be assumed to be simply supported.

Where the cross section of hatch cover stiffeners is not constant along the span, Ch.2 Appendix A6 may be used to determine required scantlings.

4.1.2 Cleats

Cleats are to be set to fit the taper of the wedges. They are to be at least 65 mm wide and spaced not more than 600 mm center to center. The cleats along each side or end are to be not more than 150 mm from the hatch corners.

4.1.3 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.

4.1.4 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.

4.1.5 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

4.1.6 Security of Hatch Covers

For all hatchways in Position 1 or 2, steel bars or other equivalent means are to be provided in order to efficiently and independently secure each section of hatch covers after the tarpaulins are battened down. Hatch covers of more than 1.5 m in length are to be secured by at least two such securing appliances.

4.2 Wood Hatch Covers

4.2.1 Hatch Boards

Wood hatch covers on exposed hatchways are to have a finished thickness not less than 60 mm, where the span is not more than 1.5 m. The wood is to be of satisfactory quality, straight-grained, reasonably free from knots, sap and shakes, and is to be examined before being coated. Hatch rests are to be beveled where necessary, so as to provide a solid bearing surface.

4.2.2 Portable Beams

Where portable beams for supporting wood hatch boards are made of steel, the maximum allowable stress and deflection under the design loads 2.2 are as follows.

Maximum allowable stress	0.68Y
Maximum allowable deflection	0.0044 times the span

where Y is as defined in 4.1.1.

Where the cross section of portable beams is not constant along the span, Ch.2 Appendix A6 may be used to determine required beam scantlings.

4.2.3 Closing/Securing Arrangements

Closing arrangements are to be in accordance with 4.1.2 through 4.1.6.

4.2.4 Carriers and Sockets

Carriers or sockets 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 unless the carriers are of an interlocking type with the beam ends. Carriers for beams are to extend to the deck level or the coamings are to be fitted with stiffeners or external brackets in way of each beam.

4.3 Steel Hatch Covers

4.3.1 Scantlings

Where steel hatch covers are fitted on portable beams in place of wooden hatch boards, the maximum allowable stress and deflection under the design loads in 2.2 are as follows.

Maximum allowable stress 0.8Y, and not exceed the critical buckling strength in compression

Maximum allowable deflection	0.0056 times the span
Top plate thickness	0.01s, but not less than 6 mm

where Y is as defined in 4.1.1.

Covers are to be assumed to be simply supported.

Portable beams are to be in accordance with 4.2.2.

4.3.2 Closing Arrangements

Closing arrangements are to be in accordance with 4.1.2 through 4.1.6.

4.4 Bearing Surface

The width of each bearing surface for hatchway covers is to be at least 65 mm.

4.5 Materials Other Than Steel

The strength and stiffness of covers made of materials other than steel are to be equivalent to those of steel and will be subject to special consideration.

5 Hatchways Closed by Covers of Steel Fitted with Gaskets and Clamping Devices

5.1 Strength of Covers

5.1.1 Scantlings

Where weathertight covers are steel, the maximum allowable stress and deflection under the design loads in 2.2 and the minimum top plate thickness are as follows.

Maximum allowable stress 0.8Y, and not to exceed the critical buckling strength in compression

Maximum allowable deflection 0.0056 times the span

Top plate thickness 0.01s, but not less than 6 mm

where Y and s are as defined in 4.1.1.

The following corrosion margin is to be incorporated into each strength member of the hatch cover:

- Single skin hatch covers, a corrosion addition t_s = 2.0 mm (*) for all plating and stiffeners.
- Double skin hatch covers, a corrosion addition t_s = 1.5 mm (*) for top and bottom plating and ts = 1.0 mm for the internal structure.

(*) Corrosion addition t_s = 1.0 mm for the hatch covers in way of cellular cargo holds intended for containers.

Where the cross section of hatch cover stiffeners is not constant along the span, Ch.2 Appendix A6 may be used to determine required scantlings.

5.2 Other Materials

The strength and stiffness of covers made of materials other than steel is to be equivalent to those of steel and is to be subject to special consideration.

5.3 Means for Securing Weathertightness

The means for securing and maintaining weathertightness are to be such that the tightness can be maintained in any sea conditions. The arrangements and the strength of these means of closing and securing of the covers to the anticipated sea loads are to comply with the requirements.

Where it is intended to carry cargoes on the covers, the securing means are also take into consideration these loads, including dynamic effects. Strength calculations for the means of securing hatch covers carrying cargoes are to be submitted for review. The covers are to be hose-tested in position under a water pressure of at least 2.1 bar at the time of construction and, if considered necessary, at subsequent surveys.

5.4 Flush Hatch Covers

Where flush hatch covers are fitted on the freeboard deck, within the forward one-fourth length (L_f /4), and the vessel 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 5.1.

5.5 Container Loading

Where it is intended to carry containers on steel hatch covers, 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 obtained from the following equation:

SM = M/f

where

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

f = permissible maximum bending stress, not to exceed 0.46Y

Y = specified yield point or yield strength, in kN/cm^2, but is not to exceed 72% of the specified minimum tensile strength.

In determining the maximum bending moment, members are to be considered simply-supported.

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

A = F/q

where

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

q = permissible average shear stress in the web, not to exceed 0.34Y

The hatch cover is to be so designed as to limit the deflection to 0.0028 times the span under the static container load.

In addition, the dynamic forces associated with roll, pitch and heave motions of the vessel are to be considered for the design of the hatch cover. Where predicted by ship motion calculations, the statistically appropriate effects of roll, pitch and heave may be used. The following permissible stresses may be used for those dynamic loading conditions:

f = permissible maximum bending stress, not to exceed 0.80Y

q = permissible average shear stress in the web, not to exceed 0.53Y

Where higher strength steels are used, calculations are to be submitted to show adequate provision against buckling.

6 Hatchways in Decks at Higher Levels

6.1 Gasketless 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 weathertight. The procedure for testing such covers will also be subject to special consideration.

7 Hatchways in Lower Decks or within Fully Enclosed Superstructures

7.1 General

The following scantlings are intended for ocean-going vessels and conventional type covers. Those scantlings for covers of special types or for vessels of restricted service are to be specially considered.

7.2 Beams and Wood Covers

Hatchways in lower decks or within fully enclosed superstructures 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 that obtained from the following equation:

$SM = 7.8chsl^2$ cm^3

where

c = 1.18

h = tween-deck height, in m. When a design load is specified, h is to be taken as p/n

where p is the specified design pressure, in kN/m^2, and n is defined as 7.04.

s = spacing of hatch beams, in m

l = 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 1.52 m. Where the height to which the cargo may be loaded on top of a hatch exceeds about 2.6 m, or where the spacing of the beams exceeds 1.52 m, the thickness of the wood covers is to be suitably increased.

7.3 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 Ch.2 Sec.3/3.1. 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 that obtained from the following equation:

$SM = 7.8hsl^2$ cm^3

where

h = tween-deck height, in m. When a design load is specified, h is to be taken as p/n

where p is the specified design pressure, in kN/m^2, and n is defined as 7.04.

s = spacing of the stiffeners, in m

l = length of the stiffener, in m

7.4 Wheel Loading

Where provision is to be made for the operation or stowage of vehicles having rubber tires, the thickness of the hatch cover plating is to be not less than obtained from Ch.2 Sec.3/3.9, for platform deck plating, except that the thickness of plate panels adjacent to the edges of the covers is to be at least 15% greater than obtained from Ch.2 Sec.3/3.9.

8 Small Hatches on the Exposed Fore Deck

8.1 Application

The requirements of this subsection apply to all small hatches [opening normally 2.5 m^2 or less] located on the exposed fore deck within the forward 0.25*L*, where the deck in way of the hatch is less than 0.1*L* or 22 m above the summer load line, whichever is less.

Hatches designed for emergency escape need not comply with 8.3i), 8.3ii), the third paragraph of 8.4 and 8.5.

8.2 Strength

For small rectangular steel hatch covers, the plate thickness, stiffener arrangement and scantlings are to be in accordance with Table 8.1 and Figure 8.1. Stiffeners, where fitted, are to be aligned with the metal-to-metal contact points required in 8.4 (see also Figure 8.1). Primary stiffeners are to be continuous. All stiffeners are to be welded to the inner edge stiffener (see Figure 8.2).

The upper edge of the hatchway coaming is to be suitably reinforced by a horizontal section, normally not more than 170 to 190 mm from the upper edge of the coaming.

For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement is to provide strength and stiffness equivalent to the requirements for small rectangular hatches.

For small hatch covers constructed of materials other than steel, the required scantlings are to provide strength and stiffness equivalent to 235 N/mm^2 yield strength steel.

8.3 Primary Securing Devices

The primary securing devices are to be such that their hatch covers can be secured in place and made weathertight by means of a mechanism employing any one of the following methods:

i) Butterfly nuts tightening onto forks (clamps), or

ii) Quick acting cleats, or

iii) A central locking device.

Dogs (twist tightening handles) with wedges are not acceptable.

8.4 Requirements for Primary Securing

The hatch cover is to be fitted with a gasket of elastic material. This is to be designed to allow a metal to metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged. The metal-to-metal contacts are to be arranged close to each securing device, in accordance with Figure 8.1, and of sufficient capacity to withstand the bearing force.

The primary securing method is to be designed and manufactured such that the designed compression pressure is achieved by one person without the need of any tools.

For a primary securing method using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed to minimize the risk of butterfly nuts being dislodged while in use, by means of curving the forks upward and a raised surface on the free end, or a similar method. The plate thickness of unstiffened steel forks is not to be less than 16 mm. An example arrangement is shown in Figure 8.2.

For small hatch covers located on the exposed deck forward of the fore-most cargo hatch, the hinges are to be fitted such that the predominant direction of green sea will cause the cover to close, which means that the hinges are normally to be located on the fore edge.

On small hatches located between the main hatches, for example, between Nos. 1 and 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green water in beam sea and bow quartering conditions.

8.5 Secondary Devices

Small hatches on the fore deck are to be fitted with an independent secondary securing device, e.g., by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

Table 8.1: Scantlings for Small Steel Hatch Covers on the Fore Deck

Nominal Size (mm × mm)	*Cover Plate Thickness (mm)*	*Primary Stiffeners*	*Secondary Stiffeners*
		Flat Bar (mm × mm); number	
630 × 630	8	---	---
630 × 830	8	100 × 8; 1	---
830 × 630	8	100 × 8; 1	---
830 × 830	8	100 × 10; 1	---
1030 × 1030	8	120 × 12; 1	80 × 8; 2
1330 × 1330	8	150 × 12; 2	100 × 10; 2

Figure 8.1

Arrangement of Stiffeners

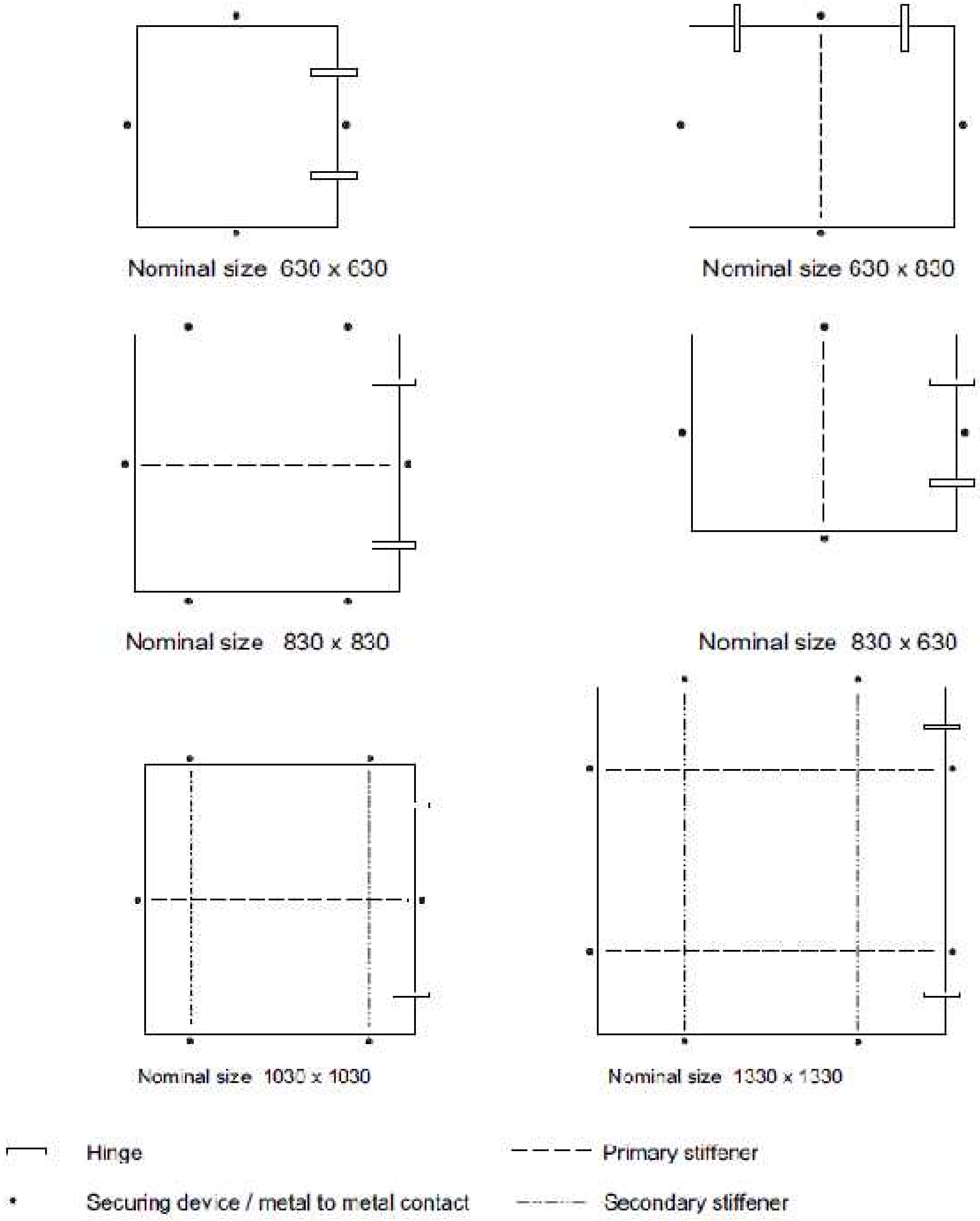
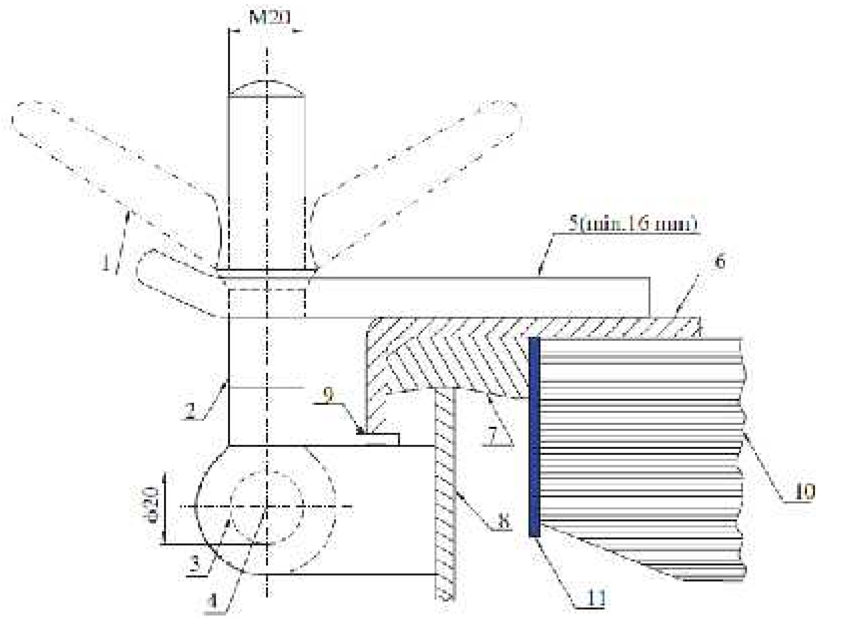


Figure 8.2: Example of Primary Securing Method



1: butterfly nut	2: bolt	3: pin	4: center of pin
5: fork (clamp) plate	6: hatch cover	7: gasket	8: hatch coaming

9: bearing pad welded on the bracket of a toggle bolt for metal to metal contact

10: stiffener 11: inner edge stiffener

9 Other Hatchways

9.1 Hatchways within Open Superstructures

Hatchways within open superstructures are to be considered as exposed.

9.2 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.

10 Additional Requirements for Subdivision

10.1 External Opening below Damage Waterline

All external openings leading to compartments assumed intact in the damage analysis, which are permitted by Ch.3 to be below the final damage waterline, are to be watertight. Except for hatch covers, these openings are to be fitted with indicators on the bridge showing whether the closing appliances are open or closed.

10.2 Internal Openings

The openings and penetrations in internal decks required to be watertight for subdivision are to meet the corresponding requirements for watertight doors in Ch.2 Sec.9/1.2 and Ch.2 Sec.9/5.

11 Machinery Casings

11.1 Arrangement

Machinery-space openings in Position 1 or 2 are to be framed and efficiently enclosed by steel casings of ample strength, and, wherever practicable, those in freeboard decks are to be within superstructures or deckhouses. Where the machinery casings are exposed, plating and stiffeners are to be in accordance with the requirements in Ch.2 Sec.11/2. Access openings in exposed casings are to be fitted with doors complying with the requirements of Ch.2 Sec.11/3.2, the sills of which are to be at least 600 mm above the deck if in Position 1, and at least 380 mm above the deck if in Position 2. Where the vessel is assigned a freeboard less than that based on Table B as allowed by the International Convention on Load Lines, 1966, there are generally to be no openings giving direct access from the freeboard deck to the machinery space.

A door, complying with the requirements of Ch.2 Sec.11/3.2, may however be permitted in the exposed machinery casing, provided that it leads to a space or passageway that is as strongly constructed as the casing and is separated from the engine room by a second door complying with Ch.2 Sec.11/3.2. The sill of the exterior door is not to be less than 600 mm, and the sill of the second/interior door is to be not less than 230 mm. Other openings in such casings are to be fitted with equivalent covers, permanently attached in their proper positions.

11.2 Fiddleys, Funnels, and Ventilators

Coamings of any fiddley, funnel 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 and practicable. Fiddley openings are to be fitted with strong covers of steel or other equivalent material, permanently attached in their proper positions and capable of being secured weathertight.

11.3 Casings within Open Superstructures

Casings within open superstructures are to be of similar scantlings to those obtained from Ch.2 Sec.11/2 for exposed casings on superstructure decks. Where there are no end bulkheads to the superstructures, the arrangements and scantlings are to be in compliance with Ch.2 Sec.11/2 for an exposed casing on the freeboard deck.

11.4 Casings within Enclosed Superstructures

The thickness of casings within enclosed superstructures is to be not less than obtained from the following equation:

$t = 4.6 + L/64 + (s - 760)/150$ mm but not less than 6.0 mm

The thickness of casing sides in accommodation spaces above the crown of the machinery space is not to be less than obtained from the following equation:

$t = 4.5 + (s - 760)/150$ mm

where

L = length of vessel, as defined in Ch.1 Sec.1/1.1, in m but need not be taken greater than 122 m

s = the stiffener spacing, in mm, but is not to be taken less than 760 mm

Where accelerated corrosion is expected, such as in way of wet spaces, the thickness of coaming plates may need to be increased. Where casings are used in lieu of girders or deep beams, the plating in way is to be suitably increased. Stiffeners are to be fitted in line with the beams and are to have a section modulus SM not less than obtained from the following equation:

$SM = 7.8chsl^2$ cm^3

where

c = 0.14

s = spacing of stiffeners, in m

h = tween-deck height, in m

l = length, between support, of the stiffeners, in m

Casings which support girders or pillars are to be suitably stiffened in such manner as to provide supports not less effective than required for stanchions or pillars.

11.5 Casings within Deckhouses

Casings within deckhouses are to have scantlings, sill heights 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.

12 Miscellaneous Openings in Freeboard and Superstructure Decks

12.1 Manholes and Scuttles

Manholes and flush scuttles in Position 1 or 2 or within superstructures other than enclosed superstructures are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

12.2 Other Openings

Openings in freeboard decks other than hatchways, machinery-space openings, manholes and flush scuttles are to be protected by an enclosed superstructure, or by a deckhouse or companionway of equivalent strength and weathertightness. 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 or a space within an enclosed superstructure 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 Ch.2 Sec.11/3.2.

12.3 Escape Openings

The closing appliances of escape openings are to be readily operable from each side.

12.4 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.

12.5 Mast Openings

Openings penetrating decks and other structures to accommodate masts, kingposts and similar members are to be reinforced by fitting doublings or plating of increased thickness.

12.6 Chain Pipe Opening

Chain pipes through which anchor cables are led are to be provided with permanently attached closing appliances to minimize the ingress of water. A canvas cover with appropriate lashing arrangement will be acceptable for this purpose. A cement and wire mesh arrangement is not permitted.

The arrangement on vessels that are not subject to the International Convention on Load Lines or its Protocol may be specially considered.

Section 16 Protection of Shell Openings

1 Cargo, Gangway, or Fueling Ports

1.1 Construction

Cargo, gangway, or fueling ports in the sides of vessels 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 openings, and 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.

Indicators showing whether the ports in the side shell below the freeboard or superstructure deck are secured closed or open are to be provided on the navigation bridge.

Where allowed by 1.2, cargo ports or similar openings located with their lower edge below the line defined in 1.2 are to be fitted with a second door of equivalent strength and watertightness with a leakage detection device for the compartment between the doors. The drain from this compartment is to be led to the bilge with a screw down valve operable from an accessible location.

In general, all outer doors are to open outwards.

1.2 Location

Unless especially approved, the lower edge of cargo, gangway, or fueling 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.

Cargo ports or similar openings may be located with their lower edge below the above defined line, provided they meet the additional construction requirements of 1.1.

1.3 Subdivision Requirements

Openings in the shell plating below the deck, limiting the vertical extent of damage, are to be kept permanently closed while at sea. Should any of these openings be accessible during the voyage, their closing appliances are to be fitted with a device which prevents unauthorized opening.

Closing appliances which are kept permanently closed at sea to ensure the watertight integrity of external openings but are not fitted with a device which prevents unauthorized opening, due to their inaccessibility during the voyage, are to be provided with a notice affixed to each such closing appliance to the effect that it is to be kept closed.

2 Bow Doors, Inner Doors, Side Shell Doors and Stern Doors

2.1 General

Where bow doors of the visor or side-opening type are fitted leading to complete or long forward enclosed superstructures, or to long superstructures with closing appliances to the satisfaction of the Administration, bow doors and inner doors are to meet the requirements of this section. Hull supporting structure in way of the bow doors is to be able to withstand the loads imposed by the bow door securing and supporting devices without exceeding the allowable stresses for those devices, both given in this section.

Side shell doors fitted abaft of the collision bulkhead and stern doors leading into enclosed spaces are to meet the requirements of this section.

2.2 Arrangement

2.2.1 General

As far as practicable, bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door.

2.2.2 Bow Doors

Bow doors are to be situated above the freeboard deck, except that where a watertight recess fitted for arrangement of ramps or other related mechanical devices is located forward of the collision bulkhead and above the deepest waterline, the bow doors may be situated above the recess.

2.2.3 Inner Doors

An inner door is to be fitted in the extension of the collision bulkhead required by Ch.2 Sec. 9/2.1.1. A vehicle ramp made watertight and conforming to Ch.2 Sec.9/Figure 2.1 in the closed position may be accepted for this purpose.

2.2.4 Side Shell and Stern Doors

Stern doors for passenger vessels are to be situated above the freeboard deck. Stern doors for ro-ro cargo vessels and all side shell doors need not be situated above the freeboard deck.

3 Securing, Locking and Supporting of Doors

3.1 Definitions

3.1.1 Securing Device

A device used to keep the door closed by preventing it from rotating about its hinges or its pivoted attachments to the vessel.

3.1.2 Supporting Device

A device used to transmit external or internal loads from the door to a securing device and from the securing device to the vessel's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the vessel's structure.

3.1.3 Locking Device

A device that locks a securing device in the closed position.

4 Securing and Supporting Devices

4.1 General

Securing and supporting devices are to be arranged in accordance with this subsection, and are to have scantlings as required by 7.5, 8.3 or 9.5, as appropriate.

4.2 Bow Doors

Means are to be provided to prevent lateral or vertical movement of the bow doors when closed. Means are also to be provided for mechanically fixing the door in the open position.

Means of securing and supporting the door are to maintain equivalent strength and stiffness of the adjacent structure.

4.2.1 Clearance and Packing

The maximum design clearance between the door and securing/supporting devices is not to exceed 3 mm. Where packing is fitted, it is to be of a comparatively soft type and the supporting forces are to be carried by the steel structure only.

4.2.2 Visor Door Arrangement

The pivot arrangement is to be such that the visor is self-closing under external loads. The closing moment, M_y, as defined in 10.3.1, is not to be less than M_{yo}, as given by the following equation:

$$M_{yo} = W_c + 0.1\sqrt{(a^2 + b^2)}\sqrt{(F_x^2 + F_z^2)}$$

where W, a, b, c, F_x and F_z are as defined in 9.

In addition, the arrangement of the door is to be such that the reaction forces of pin or wedge

supports at the base of the door does not act in the forward direction when the door is loaded in accordance with 10.3.4.

4.3 Side Shell and Stern Doors

Means are to be provided to prevent lateral or vertical movement of the side shell or stern doors when closed. Means are also to be provided for mechanically fixing the doors in the open position.

The means of securing and supporting the doors are to have strength and stiffness equivalent to the adjacent structure.

Clearance and packing for side shell and stern doors are to be in accordance with 4.2.1.

5 Securing and Locking Arrangement

5.1 General

Securing devices are to be provided with a mechanical locking arrangement (self locking or separate arrangement), or are to be of the gravity type.

5.2 Operation

Securing devices are to be simple to operate and readily accessible. The opening and closing systems as well as the securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

6 Tightness

6.1 Bow Doors

Bow doors are to be so fitted as to ensure tightness consistent with operational conditions and to give effective protection to the inner doors.

6.2 Inner Doors

Inner doors forming part of the extension of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

6.3 Side Shell and Stern Doors

Side shell doors and stern doors are to be so fitted as to ensure water tightness.

7 Bow Door Scantlings

7.1 General

Bow doors are to be framed and stiffened so that the whole structure is equivalent to the intact bow structure when closed.

7.2 Primary Structure

Scantlings of primary members are to be designed so that the allowable stresses indicated in 13.1 are not exceeded when the structure is subjected to the design loads indicated in 10.1. Normally, simple beam theory may be applied to determine the bending stresses. Members are to be considered to have simply supported end connections.

7.3 Secondary Stiffeners

Secondary stiffeners are to be supported by primary members constituting the main stiffening of the door.

The section modulus, *SM*, of secondary stiffeners is to be as required in Ch.2 Sec.5/1.1 and Ch.2 Sec.5/3. Consideration is to be given, where necessary, to differences in fixity between the requirements in Ch.2 Sec.5/1.1, Ch.2 Sec.5/3, and bow door stiffeners.

In addition, stiffener webs are to have a net sectional area not less than that obtained from the following equation:

$A = VQ/10$ cm^2

where

V = shear force, in kN , in the stiffener calculated using the uniformly distributed external pressure, P_{eb}, given in 3-2-16/10.1

Q = as defined in Ch.2 Sec.1/3.3

7.4 Plating

The thickness of bow door plating is to be not less than that required for side shell plating at the same location.

7.5 Securing and Supporting Devices

Scantlings of securing and supporting devices are to be designed so that the allowable stresses indicated in 13.1 are not exceeded when the structure is subjected to the design loads indicated in 10.2.

All load-transmitting elements in the design load path from the door through securing and supporting devices into the vessel structure, including welded connections, are to meet the strength standards required for securing and supporting devices. These elements include pins, support brackets and back-up brackets.

Where fitted, threaded bolts are not to carry support forces, and the maximum tensile stress in way of the threads is not to exceed the allowable stress given in 13.3.

In determining the required scantlings, the door is to be assumed to be a rigid body. Only those active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered when calculating the reaction forces on the devices. Small or flexible devices such as cleats intended to provide compression load on the packing material are not to be included in the calculations.

7.5.1 Bearing Pressure

The bearing pressure on steel to steel bearings is to be calculated by dividing the design force by the projected bearing area, and is not to exceed the allowable stress given in 13.2.

7.5.2 Redundancy

In addition to the above requirements, the arrangement of the securing and supporting devices is to be designed with redundancy such that in the event of failure of any single securing or supporting device, the stresses in the remaining devices do not exceed the allowable stresses indicated in 13.1 by more than 20% under the above loads.

7.5.3 Visor Door Securing and Supporting Devices

Securing and supporting devices, excluding the hinges, are to be capable of resisting the vertical design force given in 10.3.3 without exceeding the allowable stresses in 13.1.

Two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door without stresses exceeding the allowable stresses indicated in 13.1. The opening moment, M_o, to be balanced by this force is as given in 10.3.2.

7.5.4 Side-opening Door Thrust Bearing

A thrust bearing is to be provided in way of girder ends at the closing of the two doors, and is to prevent one door from shifting towards the other one under the effect of unsymmetrical pressure.

Securing devices are to be fitted to secure sections thrust bearing to one another.

7.6 Visor Door Lifting Arms and Supports

Where visor type bow doors are fitted, calculations are to be submitted verifying that lifting arms and their connections to the door and vessel structure are adequate to withstand the static and dynamic forces applied during the lifting and lowering operations under a wind pressure of at least 1.5 kN/m^2 .

8 Inner Door Scantlings

8.1 General

Scantlings of inner doors are to meet the requirements of this subsection. In addition, where inner doors are used as vehicle ramps, scantlings are not to be less than required for vehicle decks in Ch.2 Sec.3, Sec.7 and Sec.8.

8.2 Primary Structure

Scantlings of primary members are to be designed so that the allowable stresses indicated in 13.1 are not exceeded when the structure is subjected to the design loads indicated in 11.1.

8.3 Securing and Supporting Devices

Scantlings of securing and supporting devices are to be designed so that the allowable stresses indicated in 13.1 are not exceeded when the structure is subjected to the design loads indicated in 11.

Where fitted, threaded bolts are not to carry support forces, and the maximum tensile stress in way of the threads is not to exceed the allowable stress given in 13.3.

The bearing pressure on steel to steel bearings is to be calculated by dividing the design force by the projected bearing area, and is not to exceed the allowable stress given in 13.2.

9 Side Shell Door and Stern Door Scantlings

9.1 General

Scantlings of side shell doors or stern doors are to meet the requirements of this subsection. In addition, where the doors are used as vehicle ramps, scantlings are not to be less than required for vehicle decks in Ch.2 Sec.3, Sec.7 and Sec.8.

9.2 Primary Structure

Scantlings of primary members are to be designed so that the allowable stresses indicated in 13.1 are not exceeded when the structure is subjected to the design loads indicated in 12. Normally, simple beam theory may be applied to determine the bending stresses. Members are considered to have simply supported end connections.

9.3 Secondary Stiffeners

Secondary stiffeners are to be supported by primary members constituting the main stiffening of the door.

The section modulus, *SM*, of secondary stiffeners is to be not less than required by Ch.2 section 5 for frames in the same location. In addition, the net sectional area of stiffener webs is to be in accordance with 7.3, using the external pressure, p_e, given in 12.

9.4 Plating

The thickness of side or stern door plating is to be not less than that required for side shell plating at the same location.

9.5 Securing and Supporting Devices

Scantlings of securing and supporting devices are to be designed so that the allowable stresses indicated in 13.1 are not exceeded when the structure is subjected to the design loads indicated in 12. All load-transmitting elements in the design load path from the door through securing and supporting devices into the vessel structure, including welded connections, are to meet the strength standards required for securing and supporting devices. Where fitted, threaded bolts are not to carry support forces, and the maximum tensile stress in way of the threads is not to exceed the allowable stress given in 13.3.

In determining the required scantlings, the door is to be assumed to be a rigid body. Only those active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered when calculating the reaction forces on the devices. Small or flexible devices such as cleats intended to provide compression load on the packing material are not to be included in the calculations.

9.5.1 Bearing Pressure

The bearing pressure on steel-to-steel bearings is to be calculated by dividing the design force by the projected bearing area, and is not to exceed the allowable stress given in 13.2.

9.5.2 Redundancy

In addition to the above requirements, the arrangement of the securing and supporting devices is to be designed with redundancy such that in the event of a failure of any single securing or supporting device, the stresses in the remaining devices do not exceed the allowable stresses indicated in 13.1 by more than 20% under the above loads.

10 Bow Door Design Loads

10.1 External Pressure

The design external pressure, P_{eb} , is to be taken as indicated by the following equation:

$$P_{eb} = nc(0.22 + 0.15\tan\quad)(0.4V_d \sin\sim + 0.6\sqrt{kL_1})^2 \quad \text{kN/m}^2$$

where

n = 2.75

c = 1.0

L = length of vessel, as defined in Ch.1 Sec.1/1.1, in m.

L_1 = length of vessel, in m, as defined in Ch.1 Sec.1/1.1, but need not be taken as greater than 200 m

β = flare angle at the point to be considered, defined as the angle between a vertical line

and the tangent to the side shell plating measured in a vertical plane normal to the horizontal tangent to the shell plating. See Figure 10.1.

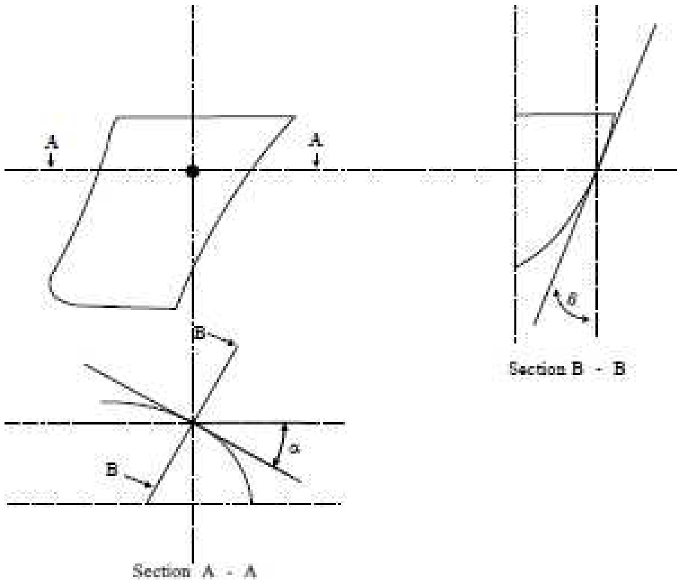
α = entry angle at the point to be considered, defined as the angle between a longitudinal

line parallel to the centerline and the tangent to the shell plating in a horizontal plane. See Figure 10.1.

k = 1.0

V_d = vessel design speed, as defined in Ch.2 Sec.14/2.1.

Figure 10.1: Entry and Flare Angles



10.2 External Forces (2005)

The design external forces considered in determining scantlings of securing and supporting devices of bow doors are not to be taken less than those given by the following equations:

$F_x = P_{em}A_x$

$F_y = P_{em}A_y$

$F_z = P_{em}A_z$

where

F_x = the design external force in the longitudinal direction, in kN

F_y = the design external force in the horizontal direction, in kN

F_z = the design external force in the vertical direction, in kN

A_x = area, in m^2, of the transverse projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark or between the bottom of the door and the top of the door, whichever is the lesser. Where the flare angle of the bulwark is at least 15° less than the flare of the adjacent shell plating, the bulwark may be excluded and the distance may be measured from the bottom of the door to the upper deck or to the top of the door, whichever is the lesser.

A_y = area, in m^2, of the longitudinal projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark or between the bottom of the door and the top of the door, whichever is the lesser. Where the flare angle of the bulwark is at least 15º less than the flare of the adjacent shell plating, the bulwark may be excluded and the distance may be measured from the bottom of the door to the upper deck or to the top of the door, whichever is the lesser.

A_z = area, in m^2, of the horizontal projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark or between the bottom of the door and the top of the door, whichever is the lesser. Where the flare angle of the bulwark is at least 15º less than the flare of the adjacent shell plating, the bulwark may be excluded and the distance may be measured from the bottom of the door to the upper deck or to the top of the door, whichever is the lesser.

P_{em} = bow door pressure, P_{eb}, determined using α_m and β_m in place of α and β

β_m = flare angle measured at a point on the bow door $l/2$ aft of the stem line on a plane $h/2$

above the bottom of the door as shown in Figure 10.2

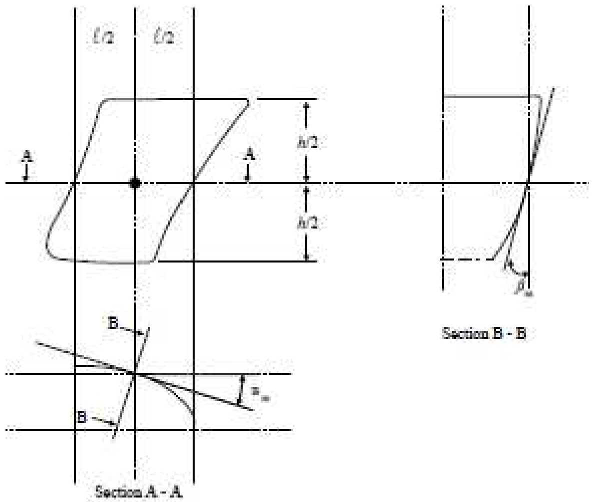
α_m = entry angle measured at the same point as β_m. See Figure 10.2

h = height, in m, of the door between the levels of the bottom of the door and the upper

deck or between the bottom of the door and the top of the door, whichever is less

l = fore and aft length, in m, of the door at a height $h/2$ above the bottom of the door

Figure 10.2: Definition of α_m and β_m



10.3 Visor Door Forces, Moments and Load Cases

10.3.1 Closing Moment

For visor doors, the closing moment, M_y, is to be taken as indicated by the following equation:

$M_y = F_x\, a + Wc - F_z\, b$ kN-m

where

W = weight of the visor door, in kN

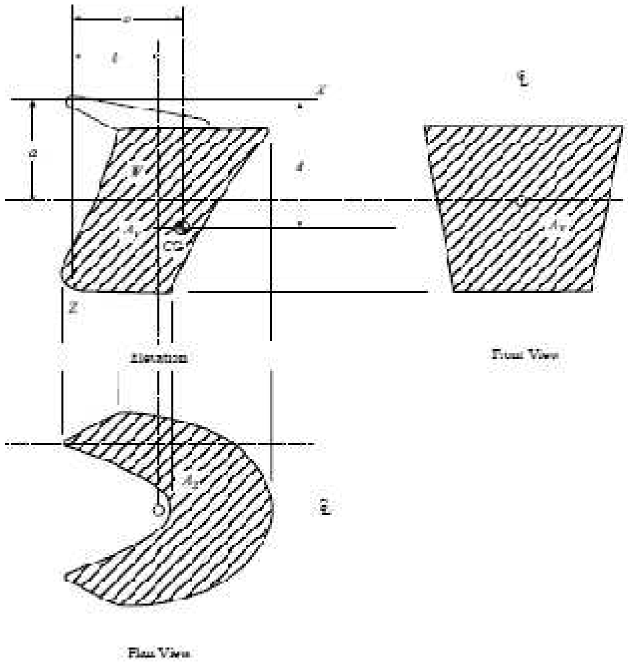
a = vertical distance, in m, from the visor pivot to the centroid of the transverse vertical projected area of the visor door. See Figure 10.3.

b = horizontal distance, in m, from visor pivot to the centroid of the horizontal projected area of the visor door. See Figure 10.3.

c = horizontal distance, in m, from the visor pivot to the center of gravity of the visor. See Figure 10.3.

F_x and F_z are as defined in 10.2.

Figure 10.3: Visor Type Bow Door



10.3.2 Opening Moment

The opening moment, *Mo*, is to be taken as indicated by the following equation:

$M_o = Wd + 5A_x\, a$ kN-m

where

d = vertical distance, in m, from the hinge axis to the center of gravity of the door

W, A_x and a are as indicated above.

10.3.3 Vertical Design Force

The vertical design force is to be taken as $F_z - W$ where F_z is as defined in 10.3 and W is as

defined in 10.3.1.

10.3.4 Combined Load Case 1

The visor doors are to be evaluated under a load of F_x, F_z and W acting simultaneously with F_x and F_z acting at the centroid of their respective projected areas.

10.3.5 Combined Load Case 2

The visor doors are to be evaluated under a load of $0.7F_y$ acting on each side separately, together with $0.7F_x$, $0.7F_z$ and W.

F_x, F_y and F_z are to be taken as acting at the centroid of their of their respective projected areas.

10.4 Side-Opening Door Load Cases

10.4.1 Combined Load Case 1

Side opening doors are to be evaluated under a load of F_x, F_y, F_z and W acting simultaneously with F_x, F_y and F_z acting at the centroid of their respective projected areas.

10.4.2 Combined Load Case 2

Side opening doors are to be evaluated under a load of $0.7F_x$, $0.7F_x$ and W acting on both doors simultaneously and $0.7F_y$ acting on each door separately.

11 Inner Door Design Loads

11.1 External Pressure

The design external pressure is to be taken as the greater of P_{ei} or P_h, as given by the following equations:

$P_{ei} = 0.45L_1$ kN/m^2

$P_h = 10h$ kN/m^2

where

L_1 is as defined in 10.1.

h = the distance, in m, from the load point to the top of the cargo space.

11.2 Internal Pressure

The design internal pressure, P_i, is to be taken as not less than 25 kN/m^2.

12 Side Shell and Stern Doors

12.1 Design Forces for Primary Members

The design force, in kN, for primary members is to be the greater of the following:

External force: $F_e = A\,p_e$

Internal force: $F_i = F_o + W$

12.2 Design Forces for Securing or Supporting Devices of Doors Opening Inwards

The design force, in kN, for securing or supporting devices of doors opening inwards is to be the greater of the following:

External force: $F_e = A\,p_e + F_p$

Internal force: $F_i = F_o + W$

12.3 Design Forces for Securing or Supporting Devices of Doors Opening Outwards

The design force, in kN, for securing or supporting devices of doors opening outwards is to be the greater of the following:

External force: $F_e = A\,p_e$

Internal force: $F_i = F_o + W + F_p$

where

A = area, in m^2, of the door opening

W = weight of the door, in kN

F_p = total packing force, in kN. Packing line pressure is normally not to be taken less than 5.0 N/mm.

F_o = the greater of F_c and kA, in kN

$k = 5$

F_c = accidental force, in kN, due to loose cargo, etc., to be uniformly distributed over the area A and not to be taken less than 300 kN. For small doors such as bunker doors and pilot doors, the value of F_c may be appropriately reduced.

However, the value of F_c may be taken as zero, provided an additional structure such as an inner ramp is fitted which is capable of protecting the door from accidental forces due to loose cargoes.

p_e = external design pressure, in kN/m^2, determined at the center of gravity of the door opening and not taken less than:

$p_e = 25$ for $Z_G \geq d$

$p_e = 10(d - Z_G) + 25$ for $Z_G < d$

Moreover, for vessels fitted with bow doors, p_e for stern doors is not to be taken less than:

$p_e = 0.605(0.8 + 0.6(L)^{0.5})^2$

For vessels fitted with bow doors and operating in restricted service, the value of p_e for stern doors will be specially considered.

d = draft, in m, as defined in Ch.1 Sec.1/1.4

Z_G = height of the center of area of the door, in m, above the baseline.

L = length of vessel, in m, as defined in Ch.1 Sec.1/1.1, but need not be taken as greater than 200 m.

13 Allowable Stresses

13.1 Primary Structure and Securing and Supporting Devices

The following stresses are not to be exceeded under the loads indicated above.

Shear Stress:	$\tau = 80/Q$	N/mm^2
Bending Stress:	$\sigma = 120/Q$	N/mm^2
Equivalent Stress: $(\sqrt{\sigma^2 + 3\tau^2})$	$\sigma_e = 150/Q$	N/mm^2

where Q is as defined in Ch.2 Sec.1/3.3.

13.2 Steel Securing and Supporting Devices Bearing Stress

For steel-to-steel bearings in securing and supporting devices, the nominal bearing pressure is not to exceed 0.8 σ_f, where σ_f is the yield stress of the bearing material.

13.3 Tensile Stress on Threaded Bolts

The tensile stress in threaded bolts is not to exceed $125/Q$ N/mm^2.

14 Operating and Maintenance Manual

The following information is to be submitted for review.

14.1 Manual

An operating and maintenance manual for the doors is to be provided onboard and is to contain at least the following:

- Main particulars and design drawings
- Service conditions, e.g., service area restrictions, emergency operations, acceptable clearances for supports
- Maintenance and function testing
- Register of inspections and repairs

14.2 Operating Procedures

Documented operating procedures for closing and securing the doors are to be kept onboard and posted at an appropriate location.

Section 17 Bulwarks, Rails, Freeing Ports, Portlights, Ventilators, Tank Vents and Overflows

1 Bulwarks and Guard Rails

1.1 Height on Manned Vessels

The height of bulwarks and guard rails 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 vessel, a lesser height may be approved if adequate protection is provided. Where approval of a lower height is requested, justifying information is to be submitted.

1.2 Strength of Bulwarks

Bulwarks are to be of ample strength in proportion to their height and are to be efficiently stiffened at the upper edge. Bulwark plating on freeboard decks is not to be less than 6.5 mm in thickness. The bulwark plating is to be kept clear of the sheer strake and the lower edge effectively stiffened. Bulwarks are to be supported by efficient stays; those on freeboard decks are to have stays spaced not more than 1.83 m apart. The stays are to be formed of plate and angle or built-up tee sections and are to be efficiently attached to the bulwark and deck plating. Where it is intended to carry timber deck cargoes, the bulwark stays are to be not over 1.52 m apart and have increased attachment to deck and bulwark. Gangways and other openings in bulwarks are to be kept well away from breaks of superstructures, and heavy plates are to be fitted in way of mooring pipes.

1.3 Guard Rails

1.3.1 Fixed, removable or hinged stanchions are to be fitted at approximately 1.5 m apart. Removable or hinged stanchions are to be capable of being locked in the upright position.

1.3.2 At least every third stanchion is to be supported by a bracket or stay. Where the arrangements would interfere with the safe traffic of persons on board, the following alternative arrangements of stanchions may be acceptable:

i) At least every third stanchion is to be of increased breadth, $kb_s = 2.9b_s$ at the attachment

of stanchion to the deck, or,

ii) At least every second stanchion is to be of increased breadth, $kb_s = 2.4b_s$ at the attachment

of stanchion to the deck, or,

iii) Every stanchion is to be of increased breadth, $kb_s = 1.9b_s$ at the attachment of stanchion to the deck.

where, b_s is the breadth of normal stanchion according to the recognized design standard.

(see Figure 1.1)

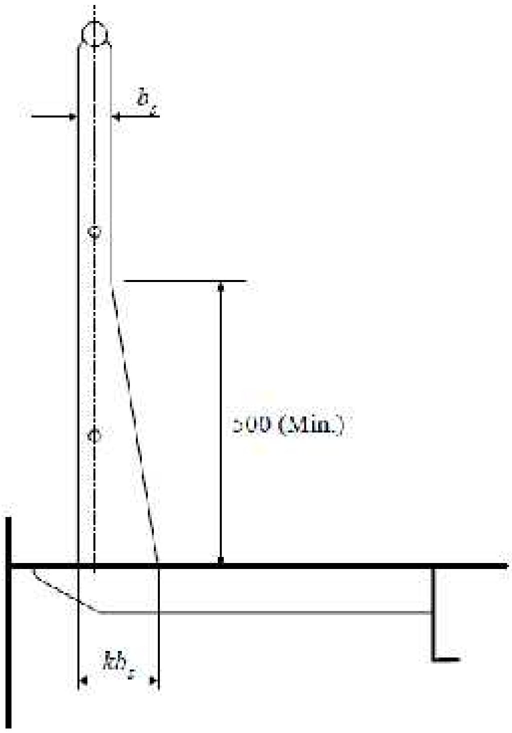
In any arrangement of *i), ii)* or *iii)* above, the following details are to be complied with:

iv) Flat steel stanchion required by *i), ii)* or *iii)* above is to be aligned with member below

deck unless the deck plating thickness exceeds 20 mm

v) The supporting member of the stanchion is to be of 100 × 12 mm flat bar welded to deck by double continuous fillet weld with minimum leg size of 7.0 mm or specified by the recognized design standard.

Figure 1.1: Guardrail Stanchion



1.3.3 The opening below the lowest course is not to exceed 230 mm. The distance between the remaining courses is not to be more than 380 mm.

1.3.4 For vessels with rounded gunwales, stanchions are to be placed on the flat of the deck.

2 Access and Crew Protection

2.1 General

Vessels with the keel laid or in similar stage of construction on or after 1 July 1998 are to meet the following requirements. Satisfactory means in the form of guard rails, lifelines, gangways or underdeck passages, etc., are to be provided for the protection of the crew in getting to and from their quarters, the machinery space, and all other parts used in the necessary work of the vessel. See Table 2.1

2.2 Access to Bow on Tankers

Tankers, including oil carriers, fuel oil carriers, gas carriers and chemical carriers, are to be provided with means to enable the crew to gain safe access to the bow even in severe weather conditions.

Table 2.1: Acceptable Arrangement for Access

<table>
<tr><th rowspan="2">Type of ship</th><th rowspan="2">Locations of access in ship</th><th rowspan="2">Assigned summer freeboard</th><th colspan="4">Acceptable arrangements according to type of Freeboard Assigned:</th></tr>
<tr><th>Type A</th><th>Type B−100</th><th>Type B−60</th><th>Type B & B+</th></tr>
<tr><td rowspan="4">All ships other than Oil Tankers*, Chemical Tankers* and Gas Carriers*</td><td rowspan="2">1.1: Access to Midship Quarters
1.1.1. Between poop and bridge, or
1.1.2 Between poop and deckhouse containing living accommodation, or navigation equipment, or both.</td><td>≤ 3000 mm</td><td>a
b
e</td><td>a
b
e</td><td>a
b
c(1)
e
f(1)</td><td rowspan="4">a
b
c(1)
c(2)
c(4)
d(1)
d(2)
d(3)
e
f(1)
f(2)
f(4)</td></tr>
<tr><td>> 3000 mm</td><td>a
b
e</td><td>a
b
e</td><td>a
b
c(1)
c(2)
e
f(1)
f(2)</td></tr>
<tr><td rowspan="2">1.2: Access to Ends
1.2.1Between poop and bow (if there is no bridge),
1.2.2. Between bridge and bow, or
1.2.3. Between a deckhouse containing living accommodation or navigation equipment, or both, and bow, or
1.2.4 In the case of a flush deck vessel, between crew accommodation and the forward and after ends of vessel.</td><td>≤ 3000 mm</td><td>a
b
c(1)
e
f(1)</td><td>a
b
c(1)
c(2)
e
f(1)
f(2)</td><td>a
b
c(1)
c(2)
e
f(1)
f(2)</td></tr>
<tr><td>> 3000 mm</td><td>a
b
c(1)
d(1)
e
f(1)</td><td>a
b
c(1)
c(2)
d(1)
d(2)
e
f(1)
f(2)</td><td>a
b
c(1)
c(2)
c(4)
d(1)
d(2)
d(3)
e
f(1)
f(2)
f(4)</td></tr>
<tr><td rowspan="3">Oil Tankers*, Chemical Tankers* and Gas Carriers*</td><td rowspan="2">2.1: Access to Bow
2.1.1. Between poop and bow, or
2.1.2. Between a deckhouse containing living accommodation or navigation equipment, or both, and bow, or
2.1.3. In the case of a flush deck vessel, between crew accommodation and the forward end of vessel.</td><td>$\le(A_f + H_s)$*</td><td colspan="4">A
e
f(1)
f(5)</td></tr>
<tr><td>$>(A_f + H_s)$**</td><td colspan="4">A
e
f(1)
f(2)</td></tr>
<tr><td>2.2: Access to After End
In the case of a flush deck vessel, between crew accommodation and the after end of vessel.</td><td colspan="5">As required in 1.2.4 for other types of vessels</td></tr>
</table>

* Oil Tanker, Chemical Tanker and Gas Carrier as defined in SOLAS: II-1/2.12, VII/8.2 and VII/11.2 respectively.

** A_f: the minimum summer freeboard calculated as type A ship regardless of the type freeboard actually assigned.

H_s: the standard height of superstructure as defined in ICLL Regulation 33.

Note: Deviations from some or all of these requirements or alternative arrangements for such cases as vessels with very high gangways (i.e.: certain gas carriers) may be allowed, subject to agreement on a case-by-case basis with the relevant Flag Administration.

I. Construction Keys (a) through (f)

(a) A well lighted and ventilated underdeck passageway with clear opening at least 0.8 m in width and 2.0 m in height, providing access to the locations in question and located as close as practicable to the freeboard deck.

(b) A permanently constructed gangway fitted at or above the level of the superstructure deck on or as near as practicable to the center line of the vessel, providing a continuous platform of a non-slip surface at least 0.6 m in width, with a foot-stop and guard rails extending on each side throughout its length. Guard rails are to be as required in 2.1 and 1.3, except that stanchions are to be fitted at intervals not more than 1.5 m.

(c) A permanent walkway at least 0.6 m in width fitted at freeboard deck level consisting of two rows of guard rails with stanchions spaced not more than 3 m. The number of courses of rails and their spacing are to be as required in 1.3. On Type B ships, hatchway coamings not less than 0.6 m in height may be regarded as forming one side of the walkway, provided that two rows of guard rails are fitted between the hatchways.

(d) A 10 mm minimum diameter wire rope lifeline supported by stanchions about 10 m apart, or A single hand rail or wire rope attached to hatch coamings, continued and adequately supported between hatchways.

(e) A permanently constructed gangway fitted at or above the level of the superstructure deck on or as near as practicable to the center line of the vessel:

- located so as not to hinder easy access across the working areas of the deck;
- providing a continuous platform at least 1.0 m in width*;
- constructed of fire resistant and non-slip material;
- fitted with guard rails extending on each side throughout its length. Guard rails are to be as required in 2.1 and 1.3, except that stanchions are to be fitted at intervals not more than 1.5 m;
- provided with a foot stop on each side;
- having openings, with ladders where appropriate, to and from the deck. Openings are to be not more than 40 m apart;
- having shelters of substantial construction, set in way of the gangway at intervals not exceeding 45 m if the length of the exposed deck to be traversed exceeds 70 m. Every

such shelter is to be capable of accommodating at least one person and be so constructed as to afford weather protection on the forward, port and starboard sides.

(f) A permanent and efficiently constructed walkway fitted at freeboard deck level on or as near as practicable to the center line of the vessel having the same specifications as those for a permanent gangway listed in (e)*, except for foot-stops. On Type B ships certified for the carriage of liquids in bulk, the hatch coamings may be accepted as forming one side of the walkway, provided a combined height of hatch coaming and hatch cover in the closed condition is not less than 1 m and two rows of guard rails are fitted between the hatchways.

(*) For tankers less than 100 m in length, the minimum width of the gangway platform or deck level walkway fitted in accordance with arrangement (e) or (f), respectively, may be reduced to 0.6 m.

II. Transverse Location Keys (1) through (5) - for Construction (c), (d) and (f) where specified in the Table

(1) At or near the centerline of vessel or fitted on hatchways at or near the centerline of vessel.

(2) Fitted on each side of the vessel.

(3) Fitted on one side of the vessel, provision being made for fitting on either side.

(4) Fitted on one side only.

(5) Fitted on each side of the hatchways as near to the centerline as practicable.

III. Notes:

1. In all cases where wire ropes are fitted, adequate devices are to be provided to enable maintaining their tautness.
2. A means of passage over obstructions, if any, such as pipes or other fittings of a permanent nature is to be provided.
3. Generally, the width of the gangway or walkway should not exceed 1.5 m.

3 Freeing Ports

3.1 Basic Area

Where bulwarks on the weather portions of freeboard or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of water and for draining them. Except as provided in 3.2 and 3.3, the minimum freeing-port area A on each side of the vessel 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 area for each well on superstructure decks is to be one-half of the area obtained from the following equation:

Where the length of bulwark *l* in the well is 20 m or less:

$A = 0.7 + 0.035l \quad m^2$

Where l exceeds 20 m:

$A = 0.07l$ m^2

In no case need l be taken as greater than $0.7L_f$ where L_f is as defined in Ch.1 Sec.1/1.1. If the bulwark is more than 1.2 m in average height, the required area is to be increased by 0.004 m^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 in height.

3.2 Vessels with Less than Standard Sheer

In vessels with no sheer, the calculated area is to be increased by 50%. Where the sheer is less than the standard, the percentage is to be obtained by interpolation.

3.3 Trunks

Where a vessel 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, or where continuous or substantially continuous hatchway side coamings are fitted between detached superstructures, the minimum area of the freeing-port openings is to be calculated from the following table.

Area of freeing ports in relation to the total area of the bulwarks	Breadth of hatchway or trunk in relation to the breadth of vessel
40% or less	20%
75% or more	10%

The area of freeing ports at intermediate breadths is to be obtained by linear interpolation.

3.4 Open Superstructures

In vessels having superstructures which are open at either or both ends, adequate provision for freeing the space within such superstructures is to be provided, and the arrangements are to be subject to special approval.

3.5 Details of Freeing Ports

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 or bars 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 or bearings of noncorrodible material and in general are to be located at or near the top of the shutters. If shutters are fitted with securing appliances, these are to be of approved construction.

4 Portlights

4.1 Application

This subsection applies to passenger vessels and cargo vessels.

As such, any reference to bulkhead/freeboard deck means bulkhead deck in the case of passenger vessels and freeboard deck in the case of cargo vessels.

4.2 Location

No portlight is to be fitted in a position with its sill below a line drawn parallel to the bulkhead/ freeboard deck at side and having its lowest point 2.5% of the breadth of the vessel above the load waterline (or summer timber load waterline, if assigned), or 500 mm, whichever is the greater distance.

In addition, portlights are not to be fitted in spaces which are used exclusively for the carriage of cargo.

4.3 Construction

4.3.1 General

Portlights to spaces below the bulkhead/freeboard deck or to spaces within enclosed superstructures are to be fitted with efficient hinged, inside deadlights arranged so that they can be effectively closed and secured watertight. The portlights, together with their glasses and deadlights, are to comply with a recognized standard. They are to have strong frames (other than cast iron) and opening-type portlights are to have noncorrosive hinge pins.

4.3.2 Non-opening Type

Where vessels are subject to damage stability requirements, portlights found to be situated below a final damage equilibrium waterline are to be of non-opening type.

4.3.3 Locked Type

Portlights where permitted in 4.3.2 to be of opening type are to be of such construction as will prevent unauthorized opening where:

4.3.3(a) the sills of which are below the bulkhead/freeboard deck as permitted in 4.2, or 4.3.3(b) fitted in spaces used alternatively for the carriage of cargo or passengers.

4.3.4 Automatic Ventilating Type

Automatic ventilating portlights are not to be fitted in the shell plating below the bulkhead/freeboard deck without special approval.

5 Ventilators, Tank Vents and Overflows

5.1 General

Ventilators are to comply with the requirements of 5.2. Tank vents and overflows are to comply with the requirements in 5.3. In addition, for those located on the fore deck, the requirements given in 5.4 are to be complied with.

5.2 Ventilators

5.2.1 Construction of Coamings

Ventilators 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 in diameter, and 10 mm for diameters of 457 mm and above; the thicknesses for intermediate diameters may be obtained by interpolation. Coamings are to be effectively and properly 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.

Where a fire damper is located within a ventilation coaming, an inspection port or opening at least 150 mm in diameter is to be provided in the coaming to facilitate survey of the damper without disassembling the coaming or the ventilator. The closure provided for the inspection port or opening is to maintain the watertight integrity of the coaming and, if appropriate, the fire integrity of the coaming.

5.2.2 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. (See Ch.2 Sec.15/2 for definition of Positions 1 and 2.) In exposed positions, the height of coamings may be required to be increased.

5.2.3 Means for Closing Openings

Except as provided below, ventilator openings are to be provided with efficient, permanently attached 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 make it necessary.

5.3 Tank Vents and Overflows

Tank vents and overflows are to be in accordance with the requirements of Rules. In addition, where applicable, the requirements given below in 5.4 are to be complied with.

5.4 Ventilators, Tank Vents and Overflows on the Fore Deck

5.4.1 Application

The requirements of this paragraph apply to all ventilators, tank vents and overflows located on the exposed fore deck within the forward 0.25L and where the height of the exposed deck in way of the item is less than 0.1L or 22 meters above the summer load waterline, whichever is the lesser.

5.4.2 Applied Loading to the Air Pipes and Ventilators

5.4.2 (a) Pressure. The pressures p, in kN/m^2, acting on air pipes, ventilator pipes and their closing devices, may be calculated from:

$p = 0.5\,\rho\,V^2\,C_d\,C_s\,C_p$ kN/m^2

where:

ρ = density of sea water, 1.025 t/m^3

V = velocity of water over the fore deck, 13.5 m/sec

C_d = shape coefficient, 0.5 for pipes, 1.3 for pipes or ventilator heads in general, 0.8 for pipes or ventilator heads of cylindrical form with their axis in the vertical direction

C_s = slamming coefficient, 3.2

C_p = protection coefficient:

= 0.7 for pipes and ventilator heads located immediately behind a breakwater or forecastle

= 1.0 elsewhere, including immediately behind a bulwark

5.4.2 (b) Force. Forces acting in the horizontal direction on the pipe and its closing device may be calculated from the above pressure using the largest projected area of each component.

5.4.3 Strength Requirements for Ventilators, Tank Vents and Overflows and their Closing Devices

5.4.3 (a) Bending Moment and Stress. Bending moments and stresses in air pipes and ventilator pipes are to be calculated at critical positions: at penetration pieces, at weld or flange connections, at toes of supporting brackets. Bending stresses in the net section are not to exceed 0.8Y, where Y is the specified minimum yield stress or 0.2% proof stress of the steel at room temperature.

Irrespective of corrosion protection, a corrosion addition to the net section of 2.0 mm is then to be applied.

5.4.3 (b) Tank Vents and Overflows

i) For standard tank vents and overflows of 760 mm height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in Table 5.1. Where brackets are required, three or more radial brackets are to be fitted.

ii) Brackets are to be of gross thickness of 8 mm or more, of minimum length of 100 mm, and height according to Table 5.1, but need not extend over the joint flange for the head. Bracket toes at the deck are to be suitably supported.

iii) For other configurations, loads according to 5.4.2 are to be applied, and means of support determined in order to comply with the requirements above. Brackets, where fitted, are to be of suitable thickness and length according to their height.

iv) Final (gross) pipe thickness is not to be taken less than as indicated in Rules.

v) The minimum internal diameter of the air pipe or overflow is not to be less than 65 mm.

5.4.3 (c) Ventilators

i) For standard ventilators of 900 mm height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in Table 5.2.

Brackets, where required, are to be as specified in 5.4.3(b)iii).

ii) For ventilators of height greater than 900 mm, brackets or alternative means of support are to be provided. Coamings are not to be taken less than as indicated in 5.2 nor in Table 5.1.

5.4.3 (d) Components and Connections. All component parts and connections of the tank vents and overflows or ventilators are to be capable of withstanding the loads defined in 5.4.2.

5.4.3 (e) Rotary Heads. Rotating type mushroom ventilator heads are not to be used for applications in this location

Table 5.1: 760 mm High Tank Vents and Overflows Thickness and Bracket Standards

Nominal Pipe Size mm	Minimum Fitted Gross Thickness mm	Maximum Projected Area of Head cm^2	Height (1) of Brackets mm
65	6.0	-	480
80	6.3	-	460
100	7.0	-	380
125	7.8	-	300
150	8.5	-	300
175	8.5	-	300
200	8.5 (2)	1900	300
250	8.5 (2)	2500	300 (2)
300	8.5 (2)	3200	300 (2)
350	8.5 (2)	3800	300 (2)
400	8.5 (2)	4500	300 (2)

Notes:

1) Brackets [see 5.4.3(b)] need not extend over the joint flange for the head.

2) Brackets are required where the as fitted (gross) thickness is less than 10.5 mm or where the tabulated projected head area is exceeded.

Note: For other air pipe heights, the relevant requirements of 5.4.3 are to be applied.

Table 5.2: 900 mm High Ventilator Thickness and Bracket Standards

Nominal Pipe Size mm	Minimum Fitted Gross Thickness mm	Maximum Projected Area of Head cm^2	Height (1) of Brackets mm
80	6.3	-	460
100	7.0	-	380
150	8.5	-	300
200	8.5	550	-
250	8.5	880	-
300	8.5	1200	-
350	8.5	2000	-
400	8.5	2700	-
450	8.5	3300	-
500	8.5	4000	-

Note: For other ventilator heights, the relevant requirements of 5.4.3 are to be applied.

Section 18 Ceiling, Sparring and Protection of Steel

1 Close Ceiling

Ceiling, where fitted, is to be laid either directly on a tightening and preserving compound or on battens.

On vessels with sloping margin plate, the ceiling from the margin plate to the upper part of the bilge is to be arranged so as to be readily removable for inspection. Except for holds intended exclusively for the carriage of containers on the inner bottom, ceiling is to be fitted under all hatchways unless the inner bottom plating is increased by at least 2 mm.

2 Sparring

Sparring is to be fitted to the sides above the bilge ceiling, if any, in all cargo spaces where it is intended to carry general cargo. 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, finished, and spaced 380 mm center to center. Sparring is to be bolted, fitted in cleats, or in portable frames for convenience in removal. Sparring may be omitted in vessels engaged in the carriage of coal, bulk cargoes, containers and similar cargoes. In such cases, the notation NS will be entered in the Record, indicating no sparring.

3 Corrosion Protection of Steel

3.1 All Spaces

Unless otherwise approved, all steel work is to be suitably protected by an efficient corrosion prevention system, such as hard protective coatings or equivalent.

3.2 Dedicated Salt Water Ballast Tanks and Double-side Skin Spaces

For new construction, steel structure within dedicated seawater ballast tanks in all ships greater than or equal to 500 gross tonnage and double-side skin spaces of bulk carriers greater than or equal to 150 m in length shall be protected by protective coating in accordance with SOLAS II-1/A-1/3-2 regulation amended by IMO Resolution MSC.216(82) and adopted by IMO Resolution MSC.215(82) – IMO PSPC (Performance Standard for Protective Coatings for Dedicated Seawater Ballast Tanks in all Types of Ships and Double-Side Skin Spaces of Bulk Carriers), as interpreted by IACS' latest UIs together with any special instruction from the Flag Administration.

For CSR vessels contracted for new construction on or after the IMO PSPC adoption date (8 December 2006) the IMO PSPC requirement is mandatory. The IMO PSPC became mandatory for all type of ships contracted for new construction on or after 1 July 2008.

All dedicated seawater ballast tanks arranged in oil tankers and bulk carriers, constructed on or after 1 July 1998 and before 8 December 2006 (IMO PSPC adoption date), shall have an efficient corrosion prevention system, such as hard protective coatings or equivalent in accordance with SOLAS Regulation II-1/3-2 amended by IMO Resolution MSC.47(66). The scheme for the selection, application and maintenance of the system shall be approved by ACS, based on IMO Resolution A.798(19) and IACS UI SC 122.

3.3 Corrosion Protection of Cargo Oil Tanks of Crude Oil Tankers (2012)

Corrosion protection of cargo oil tanks of crude oil tankers greater than or equal to 5000 tonnes eadweight is required in accordance with SOLAS II-1/A-1/3-11, adopted by IMO Resolution MSC.291(87), for the standard of the IMO Resolution MSC.288(87) – IMO PSPC (Performance Standard for Protective Coatings for Cargo Oil Tanks of Crude Oil Tankers), as interpreted by relevant latest UIs together with any special instruction from the Flag Administration. This IMO PSPC for cargo oil tanks of crude oil tankers will become mandatory on or after 1 January 2013 (contract date of ship's new construction).

The cargo oil tanks can also be protected by alternative means of corrosion protection or utilization of corrosion resistance material to maintain required structural integrity for 25 years in accordance with the Performance standard for alternative means of corrosion protection for cargo oil tanks of crude oil tankers, adopted by the IMO resolution MSC.289(87), as interpreted by relevant latest UIs together with any special instruction from the Flag Administration.

The following areas, See Figure 3.1, are the minimum areas that shall be protected according to the IMO PSPC:

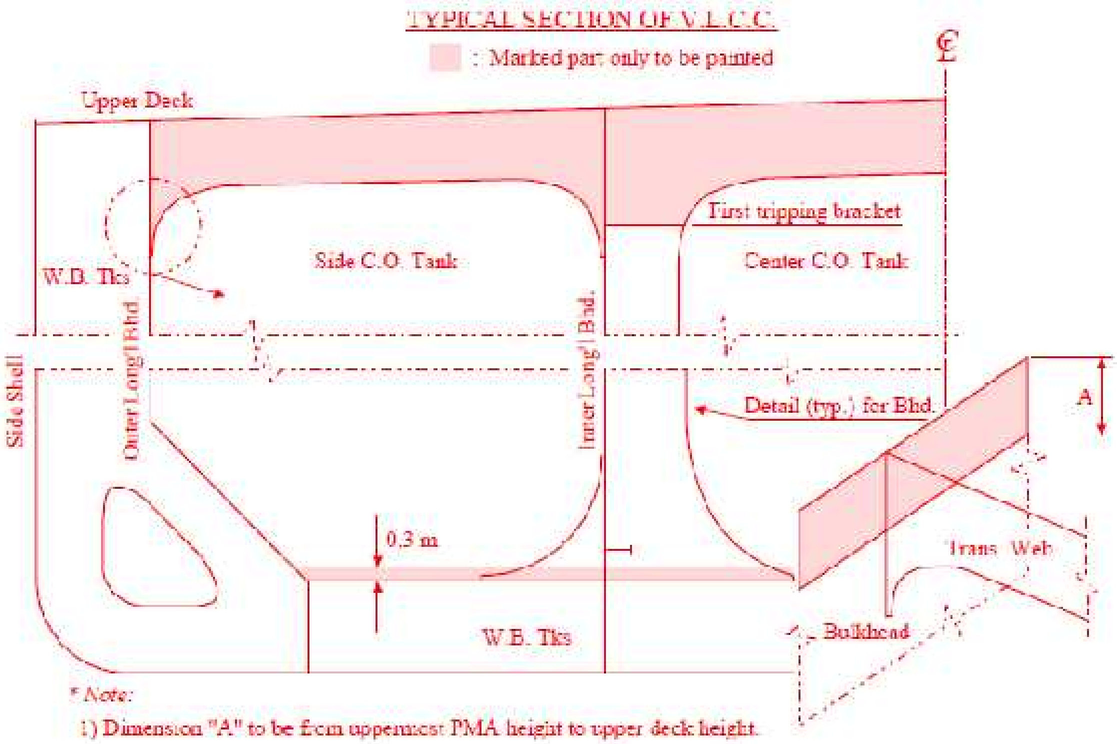
i) Deckhead with complete internal structure, including brackets connecting to longitudinal and transverse bulkheads. In tanks with ring frame girder construction the underdeck transverse framing to be coated down to level of the first tripping bracket below the upper faceplate.

ii) Longitudinal and transverse bulkheads to be coated to the uppermost means of access level. The uppermost means of access and its supporting brackets to be fully coated.

iii) On cargo tank bulkheads without an uppermost means of access the coating to extend to 10% of the tanks height at centerline but need not extend more than 3 m down from the deck.

iv) Flat inner bottom and all structure to height of 0.3 m above inner bottom to be coated.

Figure 3.1 :Typical section of V.L.C.C.



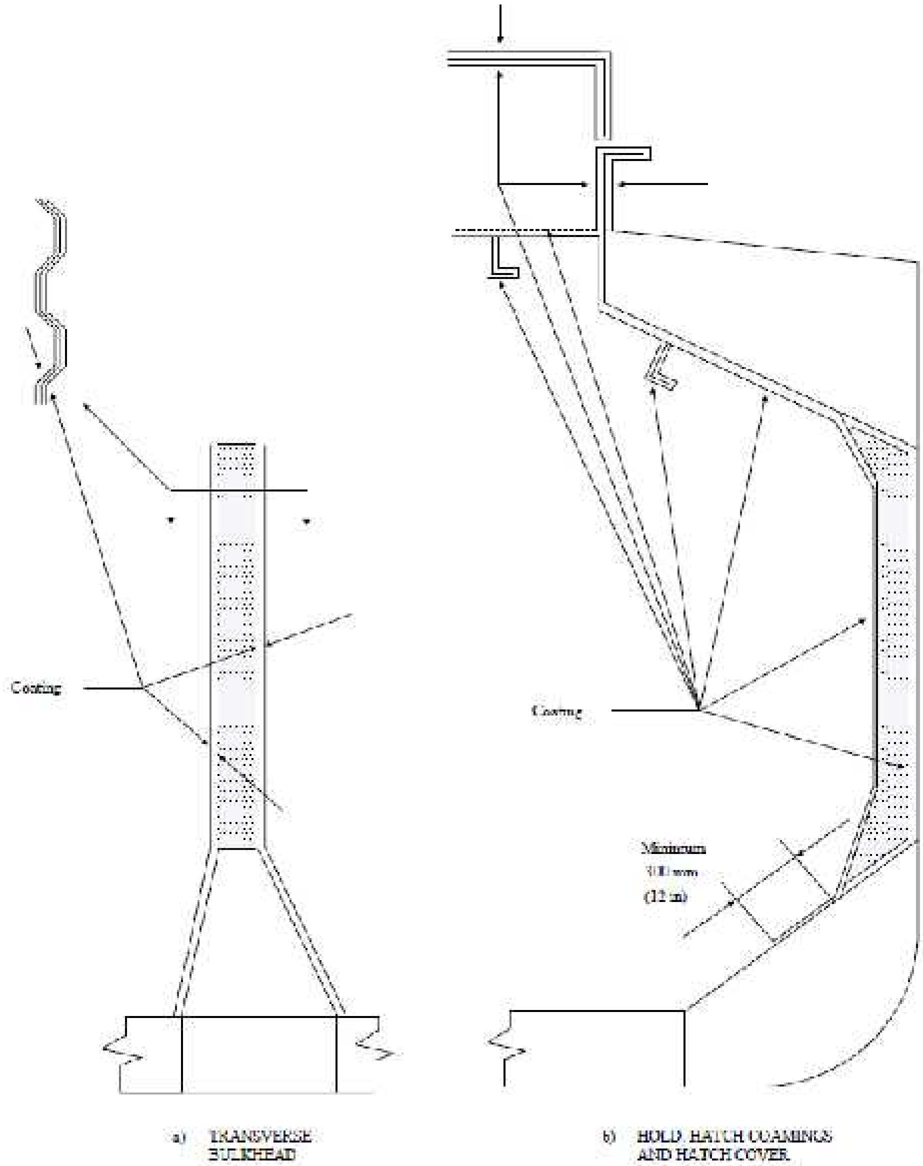
* Note: 1) Dimension "A" to be from uppermost PMA height to upper deck height.

3.4 Cargo Holds on Bulk Carriers (including Combination Carriers)

All internal and external surfaces of hatch coamings and hatch covers, and all internal surfaces of cargo holds, excluding the flat tank top areas and the hopper tank sloping plating up to approximately 300 mm below the side shell frame end brackets, are to have an epoxy or equivalent coating applied in accordance with the manufacturer’s recommendations. The internal surface of the cargo hold includes those surfaces of stiffening members of the top wing tank bottom, where fitted on the hold side, and deck plating and associated beams, girders, etc. facing holds such as those between the main hatchways. See Figure 3.2.

In the selection of coatings, due consideration is to be given by the Owner to the intended cargoes and conditions expected in service.

Figure 3.2: Extent of Coatings



3.5 Void Spaces

Double side skin spaces in bulk carriers in length of 150 m or above are to comply with the IMO Resolution MSC.215 (82), as given in 3.2 above.

All other void spaces of oil tankers and bulk carriers are recommended to be coated under IMO Resolution MSC.244 (83).

3.6 Fuel Oil Tanks

Corrosion protective coating is not required for internal surfaces of spaces intended for the carriage of fuel oil.

Section 19 Weld Design

1 Fillet Welds

1.1 General

1.1.1 Plans and Specifications

The actual sizes of fillet welds are to be indicated on detail drawings or on a separate welding schedule and submitted for approval in each individual case. In determining weld sizes based on the equations in this Section, the nearest 1/2 mm may be used.

1.1.2 Workmanship

Completed welds are to be to the satisfaction of the attending Surveyor. The gaps between the faying surfaces of members being joined should be kept to a minimum. Where the opening between members being joined exceeds 2.0 mm and is not greater than 5 mm, the weld leg size is to be increased by the amount of the opening in excess of 2.0 mm.

Where the opening between members is greater than 5 mm, corrective procedures are to be specially approved by the Surveyor.

1.1.3 Special Precautions

Special precautions, such as the use of preheat or low-hydrogen electrodes or low-hydrogen welding processes, may be required where small fillets are used to attach heavy plates or sections.

When heavy sections are attached to relatively light plating, the weld size may be required to be modified.

2 Tee Connections

2.1 Size of Fillet Welds

Tee connections are generally to be formed by continuous or intermittent fillet welds on each side, as required by Table 2.1. The leg size, w, of fillet welds (see figure in Table 2.1) is obtained from the following equations:

$w = t_{pl} \times C \times s/l + 2.0$ mm

$w_{min} = 0.3t_{pl}$ or 4.5 mm [4.0 mm where 5 is applicable], whichever is greater.

where

l = the actual length of weld fillet, clear of crater, in mm

s = the distance between successive weld fillets, from center to center, in mm

s/l = 1.0 for continuous fillet welding

t_{pl} = thickness of the thinner of the two members being joined, in mm

C = weld factors given in Table 2.1

In selecting the leg size and spacing of matched fillet welds, the leg size for the intermittent welds is to be taken as not greater than the designed leg size w or $0.7t_{pl}$ + 2.00 mm, whichever is less.

The throat size, t, is to be not less than 0.70 w.

For the weld size for t_{pl} 6.5 mm or less, see 2.6.

2.2 Length and Arrangement of Fillet

Where an intermittent weld is permitted by Table 2.1, the length of each fillet weld is to be not less than 75 mm for t_{pl} of 7 mm or more, nor less than 65 mm for lesser t_{pl}. The unwelded length on one side is to be not more than $32t_{pl}$.

2.3 Intermittent Welding at Intersection

Where beams, stiffeners, frames, etc, are intermittently welded and pass through slotted girders, shelves or stringers, there is to be a pair of matched intermittent welds on each side of each such intersection, and the beams, stiffeners and frames are to be efficiently attached to the girders, shelves and stringers.

2.4 Welding of Longitudinal to Plating

Welding of longitudinals to plating is to have double continuous welds at the ends and in way of transverses equal in length to depth of the longitudinal. For deck longitudinals only, a matched pair of welds is required at the transverses.

2.5 Stiffeners and Webs to Hatch Covers

Unbracketed stiffeners and webs of hatch covers are to be welded continuously to the plating and to the face plate for a length at ends equal to the end depth of the member.

2.6 Thin Plating

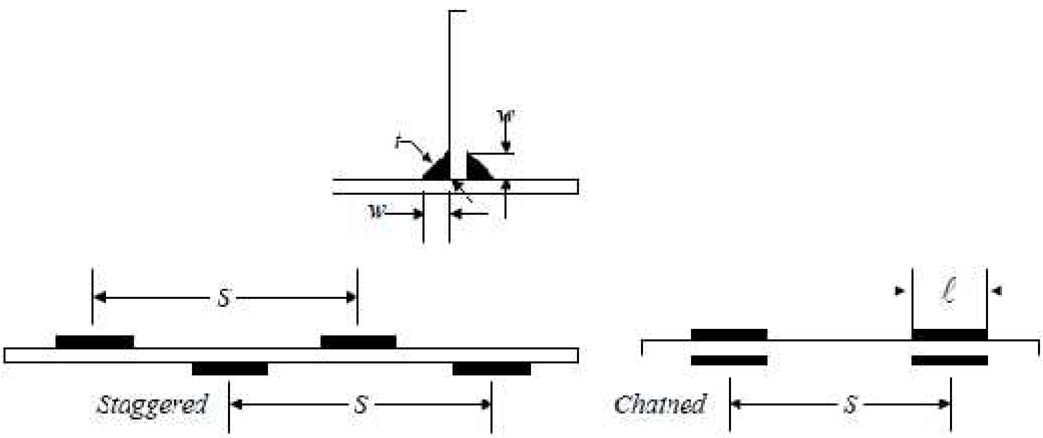
For plating of 6.5 mm or less, the requirements of 2.1 may be modified as follows:

$w = t_{pl} C\, s/l + 2.0\,(1.25 - l/s)$ mm

$w_{min} = 3.5$ mm

The use of the above equations for plating in excess of 6.5 mm may be specially considered depending upon the location and the quality control procedure.

Table 2.1: Weld Factors



w = leg size in mm   t = throat size in mm

I. Periphery Connections	Factor C
C = Continuous DC = Double Continuous	
A. Tight Joints	
1. Strength deck to sheer strake (See 8)	0.42 DC
2. Main longitudinal bulkhead to deck, bottom or inner bottom (See 8)	0.42 DC
3. All other tight joints except X.B. (See Ch.2 Sec.9/4.3)	
a. watertight bulkhead, tpl ≤ 12.5 mm where one side intermittent and the other side continuous	0.12 &0.58 C
where double continuous	0.35 DC
b. all other joints	0.35 DC
B. Non-tight Joints	
1. Platform decks	0.28 DC
2. Swash bulkheads in deep tanks	0.20
3. Non-tight bulkheads other than B2	0.15
II. Bottom Floors	
1. To Shell	
a. in aft peak below waterline	0.25 DC
b. in machinery space	0.20 DC
c. flat of bottom forward	0.15
d. in aft peak above waterline and in forward peak	0.15
e. elsewhere (See note 5)	0.12
2. To Inner Bottom	
a. in machinery space	0.20 DC
b. at forward end (fore end strengthening)	0.15
c. elsewhere (See note 5)	0.12
3. To Center or Side Girder	
a. in way of engine	0.30 DC
b. with longitudinal framing	0.30 DC
c. with transverse framing	0.17
4. To Margin Plate, Side Shell, Longitudinal Bulkhead or Bilge	0.35 DC
5. Open Floor Bracket	
a. to center girder	0.15
b. to margin plate	0.30 DC
III. Bottom Girder	
1. Center Girder	
a. to inner bottom in way of engine	0.30 DC
b. to inner bottom clear of engine, non-tight	0.23
c. to shell, non-tight	0.25 DC
2. Side Girder	
a. to floors in way of transverse bulkheads	0.35 DC
b. to shell—flat of bottom forward	0.23
—elsewhere	0.15
c. to inner bottom—in way of engine	0.23
—elsewhere	0.15
IV. Web Frames, Stringers, Deck Girders and Deck Transverses	
1. To Plating	
a. in tanks	0.20
b. elsewhere	0.15
2. To Face Plates	
a. face area ≤ 64.5 cm^2	0.12
b. face area > 64.5 cm^2	0.15
3. End Attachment	
a. unbracketed (see note 1)	0.55 DC
b. bracketed	0.40 DC

I. Periphery Connections	Factor C
V. Frames, Beams and Stiffeners	
1. To Shell	
a. in aft peak below waterline	0.25 DC
b. flat of bottom forward	0.25 DC
c. 0.125L forward	0.15
d. in aft peak above waterline and in forward peak	0.15
2. Slab longitudinals	(see note 2)
3. To plating elsewhere	0.12
4. End attachment	
a. unbracketed (see note 1)	0.45 DC
b. bracketed	0.35 DC
VI. Hatch Covers	
1. Oiltight Joints	0.40 DC
2. Watertight Joints	
Outside	0.40 C
Inside	0.15
3. Stiffeners and Webs to Plating and to Face Plate (see note 4)	0.12
4. Stiffeners and Web to Side Plating or other stiffeners	
—unbracketed (see note 1)	0.45 DC
—bracketed	0.35 DC
VII. Hatch Coamings and Ventilators	
1. To Deck	
a. at hatch corner	0.45 DC
b. elsewhere	0.25 DC
2. Coaming stays	
a. to deck	0.20 DC
b. to coaming	0.15 DC
VIII. Foundations (See 8)	
1. Main Engine and Major Auxiliaries	0.40 DC
2. Boilers and other Auxiliaries	0.35 DC
IX. Rudders—Diaphragms	
1. To Side Plating	
a. in way of rudder axis	0.45 DC
b. elsewhere	0.20
c. slot welds (see note 6)	0.45 DC
2. To Diaphragms	
a. to vertical diaphragms in way of rudder axis	0.45 DC
b. elsewhere	0.20
c. to top and bottom casting in way of rudder axis Full penetration welds	
X. Additional Weld Factors for Oil Carriers and Similar Vessels	
A. Deep Supporting Members	
1. To Bottom Shell	
a. end quarter span	0.45 DC
b. mid half span (See note 3)	0.40 DC
2. To Deck	
a. end quarter span	0.40 DC
b. mid half span (See note 3)	0.35 DC
3. To Side Shell and Longitudinal Bulkheads	0.40 DC
4. To Transverse Bulkheads	
a. end quarter span	0.45 DC
b. mid half span	0.35 DC
5. To Face Plate	0.30 DC
B. Boundaries of Cargo Segregation (See 8 and Ch.2 Sec.9/4)	0.42 DC
XI. Additional Weld Factors for Double Hull Tankers	
A. Deep Supporting Members in Double Hull (see General Notes 2)	
1. To Side Shell	0.20 DC
2. To Inner Skin Bulkhead	

I. Periphery Connections	Factor C
a. in way of deck transverse/bracket	0.35 DC
b. in way of strut, as applicable	0.35 DC
c. elsewhere	0.20 DC
XI. Additional Weld Factors for Double Hull Tankers	
3. To Inner Bottom (floor)	
a. in way of longitudinal bulkhead web/bracket	0.45 DC
b. elsewhere	0.12 DC
4. To bottom side girder in way of bilge	0.35 DC
5. To horizontal shelf plate in way of bilge	0.35 DC
XII. Additional Weld Factors for Single Side Skin Bulk Carriers	
A. Transverse Hold Frames (see notes 1 and 7)	
1. To Side Shell	
a. End Quarter Span	$(0.63 - C_{pl}/t_{pl})$DC
b. Remainder	$(0.57 - C_{pl}/t_{pl})$DC
2. End Attachment (to sloping wing tank plating)	$(0.63 - C_{pl}/t_{pl})$DC
a. bracketed	
C_{pl} = 2.00 (0.08) mm	

Notes

1) The weld size is to be determined from the thickness of the member being attached.
2) Slab longitudinals within Ds/4 from strength deck – For these slab longitudinals, the leg size w and wmin in 2.1 may both be taken as 0.23tpl + 1.0 mm with a minimum of 4.5 mm, but need not be greater than 8 mm. Where the slab longitudinal is located more than Ds/4 from the strength deck, special consideration will be given to the weld size.
3) This may be applied only where the shearing forces over the mid-half span are no greater than one-half the maximum shearing-force on the member and where the web is of the same depth, clear of end brackets and of the same thickness throughout the length of the member. The weld size is to be determined from the thickness of member being attached.
4) Unbracketed stiffeners and webs of hatch covers are to be welded continuously to the plating and to the face plate for a length at ends equal to the end depth of the member.
5) With longitudinal framing, the weld size is to be increased to give an equivalent weld area to that obtained without cut-outs for longitudinals.
6) The weld size is to be determined from the thickness of the side plating.
7) Where the hull form is such that an effective fillet weld cannot be produced, edge preparation of the frame web and bracket may be required to provide the same efficiency of the connection.

General Notes

1) For oil carriers and similar vessels, the leg size in cargo tanks and in ballast tanks in the cargo area is not to be less than 6 mm, except where approval has been given in accordance with 5

3 Tee-Type End Connections

Tee-type end connections where fillet welds are used are to have continuous welds on each side. In General, the leg sizes of the welds are to be in accordance with Table 2.1 for unbracketed end attachment, but in special cases where heavy members are attached to relatively light plating, the sizes may be modified.

Where only the webs of girders, beams and stiffeners are required to be attached to plating, it is recommended that the unattached face plate or flanges be cut back.

4 Ends of Unbracketed Stiffeners

Unbracketed stiffeners of shell, watertight and oiltight bulkheads and house fronts are to have double continuous welds for one-tenth of their length at each end.

Unbracketed stiffeners of non-tight structural bulkheads, deckhouse sides and after ends are to have a pair of matched intermittent welds at each end.

5 Reduced Weld Size

5.1 General

Reduction in fillet weld sizes, except for slab longitudinals of thickness greater than 25 mm, may be specially approved by the Surveyor in accordance with either 5.2 or 5.3, provided that the requirements of 2 are satisfied.

5.2 Controlled Gaps

Where quality control facilitates working to a gap between members being attached of 1 mm or less, a reduction in fillet weld leg size w of 0.5 mm may be permitted.

5.3 Deep Penetration Welds

Where automatic double continuous fillet welding is used and quality control facilitates working to a gap between members being attached of 1 mm or less, a reduction in fillet weld leg size of 1.5 mm may be permitted, provided that the penetration at the root is at least 1.5 mm into the members being attached.

6 Lapped Joints

6.1 General

Lapped joints are generally to have overlaps of not less width than twice the thinner plate thickness plus 25 mm.

6.2 Overlapped End Connections

Overlapped end connections of longitudinal strength members within the midship 0.4L are to have continuous fillet welds on both edges each equal in size w to the thickness of the thinner of the two plates joined. All other overlapped end connections are to have continuous welds on each edge of size w such that the sum of the two is not less than 1.5 times the thickness of the thinner plate.

6.3 Overlapped Seams

Overlapped seams are to have continuous welds on both edges of the sizes required by Table 2.1 for the boundaries of deep tank or watertight bulkheads, except that for seams of plates

12.5 mm or less clear of tanks one edge may have intermittent welds in accordance with Table 2.1 for watertight bulkhead boundaries.

7 Plug Welds or Slot Welds

Plug welds or slot welds may be specially approved for particular applications. Where used in the body of doublers and similar locations, such welds may be spaced about 305 mm between centers in both directions.

8 Full or Partial Penetration Corner or Tee Joints

A full or partial penetration weld may be required for highly stressed (75% or more of the yield) or critical (e.g., oil/water boundary) joints.

Measures taken to achieve full or partial penetration corner or tee joints, where specified, are to be to the satisfaction of the attending Surveyor. The designer is to give consideration to minimize the possibility of lamellar tearing in such joints.

9 Alternatives

The foregoing are considered minimum requirements for electric-arc welding in hull construction, but alternative methods, arrangements and details will be considered for approval. Fillet weld sizes may be determined from structural analyses based on sound engineering principles, provided that they meet the overall strength standards of the Rules.

Appendix 1 Calculation of Shear Stresses for Vessels Having Longitudinal Bulkheads

1 Methods of Calculation

The nominal total shear stress f_s in the side shell or longitudinal bulkhead plating is related to the shear flow N at that point, by the following equation:

f_s = N/t, kN/cm^2

N = shear flow, kN/cm

t = thickness of the plating, cm

2 Calculation of the Shear Flow Around Closed Sections

The shear flow of a closed and prismatic structure is expressed by the following equation.

N = (F m/I) + N_i, kN/cm

F = total shear force at the section under consideration, in kN

m = first moment about the neutral axis of the section, in cm^3, of the area of the longitudinal material between the zero shear level and the vertical level, at which the shear stress is being calculated

$$m = \int_0^p Z t\, ds + \sum_{i=0}^{n} a_i z_i \qquad \text{cm}^3$$

I = moment of inertia of the section, in cm^4

N_i = constant shear flow around the cell regarded as an integration constant of unknown value arising from substituting the statically indeterminate structure by statically determinate one, in kN/cm

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

a = equivalent sectional area of the stiffener or girder attached to the deck, shell and bulkhead plating, in cm^2

s = length along girth and longitudinal bulkhead, in cm

3 Calculation of *m*

To calculate the value of *m* 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 centerline is a known point of zero shear in the absence of the centerline 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 yield to the correct shear flow around the wing cell.

4 Determination of N_i

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 $\int N ds/t = 0$. In a multicell structure of *n* number of cells, the formula can be written for the i[th] cell as follows.

$$\int_i N\frac{ds}{t} = \frac{F}{I}\int_i m_i \frac{ds}{t} + N_{i-1}\int_{Div}\frac{ds}{t} + N_i\int\frac{ds}{t} + N_{i+1}\int_{Div}\frac{ds}{t} = 0$$

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.

Chapter 2 Hull Structures and Arrangements

Appendix 2 Loading Manuals and Loading Instruments

Note: These requirements are intended to satisfy Regulation 10(1) of the International Convention on Load Lines, 1966.

1 General

1.1 Application

The requirements in this Appendix apply to all classed cargo vessels that are contracted for construction on or after 1 July 1998.

For bulk carriers, ore carriers and combination carriers having a freeboard length (L_f), of 150 m and above, additional requirements in Appendix 3 will also apply.

2 Definitions

2.1 Loading Guidance

Loading guidance is a generic term covering both loading manual and loading instrument, as defined below.

2.1.1 Loading Manual

A loading manual is a document containing sufficient information to enable the master of the vessel to arrange for the loading and ballasting of the vessel in such a way as to avoid the creation of any unacceptable stresses in the vessel's structure.

2.1.2 Loading Instrument

A loading instrument is an instrument by means of which it can be easily and quickly ascertained that the still-water bending moments, shear forces, and, where applicable, the still-water torsional moments and lateral loads at specified points along the length of the vessel will not exceed the specified values in any load or ballast condition.

2.2 Category I Vessels

Category I vessels are any of the following:

2.2.1 Vessels, such as container carriers, with large deck openings where combined stresses due to vertical and horizontal hull girder bending, torsional and lateral loads need be considered

2.2.2 Vessels, such as bulk carriers, ore carriers and combination carriers, designed for non-homogeneous loading, where the cargo and/or ballast may be unevenly distributed, except those belonging to 2.3.3.

2.2.3 Tank vessels, such as oil carrier and fuel carriers, except those belonging to 2.3.3.

2.2.4 Chemical carriers and gas carriers

2.3 Category II Vessels

Category II vessels are any of the following:

2.3.1 Vessels, such as passenger vessels and others, with such arrangements that would allow only a small possibility for variation in the distribution of cargo and ballast

2.3.2 Vessels, such as ro-ro ferries, on regular and fixed trading patterns where the loading manual gives sufficient guidance

2.3.3 Vessels less than 120 m in length, L, when their design takes into account the uneven distribution of cargo or ballast.

3 Required Loading Guidance

3.1 Loading Manual

All vessels are to be provided with a loading manual reviewed and stamped by ACS in accordance with 4.

3.2 Loading Instrument

In addition to the loading manual, vessels of Category 1 of 100 m or more in length are to be provided with a loading instrument verified in accordance with 5.

3.3 Modifications

Where modifications to the vessel or to the loading/trading pattern result in changes to the input information, a revised or new loading manual is to be submitted and a stamped copy is to be placed aboard the vessel to replace the existing manual. The loading instrument is to be verified in accordance with 5.2 or newly installed and verified in such cases.

Where changes due to modification of the vessel are such that the still water bending moments and shear forces corresponding to the new loading conditions are within ±2% of the existing allowable values, the existing allowable values need not be modified.

4 Loading Manual

4.1 Required Information

The loading manual is to be based on the final data of the vessel and is to include at least the following information:

i) The loading conditions upon which the design of this vessel is approved.

ii) The results of the calculations of still water bending moments and shear forces.

iii) Permissible limits of still water bending moments and shear forces and, where applicable, limitations due to torsional and lateral loads.

iv) Maximum allowable local double bottom loading.

v) If cargoes other than bulk cargoes are contemplated, such cargoes are to be listed together with any specific instructions for loading.

vi) Maximum allowable load on deck and hatch covers. If the vessel is not approved to carry load on deck or hatch covers, that fact is to be clearly stated in the loading manual.

4.2 Loading Conditions

The above information is to be based on the intended service conditions. See Table 2.1 for the selection of loading conditions.

4.3 Language

The loading manual is to be prepared in, or is to include, a language understood by the user. English may be considered to be a language understood by the user.

5 Loading Instrument

5.1 Type

A loading instrument is to be digital. A single point loading instrument is not acceptable.

5.2 Required Verifications

Before a loading instrument is accepted for the vessel, all relevant aspects of the instrument, including but not limited to, the following, are to be demonstrated to the Surveyor for his/her personal verification:

- That the instrument is type approved, where applicable
- That the instrument is based on the final data of the vessel
- That the number and position of read-out points are satisfactory
- That the relevant limits for all read-out points are satisfactory
- That the operation of the instrument after installation onboard, in accordance with the approved test conditions has been found satisfactory
- That approved test conditions are available onboard
- That an operational manual, which does not require approval, is available onboard for the instrument

5.3 Language

The operation manual and the instrument output are to be prepared in, or are to include, a language understood by the user. English may be considered to be a language understood by the user.

6 Annual Surveys

At each Annual Survey, it is to be verified that the loading manual is onboard and, where applicable, a loading instrument is to be verified in working order. The operation manual for the loading instrument is also to be verified as being onboard.

Table 2.1: Loading Conditions in the Loading Manual

1.	The loading manual is to include at least
1.1	full load conditions, for both departure and arrival conditions,
1.2	ballast conditions, for both departure and arrival conditions (see also 1.5)
1.3	any other critical loading conditions on which the design of the vessel is based.
1.4	in-port conditions (see also 1.5.3)
1.5	Intermediate conditions, including but not limited to 1.5.1 before and after any ballasting/deballasting during the voyage. 1.5.2 ballast exchange and its sequence, where intended, 1.5.3 during loading/unloading (for vessels in 2.1, 2.2 where applicable, and 2.5)
2	The following conditions are to be considered for the particular type of vessel. The list does not preclude any loading conditions that are necessary for the particular service intended:
2.1	2.1 Oil Carriers: 2.1.1 homogeneous cargo if consistent with the service of the vessel 2.1.2 cargoes of typical densities within the expected range 2.1.3 part loaded conditions 2.1.4 short voyages (e.g. half bunker) 2.1.5 tank cleaning conditions 2.1.6 docking conditions afloat
2.2	2.2 Bulk Carriers, Ore Carriers, Container Carriers, Dry Cargo Vessels, Other Specialized Carriers: 2.2.1 homogeneous cargo if consistent with the service of the vessel 2.2.2 cargoes of typical densities within the expected range 2.2.3 heavy cargo with empty holds or non-homogeneous conditions 2.2.4 short voyages (e.g. half bunker) 2.2.5 deck cargoes 2.2.6 docking conditions afloat
2.3	2.3 Liquefied Gas Carriers: 2.3.1 homogeneous loading for all approved cargoes 2.3.2 with empty or partially filled tank(s) 2.3.3 docking conditions afloat
2.4	2.4 Chemical Carriers: 2.4.1 conditions for oil carriers 2.4.2 all approved high density cargoes
2.5	2.5 Combination Carriers 2.5.1 conditions as specified in 2.1 and 2.2 above.

Appendix 3 Loading Manuals and Loading Instruments-Additional Requirements

Additional Requirements for Bulk Carriers, Ore Carriers and Combination Carriers 150 meters and above in Length (L_f)

1 General

1.1 Application

The requirements in this Appendix apply to bulk carriers, ore carriers and combination carriers having a freeboard length (L_f), of 150 m and above. Unless otherwise stated, these requirements are additional to those in Appendix 2.

1.2 Definitions

For the purpose of this Appendix, the definitions in sub-section 2 of Appendix 2 will apply.

2 Required Loading Guidance

2.1 Loading Manual

All vessels are to be provided with a Loading Manual, reviewed and stamped by ACS in accordance with 3.

2.2 Loading Instrument

In addition to the loading manual, all vessels of Category I are to be provided with a loading instrument calibrated in accordance with 4.

2.3 Modifications

Where modifications to the vessel or to the loading/trading pattern affect the required information, a revised or new loading manual is to be submitted and a stamped copy is to be placed aboard the vessel, replacing where applicable the invalidated manual. The loading instrument is to be re-calibrated or newly installed and calibrated in such cases.

Where the difference in the calculated still-water bending moments or shear forces is within ±2% of the allowable value, those values may be considered as not being affected.

3 Loading Manual

3.1 Required Information

3.1.1 Permissible Limits

In addition to 4.1, the loading manual is to include the following information:

3.1.1 (a) For single side skin bulk carriers,

i) The permissible limits of still water bending moments and shear forces in the hold flooded condition.

ii) The still water bending moment limits are to be presented in the form of an envelope curve for all combinations of loading conditions and flooded holds.

3.1.1 (b) The cargo hold(s) or combination of cargo holds that might be empty at full draft. If it is not permitted to have an empty cargo hold at full draft, this is to be clearly stated in the loading manual.

3.1.1 (c) Maximum allowable and minimum required mass of contents of each cargo hold and double bottom space in way thereof, as a function of the draft at the mid length of the hold.

3.1.1 (d) Maximum allowable and minimum required mass of contents of two cargo holds and double bottom spaces forward and aft of any cargo hold bulkhead, as a function of the mean draft. This mean draft may be taken as the average of the drafts at the mid-length of two holds.

3.1.2 Loading Rate and Sequence

3.1.2 (a) The maximum rate of ballast change

3.1.2 (b) An instruction that a loading plan is to be agreed with the terminal on the basis of the achievable rates of change of ballast.

3.1.2 (c)Typical sequence of loading from commencement to full deadweight or any contemplated part load conditions. Where applicable, homogeneous conditions and alternate loading conditions are to be included. The typical loading sequences shall be developed with due attention being paid to the loading rate, the deballasting capacity and applicable strength limitations.

The Annex to this Appendix and Table 3.2 contain, as guidance only, an example of a Loading Sequence Summary Form and aspects that may be considered in developing the sequence.

3.1.2 (d) Typical sequences for change of ballast at sea, where applicable.

3.2 Loading Conditions

The above information is to be based on the intended service conditions. See Table 3.1 for the selection of loading conditions, which replaces Table 3.1 for the vessels covered by this Appendix.

4 Loading Instrument

4.1 Required Verifications

In addition to Appendix 2 /5.2, at least the following aspects are to be demonstrated to the Surveyor for his/her verification:

4.1.1 That the instrument can easily and quickly perform calculations to determine that the permissible values at the specified points along the vessel will not be exceeded in any loaded or ballast condition;

4.1.2 That the relevant limits for the mass of contents of each cargo hold and double bottom spaces in way thereof, as a function of the draft at the mid-hold position, are satisfactory;

4.1.3 That the relevant limits for the mass of contents of two cargo holds and double bottom spaces forward and aft of any cargo hold bulkhead, as a function of the mean draft in way of these holds, are satisfactory;

4.1.4 Where applicable for single side skin bulk carriers, that the relevant limits for the still water bending moments and shear forces in any one hold flooded conditions are satisfactory.

Table 3.1: Loading Conditions in the Loading Manual for Bulk Carriers, Ore Carriers and Combination Carriers 150 Meters and above in Length (L_f)

1	The loading manual is to include at least the following loading conditions, upon which the design of the vessel is based.
1.1	full load conditions, subdivided into departure and arrival conditions 1.1.1 cargoes of typical densities within the expected range 1.1.2 alternate heavy cargo loading condition (see notes 1 & 5 below) 1.1.3 alternate light cargo loading condition (see notes 2 & 5 below) 1.1.4 homogeneous heavy cargo loading (see notes 3 & 5 below) 1.1.5 homogeneous light cargo loading (see notes 4 & 5 below) 1.1.6 short voyages (e.g. half bunker) 1.1.7 deck cargoes
1.2	multiple port loading/unloading conditions, subdivided into departure and arrival conditions (see note 5 below)
1.3	ballast conditions, subdivided into departure and arrival conditions
1.4	critical loading conditions
1.5	intermediate conditions, including but not limited to 1.5.1 before and after any ballasting/deballasting during the voyage 1.5.2 ballast exchange and its sequence {see Appendix 3/3.1.2(a), (b) and (d)}
1.6	in-port conditions
1.7	docking conditions afloat
2.	The following conditions are to be considered for combination carriers, in addition to the conditions as specified above. The list does not preclude any loading conditions that are necessary for the particular service intended:
2.1	part loaded conditions (see note 5 below)

Notes:

1) Heaviest cargo can be carried and the draft is corresponding to the summer load water line. Loaded holds may not be filled completely with cargo.

2) Lightest cargo can be carried at the summer load water line. Loaded holds may or may not be filled completely with cargo.

3) Heaviest cargo loaded in all cargo holds at the same filling ratio (cargo volume/hold cubic capacity) and at the draft corresponding to the summer load water line. All loaded holds may not be filled up with cargo.

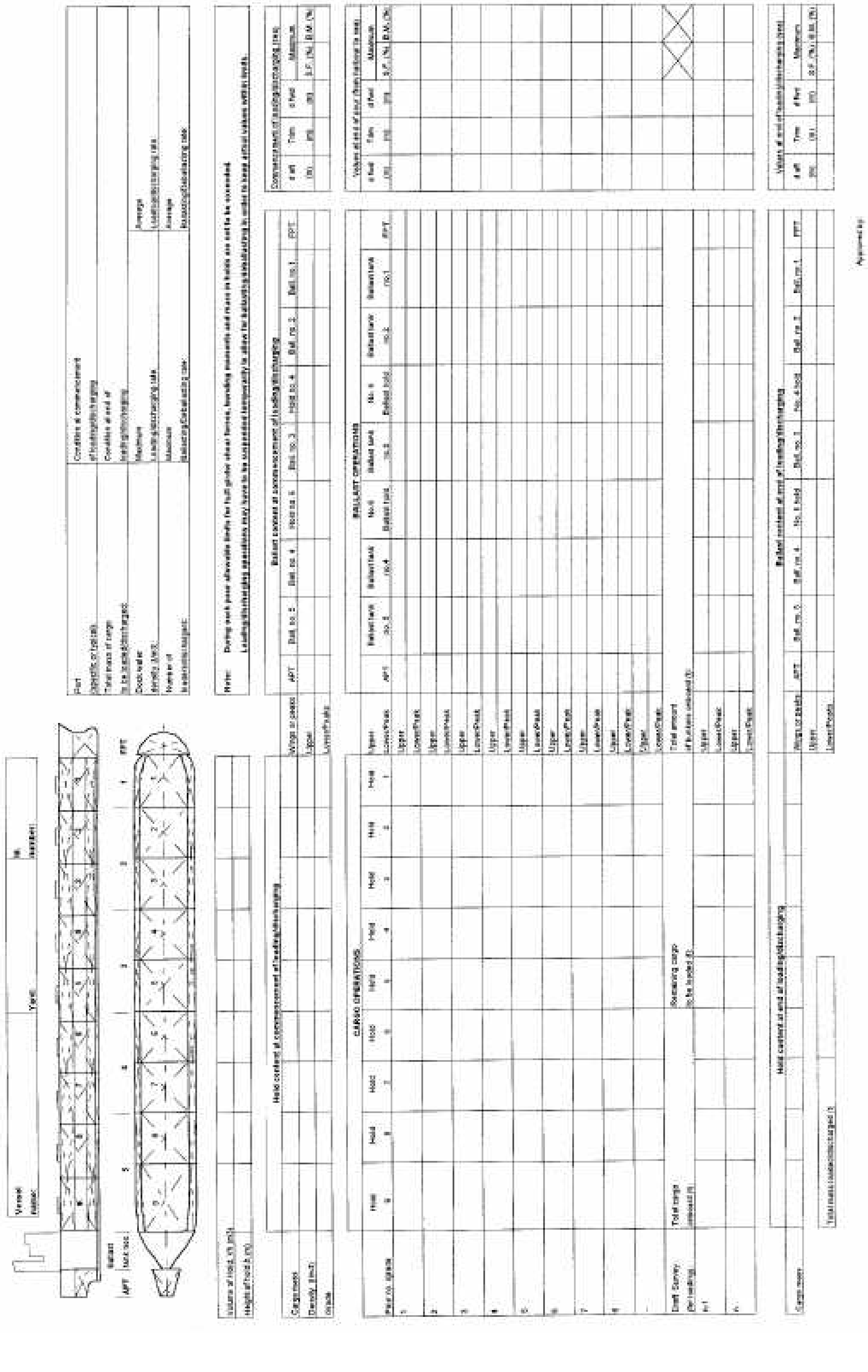
4) Homogeneous loading condition. All cargo holds are filled completely with cargo and the draft is corresponding to the summer load water line.

5) Conditions during loading/unloading are also to be included.

Table 3.2: Guidance on Loading/Unloading Sequences:

1.	In addition to Appendix 3/3.1.2(c), due attention is to be paid to the following items in the development of typical loading/unloading sequences being submitted for review.
2.	The typical sequences are to include, but not limited to, the following: - alternate hold light and heavy cargo condition - homogeneous light and heavy cargo condition - short voyage (full load with less than full fuel) - multiple port loading/unloading - deck cargo condition - block loading
3.	The sequences may be port specific if so desired.
4.	The sequence should include each and every stage from commencement to full deadweight or vise versa. Whenever the loading/unloading equipment moves to the next location, it constitutes the end of that stage. For each stage, longitudinal as well as local strength of double bottom are to be considered.
5.	for each stage, a summary highlighting the essential information such as the following is to be prepared: - the amount of cargo loaded/unloaded during that stage - the amount of ballast discharged/ballasted during that stage - the still-water bending moment and shearing forces at the end of the stage - trim and draft at the end of the stage

ANNEX Guidance on Loading Summary Sequence Form [see Appendix 3/3.1.2(c)]



Vessel name: | Yard: | IMO number:

Ballast tank nos: APT 5 4 3 2 1 FPT

Port (specific or typical):		Condition at commencement of loading/discharging:	
Total mass of cargo to be loaded/discharged:		Condition at end of loading/discharging:	
Dock water density (t/m3):		Maximum Loading/discharging rate:	Average Loading/discharging rate:
Number of loaders/discharger:		Maximum Ballasting/Deballasting rate:	Average Ballasting/Deballasting rate:

Note: During each pour allowable limits for hull girder shear forces, bending moments and mass in holds are not to be exceeded. Loading/discharging operations may have to be suspended temporarily to allow for ballasting/deballasting in order to keep actual values within limits.

Volume of Hold, V (m3)									
Height of hold h (m)									

Hold content at commencement of loading/discharging

Cargo mass									
Density (t/m3)									
Grade									

Ballast content at commencement of loading/discharging

Wings or peaks	APT	Ball. no. 5	Ball. no. 4	Hold no. 6	Ball. no. 3	Hold no. 4	Ball. no. 2	Ball. no. 1	FPT
Upper									
Lower/Peaks									

Commencement of loading/discharging (sea)

d aft (m)	Trim (m)	d fwd (m)	Maximum S.F. (%)	Maximum B.M. (%)

CARGO OPERATIONS

Pour no. /grade	Hold 9	Hold 8	Hold 7	Hold 6	Hold 5	Hold 4	Hold 3	Hold 2	Hold 1
1									
2									
3									
4									
5									
6									
7									
8									
-									
Draft Survey (for loading)	Total cargo onboard (t)			Remaining cargo to be loaded (t)					
n-1									
n									

BALLAST OPERATIONS

	APT	Ballast tank no. 5	Ballast tank no. 4	No. 6 Ballast hold	Ballast tank no. 3	No. 4 Ballast hold	Ballast tank no. 2	Ballast tank no. 1	FPT
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Total amount of ballast onboard (t)									
Upper									
Lower/Peak									
Upper									
Lower/Peak									

Values at end of pour (from harbour to sea)

d fwd (m)	Trim (m)	d fwd (m)	Maximum S.F. (%)	Maximum B.M. (%)

Hold content at end of loading/discharging

Cargo mass									

Total mass loaded/discharged (t)

Ballast content at end of loading/discharging

Wings or peaks	APT	Ball. no. 5	Ball. no. 4	No. 6 hold	Ball. no. 3	No. 4 hold	Ball. no. 2	Ball. no. 1	FPT
Upper									
Lower/Peaks									

Values at end of loading/discharging (sea)

d aft (m)	Trim (m)	d fwd (m)	Maximum S.F. (%)	Maximum B.M. (%)

Approved by:

Appendix 4 Buckling Strength of Longitudinal Strength Members

1 Application

These requirements apply to plate panels and longitudinals subject to hull girder bending and shear stresses.

2 Elastic Buckling Stresses

2.1 Elastic Buckling of Plates

2.1.1 Compression

The ideal elastic buckling stress is given by:

$$\pm_E = 0.9 m E (t_b / s)^2 \quad \text{N/mm}^2$$

For plating with longitudinal stiffeners (parallel to compressive stress):

$$m = 8.4/(\Psi + 1.1) \quad \text{for } (0 \le \Psi \le 1)$$

For plating with transverse stiffeners (perpendicular to compressive stress):

$$m = c[1 + (s/l)^2]^2 \frac{2.1}{(\Psi + 1.1)} \text{ for } (0 \le \Psi \le 1)$$

where

E = 2.06 × 10^5 N/mm^2

t_b = net thickness of plating, in mm, after making standard deductions as given in Table 2.1

s = shorter side of plate panel, in mm

l = longer side of plate panel, in mm

c = 1.3 when plating stiffened by floors or deep girders

= 1.21 when stiffeners are angles or T-sections

= 1.10 when stiffeners are bulb flats

= 1.05 when stiffeners are flat bars

Ψ = ratio of smallest to largest compressive stress, σ_a (see 4.1), varying linearly across panel.

2.1.2 Shear

The ideal elastic buckling stress is given by:

$${}^2_E = 0.9 k_t E (t_b / s)^2 \text{ N/mm}^2$$

where

$$k_t = 5.34 + 4(s/l)^2$$

E, t_b, s and l are as defined in 2.1.1.

2.2 Elastic Buckling of Longitudinals

2.2.1 Column Buckling without Rotation of the Cross Section

For the column buckling mode (perpendicular to plane of plating), the ideal elastic buckling stress is given by:

$$\pm_E = 0.001 E (I_a / A l^2) \quad \text{N/mm}^2$$

where

I_a = moment of inertia, in cm^4, of longitudinal, including plate flange and calculated with thickness, as specified in 2.1.1

A = cross-sectional area, in cm^2, of longitudinal, including plate flange and calculated with thickness, as specified in 2.1.1

l = span, in m, of longitudinal

E = as defined in 2.1.1

2.2.2 Torsional Buckling Mode

The ideal elastic buckling stress for the torsional mode is given by:

$$\pm_E = \frac{®^2 E I_w}{10^4 I_p l^2}(m^2 + k/m^2) + 0.385 E (I_t / I_p) \quad \text{N/mm}^2$$

where

$$K = \frac{C l^4}{®^4 E I_w} 10^6$$

m = number of half waves given by Table 2.2

E = as defined in 2.1.1

I_t = St. Venant's moment of inertia, in cm^4, of profile (without plate flange)

$= \dfrac{h_w t_w^3}{3} 10^{-4}$ for flat bars (slabs)

$= \dfrac{1}{3}\left[h_w t_w^3 + b_f t_f^3 (1 - 0.63 \dfrac{t_f}{b_f})\right] 10^{-4}$ for flanged profiles

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

$= \dfrac{h_w t_w^3}{3} 10^{-4}$ for flat bars (slabs)

$= \left(\dfrac{h_w^3 t_w}{3} + h_w^2 b_f t_f\right) 10^{-4}$ for flanged profiles

I_w = warping constant, in cm^6, of profile about connection of stiffener to plate

$$= \frac{h_w^3 t_w^3}{36} 10^{-6} \quad \text{for flat bars (slabs)}$$

$$= \left(\frac{t_f b_f^3 h_w^2}{12} \right) 10^{-6} \quad \text{for “Tee” profiles}$$

$$= \frac{b_f^3 h_w^2}{12(b_f + h_w)^2} \left[t_f (b_f^2 + 2b_f h_w + 4h_w^2) + 3t_w b_f h_w \right] 10^{-6} \quad \text{for angles and bulb profiles}$$

h_w = web height, in mm

t_w = web thickness, in mm, after making standard deductions, as specified in 2.1.1.

b_f = flange width, in mm

t_f = flange thickness, in mm, after making standard deductions, as specified in 2.1.1. For bulb profiles the mean thickness of the bulb may be used.

l = span of profile, in m

s = spacing of profiles, in mm

C = spring stiffness exerted by supporting plate panel

$$= \frac{k_p E t_p^3}{3s\left(1 + (1.33 k_p h_w t_p^3)/(s\, t_w^3)\right)} \quad \text{N}$$

k_p = 1− η_p, not to be taken less than zero

t_p = plate thickness, in mm, after making standard deductions, as specified in 2.1.1

$\eta_p = \sigma_a / \sigma_{Ep}$

σ_a = calculated compressive stress. For longitudinals, see 4.1

σ_{Ep} = elastic buckling stress of supporting plate, as calculated in 2.1

For flanged profiles, k_p ,need not be taken less than 0.1.

Table 2.1: Standard Deduction

Structure	Standard Deduction (mm)	Limit Values min.-max. (mm)
- Compartments carrying dry bulk cargoes - One side exposure to ballast and/or liquid cargo Vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line	0.05t	0.5–1.0
- One side exposure to ballast and/or liquid cargo Horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line - Two side exposure to ballast and/or liquid cargo Vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line	0.10t	2.0–3.0
- Two side exposure to ballast and/or liquid cargo Horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line	0.15t	2.0–4.0

Table 2.2: Number of half waves

	$0<K<4$	$4<K<36$	$36<K<144$	$144<K<400$	$(m-1)^2 m^2 < K \le m^2 (m+1)^2$
m	1	2	3	4	m

2.2.3 Web and Flange Buckling

For web plate of longitudinals the ideal buckling stress is given by:

$$\sigma_E = 3.8\,E\,(t_w / h_w)^2 \text{ N/mm}^2$$

For flanges on angles and T-sections of longitudinals, the following requirements will apply:

$$b_f / t_f \le 15$$

b_f = flange width, in mm, for angles, half the flange width for T-sections.

t_f = as built flange thickness, in mm

3 Critical Buckling Stresses

3.1 Compression

The critical buckling stress in compression, σ_C, is determined as follows:

$$\sigma_C = \sigma_E \qquad \text{when} \quad \sigma_E \le \sigma_F / 2$$

$$\sigma_C = \sigma_F (1 - \sigma_F / 4\sigma_E) \qquad \text{when} \quad \sigma_E > \sigma_F / 2$$

where

σ_F = yield stress of material, in N/mm^2 . σ_F may be taken as 235 N/mm^2 for mild steel.

σ_E = ideal elastic buckling stress calculated according to 2.

3.2 Shear

The critical buckling stress in shear, τ_C, is determined as follows:

$$\tau_C = \tau_E \qquad \text{when} \quad \tau_E \le \frac{\tau_F}{2}$$

$$\tau_C = \tau_F \left(1 - \tau_F / 4\tau_E\right) \qquad \text{when} \quad \tau_E \succ \frac{\tau_F}{2}$$

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

σ_F = as given in 3.1

τ_E = ideal elastic buckling stress in shear calculated according to 2.1.2

4 Working Stress

4.1 Longitudinal Compressive Stress

The compressive stresses are given in the following formula:

$$\pm_a = \frac{M_w + M_{sw}}{I_n} y \times 10^5 \qquad \text{N/mm}^2$$

$$= \text{minimum } 30/K \qquad \text{N/mm}^2$$

where

M_{sw} = still water bending moment, as given in section 1, 2.4.1(a), in kN-m

M_w = wave bending moment, as given in section 1, 2.4.1(a), in kN-m

I_n = moment of inertia, in cm4 , of the hull girder

y = vertical distance, in m, from the neutral axis to the considered point

K = as defined in section 1, 3.3 (1.0 for ordinary strength steel)

M_w and M_{sw} are to be taken as sagging or hogging bending moments, respectively, for members above or below the neutral axis.

4.2 Shear Stresses

4.2.1 Ships without Effective Longitudinal Bulkheads

The working shear stress, ² $_a$, in the side shell of vessels without effective longitudinal bulkheads is given by the following formula:

$$²_a = \frac{0.5(F_{sw} + F_w)}{t_s} \frac{m_s}{I} \times 10 \qquad N/mm^2$$

where

I = moment of inertia of the hull girder section, in cm^4, at the section under consideration.

m_s = first moment, in cm^4, about the neutral axis of the area of the effective longitudinal material between the horizontal level at which the shear stress is being determined and the vertical extremity of effective longitudinal material, taken at the position under consideration.

t_s = thickness of the side shell plating, in cm, at the position under consideration.

F_{sw} = hull girder shearing force in still water, in kN.

F_w = F_{wp} or F_{wn}, in kN, as specified by section 1, 2.3.3, depending upon loading

4.2.2 Vessels with Two or More Effective Longitudinal Bulkheads

The working shear stress,² $_a$, in the side shell or longitudinal bulkhead plating is to be calculated by an acceptable method and in accordance with section 1, 2.5.4.

5 Scantling Criteria

5.1 Buckling Stress

The design buckling stress, σ_c, of plate panels and longitudinals (as calculated in 3.1) is to be such that:

$\sigma_c \geq \beta\, \sigma_a$

where

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

= 1.1 for stiffeners

The critical buckling stress, τ_C, of plate panels (as calculated in 3.2) is to be such that:

$\tau_C \geq \tau_a$

where

τ_a = working shear stress in the plate panel under consideration, in N/mm^2, as determined by 4.2.

APPENDIX 5 Guidelines for Calculating Bending Moment and Shear Force in Rudders and Rudder Stocks

1 Application

Bending moments, shear forces and reaction forces of rudders, stocks and bearings may be calculated according to this Appendix for the types of rudders indicated. Moments and forces on rudders of different types or shapes than those shown are to be calculated using alternative methods and will be specially considered.

2 Spade Rudders

2.1 Rudder

2.1.1 Shear Force

Lateral shear force, *V(z)*, at a horizontal section of the rudder *z* meters above the bottom of l_R is given by the following equation:

$$V(z) = \frac{zC_R}{A}[C_l + z(c_u - c_l)/2l_R] \qquad \text{kN}$$

where

z = distance from the bottom of l_R to the horizontal section under consideration, in m

C_R = rudder force, as defined in Ch.2 Sec.14/2, in kN

A = rudder blade area, in m^2

c_l, c_u and l_R are dimensions as indicated in Figure 2.1, in m.

2.1.2 Bending Moment

Bending moment, *M(z)*, at a horizontal section *z* meters above the baseline of the rudder is

given by the following equation:

$$M(z) = \frac{z^2C_R}{2A}[C_l + z(c_u - c_l)/3l_R] \qquad \text{kN-m}$$

where z, C_R, A, c_l, c_u and l_R are as defined in 2.1.1.

2.2 Lower Stock

2.2.1 Shear Force

Lateral shear force at any section of the lower stock between the top of the rudder and the neck bearing, V_l, is given by the following equation:

$V_l = C_R$ kN

where C_R is as defined in 2.1.1

2.2.2 Bending Moment at Neck Bearing

The bending moment in the rudder stock at the neck bearing, M_n, is given by the following equation:

$$M_n = C_R[l_l + l_R(2c_l + c_u)/3(c_l + c_u)] \quad \text{KN-m}$$

where

C_R = rudder force as defined in 2.1.1

c_l, c_u, l_l and l_R are dimensions as indicated in Figure 2.1, in m.

2.3 Moment at Top of Upper Stock Taper

The bending moment in the upper rudder stock at the top of the taper, Mt, is given by the following equation:

$$M_t = C_R[l_l + l_R(2c_l + c_u)/3(c_l + c_u)][(l_u + l_R + l_l - z_t)/(l_u)] \quad \text{kN-m}$$

where

z_t = distance from the rudder baseline to the top of the upper rudder stock taper in m

C_R = rudder force, as defined in 2.1.1

c_l, c_u, l_l, l_u and l_R are dimensions as indicated in Figure 2.1, in m.

2.4 Bearing Reaction Forces

Reaction forces at the bearings are given by the following equations:

P_u = reaction force at the upper bearing

$= - M_n / l_u$ kN

P_n = reaction force at the neck bearing

$= C_R + M_n / l_u$ kN

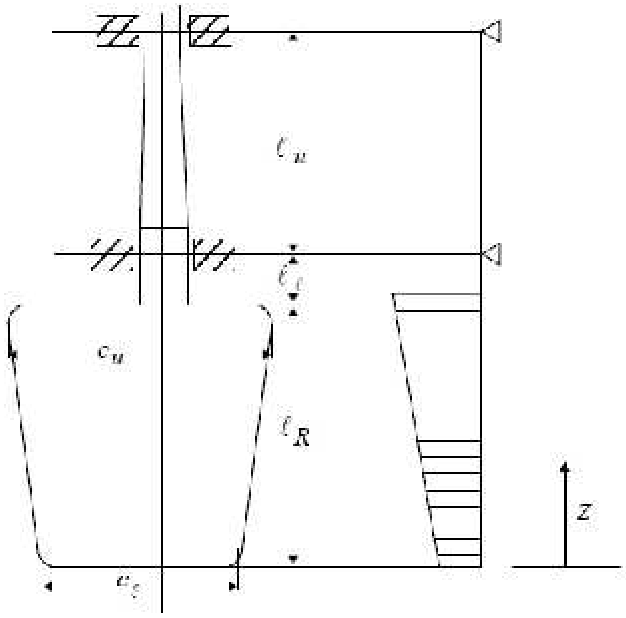
where

M_n = bending moment at the neck bearing, as defined in 2.2.2

C_R = rudder force, as defined in Ch.2 Sec.4/2

l_u is as indicated in Figure 2.1, in m.

Figure 2.1: Spade Rudder



3 Rudders Supported by Shoe Piece

3.1 Shear Force, Bending Moment and Reaction Forces

Shear force, bending moment and reaction forces are to be assessed by the simplified beam model given in Figure 3.1.

w_R = rudder load per unit length

$= C_R / l_R$ kN/m

where

C_R = rudder force, as defined in Ch.2 Sec.14/2

k_s = spring constant reflecting support of the shoe piece

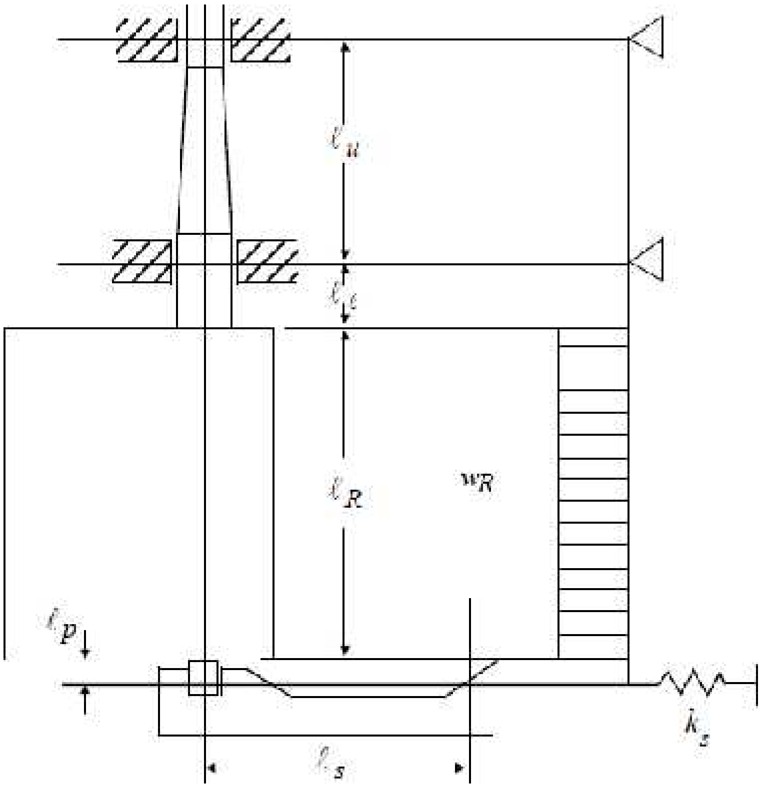
$= n_s I_s / l_s^3$ kN/m

$n_s = 6.18$

I_s = moment of inertia of shoe piece about the vertical axis, in cm^4

l_s, l_R and l_p are dimensions as indicated in Figure 3.1, in m.

Figure 3.1: Rudder Supported by Shoe Piece



4 Rudders Supported by a Horn with One Pintle

4.1 Shear Force, Bending Moment and Reaction Forces

Shear force, bending moment and reaction forces are to be assessed by the simplified beam model shown in Figure 4.1.

w_{R1} = rudder load per unit length above pintle

$= C_{R1} / l_{R1}$ kN/m

w_{R2} = rudder load per unit length below pintle

$= C_{R2} / l_{R2}$ kN/m

where

C_{R1} = rudder force, as defined in Ch.2 Sec.14/2.2

C_{R2} = rudder force, as defined in Ch.2 Sec.14/2.2

k_h = spring constant reflecting support of the horn

$$= \frac{1}{(l_h^3 / n_b I_h + (\sum (s_i / l_i) e^2 l_h) / (n_t a^2))} \quad \text{kN/m}$$

$n_b = 4.75$

n_t = 3.17

a = mean area enclosed by the outside lines of the rudder horn, in cm^2

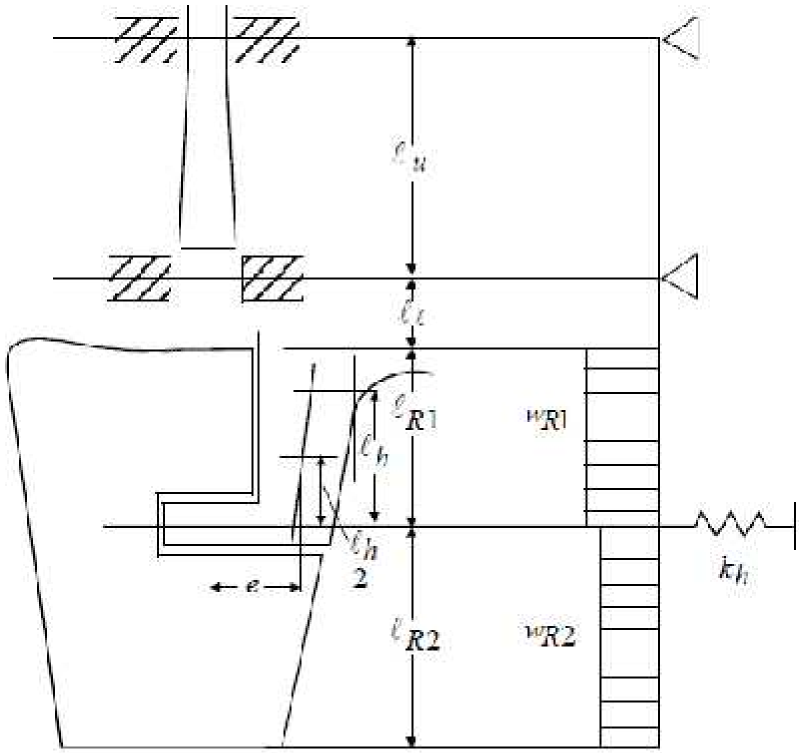
s_i = the girth length of each segment of the horn of thickness ti, in cm

t_i = the thickness of each segment of horn outer shell of length si, in cm

I_h = moment of inertia of horn section at lh about the longitudinal axis, in cm^4

e, l_h, l_{R1} and l_{R2} are dimensions as indicated in Figure 4.1, in m .

Figure 4.1: Rudder Supported by a Horn with One Pintle



Appendix 6 Portable Beams and Hatch Cover Stiffeners of Variable Cross Section

1 Application

For portable beams and hatch cover stiffeners with free ends and varying cross section along their span, the section modulus SM and inertia I at the midspan required by Ch.2 Sec.15/4.1.1, 4.2.2, 4.3.1 and 5.1 may be obtained from the following equations.

$$SM = \frac{125 K_1 psl^2}{\sigma_a} \quad \text{cm}^3$$

$I = C_2 K_2 psl^3$ cm^4

where

$C_1 = 125$

$C_2 = 2.87$ for 4.1.1 and 4.2.2

$= 2.26$ for 4.3.1 and 5.1

$$K_1 = 1 + \frac{3.2\alpha - \gamma - 0.8}{7\gamma + 0.4}$$, but not less than 1.0

α = length ratio

$= l_1 / l$

γ = SM ratio = SM_1 /SM

l_1, l, SM_1 and SM are as indicated in Figure 1.1.

σ_a = allowable stress given in 4.1.1, 4.2.2, 4.3.1 and 5.1, in kN/mm^2

$$K_2 = 1 + 8\alpha^3 \frac{(1-\ )}{(0.2 + 3\sqrt{\ })}$$, but not less than 1.0

β = ratio of the moments of inertia, I1 and I, at the locations indicated in Figure 1.1.

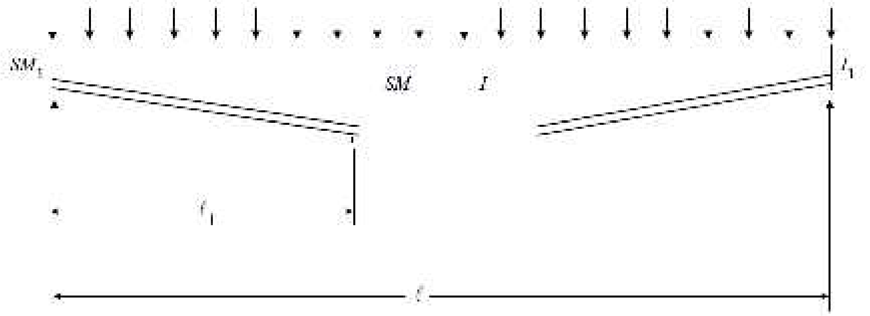
$= I_1/I$

p = design load given in Ch.2 Sec.15/2.2, in kN/m^2

s = spacing of beams or stiffeners, in m.

l = span of free ended constructional elements, in m.

Figure 1.1: SM and I of Construction Elements



Chapter 3 Subdivision

Symbols used in this Chapter

FP_{LL} : "forward freeboard perpendicular". The forward freeboard perpendicular is to be taken at the forward end of the freeboard length L_{LL} and is to coincide with the foreside of the stem on the waterline on which the length L_{LL} is measured.

AP_{LL} : "after freeboard perpendicular". The after freeboard perpendicular is to be taken at the after end the length L_{LL}.

Section 1 Subdivision Arrangement

1 Number and arrangement of transverse watertight bulkheads

1.1 Number of watertight bulkheads

1.1.1 General

All ships, in addition to complying with the requirements of 1.1.2, are to have at least the following transverse watertight bulkheads:

- one collision bulkhead
- one after peak bulkhead for passenger ships and ro-ro passenger ships
- • two bulkheads forming the boundaries of the machinery space in ships with machinery amidships, and a bulkhead forward of the machinery space in ships with machinery aft. In the case of ships with an electrical propulsion plant, both the generator room and the engine room are to be enclosed by watertight bulkheads.

1.1.2 Additional bulkheads

For ships not required to comply with subdivision regulations, transverse bulkheads adequately spaced and in general not less in number than indicated in Table 1.1 are to be fitted.

Additional bulkheads may be required for ships having to comply with subdivision or damage stability criteria.

1.2 Water ingress detection

1.2.1 General

When a ship with a length less than 80 m and of 500 GT and over is fitted, below the freeboard deck, with single cargo hold or cargo holds which are not separated by at least one bulkhead made watertight up to the freeboard deck, water ingress detection system is to be fitted according to rules.

1.2.2 Bulk carriers

For ships granted with the service notation bulk carrier, bulk carrier ESP, ore carrier ESP, combination carrier/ OBO ESP or combination carrier/OOC ESP, water ingress detection system is to be fitted according to rules.

Table 1.1: Number of bulkheads

Length (m)	Number of bulkheads for ships with aft machinery [1]	Number of bulkheads for other ships
L < 65	3	4
65 ≤ L < 85	4	5
85 ≤ L < 105	4	5
105 ≤ L < 120	5	6
120 ≤ L < 145	6	7
145 ≤ L < 165	7	8
165 ≤ L < 190	8	9
L ≥ 190	to be defined on a case by case basis	

(1) After peak bulkhead and aft machinery bulkhead are the same.

2 Collision bulkhead

2.1

2.1.1 A collision bulkhead is to be fitted which is to be watertight up to the bulkhead deck. This bulkhead is to be located at a distance from the forward perpendicular FP_{LL} of not less than 5 per cent of the length L_{LL} of the ship or 10 m, whichever is the less, and, except as may be permitted by the Society, not more than 8 per cent of L_{LL} or 5 per cent of the L_{LL} + 3 m, whichever is the greater.

For ships not covered by the SOLAS Convention, the length L_{LL} need not be taken less than 50 m, unless required by the National Authorities.

2.1.2 Where any part of the ship below the waterline extends forward of the forward perpendicular, e.g. a bulbous bow, the distances, in meters, stipulated in 2.1.1 are to be measured from a point either:

- at the midlength of such extension, or
- at a distance 1,5 percent of the length L_{LL} of the ship forward of the forward perpendicular, or
- at a distance 3 meters forward of the forward perpendicular; whichever gives the smallest measurement.

2.1.3 The bulkhead may have steps or recesses provided they are within the limits prescribed in 2.1.1 or 2.1.2.

No door, manhole, ventilation duct or any other opening is to be fitted in the collision bulkhead below the bulkhead deck.

2.1.4 At Owner request and subject to the agreement of the flag Administration, the Society may, on a case by case basis, accept a distance from the collision bulkhead to the forward perpendicular FP_{LL} greater than the maximum specified in 2.1.1 and 2.1.2, provided that subdivision and stability calculations show that, when the ship is in upright condition on full load summer waterline, flooding of the space forward of the collision bulkhead will not result in any part of the freeboard deck becoming submerged, or in any unacceptable loss of stability.

In such a case, the attention of the Owner and the Shipyard is drawn to the fact that the flag Administration may impose additional requirements and that such an arrangement is, in principle, officialized by the issuance of a certificate of exemption under the SOLAS Convention provisions. Moreover, in case of change of flag, the taking Administration may not accept the exemption.

2.1.5 Where a long forward superstructure is fitted, the collision bulkhead is to be extended weathertight to the next deck above the bulkhead deck. The extension need not be fitted directly above the bulkhead below provided it is located within the limits prescribed in 2.1.1 or 2.1.2 with the exemption permitted by 2.1.6 and the part of the deck which forms the step is made effectively weathertight.

2.1.6 Where bow doors are fitted and a sloping loading ramp forms part of the extension of the collision bulkhead above the freeboard deck, the part of the ramp which is more than 2,3 m above the freeboard deck may extend forward of the limit specified in 2.1.1 or 2.1.2 The ramp is to be weathertight over its complete length.

2.1.7 The number of openings in the extension of the collision bulkhead above the freeboard deck is to be restricted to the minimum compatible with the design and normal operation of the ship. All such openings are to be capable of being closed weathertight.

3 After peak, machinery space bulkheads and stern tubes

3.1

3.1.1 General

Bulkheads are to be fitted separating the machinery space from the cargo and accommodation spaces forward and aft and made watertight up to the bulkhead deck. In passenger ships, an after peak bulkhead is also to be fitted and made watertight up to the bulkhead deck. The after peak bulkhead may, however, be stepped below the bulkhead deck, provided the degree of safety of the ship as regards subdivision is not thereby diminished.

3.1.2 Sterntubes

In all cases, sterntubes are to be enclosed in watertight spaces of moderate volume. In passenger ships, the stern gland is to be situated in a watertight shaft tunnel or other watertight space separate from the sterntube compartment and of such volume that, if flooded by leakage through the stern gland, the bulkhead deck will not be immersed.

In cargo ships, other measures to minimise the danger of water penetrating into the ship in case of damage to sterntube arrangements may be taken at the discretion of the Society.

For ships less than 65 m, where the after peak bulkhead in way of the sterntube stuffing box is not provided, sterntubes are to be enclosed in watertight spaces of moderate volume.

4 Height of transverse watertight bulkheads other than collision bulkhead and after peak bulkhead

4.1

4.1.1 Transverse watertight bulkheads are to extend watertight up to the bulkhead deck. In exceptional cases at the request of the Owner, the Society may allow transverse watertight bulkheads to terminate at a deck below that from which freeboard is measured, provided that this deck is at an adequate distance above the full load waterline.

4.1.2 Where it is not practicable to arrange a watertight bulkhead in one plane, a stepped bulkhead may be fitted. In this case, the part of the deck which forms the step is to be watertight and equivalent in strength to the bulkhead.

5 Openings in watertight bulkheads and decks for ships with service notation other than passenger ship or ro-ro passenger ship

5.1 Application

5.1.1 The requirements in 5.2 and 5.3 apply to ships with service notation other than passenger ship or ro-ro passenger ship.

The requirements for openings in watertight bulkheads below the bulkhead deck in ships with service notation passenger ship and ro-ro passenger ship are to comply with their respective requirements.

5.2 General

5.2.1 The number of openings in watertight subdivisions is to be kept to a minimum compatible with the design and proper working of the ship. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity. The Society may permit relaxation in the watertightness of openings above the freeboard deck, provided that it is demonstrated that any progressive flooding can be easily controlled and that the safety of the ship is not impaired.

5.2.2 No door, manhole ventilation duct or any other opening is permitted in the collision bulkhead below the subdivision deck.

5.2.3 Lead or other heat sensitive materials may not be used in systems which penetrate watertight subdivision bulkheads, where deterioration of such systems in the event of fire would impair the watertight integrity of the bulkheads.

5.2.4 Valves not forming part of a piping system are not permitted in watertight subdivision bulkheads.

5.2.5 The requirements relevant to the degree of tightness, as well as the operating systems, for doors or other closing appliances complying with the provisions in 5.3 are specified in Table 5.1.

5.3 Openings in the watertight bulkheads and internal decks

5.3.1 Openings used while at sea

Doors provided to ensure the watertight integrity of internal openings which are used while at sea are to be sliding watertight doors capable of being remotely closed from the bridge and are also to be operable locally from each side of the bulkhead. Indicators are to be provided at the control position showing whether the doors are open or closed, and an audible alarm is to be provided at the door closure. The power, control and indicators are to be operable in the event of main power failure. Particular attention is to be paid to minimise the effect of control system failure. Each power-operated sliding watertight door is to be provided with an individual hand-operated mechanism. The possibility of opening and closing the door by hand at the door itself from both sides is to be assured.

5.3.2 Openings normally closed at sea

Access doors and access hatch covers normally closed at sea, intended to ensure the watertight integrity of internal openings, are to be provided with means of indication locally and on the bridge showing whether these doors or hatch covers are open or closed. A notice is to be affixed to each such door or hatch cover to the effect that it is not to be left open.

5.3.3 Doors or ramps in large cargo spaces

Watertight doors or ramps of satisfactory construction may be fitted to internally subdivide large cargo spaces, provided that the Society is satisfied that such doors or ramps are essential. These doors or ramps may be hinged, rolling or sliding doors or ramps, but are not to be remotely controlled.

Such doors are to be closed before the voyage commences and are to be kept closed during navigation. Should any of the doors or ramps be accessible during the voyage, they are to be fitted with a device which prevents unauthorized opening.

The word “satisfactory” means that scantlings and sealing requirements for such doors or ramps are to be sufficient to withstand the maximum head of the water at the flooded waterline.

5.3.4 Openings permanently kept closed at sea

Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of internal openings are to be provided with a notice which is to be affixed to each such closing appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

Table 5.1: Doors

			Sliding type			Hinged type			Rolling type (cargo between deck spaces)
			Remote operation indication on the bridge	Indicator on the bridge	Local operation only	Remote operation indication on the bridge	Indicator on the bridge	Local operation only	
Watertight	Below the freeboard deck	Open at sea	X						
		Normally Closed (2)		X			X (3)		
		Remain Closed (2)			X (4) (5)			X (4) (5)	X (4) (5)
Weathertight /watertight (1)	Above the freeboard deck	Open at sea	X						
		Normally Closed (2)		X			X		
		Remain Closed (2)						X (4) (5)	

(1) Watertight doors are required when they are located below the waterline at the equilibrium of the final stage of flooding; otherwise a weathertight door is accepted.

(2) Notice to be affixed on both sides of the door: “to be kept closed at sea”.

(3) Type A ships of 150 m and upwards, and Type B ships with a reduced freeboard may have a hinged watertight door between the engine room and the steering gear space, provided that the sill of this door is above the summer load waterline.

(4) The door is to be closed before the voyage commences.

(5) If the door is accessible during the voyage, a device which prevents unauthorized opening is to be fitted.

Section 2 Compartment Arrangement

1 Definitions

1.1 Cofferdam

1.1.1 A cofferdam means an empty space arranged so that compartments on each side have no common boundary; a cofferdam may be located vertically or horizontally. As a rule, a cofferdam is to be properly ventilated and of sufficient size to allow for inspection.

1.2 Machinery spaces of category A

1.2.1 Machinery spaces of category A are those spaces or trunks to such spaces which contain:

- internal combustion machinery used for main propulsion; or
- internal combustion machinery used for purposes other than propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
- any oil fired boiler or fuel oil unit.

2 Cofferdams

2.1 Cofferdam arrangement

2.1.1 Cofferdams are to be provided between:

- fuel oil tanks and lubricating oil tanks
- compartments intended for liquid hydrocarbons (fuel oil, lubricating oil) and compartments intended for fresh water (drinking water, water for propelling machinery and boilers)
- compartments intended for liquid hydrocarbons (fuel oil, lubricating oil) and tanks intended for the carriage of liquid foam for fire extinguishing.

2.1.2 Cofferdams separating:

- fuel oil tanks from lubricating oil tanks
- lubricating oil tanks from compartments intended for fresh water or boiler feed water
- lubricating oil tanks from those intended for the carriage of liquid foam for fire extinguishing,
- may not be required when deemed impracticable or unreasonable by the Society in relation to the characteristics and dimensions of the spaces containing such tanks, provided that:
- the thickness of common boundary plates of adjacent tanks is increased by 2 mm in the case of tanks carrying fresh water or boiler feed water, and by 1 mm in all other cases

- the sum of the throats of the weld fillets at the edges of these plates is not less than the thickness of the plates Themselves
- the structural test is carried out with a head increased by 1 m.

2.1.3 Spaces intended for the carriage of flammable liquids are to be separated from accommodation and service spaces by means of a cofferdam. Where accommodation and service spaces are arranged immediately above such spaces, the cofferdam may be omitted only where the deck is not provided with access openings and is coated with a layer of material recognized as suitable by the Society.

The cofferdam may also be omitted where such spaces are adjacent to a passageway, subject to the conditions stated in 2.1.2 for fuel oil or lubricating oil tanks.

3 Double bottoms

3.1 Double bottoms for ships other than tankers

3.1.1 A double bottom is to be fitted extending from the collision bulkhead to the after peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

3.1.2 Where a double bottom is required to be fitted, the inner bottom is to be continued out to the ship's sides in such a manner as to protect the bottom to the turn of the bilge. Such protection is to be deemed satisfactory if the inner bottom is not lower at any part than a plane parallel with the keel line and which is located not less than a vertical distance h measured from the keel line, as calculated by the formula:

$h = B/20$

However, in no case is the value of h to be less than 760 mm, and need not to be taken as more than 2 m.

3.1.3 Small wells constructed in the double bottom, in connection with the drainage arrangements of holds, are not to extend downward more than necessary. A well extending to the outer bottom, is, however, permitted at the after end of the shaft tunnel of the ship. Other wells may be permitted by the Society if it is satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with 3.1. In no case, the vertical distance from the bottom of such a well to a plane coinciding with the keel line is to be less than 500 mm.

3.1.4 A double bottom need not be fitted in way of watertight tanks, including dry tanks of moderate size, provided the safety of the ship is not impaired in the event of bottom or side damage as defined in Ch.4 Sec.3/3.4.

3.1.5 Any part of a ship that is not fitted with a double bottom in accordance with 3.1.1 or 3.1.4 is to be capable of withstanding bottom damages, as specified in Ch.4 Sec.3/3.4, in that part of the ship.

3.1.6 In the case of unusual bottom arrangements, it is to be demonstrated that the ship is capable of withstanding bottom damages as specified in Ch.4 Sec.3/3.4.

3.1.7 Special requirements for passenger ships and tankers to be complied with.

4 Compartments forward of the collision bulkhead

4.1 General

4.1.1 The fore peak and other compartments located forward of the collision bulkhead cannot be used for the carriage of fuel oil or other flammable products.

This requirement does not apply to ships of less than 400 tons gross tonnage, except for those where the fore peak is the forward cofferdam of tanks arranged for the carriage of flammable liquid products having a flash point not exceeding 60°C.

5 Minimum bow height

5.1 General

5.1.1 The bow height F_b defined as the vertical distance at the forward perpendicular between the waterline corresponding to the assigned summer freeboard and the designed trim and the top of the exposed deck at side, is to be not less than:

$F_b = (6075(L_{LL}/100) - 1875(L_{LL}/100)^2 + 200(L_{LL}/100)^3) \times (2.08 + 0.609C_b - 1.603C_{wf} - 0.0129(L/T_1))$

where:

F_b : Calculated minimum bow height, in mm

T_1 : Draught at 85% of the least molded depth, in m

C_{wf} : Waterplane area coefficient forward of $L_{LL}/2$:

$C_{wf} = A_{wf} /(L_{LL}\, B /2)$

A_{wf} : Waterplane area forward of $L_{LL}/2$ at draught T_1,in m^2.

For ships to which timber freeboards are assigned, the summer freeboard (and not the timber summer freeboard) is to be assumed when applying the formula above.

5.1.2 Where the bow height required in 5.1.1 is obtained by sheer, the sheer is to extend for at least 15% of the length of the ship measured from the forward perpendicular.

Where it is obtained by fitting a superstructure, such superstructure is to extend from the stem to a point at least 0,07L abaft the forward perpendicular and is to be enclosed.

5.1.3 Ships which, to suit exceptional operational requirements, cannot meet the requirements in 5.1.1 and 5.1.2 will be considered by the Society on a case by case basis.

5.1.4 The sheer of the forecastle deck may be taken into account, even if the length of the forecastle is less than 0.15L, but greater than 0.07L, provided that the forecastle height is not less than one half of standard height of superstructure between 0.07L and the forward perpendicular.

5.1.5 Where the forecastle height is less than one half of the standard height of superstructure, the credited bow height may be determined as follows:

a) Where the freeboard deck has sheer extending from abaft 0.15L, by a parabolic curve having its origin at 0.15L abaft the forward perpendicular at a height equal to the midship depth of the ship, extended through the point of intersection of forecastle bulkhead and deck, and up to a point at the forward perpendicular not higher than the level of the forecastle deck (see Fig 5.1).

However, if the value of the height denoted h_t in Fig 5.1 is smaller than the value of the height denoted h_b then h_t may be replaced by h_b in the available bow height, where:

$h_t = Z_b(0.15L / x_b)^2 - Z_t$

Z_b , Z_t : As defined in Fig 5.1

h_f : Half standard height of superstructure.

b) Where the freeboard deck has sheer extending for less than 0.15L or has no sheer, by a line from the forecastle deck at side at 0.07L extended parallel to the base line to the forward perpendicular (see Fig 5.2).

Figure 5.1: Credited bow height where the freeboard deck has sheer extending from abaft 0.15 L

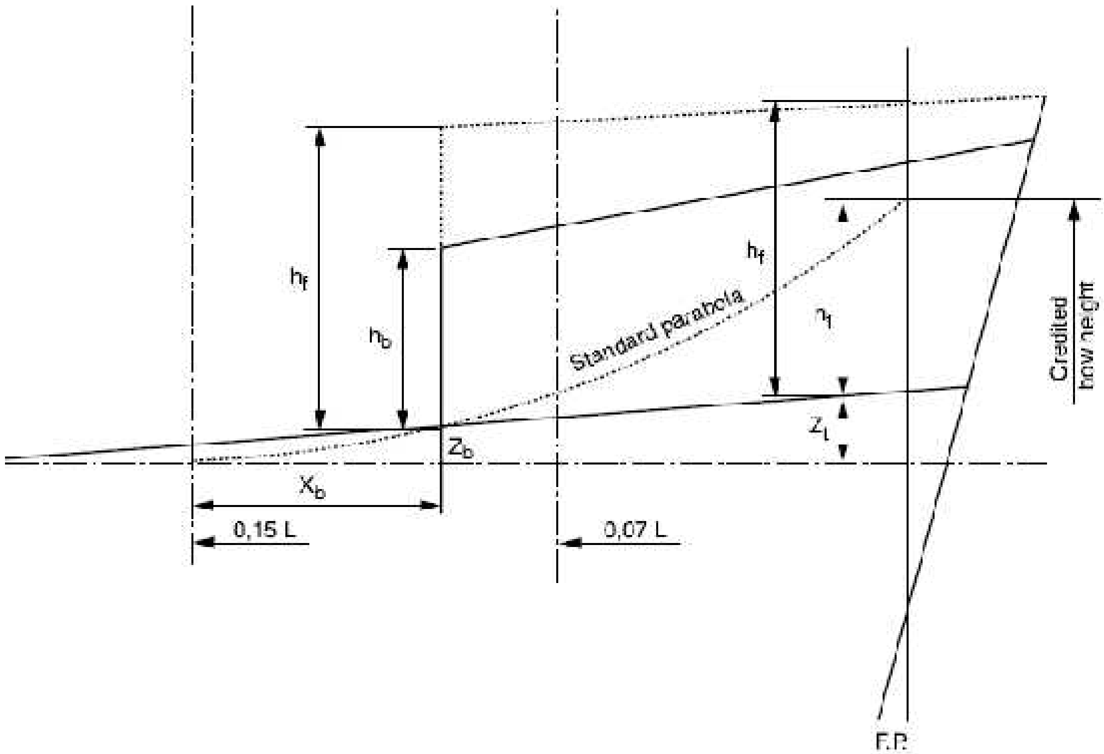
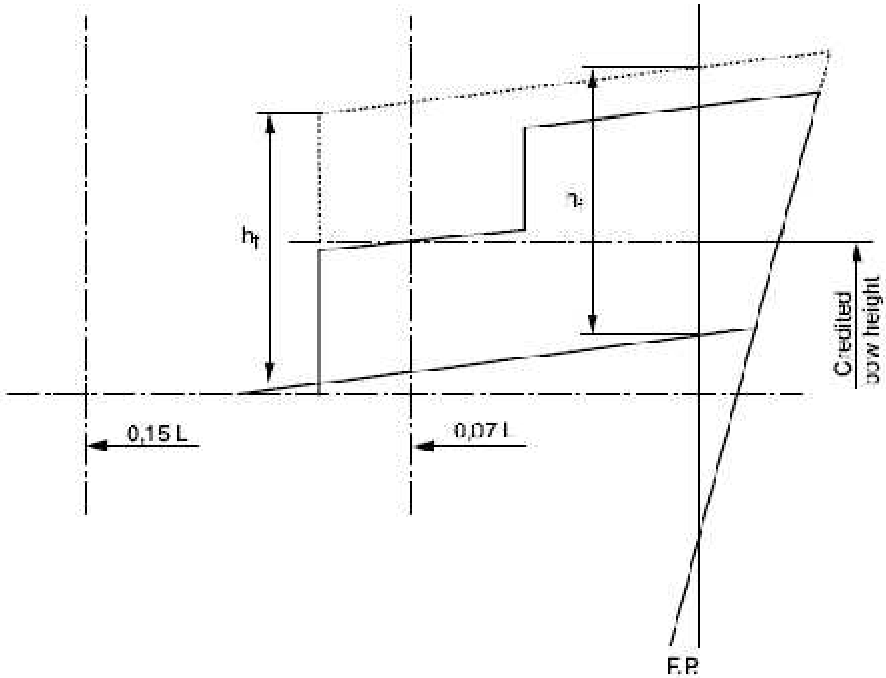


Figure 5.2: Credited bow height where the freeboard deck has sheer extending for less than 0.15 L



5.1.6 All ships assigned a type B freeboard, other than oil tankers, chemical tankers and gas carriers, are to have additional reserve buoyancy in the fore end. Within the range of $0.15L_{LL}$ abaft of the forward perpendicular, the sum of the projected area between the summer load waterline and the deck at side (A_1 and A_2 in Fig 5.3) and the projected area of an enclosed superstructure, if fitted, is, in m^2, to be not less than:

$A_3 = (0.15\ F_{min} + 4\ (L_{LL}/3 + 10))\ L_{LL}/1000$

where:

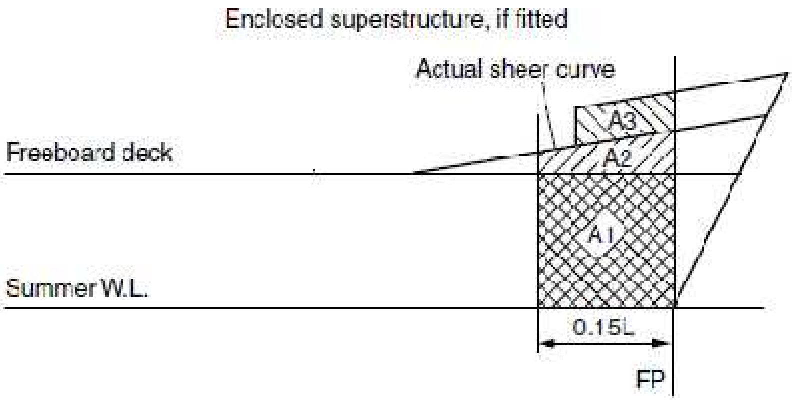
F_{min} : $F_{min} = (F_0 \ .\ f_1) + f_2$

F_0 : Tabular freeboard, in mm, taken from the International Convention on Load Lines, as amended, Table 28.2, corrected for regulation 27(9) or 27(10), as applicable

f_1 : Correction for block coefficient given in the International Convention on Load Lines, as amended, regulation 30

f_2 : Correction for depth, in mm, given in the International Convention on Load Lines, as amended, regulation 31.

Figure 5.3: Areas A1, A2 and A3



6 Shaft tunnels

6.1 General

6.1.1 Shaft tunnels are to be watertight.

7 Watertight ventilators and trunks

7.1 General

7.1.1 Watertight ventilators and trunks are to be carried at least up to the bulkhead deck in passenger ships and up to the freeboard deck in ships other than passenger ships.

8 Fuel oil tanks

8.1 General

8.1.1 The arrangements for the storage, distribution and utilisation of the fuel oil are to be such as to ensure the safety of the ship and persons on board.

8.1.2 As far as practicable, fuel oil tanks are to be part of the ship's structure and are to be located outside machinery spaces of category A.

Where fuel oil tanks, other than double bottom tanks, are necessarily located adjacent to or within machinery spaces of category A, at least one of their vertical sides is to be contiguous to the machinery space boundaries, they are preferably to have a common boundary with the double bottom tanks and the area of the tank boundary common with the machinery spaces is to be kept to a minimum.

Where such tanks are situated within the boundaries of machinery spaces of category A, they may not contain fuel oil having a flashpoint of less than 60°C.

8.1.3 Fuel oil tanks may not be located where spillage or leakage therefrom can constitute a hazard by falling on heated surfaces.

Precautions are to be taken to prevent any oil that may escape under pressure from any pump, filter or heater from coming into contact with heated surfaces.

Fuel oil tanks in boiler spaces may not be located immediately above the boilers or in areas subjected to high temperatures, unless special arrangements are provided in agreement with the Society.

8.1.4 Where a compartment intended for goods or coal is situated in proximity of a heated liquid container, suitable thermal insulation is to be provided.

8.2 Fuel oil tank protection

8.2.1 All ships with an aggregate oil fuel capacity of 600 m^3 and above are to comply with the requirements of the Regulation 12 A of Annex I to Marpol Convention, as amended.

Section 3 Access Arrangement

1 General

1.1 The number and size of small hatchways for trimming and access openings to tanks or other enclosed spaces, are to be kept to the minimum consistent with access and maintenance of the space.

2 Double bottom

2.1 Inner bottom manholes

2.1.1 Inner bottom manholes are to be not less than 400 mm x 400 mm. Their number and location are to be so arranged as to provide convenient access to any part of the double bottom.

2.1.2 Inner bottom manholes are to be closed by watertight plate covers.

Doubling plates are to be fitted on the covers, where secured by bolts.

Where no ceiling is fitted, covers are to be adequately protected from damage by the cargo.

2.2 Floor and girder manholes

2.2.1 Manholes are to be provided in floors and girders so as to provide convenient access to all parts of the double bottom.

2.2.2 The size of manholes and lightening holes in floors and girders is, in general, to be less than 50 per cent of the local height of the double bottom.

Where manholes of greater sizes are needed, edge reinforcement by means of flat bar rings or other suitable stiffeners may be required.

2.2.3 Manholes may not be cut into the continuous centerline girder or floors and girders below pillars, except where allowed by the Society on a case by case basis.

3 Access arrangement to and within spaces in, and forward of, the cargo Area

3.1 General

3.1.1 The requirements in 3.2 to 3.4 are not applicable to ships with service notations bulk carrier ESP , ore carrier ESP , combination carrier ESP, of 20,000 gross tonnage and over, and to ships with service notation oil tanker ESP of 500 gross tonnage and over. For such ships, their respective requirements apply.

3.2 Access to tanks

3.2.1 Tanks with a length equal to or greater than 35 m

Tanks and subdivisions of tanks having lengths of 35 m and above are to be fitted with at least two access hatchways and ladders, as far apart as practicable longitudinally.

3.2.2 Tanks with a length less than 35 m

Tanks less than 35 m in length are to be served by at least one access hatchway and ladder.

3.2.3 Dimensions of access hatchways

The dimensions of any access hatchway are to be sufficient to allow a person wearing a self-contained breathing apparatus to ascend or descend the ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the tank. In no case is the clear opening to be less than 600 mm x 600 mm.

3.2.4 Tanks subdivided by wash bulkheads

When a tank is subdivided by one or more wash bulkheads, at least two hatchways are to be fitted, and these hatchways are to be so located that the associated ladders effectively serve all subdivisions of the tank.

3.3 Access within tanks

3.3.1 Wash bulkheads in tanks

Where one or more wash bulkheads are fitted in a tank, they are to be provided with openings not less than 600 x 800 mm and so arranged as to facilitate the access of persons wearing breathing apparatus or carrying a stretcher with a patient.

3.3.2 Passage on the tank bottom

To provide ease of movement on the tank bottom throughout the length and breadth of the tank, a passageway is to be fitted on the upper part of the bottom structure of each tank, or alternatively, manholes having at least the dimensions of 600 mm x 800 mm are to be arranged in the floors at a height of not more than 600 mm from the bottom shell plating.

3.3.3 Passageways in the tanks

a) Passageways in the tanks are to have a minimum width of 600 mm considering the requirement for the possibility of carrying an unconscious person. Elevated passageways are to be provided with guard rails over their entire length. Where guard rails are provided on one side only, foot rails are to be fitted on the opposite side. Shelves and platforms forming a part of the access to the tanks are to be of non-skid construction where practicable and be fitted with guard rails. Guard rails are to be fitted to bulkhead and side stringers when such structures are being used for recognized access.

b) Access to elevated passageways from the ship's bottom is to be provided by means of easily accessible passageways, ladders or treads. Treads are to provide lateral support for the foot. Where rungs of ladders are fitted against a vertical surface, the distance from the centre of the rungs to that surface is to be at least 150 mm.

c) When the height of the bottom structure does not exceed 1.50 m, the passageways required in a) may be replaced by alternative arrangements having regard to the bottom structure and requirement for ease of access of a person wearing a self-contained breathing apparatus or carrying a stretcher with a patient.

3.3.4 Manholes

Where manholes are fitted, as indicated in 2.2.2, access is to be facilitated by means of steps and hand grips with platform landings on each side.

3.3.5 Guard rails

Guard rails are to be 900 mm in height and consist of a rail and intermediate bar. These guard rails are to be of substantial construction.

3.4 Construction of ladders

3.4.1 General

In general, the ladders are not to be inclined at an angle exceeding 70°. The flights of ladders are not to be more than 9 m in actual length. Resting platforms of adequate dimensions are to be provided.

3.4.2 Construction

Ladders and handrails are to be constructed of steel of adequate strength and stiffness and securely attached to the tank structure by stays. The method of support and length of stay are to be such that vibration is reduced to a practical minimum.

3.4.3 Corrosive effect of the cargo

Provision is to be made for maintaining the structural strength of the ladders and railings taking into account the corrosive effect of the cargo.

3.4.4 Width of ladders

The width of ladders between stringers is not to be less than 400 mm.

3.4.5 Treads

The treads are to be equally spaced at a distance apart measured vertically not exceeding 300 mm. They are to be formed of two square steel bars of not less than 22 mm by 22 mm in section fitted to form a horizontal step with the edges pointing upward, or of equivalent construction. The treads are to be carried through the side stringers and attached thereto by double continuous welding.

3.4.6 Sloping ladders

All sloping ladders are to be provided with handrails of substantial construction on both sides fitted at a convenient distance above the treads.

4 Shaft tunnels

4.1 General

4.1.1 Tunnels are to be large enough to ensure easy access to shafting.

4.1.2 Access to the tunnel is to be provided by a watertight door fitted on the aft bulkhead of the engine room in compliance with requirements, and an escape trunk which can also act as watertight ventilator is to be fitted up to the subdivision deck, for tunnels greater than 7 m in length.

5 Access to steering gear compartment

5.1

5.1.1 The steering gear compartment is to be readily accessible and, as far as practicable, separated from machinery spaces.

5.1.2 Suitable arrangements to ensure working access to steering gear machinery and controls are to be provided.

These arrangements are to include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

Chapter 4 Stability

Section 1 General

1 General

1.1 Application

1.1.1 General

All ships equal to or greater than 24 m in length may be assigned class only after it has been demonstrated that their intact stability is adequate. Adequate intact stability means compliance with standards laid down by the relevant Administration or with the requirements specified in this Chapter taking into account the ship's size and type. In any case, the level of intact stability is not to be less than that provided by the Rules.

1.1.2 Ships less than 24 m in length

The Rules also apply to ships less than 24 m in length. In this case, the requirements concerned may be partially omitted when deemed appropriate by the Society.

1.1.3 Approval of the Administration

Evidence of approval by the Administration concerned may be accepted for the purpose of classification.

2 Examination procedure

2.1 Documents to be submitted

2.1.1 List of documents

For the purpose of the examination of the stability, the following additional documentation is to be submitted for information.

- general arrangement
- capacity plan, indicating the volume and position of the centre of gravity of all compartments and tanks
- lines plan
- hydrostatic curves
- lightweight distribution.
- The stability documentation to be submitted for approval is as follows:
- Inclining test report for the ship, as required in 2.2 or:
  - where the stability data is based on a sister ship, the inclining test report of that sister ship along with the lightship measurement report for the ship in question; or
  - where lightship particulars are determined by methods other than inclining of the ship or its sister, the lightship measurement report of the ship along

with a summary of the method used to determine those particulars as indicated in 2.2.4.

- trim and stability booklet
- and, as applicable:
  - grain loading manual
  - damage stability calculations
  - damage control documentation
  - loading computer documentation.

A copy of the trim and stability booklet and, if applicable, the grain stability booklet, the damage control documentation or the loading computer documentation is to be available on board for the attention of the Master.

2.1.2 Provisional documentation

The Society reserves the right to accept or demand the submission of provisional stability documentation for examination.

Provisional stability documentation includes loading conditions based on estimated lightship values.

2.1.3 Final documentation

Final stability documentation based on the results of the inclining test or the lightweight check is to be submitted for examination.

When provisional stability documentation has already been submitted and the difference between the estimated values of the lightship and those obtained after completion of the test is less than:

- 2% for the displacement, and,
- 1% of the length between perpendiculars for the longitudinal position of the centre of gravity, and the determined vertical position of the centre of gravity is not greater than the estimated vertical position of the centre of gravity, the provisional stability documentation may be accepted as the final stability documentation.

2.2 Inclining test/lightweight check

2.2.1 Definitions

a) Lightship

The lightship is a ship complete in all respects, but without consumables, stores, cargo, and crew and effects, and without any liquids on board except for machinery and piping fluids, such as lubricants and hydraulics, which are at operating levels.

b) Inclining test

The inclining test is a procedure which involves moving a series of known weights, normally in the transverse direction, and then measuring the resulting change in the equilibrium heel angle of the ship. By using this information and applying basic naval architecture principles, the ship's vertical centre of gravity (VCG or KG) is determined.

c) Lightweight check

The lightweight check is a procedure which involves auditing all items which are to be added, deducted or relocated on the ship at the time of the inclining test so that the observed condition of the ship can be adjusted to the lightship condition. The weight and longitudinal, transverse and vertical location of each item are to be accurately determined and recorded. The lightship displacement and longitudinal centre of gravity (LCG) can be obtained using this information, as well as the static waterline of the ship at the time of the inclining test as

determined by measuring the freeboard or verified draught marks of the ship, the ship's hydrostatic data and the sea water density.

2.2.2 General

Any ship for which a stability investigation is requested in order to comply with class requirements is to be initially subjected to an inclining test permitting the evaluation of the position of the lightship centre of gravity, or a lightweight check of the lightship displacement, so that the stability data can be determined. Cases for which the inclining test is required and those for which the lightweight check is accepted in its place are listed in 2.2.4 and 2.2.5.

A detailed procedure of the test is to be submitted to the Society prior to the test. This procedure is to include:

a) identification of the ship by name and shipyard hull number, if applicable

b) date, time and location of the test

c) inclining weight data:

- type
- amount (number of units and weight of each)
- certification
- method of handling (i.e. sliding rail or crane)
- anticipated maximum angle of heel to each side

d) measuring devices:

- pendulums - approximate location and length
- U-tubes - approximate location and length
- inclinometers - Location and details of approvals and calibrations

e) approximate trim

f) condition of tanks

g) estimate weights to deduct, to complete, and to relocate in order to place the ship in its true lightship condition.

The inclining test or lightweight check is to be attended by a Surveyor of the Society. The Society may accept inclining tests or lightweight checks attended by a member of the flag Administration.

The inclining test is adaptable to ships less than 24 m in length, provided that precautions are taken, on a case by case basis, to ensure the accuracy of the test procedure.

2.2.3 Inclining test

The inclining test is required in the following cases:

- Any new ship, after its completion, except for the cases specified in 2.2.4
- Any ship, if deemed necessary by the Society, where any alterations are made so as to materially affect the stability.

Note 1: Due attention is to be paid to SOLAS Ch..II.1 Reg.22 (if applicable) whereby it is stipulated that such allowance is subject to the Flag Authorities agreement.

2.2.4 Lightweight check

The Society may allow a lightweight check to be carried out in lieu of an inclining test in the case of:

- stability data are available from the inclining test of a sister ship and it is shown to the satisfaction of the Society that reliable stability information for the exempted ship can be obtained from such basic data. A weight survey shall be carried out upon completion and the ship shall be inclined whenever in comparison with the data derived from the sister ship, a deviation from the lightship displacement exceeding 1% for ships of 160 m or more in length and 2% for ships of 50 m or less in length and as determined by linear interpolation for

intermediate lengths or a deviation from the lightship longitudinal centre of gravity exceeding 0.5% of L_S is found.

- special types of ship, such as pontoons, provided that the vertical centre of gravity is considered at the level of the deck.
- special types of ship provided that:
  - a detailed list of weights and the positions of their centres of gravity is submitted
  - a lightweight check is carried out, showing accordance between the estimated values and those determined
  - adequate stability is demonstrated in all the loading conditions reported in the trim and stability booklet.

2.2.5 Detailed procedure

A detailed procedure for conducting an inclining test is included in App 1. For the lightweight check, the same procedure applies except as provided for in Appendix 1/1.1.9.

Section 2 Intact Stability

1. General

1.1 Information for the Master

1.1.1 Stability booklet

Each ship is to be provided with a stability booklet, approved by the Society, which contains sufficient information to enable the Master to operate the ship in compliance with the applicable requirements contained in this Section.

Where any alterations are made to a ship so as to materially affect the stability information supplied to the Master, amended stability information is to be provided. If necessary the ship is to be re-inclined.

Stability data and associated plans are to be drawn up in the working language of the ship and any other language the Society may require. reference is also made to the International Safety Management (ISM) Code, adopted by IMO by resolution A.741(18). All translations of the stability booklet are to be approved.

The format of the trim and stability booklet and the information included are specified in Appendix 2.

1.1.2 Loading instrument

As a supplement to the approved stability booklet, a loading instrument, approved by the Society, may be used to facilitate the stability calculations mentioned in Appendix 2.

A simple and straightforward instruction manual is to be provided.

In order to validate the proper functioning of the computer hardware and software, pre-defined loading conditions are to be run in the loading instrument periodically, at least at every periodical class survey, and the print-out is to be maintained on board as check conditions for future reference in addition to the approved test conditions booklet.

The procedure to be followed, as well as the list of technical details to be sent in order to obtain loading instrument approval.

1.1.3 Operating booklets for certain ships

Ships with innovative design are to be provided with additional information in the stability booklet such as design limitations, maximum speed, worst intended weather conditions or other information regarding the handling of the craft that the Master needs to operate the ship.

1.2 Permanent ballast

1.2.1 If used, permanent ballast is to be located in accordance with a plan approved by the Society and in a manner that prevents shifting of position. Permanent ballast is not to be removed from the ship or relocated within the ship without the approval of the Society. Permanent ballast particulars are to be noted in the ship’s stability booklet.

1.2.2 Permanent solid ballast is to be installed under the supervision of the Society.

2 Design criteria

2.1 General intact stability criteria

2.1.1 General

The intact stability criteria specified in 2.1.2 to 2.1.5 are to be complied with for the loading conditions mentioned in Appendix 2, 1.2.

However, the lightship condition not being an operational loading case, the Society may accept that part of the abovementioned criteria are not fulfilled.

These criteria set minimum values, but no maximum values are recommended. It is advisable to avoid excessive values of metacentric height, since these might lead to acceleration forces which could be prejudicial to the ship, its equipment and to safe carriage of the cargo.

2.1.2 GZ curve area

The area under the righting lever curve (GZ curve) is to be not less than 0.055 m.rad up to θ=30° angle of heel and not less than 0,09 m.rad up to θ= 40° or the angle of down flooding θ_f if this angle is less than 40°. Additionally, the area under the righting lever curve (GZ curve) between the angles of heel of 30° and 40° or between 30° and θ_f , if this angle is less than 40°, is to be not less than 0.03 m.rad.

Note 1: θ_f is an angle of heel at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight submerge. In applying this criterion, small openings through which progressive flooding cannot take place need not be considered as open. This interpretation is not intended to be applied to existing ships.

The means of closing air pipes are to be weathertight and of an automatic type if the openings of the air pipes to which the devices are fitted would be submerged at an angle of less than 40 degrees (or any lesser angle which may be needed to suit stability requirements) when the ship is floating at its summer load line draught.

Pressure/vacuum valves (P.V. valves) may be accepted on tankers.

Wooden plugs and trailing canvas hoses may not be accepted in positions 1 and 2.

2.1.3 Minimum righting lever

The righting lever GZ is to be at least 0.20 m at an angle of heel equal to or greater than 30°.

2.1.4 Angle of maximum righting lever

The maximum righting arm is to occur at an angle of heel preferably exceeding 30° but not less than 25°.

When the righting lever curve has a shape with two maximums, the first is to be located at a heel angle not less than 25°.

In cases of ships with a particular design and subject to the prior agreement of the flag Administration, the Society may accept an angle of heel θ max less than 25° but in no case less than 15°, provided that the area “A” below the righting lever curve is not less than the value obtained, in m.rad, from the following formula:

$A = 0.055 + 0.,001 (30° - \theta_{max})$

where θ_{max} is the angle of heel in degrees at which the righting lever curve reaches its maximum.

2.1.5 Initial metacentric height

The initial metacentric height GM_0 is not to be less than 0.15 m.

2.1.6 Elements affecting stability

A number of influences such as beam wind on ships with large windage area, icing of topsides, water trapped on deck, rolling characteristics, following seas, etc., which adversely affect stability, are to be taken into account.

2.1.7 Elements reducing stability

Provisions are to be made for a safe margin of stability at all stages of the voyage, regard being given to additions of weight, such as those due to absorption of water and icing (details regarding ice accretion are given in 6) and to losses of weight such as those due to consumption of fuel and stores.

3 Severe wind and rolling criterion (weather criterion)

3.1 Scope

3.1.1 This criterion supplements the stability criteria given in 2.1 for ships of 24 m in length and over. The more stringent criteria of 2.1 and the weather criterion are to govern the minimum requirements.

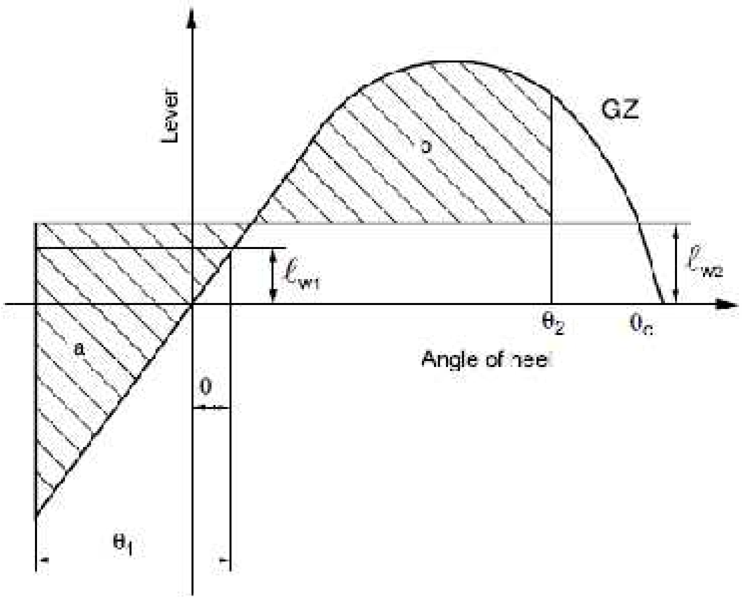
3.2 Weather criterion

3.2.1 Assumptions

The ability of a ship to withstand the combined effects of beam wind and rolling is to be demonstrated for each standard condition of loading, with reference to Fig 3.1 as follows:

- the ship is subjected to a steady wind pressure acting perpendicular to the ship’s centreline which results in a steady wind heeling lever (l_{w1})
- from the resultant angle of equilibrium (θ_0), the ship is assumed to roll owing to wave action to an angle of roll (θ_1) to windward
- the ship is then subjected to a gust wind pressure which results in a gust wind heeling lever (l_{w2})
- free surface effects, as described in 4, are to be accounted for in the standard conditions of loading as set out in Appendix 2, 1.2.

Figure 3.1: Severe wind and rolling



3.2.2 Criteria

Under the assumptions of 3.2.1, the following criteria are to be complied with:

- the area "b" is to be equal to or greater than area "a", where:

  a : Area above the GZ curve and below l_{w2}, between θ_R and the intersection of l_{w2} with the GZ curve

  b : Area above the heeling lever l_{w2} and below the GZ curve, between the intersection of

  l_{w2} with the GZ curve and θ_2

- the angle of heel under action of steady wind (θ0) (intersection of GZ curve with lw1) is to be limited to 16° or 80% of the angle of deck edge immersion, whichever is less.

3.2.3 Heeling levers

The wind heeling levers l_{w1} and l_{w2}, in m, referred to in 3.2.2, are constant values at all angles of inclination and are to be calculated as follows:

l_{w1}=PAZ/(1000gΔ)

and

l_{w2}= 1.5 l_{w1}

where:

P: 504 N/m^2 for unrestricted navigation notation. The value of P used for ships with restricted navigation notation may be reduced subject to the approval of the Society

A: Projected lateral area in m^2, of the portion of the ship and deck cargo above the waterline

Z: Vertical distance in m, from the centre of A to the centre of the underwater lateral area or approximately to a point at one half the draught

Δ: Displacement in tonnes

$g = 9.81\ m/s^2$.

3.2.4 Angles of heel

For the purpose of calculating the criteria of 3.2.2, the angles in Fig 3.1 are defined as follows:

θ_0: Angle of heel, in degrees, under action of steady wind

θ_1 : Angle of roll, in degrees, to windward due to wave action, calculated as follows:

$$\theta_1 = 109 k X_1 X_2 \sqrt{rs}$$

θ_2: Angle of downflooding (θ_f) in degrees, or 50° or θ_c, whichever is less

θ_f : Angle of heel in degrees, at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight immerse. In applying this criterion, small openings through which progressive flooding cannot take place need not be considered as open

θ_c: Angle in degrees, of second intercept between wind heeling lever l_{w2} and GZ curves

$\theta_R = \theta_0 - \theta_1$

X_1 : Coefficient defined in Table 3.1

X_2 : Coefficient defined in Table 3.2

k : Coefficient equal to:

k = 1.0 for a round-bilged ship having no bilge or bar keels

k = 0.7 for a ship having sharp bilge

For a ship having bilge keels, a bar keel or both, k is defined in Table 3.3.

$r = 0.73 \pm 0.6\ (OG)/T_1$

OG : Distance in m, between the centre of gravity and the waterline (positive if centre of gravity is above the waterline, negative if it is below)

T_1 : Mean molded draught in m, of the ship

s : Factor defined in Table 3.4.

Note 1: The angle of roll θ_1 for ships with anti-rolling devices is to be determined without taking into account the operations of these devices.

Note 2: The angle of roll θ_1 may be obtained, in lieu of the above formula, from model tests or full scale measurements.

The rolling period T_R, in s, is calculated as follows:

$$T_R = 2CB/\sqrt{GM}$$

where:

$$C = 0.373 + 0.023B/T_1 - 0.043L_W/100$$

The symbols in the tables and formula for the rolling period are defined as follows:

L_W : Length in m, of the ship at the waterline

T_1 : Mean molded draught in m, of the ship

A_K : Total overall area in m^2 of bilge keels, or area of the lateral projection of the bar keel, or sum of these areas, or area of the lateral projection of any hull appendages generating added mass during ship roll

GM: Metacentric height in m, corrected for free surface effect.

Table 3.1: Values of coefficient X1

B/T_1	≤2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.4	≥3.5
X_1	1.00	.98	.96	.95	.93	.91	.90	.88	.86	.82	.80

Table 3.2: Values of coefficient X2

C_B	≤0.45	.5	0.55	0.60	0.65	≥0.70
X_2	0.75	.82	0.89	0.95	0.97	1.00

Table 3.3: Values of coefficient k

$100A_K/LB$	0.0	1.0	1.5	2.0	2.5	3.0	3.5	≥4.0
X_1	1.00	.98	.95	.88	.79	.74	.72	.70

Table 3.4: Values of factor s

T_R	≤6	7	8	12	14	16	18	≥20
S	0.100	.098	.093	.065	.053	.044	.038	.035

(Intermediate values in these tables are to be obtained by linear interpolation)

3.2.5 Tables 3.1 to 3.4 and formulae described in 3.2.4 are based on data from ships having:

- B/T_1 smaller than 3.5
- (KG/T_1-1) between -0.3 and 0.5
- T_R smaller than 20 s.

For ships with parameters outside of the above limits the angle of roll (θ_1) may be determined with model experiments of a subject ship with the procedure described in

IMO MSC.1/Circ. 1200 as the alternative. In addition, the Society may accept such alternative determinations for any ship, if deemed appropriate.

3.2.6 Alternative means for determining the wind heeling lever (l_{W1}) may be accepted, to the satisfaction of the Society as an equivalent to the calculation in 3.2.3. When such alternative tests are carried out, reference shall be made based on the Interim Guidelines for alternative assessment of the weather criterion (IMO MSC.1/ Circ.1200). the wind velocity used in the tests shall be 26 m/s in full scale with uniform velocity profile. the value of wind velocity used for ships in restricted services may be reduced to the satisfaction of the Society.

4 Effects of free surfaces of liquids in tanks

4.1 General

4.1.1 For all loading conditions, the initial metacentric height and the righting lever curve are to be corrected for the effect of free surfaces of liquids in tanks.

4.2 Consideration of free surface effects

4.2.1 Free surface effects are to be considered whenever the filling level in a tank is less than 98% of full condition. Free surface effects need not be considered where a tank is nominally full, i.e. filling level is 98% or above. Free surface effects for small tanks may be ignored under the condition in 4.8.1.

4.2.2 Nominally full cargo tanks should be corrected for free surface effects at 98% filling level. In doing so, the correction to initial metacentric height should be based on the inertia moment of liquid surface at 5^{o} of the heeling angle divided by displacement, and the correction to righting lever is suggested to be on the basis of real shifting moment of cargo liquids.

4.3 Categories of tanks

4.3.1 Tanks which are taken into consideration when determining the free surface correction may be one of two categories:

- tanks with fixed filling level (e.g. liquid cargo, water ballast).

The free surface correction is to be defined for the actual filling level to be used in each tank.

- tanks with variable filling level (e.g. consumable liquids such as fuel oil, diesel oil, and fresh water, and also liquid cargo and water ballast during liquid transfer operations).

Except as permitted in 4.5.1 and 4.6.1, the free surface correction is to be the maximum value attainable among the filling limits envisaged for each tank, consistent with any operating instructions.

4.4 Consumable liquids

4.4.1 In calculating the free surfaces effect in tanks containing consumable liquids, it is to be assumed that for each type of liquid at least one transverse pair or a single centerline tank has a free surface and the tank or combination of tanks taken into account are to be those where the effect of free surface is the greatest.

4.5 Water ballast tanks

4.5.1 Where water ballast tanks, including anti-rolling tanks and anti-heeling tanks, are to be filled or discharged during the course of a voyage, the free surfaces effect is to be calculated to take account of the most onerous transitory stage relating to such operations.

4.6 Liquid transfer operations

4.6.1 For ships engaged in liquid transfer operations, the free surface corrections at any stage of the liquid transfer operations may be determined in accordance with the filling level in each tank at the stage of the transfer operation.

4.7 GM_0 and GZ curve corrections

4.7.1 The corrections to the initial metacentric height and to the righting lever curve are to be addressed separately as indicated in 4.7.2 and 4.7.3.

4.7.2 In determining the correction to the initial metacentric height, the transverse moments of inertia of the tanks are to be calculated at 0 degrees angle of heel according to the categories indicated in 4.3.1.

4.7.3 The righting lever curve may be corrected by any of the following methods:

- correction based on the actual moment of fluid transfer for each angle of heel calculated; corrections may be calculated according to the categories indicated in 4.3.1
- correction based on the moment of inertia, calculated at 0 degrees angle of heel, modified at each angle of heel calculated; corrections may be calculated according to the categories indicated in 4.3.1.

4.7.4 Whichever method is selected for correcting the righting lever curve, only that method is to be presented in the ship's trim and stability booklet. However, where an alternative method is described for use in manually calculated loading conditions, an explanation of the differences which may be found in the results, as well as an example correction for each alternative, are to be included.

4.8 Small tanks

4.8.1 Small tanks which satisfy the following condition sing the values of k corresponding to an angle of inclination of 30° need not be included in the correction:

$$M_{\text{fs}} / \Delta_{\min} < 0.01 \ m$$

where:

$\Delta_{\min}$: Minimum ship displacement, in t, calculated at d_{min}

d_{min} : Minimum mean service draught, in m, of ship without cargo, with 10% stores and minimum water ballast, if required.

4.9 Remainder of liquid

4.9.1 The usual remainder of liquids in the empty tanks need not be taken into account in calculating the corrections, providing the total of such residual liquids does not constitute a significant free surface effect.

5 Cargo ships carrying timber deck cargoes

5.1 Application

5.1.1 The provisions given hereunder apply to ships engaged in the carriage of timber deck cargoes. Ships that are provided with and make use of their timber load line are also to comply with the requirements of regulations 41 to 45 of the International Load Line Convention 1966, as amended.

5.2 Definitions

5.2.1 Timber

Timber means sawn wood or lumber, cants, logs, poles, pulpwood and all other types of timber in loose or packaged forms. The term does not include wood pulp or similar cargo.

5.2.2 Timber deck cargo

Timber deck cargo means a cargo of timber carried on an uncovered part of a freeboard or superstructure deck. The term does not include wood pulp or similar cargo.

5.2.3 Timber load line

Timber load line means a special load line assigned to ships complying with certain conditions related to their construction set out in the International Convention on Load Lines 1966, as amended, and used when the cargo complies with the stowage and securing conditions of the Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 1991 (Resolution A.715(17)).

5.3 Stability criteria

5.3.1 For ships loaded with timber deck cargoes and provided that the cargo extends longitudinally between superstructures (where there is no limiting superstructure at the after end, the timber deck cargo is to extend at least to the after end of the aftermost hatchway) and transversely for the full beam of ship after due allowance for a rounded gunwale not exceeding 4% of the breadth of the ship and/or securing the supporting uprights and which remains securely fixed at large angles of heel, the Society may apply the criteria given in 5.3.2 to 5.3.5, which substitute those given in 2.1.2 to 2.1.5 and in 3.2.

5.3.2 The area under the righting lever curve (GZ curve) is to be not less than 0.08 m.rad up to θ= 40° or the angle of flooding if this angle is less than 40°.

5.3.3 The maximum value of the righting lever (GZ) is to be at least 0.25 m.

5.3.4 At all times during a voyage, the metacentric height GM_0 is to be not less than 0.10 m after correction for the free surface effects of liquid in tanks and, where appropriate, the absorption of water by the deck cargo and/or ice accretion on the exposed surfaces. (Details regarding ice accretion are given in 6). Additionally, in the departure condition the metacentric height is to be not less than 0,10 m.

5.3.5 When determining the ability of the ship to withstand the combined effect of beam wind and rolling according to 3.2, the 16° limiting angle of heel under action of steady wind is to be complied with, but the additional criterion of 80% of the angle of deck edge immersion may be ignored.

5.4 Stability booklet

5.4.1 The ship is to be supplied with comprehensive stability information which takes into account timber deck cargo.

Such information is to enable the Master, rapidly and simply, to obtain accurate guidance as to the stability of the ship under varying conditions of service. Comprehensive rolling period tables or diagrams have proved to be very useful aids in verifying the actual stability conditions.

5.4.2 For ships carrying timber deck cargoes, the Society may deem it necessary that the Master be given information setting out the changes in deck cargo from that shown in the loading conditions, when the permeability of the deck cargo is significantly different from 25% (see 5.5.1).

5.4.3 For ships carrying timber deck cargoes, conditions are to be shown indicating the maximum permissible amount of deck cargo having regard to the lightest stowage rate likely to be met in service.

5.5 Calculation of the stability curve

5.5.1 In addition to the provisions given in Appendix 2, 1.3, the Society may allow account to be taken of the buoyancy of the deck cargo assuming that such cargo has a permeability of 25% of the volume occupied by the cargo.

Additional curves of stability may be required if the Society considers it necessary to investigate the influence of different permeabilities and/or assumed effective height of the deck cargo.

5.6 Loading conditions to be considered

5.6.1 The loading conditions which are to be considered for ships carrying timber deck cargoes are specified in Appendix 2, 1.2.2. For the purpose of these loading conditions, the ship is assumed to be loaded to the summer timber load line with water ballast tanks empty.

5.7 Assumptions for calculating loading conditions

5.7.1 The following assumptions are to be made for calculating the loading conditions referred to in Appendix 2, 1.2.2:

- the amount of cargo and ballast is to correspond to the worst service condition in which all the relevant stability criteria reported in 2.1.2 to 2.1.5, or the optional criteria given in 5.3, are met
- in the arrival condition, it is to be assumed that the weight of the deck cargo has increased by 10% due to water absorption.

5.7.2 The stability of the ship at all times, including during the process of loading and unloading timber deck cargo, is to be positive and in compliance with the stability criteria of 5.3. It is to be calculated having regard to:

- the increased weight of the timber deck cargo due to:
  - absorption of water in dried or seasoned timber, and
  - ice accretion, if applicable (as reported in 6)
- variations in consumable

- the free surface effect of liquid in tanks, and
- the weight of water trapped in broken spaces within the timber deck cargo and especially logs.

5.7.3 Excessive initial stability is to be avoided as it will result in rapid and violent motion in heavy seas which will impose large sliding and racking forces on the cargo causing high stresses on the lashings. Unless otherwise stated in the stability booklet, the metacentric height is generally not to exceed 3% of the breadth in order to prevent excessive acceleration in rolling provided that the relevant stability criteria given in 5.3 are satisfied.

5.8 Stowage of timber deck cargoes

5.8.1 The stowage of timber deck cargoes is to comply with the provisions of chapter 3 of the Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 1991 (resolution A.715(17)).

6 Icing

6.1 Application

6.1.1 For any ship having an ice class notation or operating in areas where ice accretion is likely to occur, adversely affecting a ship's stability, icing allowances are to be included in the analysis of conditions of loading.

6.2 Ships carrying timber deck cargoes

6.2.1 The Master is to establish or verify the stability of his ship for the worst service condition, having regard to the increased weight of deck cargo due to water absorption and/or ice accretion and to variations in consumable.

6.2.2 When timber deck cargoes are carried and it is anticipated that some formation of ice will take place, an allowance is to be made in the arrival condition for the additional weight.

6.3 Calculation assumptions

6.3.1 For ships operating in areas where ice accretion is likely to occur, the following icing allowance is to be made in the stability calculations:

- 30 kg per square metre on exposed weather decks and gangways
- 7,5 kg per square metre for the projected lateral area of each side of the ship above the water plane
- the projected lateral area of discontinuous surfaces of rail, sundry booms, spars (except masts) and rigging of ships having no sails and the projected lateral area of other small objects are to be computed by increasing the total projected area of continuous surfaces by 5% and the static moments of this area by 10%.

6.3.2 Ships intended for operation in areas where ice is known to occur are to be:

- designed to minimise the accretion of ice, and

- equipped with such means for removing ice as, for example, electrical and pneumatic devices, and/or special tools such as axes or wooden clubs for removing ice from bulwarks, rails and erections.

6.4 Guidance relating to ice accretion

6.4.1 The following icing areas are to be considered:

a) the area north of latitude 65°30'N, between longitude 28°W and the west coast of Iceland; north of the north coast of Iceland; north of the rhumb line running from latitude 66°N, longitude 15°W to latitude 73°30'N, longitude 15°E, north of latitude 73°30'N between longitude 15°E and 35°E, and east of longitude 35°E, as well as north of latitude 56°N in the Baltic Sea

b) the area north of latitude 43°N bounded in the west by the North American coast and the east by the rhumb line running from latitude 43°N, longitude 48°W to latitude 63°N, longitude 28°W and thence along longitude 28°W

c) all sea areas north of the North American Continent, west of the areas defined in (a and b)

d) the Bering and Okhotsk Seas and the Tartary Strait during the icing season, and

e) south of latitude 60°S.

6.4.2 For ships operating where ice accretion may be expected:

- within the areas defined in a), c), d) and e) of 6.4.1 known to having icing conditions significantly different from those described in 6.3, ice accretion requirements of one half to twice the required allowance may be applied
- within the area defined in b), where ice accretion in excess of twice the allowance required by 6.3 may be expected, more severe requirements than those given in 6.3 may be applied.

Section 3 Damage Stability

1 Application

1.1 Ships for which damage stability is required

1.1.1 Damage stability calculation is required for ships which have been requested to receive damage stability notation.

2 General

2.1 Approaches to be followed for damage stability investigation

2.1.1 General

Damage stability calculations are required in order to assess the attitude and stability of the ship after flooding.

In order to assess the behavior of the ship after damage, two approaches have been developed: the deterministic and the probabilistic, which are to be applied depending on the ship type.

The metacentric heights (GM), stability levers (GZ) and centre of gravity positions for judging the final conditions are to be calculated by the constant displacement (lost buoyancy) method.

2.1.2 Deterministic approach

The deterministic approach is based on standard dimensions of damage extending anywhere along the ship's length or between transverse bulkheads depending on the relevant requirements.

The consequence of such standard of damage is the creation of a group of damage cases, the number of which, as well as the number of compartments involved in each case, depend on the ship's dimensions and internal subdivision.

For each loading condition, each damage case is to be considered, and the applicable criteria are to be complied with.

Different deterministic methods in damage stability have been developed depending on ship type, on freeboard reduction, and on the kind of cargo carried.

The deterministic methods to be applied for passenger ships, oil tankers, chemical tankers, gas carriers and special purpose ships as appropriate.

2.1.3 Probabilistic Approach

The probabilistic concept takes the probability of survival after collision as a measure of ship safety in the damaged condition, referred to as the attained subdivision index A.

The damage stability calculations are performed for a limited number of draughts and relevant GM values in order to draw a minimum GM curve where the attained subdivision index A achieves the minimum required level of safety R.

For cargo ships, each case of damage is not required to comply with the applicable criteria, but the attained index A, which is the sum of the contribution of all damage cases, is to be equal to or greater than R.

The probabilistic method developed on the basis of the above mentioned concepts is detailed in Appendix 3.

As a general rule, the probabilistic method applies to cargo ships of a length not less than 80 m, and for which no deterministic methods apply; the application of the probabilistic damage stability investigation is specified in the rules.

3 Documents to be submitted

3.1 Damage stability calculations

3.1.1 Damage stability documentation

For all ships to which damage stability requirements apply, documents including damage stability calculations are to be submitted.

The damage stability calculations are to include:

- list of the characteristics (volume, centre of gravity, permeability) of each compartment which can be damaged
- a table of openings in bulkheads, decks and side shell reporting all the information about:
  - identification of the opening
  - vertical, transverse and horizontal location
  - type of closure: sliding, hinged or rolling for doors
  - type of tightness: watertight, weathertight, semiwatertight or unprotected
  - operating system: remote control, local operation, indicators on the bridge, television surveillance, water leakage detection, audible alarm, as applicable
  - foreseen utilization: open at sea, normally closed at sea, kept closed at sea
- list of all damage cases corresponding to the applicable requirements
- detailed results of damage stability calculations for all the loading conditions foreseen in the applicable requirements
- the limiting GM/KG curve, if foreseen in the applicable requirements
- capacity plan
- arrangement of cross and down flooding devices
- watertight and weathertight door plan with pressure calculation
- side contour and wind profile
- pipes and damaged area when the destruction of these pipes results in progressive flooding.

3.1.2 Additional information for the probabilistic approach

In addition to the information listed in 3.1.1, the following is to be provided:

- subdivision length L_S

- initial draughts and the corresponding GM-values
- required subdivision index R
- attained subdivision index A with a summary table for all contributions for all damaged zones.
- draught, trim, GM in damaged condition
- damage extension and definition of damage cases with probabilistic values p, v and r
- righting lever curve (including GZmax and range) with factor of survivability s
- critical weathertight and unprotected openings with their angle of immersion
- details of sub-compartments with amount of in-flooded water/lost buoyancy with their centres of gravity.

3.1.3 Loading instrument

As a supplement to the approved damage stability documentation, a loading instrument, approved by the Society, may be used to facilitate the damage stability calculations mentioned in 3.1.1.

The procedure to be followed, as well as the list of technical details to be sent in order to obtain loading instrument approval.

3.2 Permeabilities

3.2.1 Definition

The permeability of a space means the ratio of the volume within that space which is assumed to be occupied by water to the total volume of that space.

3.2.2 General

The permeabilities relevant to the type of spaces which can be flooded depend on the applicable requirements.

3.3 Progressive flooding

3.3.1 Definition

Progressive flooding is the additional flooding of spaces which were not previously assumed to be damaged. Such additional flooding may occur through openings or pipes as indicated in 3.3.2 and 3.3.3.

3.3.2 Openings

The openings may be listed in the following categories, depending on their means of closure:

- Unprotected

Unprotected openings may lead to progressive flooding if they are situated within the range of the positive righting lever curve or if they are located below the waterline after damage (at any stage of flooding). Unprotected openings are openings which are not fitted with at least weathertight means of closure.

- Weathertight

Openings fitted with weathertight means of closure are not able to sustain a constant head of water, but they can be intermittently immersed within the positive range of stability.

Weathertight openings may lead to progressive flooding if they are located below the waterline after damage (at any stage of flooding).

- Semi-watertight

Internal openings fitted with semi-watertight means of closure are able to sustain a constant head of water corresponding to the immersion relevant to the highestwaterline after damage at the equilibrium of the intermediate stages of flooding.

Semi-watertight openings may lead to progressive flooding if they are located below the final equilibrium waterline after damage.

- Watertight

Internal openings fitted with watertight means of closure are able to sustain a constant head of water corresponding to the distance between the lowest edge of this opening and the bulkhead/freeboard deck.

Air pipe closing devices may not be considered watertight, unless additional arrangements are fitted in order to demonstrate that such closing devices are effectively watertight.

The pressure/vacuum valves (PV valves) currently installed on tankers do not theoretically provide complete watertightness.

Manhole covers may be considered watertight provided the cover is fitted with bolts located such that the distance between their axes is less than five times the bolt's diameter.

Access hatch covers leading to tanks may be considered watertight.

Watertight openings do not lead to progressive flooding.

3.3.3 Pipes

Progressive flooding through pipes may occur when:

- the pipes and connected valves are located within the assumed damage, and no valves are fitted outside the damage
- the pipes, even if located outside the damage, satisfy all of the following conditions:
  - the pipe connects a damaged space to one or more spaces located outside the damage
  - the highest vertical position of the pipe is below the waterline, and
  - no valves are fitted.

The possibility of progressive flooding through ballast piping passing through the assumed extent of damage, where positive action valves are not fitted to the ballast system at the open ends of the pipes in the tanks served, is to be considered.

Where remote control systems are fitted to ballast valves and these controls pass through the assumed extent of damage, then the effect of damage to the system is to be considered to ensure that the valves would remain closed in that event.

If pipes, ducts or tunnels are situated within assumed flooded compartments, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed flooded. However, the Society may permit minor progressive flooding if it is demonstrated that the additional flooding of those compartments cannot lead to the capsizing or the sinking of the ship.

3.4 Bottom damages

3.4.1 General

Ships wich are not fitted with a double bottom as required by rules or which are fitted with unusual bottom arrangments, are to comply with 3.4.2 and 3.4.3.

3.4.2 Bottom damage description

The assumed extent of damage is described in Table 3.1.

If any damage of a lesser extent than the maximum damage specified in Table 3.1 would result in a more severe condition, such damage should be considered.

3.4.3 Stability criteria

Compliance with the requirements of Ch. 3, Sec. 2/ 3.1.5 or /3.1.6 is to be achieved for all service conditions when subject to a bottom damage assumed at any position along the ship's bottom and with an extent specified in 3.4.2 for the affected part of the ship.

Flooding of such spaces shall not render emergency power and lighting, internal communication, signals or other emergency devices inoperable in other parts of the ship

Table 3.1: Assumed extent of damage

	For 0.3 L from the forward perpendicular of the ship	Any other part of the ship
Longitudinal extent	1/3 L2/3 or 14.5 m, whichever is less	1/3 L2/3 or 14.5 m, whichever is less
Transverse extent	B/6 or 10 m, whichever is less	B/6 or 5 m, whichever is less
Vertical extent, measured from the keel line	B/20 or 2 m, whichever is less	B/20 or 2 m, whichever is less

4 Damage control documentation

4.1 General

4.1.1 Application

The damage control documentation is to include a damage control plan which is intended to provide ship's officers with clear information on the ship's watertight compartmentation and equipment related to maintaining the boundaries and effectiveness of the compartmentation so that, in the event of damage causing flooding, proper precautions can be taken to prevent progressive flooding through openings therein and effective action can be taken quickly to mitigate and, where possible, recover the ship's loss of stability.

The damage control documentation is to be clear and easy to understand. It is not to include information which is not directly relevant to damage control, and is to be provided in the language or languages of the ship's officers. If the languages used in the preparation of the documentation are not English or French, a translation into one of these languages is to be included.

The use of a loading instrument performing damage stability calculations may be accepted as a supplement to the damage control documentation. This instrument is to be approved by the Society.

The damage control plan is required for the following ships:

- Ships carrying passengers
- Dry cargo ships corresponding to:

Note 1: Dry cargo ship is intended to mean a cargo ship which has not been designed to carry liquid cargo in bulk; furthermore, the following ship types are not to be considered as dry cargo ships:

- tugs
- supply vessels
- fire-fighting ships
- oil recovery ships

5 Specific interpretations

5.1 Assumed damage penetration in way of sponsons

5.1.1 If sponsons are fitted, it is necessary to establish the maximum assumed damage penetration (B/5) to be used when deciding on the various damage cases. For this purpose, the breadth B in the way of such sponsons is to be measured to the outside of the sponsons.

Clear of any suck sponsons, the breadth B is to be the midship breadth measured to the outside of the original shell. In other words, the assumed penetration of B/5 is the same as that which applied before the fitting of sponsons.

5.2 Effect of progressive flooding on the GZ curve

5.2.1 When major progressive flooding occurs, that is when it causes a rapid reduction in the righting lever of 0.04 m or more, the righting lever curve is to be considered as terminated at the angle the progressive flooding occurs and the range and the area are to be measured to that angle, as shown in Figure 5.1.

5.2.2 In the case where the progressive flooding is of limited nature that does not continue unabated and causes an acceptably slow reduction in righting lever of less than 0,04 m, the remainder of the curve is to be partially truncated by assuming that the progressively flooded space is so flooded from the beginning, as shown in Figure 5.2.

Figure 5.1: Major progressive flooding

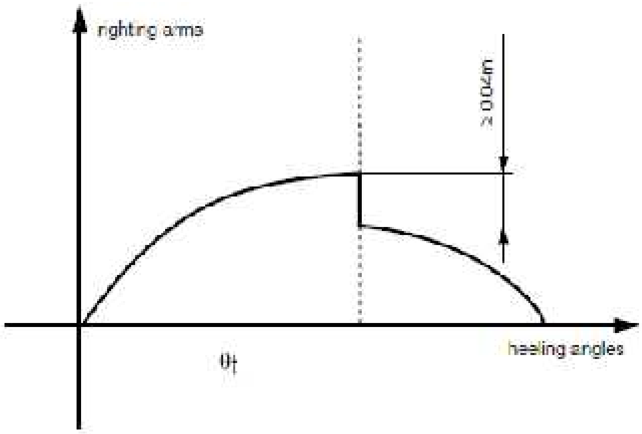
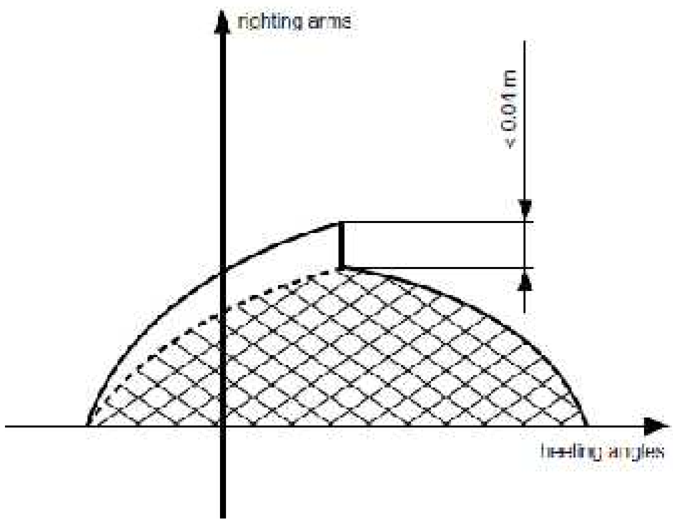


Figure 5.2: Progressive flooding of limited nature



Appendix 1 Inclining Test and Lightweight Check

1 Inclining test and lightweight check

1.1 General

1.1.1 General conditions of the ship

The following conditions are to be met, as far as practicable :

- the weather conditions are to be favourable
- the ship should be moored in a quiet, sheltered area free from extraneous forces such as propeller wash from passing vessels, or sudden discharges from shore side pumps. The tide conditions and the trim of the ship during the test should be considered. Prior to the test, the depth of water should be measured and recorded in as many locations as are necessary to ensure that the ship will not contact the bottom. The specific gravity of water should be accurately recorded. The ship should be moored in a manner to allow unrestricted heeling. The access ramps should be removed. Power lines, hoses, etc., connected to shore should be at a minimum, and kept slack at all times
- the ship should be as upright as possible; with inclining weights in the initial position, up to one-half degree of list is acceptable. The actual trim and deflection of keel, if practical, should be considered in the hydrostatic data. In order to avoid excessive errors caused by significant changes in the water plane area during heeling, hydrostatic data for the actual trim and the maximum anticipated heeling angles should be checked beforehand
- cranes, derrick, lifeboats and liferafts capable of inducing oscillations are to be secured
- main and auxiliary boilers, pipes and any other system containing liquids are to be filled
- the bilge and the decks are to be thoroughly dried
- the anticipated liquid loading for the test should be included in the planning for the test. Preferably, all tanks should be empty and clean, or completely full. The number of slack tanks should be kept to an absolute minimum. The viscosity of the fluid, the depth of the fluid and the shape of the tank should be such that the free surface effect can be accurately determined
- the weights necessary for the inclination are to be already on board, located in the correct place
- all work on board is to be suspended and crew or personnel not directly involved in the incline test are to leave the ship
- the ship is to be as complete as possible at the time of the test. The number of weights to be removed, added or shifted is to be limited to a minimum. Temporary material, tool boxes, staging, sand, debris, etc., on board is to be reduced to an absolute minimum.

- Decks should be free of water. Water trapped on deck may shift and pocket in a fashion similar to liquids in a tank. Any rain, snow or ice accumulated on the ship should be removed prior to the test.

1.1.2 Inclining weights

The total weight used is preferably to be sufficient to provide a minimum inclination of one degree and a maximum of four degrees of heel to each side. The Society may, however, accept a smaller inclination angle for large ships provided that the requirement on pendulum deflection or Utube difference in height specified in 1.1.4 is complied with. Test weights are to be compact and of such a configuration that the VCG (vertical centre of gravity) of the weights can be accurately determined. Each weight is to be marked with an identification number and its weight. Recertification of the test weights is to be carried out prior to

the incline. A crane of sufficient capacity and reach, or some other means, is to be available during the inclining test to shift weights on the deck in an expeditious and safe manner.

Water ballast transfer may be carried out, when it is impractical to incline using solid weights and subject to requirement of 1.1.3.

Weights, such as porous concrete, that can absorb significant amounts of moisture should only be used if they are weighed just prior to the inclining test or if recent weight certificates are presented. Each weight should be marked with an identification number and its weight. For small ships, drums completely filled with water may be used.

Drums should normally be full and capped to allow accurate weight control. In such cases, the weight of the drums should be verified in the presence of a surveyor of the Society using a recently calibrated scale.

Precautions should be taken to ensure that the decks are not overloaded during weight movements. If deck strength is questionable then a structural analysis should be performed to determine if existing framing can support the weight.

Generally, the test weights should be positioned as far outboard as possible on the upper deck. The test weights should be on board and in place prior to the scheduled time of the inclining test.

1.1.3 Water ballast as inclining weight

Where the use of solid weights to produce the inclining moment is deemed to be impracticable, the movement of ballast water may be permitted as an alternative method.

This acceptance would be granted for a specific test only, and approval of the test procedure by the Society is required. As a minimal prerequisite for acceptability, the following conditions are to be required:

- inclining tanks are to be wall-sided and free of large stringers or other internal members that create air pockets
- tanks are to be directly opposite to maintain ship's trim
- specific gravity of ballast water is to be measured and recorded

- pipelines to inclining tanks are to be full. If the ship's piping layout is unsuitable for internal transfer, portable pumps and pipes/hoses may be used
- blanks must be inserted in transverse manifolds to prevent the possibility of liquids being "leaked" during transfer. Continuous valve control must be maintained during the test
- all inclining tanks must be manually sounded before and after each shift
- vertical, longitudinal and transverse centres are to be calculated for each movement
- accurate sounding/ullage tables are to be provided. The ship's initial heel angle is to be established prior to the incline in order to produce accurate values for volumes and transverse and vertical centres of gravity for the inclining tanks at every angle of heel. The draught marks amidships (port and starboard) are to be used when establishing the initial heel angle
- verification of the quantity shifted may be achieved by a flowmeter or similar device
- the time to conduct the inclining is to be evaluated. If time requirements for transfer of liquids are considered too long, water may be unacceptable because of the possibility of wind shifts over long periods of time.

1.1.4 Pendulums

The use of three pendulums is recommended but a minimum of two are to be used to allow identification of bad readings at any one pendulum station. However, for ships of a length equal to or less than 30 m, only one pendulum can be accepted. They are each to be located in an area protected from the wind. The pendulums are to be long enough to give a measured deflection, to each side of upright, of at least 15 cm. To ensure recordings from individual instruments are kept separate, it is suggested that the pendulums be physically located as far apart as practical.

The use of an inclinometer or U-tube is to be considered in each separate case. It is recommended that inclinometers or other measuring devices only be used in conjunction with at least one pendulum.

1.1.5 Free surface and slack tanks

The number of slack tanks should normally be limited to one port/starboard pair or one centreline tank of the following:

- fresh water reserve feed tanks
- fuel/diesel oil storage tanks
- fuel/diesel oil day tanks
- lube oil tanks
- sanitary tanks
- potable water tanks.

To avoid pocketing, slack tanks are normally to be of regular (i.e. rectangular, trapezoidal, etc.) cross section and be 20% to 80% full if they are deep tanks and 40% to 60% full if they are double-bottom tanks. These levels ensure that the rate of shifting of liquid remains constant throughout the heel angles of the inclining test. If the trim changes as the ship is inclined, then consideration are also to be given to longitudinal pocketing. Slack tanks containing liquids of sufficient viscosity to prevent free movement of the liquids, as the ship is inclined (such as bunker at low temperature), are to be avoided since the free surface cannot be calculated accurately. A free surface correction for such tanks is not to be used unless the tanks are heated to reduce viscosity. Communication between tanks are never to be allowed.

Cross-connections, including those via manifolds, are to be closed. Equal liquid levels in slack tank pairs can be a warning sign of open cross connections. A bilge, ballast, and fuel oil piping plan can be referred to, when checking for cross connection closures.

1.1.6 Means of communications

Efficient two-way communications are to be provided between central control and the weight handlers and between central control and each pendulum station. One person at a central control station is to have complete control ver all personnel involved in the test.

1.1.7 Documentation

The person in charge of the inclining test is to have available a copy of the following plans at the time of the test:

- lines plan
- hydrostatic curves or hydrostatic data
- general arrangement plan of decks, holds, inner bottoms, etc...
- capacity plan showing capacities and vertical and longitudinal centres of gravity of cargo spaces, tanks, etc.

When water ballast is used as inclining weights, the transverse and vertical centres of gravity for the applicable tanks, for each angle of inclination, must be available

- tank sounding tables
- draught mark locations, and
- docking drawing with keel profile and draught mark corrections (if available).

1.1.8 Determination of the displacement

The operations necessary for the accurate evaluation of the displacement of the ship at the time of the inclining test, as listed below, are to be carried out:

- draught mark readings are to be taken at aft, midship and forward, at starboard and port sides
- the mean draught (average of port and starboard reading) is to be calculated for each of the locations where draught readings are taken and plotted on the ship's lines drawing or outboard profile to ensure that all readings are consistent and together define the correct waterline. The resulting plot is to yield either a

straight line or a waterline which is either hogged or sagged. If inconsistent readings are obtained, the freeboards/ draughts are to be retaken

- the specific gravity of the sea water is to be determined.

Samples are to be taken from a sufficient depth of the water to ensure a true representation of the sea water and not merely surface water, which could contain fresh water from run off of rain. A hydrometer is to be placed in a water sample and the specific gravity read and recorded. For large ships, it is recommended that samples of the sea water be taken forward, midship and aft, and the readings averaged. For small ships, one sample taken from midship is sufficient. The temperature of the water is to be taken and the measured specific gravity corrected for deviation from the standard, if necessary.

A correction to water specific gravity is not necessary if the specific gravity is determined at the inclining experiment site. Correction is necessary if specific gravity is measured when the sample temperature differs from the temperature at the time of the inclining (e.g., if the check of specific gravity is performed at the office).

Where the value of the average calculated specific gravity is different from that reported in the hydrostatic curves, adequate corrections are to be made to the displacement curve

- all double bottoms, as well as all tanks and compartments which can contain liquids, are to be checked, paying particular attention to air pockets which may accumulate due to the ship's trim and the position of air pipes, and also taking into account the provisions of 1.1.1
- it is to be checked that the bilge is dry, and an evaluation of the liquids which cannot be pumped, remaining in the pipes, boilers, condenser, etc., is to be carried out
- the entire ship is to be surveyed in order to identify all items which need to be added, removed or relocated to bring the ship to the lightship condition. Each item is to be clearly identified by weight and location of the centre of gravity
- the possible solid permanent ballast is to be clearly identified and listed in the report.
- normally , the total value of missing weights is not to exceed 2% and surplus weights, excluding liquid ballast, not exceed 4% of the lightship displacement. For smaller vessels, higher percentages may be allowed.

1.1.9 The incline

The standard test generally employs eight distinct weight movements as shown in Figure 1.1.

Movement No.8, a recheck of the zero point, may be omitted if a straight line plot is achieved after movement No.7. If a straight line plot is achieved after the initial zero and six weight movements, the inclining test is complete and the second check at zero may be omitted. If a straight line plot is not achieved, those weight movements that did not yield acceptable plotted points should be repeated or explained.

The weights are to be transversally shifted, so as not to modify the ship's trim and vertical position of the centre of gravity.

After each weight shifting, the new position of the transverse centre of gravity of the weights is to be accurately determined.

After each weight movement, the distance the weight was moved (centre to centre) is to be measured and the heeling moment calculated by multiplying the distance by the amount of weight moved. The tangent is calculated for each pendulum by dividing the deflection by the length of the pendulum. The resultant tangents are plotted on the graph as shown in Figure 1.2.

The plot is to be run during the test to ensure that acceptable data are being obtained.

The pendulum deflection is to be read when the ship has reached a final position after each weight shifting.

During the reading, no movements of personnel are allowed.

For ships with a length equal to or less than 30 m, six distinct weight movements may be accepted.

Figure 1.1: Weight shift procedure

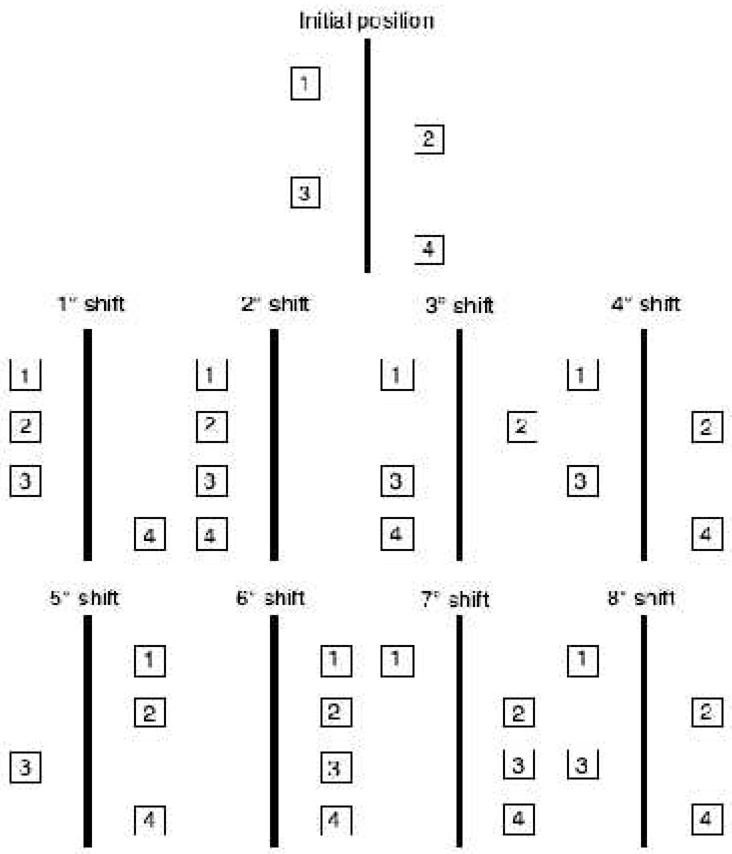
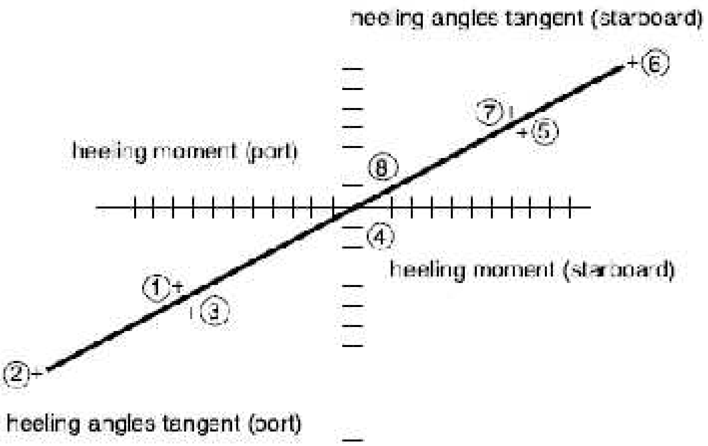


Figure 1.2: Graph of resultant tangents



Appendix 2 Trim and Stability Booklet

1 Trim and stability booklet

1.1 Information to be included in the trim and stability booklet

1.1.1 General

A trim and stability booklet is a stability manual, to be approved by the Society, which is to contain information to enable the Master to operate the ship in compliance with the applicable requirements contained in the Rules.

The format of the stability booklet and the information included vary depending on the ship type and operation.

1.1.2 List of information

The following information is to be included in the trim and stability booklet:

- a general description of the ship, including:
  - the ship's name and the Society classification number
  - the ship type and service notation
  - the class notations
  - the yard, the hull number and the year of delivery
  - the Flag, the port of registry, the international call sign and the IMO number
  - the molded dimensions
  - the draught corresponding to the assigned summer load line, the draught corresponding to the assigned summer timber load line and the draught corresponding to the tropical load line, if applicable
  - the displacement corresponding to the above- mentioned draughts
- instructions on the use of the booklet
- general arrangement and capacity plans indicating the assigned use of compartments and spaces (cargo, passenger, stores, accommodation, etc.)
- a sketch indicating the position of the draught marks referred to the ship's perpendiculars
- hydrostatic curves or tables corresponding to the design trim, and, if significant trim angles are foreseen during the normal operation of the ship, curves or tables corresponding to such range of trim are to be introduced. A reference relevant to the sea density, in t/m3, is to be included as well as the draught measure (from keel or underkeel)
- cross curves (or tables) of stability calculated on a free trimming basis, for the ranges of displacement and trim anticipated in normal operating conditions, with indication of the volumes which have been considered in the computation of these curves

- tank sounding tables or curves showing capacities, centres of gravity, and free surface data for each tank
- lightship data from the inclining test, as indicated in Ch.4 Sec.1/2.2, including lightship displacement, centre of gravity co-ordinates, place and date of the inclining test, as well as the Society approval details specified in the inclining test report. It is suggested that a copy of the approved test report be included

Where the above-mentioned information is derived from a sister ship, the reference to this sister ship is to be indicated, and a copy of the approved inclining test report relevant to this sister ship is to be included

- standard loading conditions as indicated in 1.2 and examples for developing other acceptable loading conditions using the information contained in the booklet
- intact stability results (total displacement and its centre of gravity co-ordinates, draughts at perpendiculars, GM, GM corrected for free surfaces effect, GZ values and curve, criteria as indicated in Ch. 4, Sec. 2/2 and Ch. 4, Sec. 2/3 as well as possible additional criteria specified in rules when applicable, reporting a comparison between the actual and the required values) are to be available for each of the above-mentioned operating conditions. The method and assumptions to be followed in the stability curve calculation are specified in 1.3
- information on loading restrictions (maximum allowable load on double bottom, maximum specific gravity allowed in liquid cargo tanks, maximum filling level or percentage in liquid cargo tanks, maximum KG or minimum GM curve or table which can be used to determine compliance with the applicable intact and damage stability criteria) when applicable
- information about openings (location, tightness, means of closure), pipes or other progressive flooding sources
- information concerning the use of any special crossflooding fittings with descriptions of damage conditions which may require cross-flooding, when applicable
- any other guidance deemed appropriate for the operation of the ship
- a table of contents and index for each booklet.

1.2 Loading conditions

1.2.1 General

The standard loading conditions to be included in the trim and stability booklet are:

- lightship condition
- ship in ballast in the departure condition, without cargo but with full stores and fuel
- ship in ballast in the arrival condition, without cargo and with 10% stores and fuel remaining.

Further loading cases may be included when deemed necessary or useful.

When a tropical freeboard is to be assigned to the ship, the corresponding loading conditions are also to be included.

1.2.2 Ships carrying cargo on deck

In addition to the loading conditions indicated in 1.2.1 to 1.2.13, in the case of cargo carried on deck the following cases are to be considered:

- ship in the fully loaded departure condition having cargo homogeneously distributed in the holds and a cargo specified in extension and weight on deck, with full stores and fuel
- ship in the fully loaded arrival condition having cargo homogeneously distributed in holds and a cargo specified in extension and weight on deck, with 10% stores and fuel.

1.2.3 General cargo ships

In addition to the standard loading conditions reported in 1.2.1, the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition, with cargo homogeneously distributed throughout all cargo spaces and with full stores and fuel
- ship in the fully loaded arrival condition with cargo homogeneously distributed throughout all cargo spaces and with 10% stores and fuel remaining.
- For ships with service notation general cargo ship completed by the additional feature nonhomload, the following loading cases are also to be included in the trim and stability booklet:
- ship in the departure condition, with cargo in alternate holds, for at least three stowage factors, one of which is relevant to the summer load waterline and with full stores and consumables Where the condition with cargo in alternate holds relevant to the summer load waterline leads to local loads on the double bottom greater than those allowed by the Society, it is to be replaced by the one in which each hold is filled in order to reach the maximum load allowed on the double bottom; in no loading case is such value to be exceeded
- same conditions as above, but with 10% stores and consumables.

1.2.4 Container ships

In addition to the standard loading conditions specified in 1.2.1, for ships with the service notation container ship the following loading cases are to be included in the trim and stability booklet:

- ship with a number of containers having a weight corresponding to the maximum permissible weight for each container at the summer load waterline when loaded with full stores and consumables
- same loading condition as above, but with 10% stores and consumables
- lightship condition with full stores and consumables
- lightship condition with 10% stores and consumables.

The vertical location of the centre of gravity for each container is generally to be taken at one half of the container height. Different locations of the vertical centre of gravity may be accepted in specific cases, if documented.

1.2.5 Bulk carriers, ore carriers and combination carriers

Dry cargo is intended to mean grain, as well as any other type of solid bulk cargo.

The term grain covers wheat, maize (corn), oats, rye, barley, rice, pulses, seeds and processed forms thereof, whose behavior is similar to that of grain in its natural state.

The term solid bulk cargo covers any material, other than liquid or gas, consisting of a combination of particles, granules or any larger pieces of material, generally uniform in composition, which is loaded directly into the cargo spaces of a ship without any intermediate form of containment.

In addition to the standard loading conditions defined in 1.2.1, for ships with the service notation bulk carrier ESP, ore carrier ESP and combination carrier ESP the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure conditions at the summer load waterline, with cargo homogeneously distributed throughout all cargo holds and with full stores and consumables, for at least three specific gravities, one of which is relevant to the complete filling of all cargo holds
- same conditions as above, but with 10% stores and consumables
- ship in the departure condition, with cargo holds not entirely filled, for at least three stowage factors, one of which is relevant to the summer load waterline and with full stores and consumables
- same conditions as above, but with 10% stores and consumables. or ships with one of the service notations ore carrier ESP and combination carrier ESP and for ships with the service notation bulk carrier ESP completed by the additional features BC-A or nonhomload, the following loading cases are also to be included in the trim and stability booklet:
- ship in the departure conditions, with cargo in alternate holds, for at least three stowage factors, one of which is relevant to the summer load waterline, and with full stores and consumables.

Where the condition with cargo in alternate holds relevant to the summer load waterline leads to local loads on the double bottom greater than those allowed by the Society, it is to be replaced by the one in which each hold is filled in order to reach the maximum load allowed on the double bottom; in no loading case is such value to be exceeded.

- same conditions as above, but with 10% stores and consumables.

1.2.6 Oil tankers and FLS tankers

All the intended cargo loading conditions are to be included in the trim and stability booklet for examination.

Further cases are subject to prior examination by the Society before the loading; alternatively, an approved loading instrument capable of performing damage stability calculations may be used.

In addition to the standard loading conditions specified in 1.2.1, for ships with the service notation oil tanker ESP or FLS tanker the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition at the summer load waterline, with cargo homogeneously distributed throughout all cargo tanks and with full stores and consumables
- same condition as above, but with 10% stores and consumables
- ship in the departure condition loaded with a cargo having a density in order to fill all cargo tanks, with full stores and consumables, but immersed at a draught less than the summer load waterline
- same condition as above, but with 10% stores and consumables
- ship in the fully loaded departure condition at the summer load waterline, with cargo tanks not entirely filled and with full stores and consumables
- same condition as above, but with 10% stores and consumables
- two loading conditions corresponding to different cargo segregations in order to have slack tanks with full stores and consumables When it is impossible to have segregations, these conditions are to be replaced by loading conditions with the same specific gravity and with slack cargo tanks
- same loading condition as above, but with 10% stores and consumables
- For oil tankers having segregated ballast tanks, the lightship condition with segregated ballast only is also to be included in the trim and stability booklet for examination.

1.2.7 Chemical tankers

All the intended cargo loading conditions are to be included in the trim and stability booklet for examination.

Further cases are subject to prior examination by the Society before the loading; alternatively, an approved loading instrument capable of performing damage stability calculations may be used.

In addition to the standard loading conditions defined in 1.2.1, for ships with the service notation chemical tanker ESP the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition, with cargo homogeneously distributed throughout all cargo tanks and with full stores and consumables
- same loading condition as above, but with 10% stores and consumables

- three loading conditions corresponding to different specific gravities with cargo homogeneously distributed throughout all cargo tanks and with full stores and consumables
- same loading conditions as above, but with 10% stores and consumables
- four loading conditions corresponding to different cargo segregations in order to have slack tanks with full stores and consumables. Cargo segregation is intended to mean loading conditions with liquids of different specific gravities

When it is impossible to have segregations, these conditions are to be replaced by loading conditions corresponding to different specific gravities with slack cargo tanks

- same loading conditions as above, but with 10% stores and consumables.

When it is impossible to have segregations, these conditions may be replaced by cases corresponding to different specific gravities with slack cargo tanks.

1.2.8 Liquefied gas carriers

All the intended cargo loading conditions are to be included in the trim and stability booklet for examination.

Further cases are subject to prior examination by the Society before the loading; alternatively, an approved loading instrument capable of performing damage stability calculations may be used.

In addition to the standard loading conditions defined in 1.2.1, for ships with the service notation liquefied gas carrier the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition, with cargo homogeneously distributed throughout all cargo spaces and with full stores and fuel
- ship in the fully loaded arrival condition with cargo homogeneously distributed throughout all cargo spaces and with 10% stores and fuel remaining.

1.2.9 Passenger ships

In addition to the standard loading conditions specified in 1.2.1, for ships with the service notation passenger ship the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition with full stores and fuel and with the full number of passengers with their luggage
- ship in the fully loaded arrival condition, with the full number of passengers and their luggage but with only 10% stores and fuel remaining
- ship without cargo, but with full stores and fuel and the full number of passengers and their luggage
- ship in the same condition as above, but with only 10% stores and fuel remaining.

1.2.10 Dredgers

For ships with one of the service notations dredger, hopper dredger, hopper unit, split hopper dredger and split hopper unit, the loading conditions described in a) and b) are to replace the standard loading conditions defined in 1.2.1.

a) State of cargo : liquid

- ship loaded to the dredging draught with cargo considered as a liquid
- hopper(s) fully loaded with a homogeneous cargo having density ρm, up to the spill out edge of the hopper coaming:

  $\rho_m = M_1 / V_1$

  M_1 : Mass of cargo, in t, in the hopper when loaded at the dredging draught

  V_1 : Volume, in m^3, of the hopper at the spill out edge of the hopper coaming

  The conditions of stores and fuel are to be equal to 100% and 10%, and an intermediate condition is to be considered if it is more critical than both 100% and 10%.

- hopper(s) filled or partly filled with a homogeneous cargo having densities equal to 1000, 1200, 1400, 1600, 1800 and 2000 kg/m3

When the dredging draught cannot be reached due to the density of the cargo, the hopper is to be considered filled up to the spill out edge of the hopper coaming.

The conditions of stores and fuel are to be the most conservative obtained from the stability calculations with the density ρ_m .

b) State of the cargo : solid

- ship loaded to the dredging draught with cargo considered as a solid
- hopper(s) fully loaded with a homogeneous cargo having density ρm up to the spill out edge of the hopper coaming, as calculated in a)

The conditions of stores and fuel are to be equal to 100% and 10%, and an intermediate condition is to be considered if it is more conservative than both 100% and 10%

- hopper(s) filled or partly filled with a homogeneous cargo having densities equal to 1400, 1600, 1800, 2000 and 2200 kg/m3 if greater than ρm.

1.2.11 Tugs and fire-fighting ships

In addition to the standard loading conditions defined in 1.2.1, for ships with one of the service notations tug and fire fighting ship the following loading cases are to be included in the trim and stability booklet:

- ship in the departure condition at the waterline corresponding to the maximum assigned immersion, with full stores, provisions and consumables
- same conditions as above, but with 10% stores and consumables.

1.2.12 Supply vessels

In addition to the standard loading conditions specified in 1.2.1, for ships with the service notation supply vessel the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition having under deck cargo, if any, and cargo specified by position and weight on deck, with full stores and fuel, corresponding to the worst service condition in which all the relevant stability criteria are met
- ship in the fully loaded arrival condition with cargo as specified above, but with 10 per cent stores and fuel
- vessel in the worst anticipated operating condition.

1.2.13 Fishing vessels

In addition to the standard loading conditions defined in 1.2.1, for ships with the service notation fishing vessel the following loading cases are to be included in the trim and stability booklet:

- departure conditions for the fishing grounds with full fuel stores, ice, fishing gear, etc.
- departure from the fishing grounds with full catch
- arrival at home port with 10% stores, fuel, etc. remaining and full catch
- arrival at home port with 10% stores, fuel, etc. and a minimum catch, which is normally to be 20% of the full catch but may be up to 40% if documented.

1.3 Stability curve calculation

1.3.1 General

Hydrostatic and stability curves are normally prepared on a designed trim basis. However, where the operating trim or the form and arrangement of the ship are such that change in trim has an appreciable effect on righting arms, such change in trim is to be taken into account.

The calculations are to take into account the volume to the upper surface of the deck sheathing.

1.3.2 Superstructures, deckhouses, etc. which may be taken into account

Enclosed superstructures may be taken into account.

The second tier of similarly enclosed superstructures may also be taken into account.

Deckhouses on the freeboard deck may be taken into account, provided that they comply with the conditions for enclosed superstructures.

Where deckhouses comply with the above conditions, except that no additional exit is provided to a deck above, such deckhouses are not to be taken into account; however, any deck openings inside such deckhouses are to be considered as closed even where no means of closure are provided.

Deckhouses, the doors of which do not comply with the relevant requirements, are not to be taken into account; however, any deck openings inside the deckhouse are regarded as closed where their means of closure comply with the requirements.

Deckhouses on decks above the freeboard deck are not to be taken into account, but openings within them may be regarded as closed.

Superstructures and deckhouses not regarded as enclosed may, however, be taken into account in stability calculations up to the angle at which their openings are flooded (at this angle, the static stability curve is to show one or more steps, and in subsequent computations the flooded space are to be considered non-existent).

Trunks may be taken into account. Hatchways may also be taken into account having regard to the effectiveness of their closures.

1.3.3 Angle of flooding

In cases where the ship would sink due to flooding through any openings, the stability curve is to be cut short at the corresponding angle of flooding and the ship is to be considered

to have entirely lost its stability.

Small openings such as those for passing wires or chains, tackle and anchors, and also holes of scuppers, discharge and sanitary pipes are not to be considered as open if they submerge at an angle of inclination more than 30°. If they submerge at an angle of 30° or less, these openings are to be assumed open if the Society considers this to be a source of significant progressive flooding; therefore such openings are to be considered on a case by case basis.

Appendix 3 Probabilistic Damage Stability Method for Cargo Ships

1 Probabilistic damage stability method for cargo ships

1.1 Application

1.1.1 The requirements included in this Appendix are to be applied to cargo ships over 80 m in length L_S, but are not to be applied to those ships which are shown to comply with subdivision and damage stability regulations already required in other parts of the rules.

Any reference hereinafter to regulations refers to the set of regulations contained in this Appendix.

The Society may for a particular ship or group of ships accept alternative arrangements, if it is satisfied that at least the same degree of safety as represented by these regulations is achieved.

This includes, for example, the following:

- ships constructed in accordance with a standard of damage stability with a set of damage criteria agreed by the Society
- ships of a multi-hull design, where the subdivision arrangements need to be evaluated against the basic principles of the probabilistic method since the regulations have been written specifically for mono-hulls.

1.1.2 The requirements of this appendix are to be applied in conjunction with the explanatory notes as set out by the IMO resolution MSC 281 (85).

1.2 Definitions

1.2.1 Deepest subdivision draught

The deepest subdivision draught (d_S) is the waterline which corresponds to the summer load line draught of the ship.

1.2.2 Light service draught

Light service draught (d_L) is the service draught corresponding to the lightest anticipated loading and associated tankage, including, however, such ballast as may be necessary for stability and/or immersion.

1.2.3 Partial subdivision draught

The partial subdivision draught (d_P) is the light service draught plus 60% of the difference between the light service draught and the deepest subdivision draught.

1.2.4 Subdivision length L_s

The subdivision length L_s is the greatest projected moulded length of that part of the ship at or below deck or decks limiting the vertical extent of flooding with the ship at the deepest subdivision draught.

1.2.5 Machinery space

Machinery spaces are spaces between the watertight boundaries of a space containing the main and auxiliary propulsion machinery, including boilers, generators and electric motors primarily intended for propulsion. In the case of unusual arrangements, the Society may define the limits of the machinery spaces.

1.2.6 Other definitions

Mid-length is the mid point of the subdivision length of the ship.

Aft terminal is the aft limit of the subdivision length.

Forward terminal is the forward limit of the subdivision length.

Breadth B is the greatest moulded breadth, in m, of the ship at or below the deepest subdivision draught.

Draught d is the vertical distance, in m, from the moulded baseline at mid-length to the waterline in question.

Permeability μ of a space is the proportion of the immersed volume of that space which can be occupied by water.

1.3 Required subdivision index R

1.3.1 These regulations are intended to provide ships with a minimum standard of subdivision.

The degree of subdivision to be provided is to be determined by the required subdivision index R, as follows:

• for ships over 100 m in L_S:

$$R = 1 - \frac{128}{(L_S + 152)}$$

where L_S is in m; and

• for ships of 80 m in L_S and upwards, but not exceeding 100 m in length L_S:

$$R = 1 - \frac{1}{\left(1 + \frac{L_S}{100}\frac{R_o}{(1 - R_o)}\right)}$$

where R_0 is the value R as calculated in accordance with the formula relevant to ships over 100 m in L_S.

1.4 Attained subdivision index A

1.4.1 The attained subdivision index A is obtained by the summation of the partial indices A_s, A_p and A_L, (weighted as shown) calculated for the draughts d_s, d_p and d_L defined in 1.2.1, 1.2.2 and 1.2.3 in accordance with the following formula:

$A = 0.4\ A_S + 0.4\ A_P + 0.2\ A_L$

The partial indices A_s, A_p and A_L are not to be less than 0.9 R for passenger ships and 0.5 R for cargo ships.

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

$A = \Sigma p_i s_i$

where:

i : Represents each compartment or group of compartments under consideration

p_i : Accounts for the probability that only the compartment or group of compartments under consideration may be flooded, disregarding any horizontal subdivision

s_i : Accounts for the probability of survival after flooding the compartment or group of compartments under consideration, including the effects of any horizontal subdivision.

1.4.3 In the calculation of A, the level trim is to be used for the deepest subdivision draught and the partial subdivision draught. The actual service trim is to be used for the light service draught. If in any service condition, the trim variation in comparison with the calculated trim is greater than 0.5% of L_S, one or more additional calculations of A are to be submitted for the same draughts but different trims so that, for all service conditions, the difference in trim in comparison with the reference trim used for one calculation will be less than 0.5% of L_S.

When determining the positive righting lever (GZ) of the residual stability curve, the displacement used is to be that of the intact condition. That is, the constant displacement method of calculation is to be used.

The summation indicated by the above formula is to be taken over the ship’s subdivision length (L_S) for all cases of flooding in which a single compartment or two or more adjacent compartments are involved. In the case of unsymmetrical arrangements, the calculated A value is to be the mean value obtained from calculations involving both sides.

Alternatively, it is to be taken as that corresponding to the side which evidently gives the least favourable result.

1.4.4 Wherever wing compartments are fitted, contribution to the summation indicated by the formula is to be taken for all cases of flooding in which wing compartments are involved. Additionally, cases of simultaneous flooding of a wing compartment or group of compartments and the adjacent inboard compartment or group of compartments, but excluding damage of transverse extent greater than one half of the ship breadth B, may be added. For the purpose of this regulation, transverse extent is measured inboard from ship’s side, at right angle to the centreline at the level of the deepest subdivision draught.

1.4.5 In the flooding calculations carried out according to the regulations, only one breach of the hull and only one free surface need to be assumed. The assumed vertical extent of damage is to extend from the baseline upwards to any watertight horizontal subdivision above the waterline or higher. However, if a lesser extent of damage will give a more severe result, such extent is to be assumed.

1.4.6 If pipes, ducts or tunnels are situated within the assumed extent of damage, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed flooded. However, the Society may permit minor progressive flooding if it is demonstrated that its effects can be easily controlled and the safety of the ship is not impaired.

1.5 Calculation of factor pi

1.5.1 The factor p_i for a compartment or group of compartments is to be calculated in accordance with 1.5.2 to 1.5.6 using the following notations:

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

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

k : The number of a particular longitudinal bulkhead as barrier for transverse penetration in a

damage zone counted from shell towards the centre line. The shell has k = 0

x_1 : The distance from the aft terminal of L_S to the aft end of the zone in question

x_2 : The distance from the aft terminal of L_S to the forward end of the zone in question

b : The mean transverse distance in metres measured at right angles to the centreline at the deepest subdivision draught between the shell and an assumed vertical plane extended between the longitudinal limits used in calculating the factor pi and which is a tangent to, or

common with, all or part of the outermost portion of the longitudinal bulkhead under consideration. This vertical plane is to be so orientated that the mean transverse distance to the shell is a maximum, but not more than twice the least distance between the plane and the shell. If the upper part of a longitudinal bulkhead is below the deepest subdivision draught the vertical plane used for determination of b is assumed to extend upwards to the deepest subdivision waterline. In any case, b is not to be taken greater than B/2.

If the damage involves a single zone only:

$p_i = p(x_{1(j)}, x_{2(j)}) \cdot [r(x_{1(j)}, x_{2(j)}, b_k) - r(x_{1(j)}, x_{2(j)}, b_{(k-1)})]$

If the damage involves two adjacent zones:

$p_i = p(x_{1(j)}, x_{2(j+1)}) \cdot [r(x_{1(j)}, x_{2(j+1)}, b_k) - r(x_{1(j)}, x_{2(j+1)}, b_{(k-1)})]$

$- p(x_{1(j)}, x_{2(j)}) \cdot [r(x_{1(j)}, x_{2(j)}, b_k) - r(x_{1(j)}, x_{2(j)}, b_{(k-1)})]$

$- p(x_{1(j+1)}, x_{2(j+1)}) \cdot [r(x_{1(j+1)}, x_{2(j+1)}, b_k) - r(x_{1(j+1)}, x_{2(j+1)}, b_{(k-1)})]$

If the damage involves three or more adjacent zones:

$p_i = p(x_{1(j)}, x_{2(j+n-1)}) \cdot [r(x_{1(j)}, x_{2(j+n-1)}, b_k) - r(x_{1(j)}, x_{2(j+n-1)}, b_{(k-1)})]$

$- p(x_{1(j)}, x_{2(j+n-2)}) \cdot [r(x_{1(j)}, x_{2(j+n-2)}, b_k) - r(x_{1(j)}, x_{2(j+n-2)}, b_{(k-1)})]$

$- p(x_{1(j+1)}, x_{2(j+n-1)}) \cdot [r(x_{1(j)}, x_{2(j+n-1)}, b_k) - r(x_{1(j+1)}, x_{2(j+n-1)}, b_{(k-1)})]$

$+ p(x_{1(j+1)}, x_{2(j+n-2)}) \cdot [r(x_{1(j+1)}, x_{2(j+n-2)}, b_k) - r(x_{1(j+1)}, x_{2(j+n-2)}, b)]$

and where $r(x_1, x_2, b_0) = 0$

1.5.2 The factor $p(x_1, x_2)$ is to be calculated according to the following formulae with:

J_{max} : Overall normalized max damage length

J_{max} = 10 /33

J_{kn} : Knuckle point in the distribution

J_{kn} = 5 /33

p_k : Cumulative probability at J_{kn}

p_k = 11 /12

l_{max} : Maximum absolute damage length

l_{max} = 60 m

L* : Length where normalized distribution ends

L* = 260 m

b_0 : Probability density at J = 0

$$b_0 = 2\left(\frac{p_k}{J_{kn}} - \frac{1-p_k}{J_{max} - J_{kn}}\right)$$

• When $L_S \le L^*$:

$$J_m = \min\{J_{max}, I_{max} / L_S\}$$

$$J_k = \frac{J_m}{2} + \frac{1-\sqrt{1+(1-2p_k)b_0 J_m + 0.25 b_0^2 J_m^2}}{b_0}$$

$$b_{12} = b_0$$

• When $L_S > L^*$:

$$J_m^* = \min\{J_{max}, I_{max} / L^*\}$$

$$J_k^* = \frac{J_m^*}{2} + \frac{1-\sqrt{1+(1-2p_k)b_0 J_m^* + 0.25 b_0^2 J_m^{*2}}}{b_0}$$

$$J_m = (J_m^* L^*)/L_S; \quad J_k = (J_k^* L^*)/L_S$$

$$b_{12} = 2\left(p_k / J_k - (1-p_k)/(J_m - J_k)\right)$$

$$b_{11} = 4(1-p_k)/((J_m - J_k)J_k) - 2p_k / J_k^2$$

$$b_{21} = -2(1-p_k)/(J_m - J_k)^2; \; b_{22} = -b_{12} J_m$$

The non-dimensional damage length:

$J = (x_2 - x_1)/L_s$

The normalized length of a compartment or group of compartments:

J_n is to be taken as lesser as J and J_m

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

- $J \le J_k$:

$$p(x_1,x_2) = p_1 = \frac{1}{6} J^2 (b_{11} J + 3 b_{12})$$

- $J > J_k$:

$$p(x_1,x_2) = p_2$$

$$= -\frac{b_{11} J_k^3}{3} + \frac{(b_{11} J - b_{12}) J_k^2}{2} + b_{12} J J_k - \frac{b_{21}(J_n^3 - J_k^3)}{3} + \frac{(b_{21} J - b_{22})(J_n^2 - J_k^2)}{2} + b_{12} J (J_n - J_k)$$

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

- $J \le J_k$:

$$p(x_1,x_2) = 0.5(p_1 + J)$$

- $J > J_k$:

$$p(x_1,x_2) = 0.5(p_2 + J)$$

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

$$p(x_1,x_2) = 1$$

1.5.6 The factor $r(x_1, x_2, b)$ is to be determined by the following formulae:

$$r(x_1,x_2,b) = 1 - (1 - C)\left[1 - G / p(x_1,x_2)\right]$$

where:

$$C = 12 J_b (-45 J_b + 4); \quad J_b = \frac{b}{15B}$$

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

$$G = G_1 = 0.5 b_{11} J_b^2 + b_{12} J_b$$

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

$$G=G_2=-\frac{1}{3}b_{11}J_0^3+0.5(b_{11}J-b_{12})J_0^2+b_{12}JJ_0$$

where:

$J_0=\min(J,J_b)$

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

$G=0.5\ (G_2 + G_1\ J)$

1.6 Calculation of factor si

1.6.1 The factor s_i is to be determined for each case of assumed flooding involving a compartment or group of compartments according to the requirement indicated in 1.6.2 to 1.6.9.

1.6.2 The factor s_i is to be obtained from the formula:

$$s_1=K\left[\frac{GZ_{max}}{0.12}\cdot\frac{Range}{16}\right]^{0.25}$$

where:

GZ_{max} : Maximum positive righting lever, in metres, up to the angle θ_v, GZ_{max} is not to be taken as more than 0.12 m

Range : Range of positive righting levers, in degrees, measured from the angle θ_e. The positive range is to be taken up to the angle θ_v. The range is not to be taken as more than 16°

θ_v : θ_v is the angle, where the righting lever becomes negative, or the angle at which an opening incapable of being closed weather tight becomes submerged

θ_e: Final equilibrium angle of heel (in degrees)

$K = 1$ if $\theta_e \le \theta_{min}$

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

otherwise:

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

where:

θ_{min} is equal to 25°

θ_{max} is equal to 30°

1.6.3 In all cases, s_i is to be taken as zero in those cases where the final waterline, taking into account sinkage, heel and trim, immerses:

- the lower edge of openings through which progressive flooding may take place and such flooding is not accounted for in the calculation of factor s_i. Such openings shall include air-pipes, ventilators and openings which are closed by means of weathertight doors or hatch covers; but openings closed by means of watertight manhole covers and flush scuttles, small watertight hatch covers, remotely operated sliding watertight doors, side scuttles of the non-opening type as well as watertight access doors and hatch covers required to be kept closed at sea need not be considered.
- immersion of any vertical escape hatch in the freeboard deck intended for compliance with the applicable requirements
- any controls intended for the operation of watertight doors, equalization devices, valves on piping or on ventilation ducts intended to maintain the integrity of watertight bulkheads from above the bulkhead deck become inaccessible or inoperable
- immersion of any part of piping or ventilation ducts carried through a watertight boundary that is located within any compartment included in damage cases contributing to the attained index A, if not fitted with watertight means of closure at each boundary.

1.6.4 Unsymmetrical flooding is to be kept to a minimum consistent with the efficient arrangements. Where it is necessary to correct large angles of heel, the means adopted

are, where practicable, to be self-acting, but in any case where controls to equalization devices are provided they are to be operable from above the bulkhead deck. These fittings

together with their controls shall be acceptable to the Society. Suitable information concerning the use of equalization devices shall be supplied to the master of the ship

1.6.5 Tanks and compartments taking part in such equalization is to be fitted with air pipes or equivalent means of sufficient cross-section to ensure that the flow of water into the equalization compartments is not delayed.

1.6.6 Where horizontal watertight boundaries are fitted above the waterline under consideration the s-value calculated for the lower compartment or group of compartments

is to be obtained by multiplying the value as determined in 1.6.2 by the reduction factor vm according to 1.6.7, which represents the probability that the spaces above the horizontal subdivision will not be flooded.

1.6.7 The factor v_m is to be obtained from the formula:

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

where:

$H_{j,\ n,\ m}$: Least height above the baseline, in metres, within the longitudinal range of $x_{1(j)}...x_{2(j+n-1)}$ of the mth horizontal boundary which is assumed to limit the vertical extent of flooding for the damaged compartments under consideration

$H_{j,\ n,\ m-1}$: Least height above the baseline, in metres, within the longitudinal range of $x_{1(j)}...x_{2(j+n-1)}$ of the $(m-1)^{th}$ horizontal boundary which is assumed to limit the vertical extent of flooding for the damaged compartments under consideration

j : The aft terminal of the damaged compartments under consideration

m : Each horizontal boundary counted upwards from the waterline under consideration

d : Draught in question as defined in 1.2

x_1 and x_2: Terminals of the compartment or group of compartments considered in 1.5.1.

1.6.8 The factors $\nu(H_{j,\ n,\ m,}\ d)$ and $\nu(H_{j,\ n,\ m-1,}\ d)$ are to be obtained from the formulas:

$\nu(H,d) = 0.8(H-d)/7.8$

if (H_m-d) is less than, or equal to 7.8 m,

$\nu(H,d) = 0.8+0.2[((H-d)-7.8)/4.7]$

in all other cases,

where:

- $\nu(H_{j,\ n,\ m},d)$ is to be taken as 1, if H_m coincides with the uppermost watertight boundary of the ship within the range $(x_{1(j)}...x_{2(j+n-1)})$
- $\nu(H_{j,\ n,\ 0},\ d)$ is to be taken as 0.

In no case is ν_m to be taken as less than zero or more than 1.

1.6.9 In general, each contribution dA to the index A in the case of horizontal subdivisions is obtained from the formula:

$dA=p_1[\nu_1 s_{min1}+ (\nu_2 - \nu_1)s_{min2} +\ldots+ (1-\nu_{m-1})s_{min\ m}]$

where:

ν_m : The ν-value calculated in accordance with 1.6.7 and 1.6.8

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

1.7 Permeability

1.7.1 For the purpose of the subdivision and damage stability calculations reported in this appendix, the permeability of each space or part of a space is to be as per Table 1.1.

Table 1.1: Permeabilities

Spaces	Permeabilities
Appropriated to stores	0.60
Occupied by accommodations	0.95
Occupied by machinery	0.85
Void spaces	0.95
Intended for liquids	0 or 0.95 (1)

(1) whichever results in the more severe requirements

1.7.2 For the purpose of the subdivision and damage stability calculations of the regulations, the permeability of each cargo compartment is to be as per Table 1.2.

Other figures for permeability may be used if substantiated by calculations.

1.8 Stability information

1.8.1 The master is to be supplied with such information satisfactory to the Society as is necessary to enable him by rapid and simple processes to obtain accurate guidance as to the stability of the ship under varying conditions of service. A copy of the stability information shall be furnished to the Society.

1.8.2 Information to be submitted:

- curves or tables of minimum operational metacentric height (GM) versus draught which assures compliance with the relevant intact and damage stability requirements, alternatively corresponding curves or tables of the maximum allowable vertical centre of gravity (KG) versus draught, or with the equivalents of either of these curves
- instructions concerning the operation of cross-flooding arrangements
- all other data and aids which might be necessary to maintain the required intact stability and stability after damage.

1.8.3 The stability information is to show the influence of various trims in cases where the operational trim range exceeds ±0.5% of L_S.

1.8.4 For ships which have to fulfil these stability requirements, information referred to above are determined from considerations related to the subdivision index, in the following manner: Minimum required GM (or maximum permissible vertical position of centre of gravity KG) for the three draughts d_s, d_p and d_l are equal to the GM (or KG values) of corresponding

loading cases used for the calculation of survival factor s_i. For intermediate draughts, values to be used are to be obtained by linear interpolation applied to the GM value only between the deepest subdivision draught and the partial subdivision draught and between the partial load line and the light service draught respectively. Intact stability criteria will also be taken into account by retaining for each draft the maximum among minimum required GM values or the minimum of maximum permissible KG values for both criteria. If the subdivision index is calculated for different trims, several required GM curves will be established in the same way

1.8.5 When curves or tables of minimum operational metacentric height (GM) versus draught are not appropriate, the master is to ensure that the operating condition does not deviate from a studied loading condition, or verify by calculation that the stability criteria are satisfied for this loading condition.

Table 1.2: Permeabilities of cargo compartments

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

Appendix 4 Damage Stability Calculation for Ships Assigned with a Reduced Freeboard

1 Application

1.1 General

1.1.1 The requirements of this Appendix apply to Type A ships having length greater than 150 m, Type B-60 ships and Type B-100 ships having a lenght greater than 100 m.

Any reference hereafter to regulations refers to the set of regulations contained in this Appendix.

2 Initial loading condition

2.1 Initial condition of loading

2.1.1 The initial condition of loading before flooding is to be determined according to 2.1.2 and 2.1.3.

2.1.2 The ship is loaded to its summer load waterline on an imaginary even keel.

2.1.3 When calculating the vertical centre of gravity, the following principles apply:

a) Homogeneous cargo is carried.

b) All cargo compartments, except those referred to under c), but including compartments intended to be partially filled, are to be considered fully loaded except that in the case of fluid cargoes each compartment is to be treated as 98 per cent full.

c) If the ship is intended to operate at its summer load waterline with empty compartments, such compartments are to be considered empty provided the height of the centre of gravity so calculated is not less than as calculated under b).

d) Fifty per cent of the individual total capacity of all tanks and spaces fitted to contain consumable liquids and stores is allowed for. It is to be assumed that for each type of liquid, at least one transverse pair or a single centre line tank has maximum free surface, and the tank or combination of tanks to be taken into account are to be those where the effect of free surfaces is the greatest; in each tank the centre of gravity of the contents is to be taken at the centre of volume of the tank. The remaining tanks are to be assumed either completely empty or completely filled, and the distribution of consumable liquids between these tanks is to be effected so as to obtain the greatest possible height above the keel for the centre of gravity.

e) At an angle of heel of not more than 5 degrees in each compartment containing liquids, as prescribed in b) except that in the case of compartments containing consumable fluids, as prescribed in d), the maximum free surface effect is to be taken into account.

f) Alternatively, the actual free surface effects may be used, provided the methods of calculation are acceptable to the Society.

g) Weights are to be calculated on the basis of Table 2.1.

Table 2.1: Specific gravities

Weight item	Specific gravity, in t/m^3
Salt water	1.025
Fresh water	1.000
Fuel oil	0.950
Diesel oil	0.900
Lubricating oil	0.900

3 Damage assumptions

3.1 Damage dimension

3.1.1 The principles indicated in 3.1.2 to 3.1.5 regarding the character of the assumed damage apply.

3.1.2 The vertical extent of damage in all cases is assumed to be from the base line upwards without limit.

3.1.3 The transverse extent of damage is equal to B/5 or 11.5 metres, whichever is the lesser, measured inboard from the side of the ship perpendicularly to the centre line at the level of the summer load waterline.

3.1.4 If damage of a lesser extent than specified in 3.1.2 and 3.1.3 results in a more severe condition, such lesser extent is to be assumed.

3.1.5 Except where otherwise required in 3.4.3, the flooding is to be confined to a single compartment between adjacent transverse bulkheads provided the inner longitudinal boundary of the compartment is not in a position within the transverse extent of assumed damage. Transverse boundary bulkheads of wing tanks, which do not extend over the full breadth of the ship are to be assumed not to be damaged, provided they extend beyond the transverse extent of assumed damage prescribed in 3.1.3.

3.2 Steps and recesses

3.2.1 If in a transverse bulkhead there are steps or recesses of not more than 3.05 metres in length located within the transverse extent of assumed damage as defined in 3.1.3, such transverse bulkhead may be considered intact and the adjacent compartment may be floodable singly. If, however, within the transverse extent of assumed damage there is a step or recess of more than 3.05 metres in length in a transverse bulkhead, the two compartments adjacent to this bulkhead are to be considered as flooded. The step formed by the after peak bulkhead and the after peak tank top is not to be regarded as a step for the purpose of this regulation.

3.2.2 Where a main transverse bulkhead is located within the transverse extent of assumed damage and is stepped in way of a double bottom or side tank by more than 3.05 metres, the double bottom or side tanks adjacent to the stepped portion of the main transverse bulkhead are to be considered as flooded simultaneously. If this side tank has openings into one or several holds, such as grain feeding holes, such hold or holds are to be considered as flooded simultaneously. Similarly, in a ship designed for the carriage of fluid cargoes, if a side tank has openings into adjacent compartments, such adjacent compartments are to be considered as empty and flooded simultaneously. This provision is applicable even where such openings are fitted with closing appliances, except in the case of sluice valves fitted in bulkheads between tanks and where the valves are controlled from the deck. Manhole covers with closely spaced bolts are considered equivalent to the unpierced bulkhead except in the case of openings in topside tanks making the topside tanks common to the holds.

3.2.3 Where a transverse bulkhead forming the forward or aft limit of a wing tank or double bottom tank is not in line with the main transverse bulkhead of the adjacent inboard compartment, it is considered to form a step or recess in the main transverse bulkhead.

Such a step or recess may be assumed not to be damaged provided that, either:

- the longitudinal extent of the step or recess, measured from the plan of the main transverse bulkhead, is not more than 3.05 metres, or
- any longitudinal surface forming the step or recess is located inboard of the assumed damage.

3.2.4 Where, otherwise, the transverse and longitudinal bulkheads bounding a main inboard compartment are entirely inboard of the assumed damage position, damage is assumed to occur between the transverse bulkheads and the adjacent wing compartment. Any step or recess in such wing tank is to be treated as indicated above.

Examples are shown in Figure 3.1 to Figure 3.4:

- Figure 3.1and Figure 3.2 refer to 3.2.2
- Figure 3.3 and Figure 3.4 refer to 3.2.1 and 3.2.2.

Figure 3.1: Step and recesses - Example 1

Compartments to be considered damaged simultaneously A+D, B+E, C+E+F

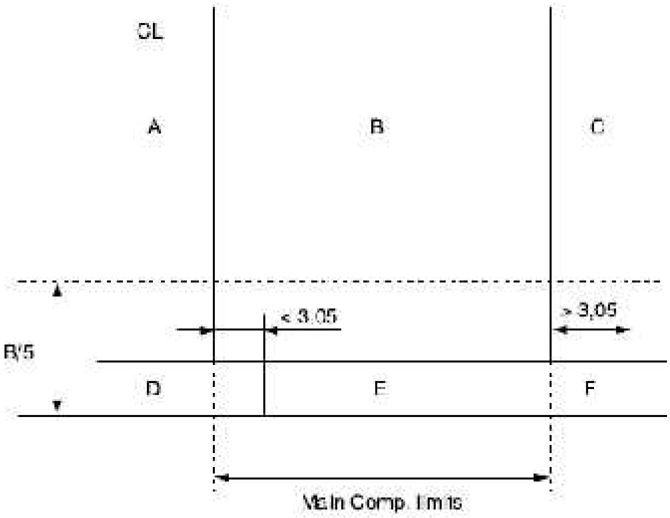


Figure 3.2: Step and recesses - Example 2

Compartments to be considered damaged simultaneously A+D+E, B+E

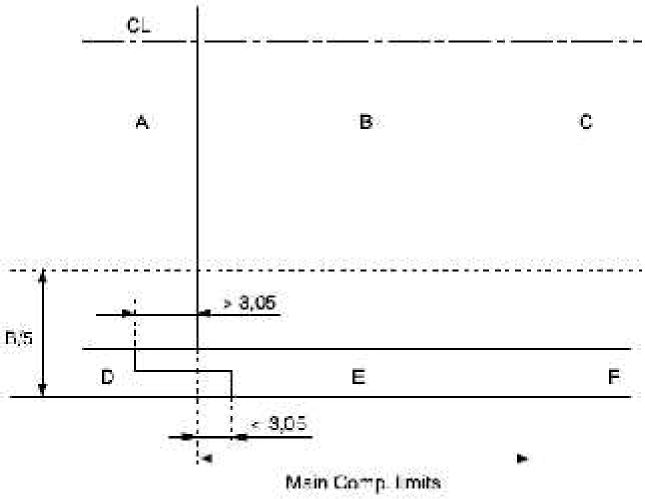


Figure 3.3: Step and recesses - Example 3

Compartments to be considered damaged simultaneously A+D, B+D+E

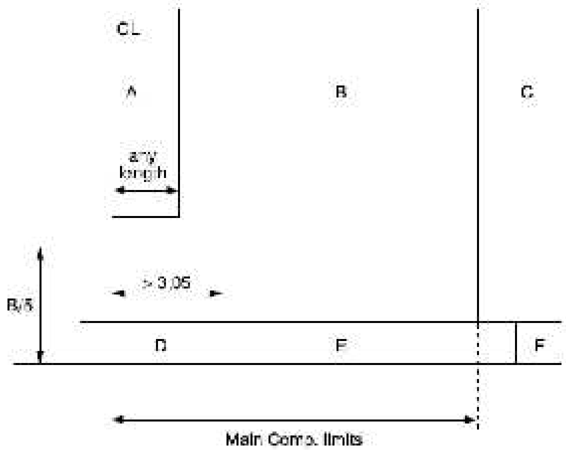
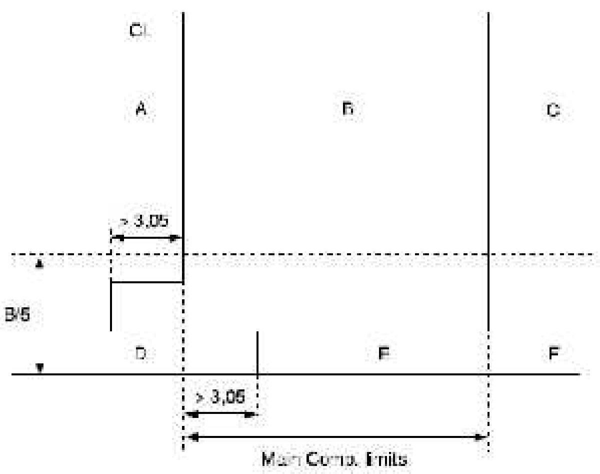


Figure 3.4: Step and recesses - Example 4

Compartments to be considered damaged simultaneously A+B+D, B+D+E



3.3 Transverse bulkhead spacing

3.3.1 Where the flooding of any two adjacent fore and aft compartments is envisaged, main transverse watertight bulkheads are to be spaced at least $1/3(L)^{2/3}$ or 14.5 metres, whichever is the lesser, in order to be considered effective.

Where transverse bulkheads are spaced at a lesser distance, one or more of these bulkheads are to be assumed as nonexistent in order to achieve the minimum spacing between bulkheads.

3.4 Damage assumption

3.4.1 A Type A ship, if over 150 metres in length to which a freeboard less than Type B has been assigned, when loaded as considered in 2.1, is to be able to withstand the flooding of any compartment or compartments, with an assumed permeability of 0.95, consequent upon the damage assumptions specified in 3.1, and is to remain afloat in a satisfactory condition of equilibrium as specified in 3.5 and 3.6. In such a ship, the machinery space is to be treated as a floodable compartment, but with a permeability of 0.85. See Table 3.1.

Table 3.1: Damage assumption

Type	L, in m	Standard of flooding (1)
A	≥ 150	one compartment
B-60	≥ 100	one compartment
B-100	≥ 100	two adjacent compartments (exemption for machinery space which is to be flooded alone)

(1) except where otherwise required by 4.2.

3.4.2 A Type B-60 ship, when loaded as considered in 2.1, is to be able to withstand the flooding of any compartment or compartments, with an assumed permeability of 0,95, consequent upon the damage assumptions specified in 3.1, and is to remain afloat in a satisfactory condition of equilibrium as specified in 3.5 and 3.6. In such a ship, if over 150 metres in length, the machinery space is to be treated as a floodable compartment, but with a permeability See Table 3.1.

3.4.3 A Type B-100 ship, when loaded as considered in 2.1, is to be able to withstand the flooding of any compartment or compartments, with an assumed permeability of 0,95, consequent upon the damage assumptions specified in 3.1, and is to remain afloat in a satisfactory condition of equilibrium as specified in 3.5 and 3.6. Furthermore all the requirements stated in 4.1 are to be complied with, provided that throughout the length of the ship any one transverse bulkhead will be assumed to be damaged, such that two adjacent fore and aft compartments are to be flooded simultaneously, except that such damage will not apply to the boundary bulkheads of a machinery space. In such a ship, if over 150 metres in length, the machinery space is to be treated as a floodable compartment, but with a permeability of 0,85. See Table 3.1.

3.5 Condition of equilibrium

3.5.1 The condition of equilibrium after flooding is to be regarded as satisfactory according to 3.5.2 and 3.5.3.

3.5.2 The final waterline after flooding, taking into account sinkage, heel and trim, is below the lower edge of any opening through which progressive downflooding may take place. Such openings are to include air pipes, ventilators and openings which are closed by means of weathertight doors or hatch covers, unless closed by watertight gasketed covers of steel or equivalent material, and may exclude those openings closed by means of manhole covers and flush scuttles, cargo hatch covers, remotely operated sliding watertight doors, and side scuttles of the non-opening type.

However, in the case of doors separating a main machinery space from a steering gear compartment, watertight doors may be of a hinged, quick acting type kept closed at sea, whilst not in use, provided also that the lower sill of such doors is above the summer load waterline.

3.5.3 If pipes, ducts or tunnels are situated within the assumed extent of damage penetration as defined in 3.1.3, arrangements are to be made so that progressive flooding cannot thereby extend to compartments other than those assumed to be floodable in the calculation for each case of damage.

3.6 Damage stability criteria

3.6.1 The angle of heel due to unsymmetrical flooding does not exceed 15 degrees. If no part of the deck is immersed, an angle of heel of up to 17 degrees may be accepted.

3.6.2 The metacentric height in the flooded condition is positive.

3.6.3 When any part of the deck outside the compartment assumed flooded in a particular case of damage is immersed, or in any case where the margin of stability in the flooded condition may be considered doubtful, the residual stability is to be investigated. It may be regarded as sufficient if the righting lever curve has a minimum range of 20 degrees beyond the position of equilibrium with a maximum righting lever of at least 0,1 metre within this range.

The area under the righting lever curve within this range is to be not less than 0,0175 metre-radians. The Society is to give consideration to the potential hazard presented by protected

or unprotected openings which may become temporarily immersed within the range of residual stability.

3.6.4 The Society is satisfied that the stability is sufficient during intermediate stages of flooding. In this regard, the Society will apply the same criteria relevant to the final stage, also during the intermediate stages of flooding.

4 Requirements for Type B-60 and B- 100 ships

4.1 Requirements for Type B-60 ships

4.1.1 Any Type B ships of over 100 metres, having hatchways closed by weathertight covers as specified in 4.3, may be assigned freeboards less than those required for Type B, provided that, in relation to the amount of reduction granted, the requirements in 4.1.2 to 4.1.4 are considered satisfactory by the Society.

In addition, the requirements stated in 3.4.2 are to be complied with.

4.1.2 The measures provided for the protection of the crew are to be adequate.

4.1.3 The freeing arrangements are to comply with the rules requirements.

4.1.4 The covers in positions 1 and 2 comply with the provisions of 4.3 and have strength complying with requirements, special care being given to their sealing and securing arrangements.

4.2 Requirements for Type B-100 ships

4.2.1 In addition to the requirements specified in 4.1, not taking into account the prescription stated in 3.4.2, the requirements in 4.2.2 to 4.2.4 are to be complied with.

In addition, the provisions of 3.4.3 are to be complied with.

4.2.2 Machinery casings

Machinery casings on Type A ships are to be protected by an enclosed poop or bridge of at least standard height, or by a deckhouse of equal height and equivalent strength, provided that machinery casings may be exposed if there are no openings giving direct access from the freeboard deck to the machinery space. A door complying with the requirements of 4.4 may, however, be permitted in the machinery casing, provided that it leads to a space or passageway which is as strongly constructed as the casing and is separated from the stairway to the engine room by a second weathertight door of steel or other equivalent material.

4.2.3 Gangway and access

An efficiently constructed fore and aft permanent gangway of sufficient strength is to be fitted on Type A ships at the level of the superstructure deck between the poop and the midship bridge or deckhouse where fitted, or equivalent means of access is to be provided to carry out the purpose of the gangway, such as passages below deck. Elsewhere, and on Type A ships without a midship bridge, arrangements to the satisfaction of the Society are to be provided to safeguard the crew in reaching all parts used in the necessary work of the ship.

Safe and satisfactory access from the gangway level is to be available between separate crew accommodation spaces and also between crew accommodation spaces and the machinery space.

4.2.4 Freeing arrangements

Type A ships with bulwarks are to be provided with open rails fitted for at least half the length of the exposed parts of the weather deck or other effective freeing arrangements.

The upper edge of the sheer strake is to be kept as low as practicable.

Where superstructures are connected by trunks, open rails are to be fitted for the whole length of the exposed parts of the freeboard deck.

4.3 Hatchways closed by weathertight covers of steel or other equivalent material fitted with gaskets and clamping devices

4.3.1 At positions 1 and 2 the height above the deck of hatchway coamings fitted with weathertight hatch covers of steel or other equivalent material fitted with gaskets and

clamping devices is to be:

• 600 millimetres if in position 1

• 450 millimetres if in position 2.

The height of these coamings may be reduced, or the coamings omitted entirely, upon proper justification. Where coamings are provided they are to be of substantial construction.

4.3.2 Where weathertight covers are of mild steel the strength is to be calculated with assumed loads according to rules.

4.3.3 The strength and stiffness of covers made of materials other than mild steel are to be equivalent to those of mild steel to the satisfaction of the Society.

4.3.4 The means for securing and maintaining weathertightness are to be to the satisfaction of the Society. The arrangements are to ensure that the tightness can be maintained in any sea conditions, and for this purpose tests for tightness are required at the initial survey, and may be required at periodical surveys and at annual inspections or at more frequent intervals.

4.4 Doors

4.4.1 All access openings in bulkheads at ends of enclosed superstructures are to be fitted with doors of steel or other equivalent material, permanently and strongly attached to the bulkhead, and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead and weathertight when closed. The means for securing these doors weathertight are to consist of gaskets and clamping devices or other equivalent means and are to be permanently attached to the bulkhead or to the doors themselves, and the doors are to be so arranged that they can be operated from both sides of the bulkhead.

4.4.2 Except as otherwise provided, the height of the sills of access openings in bulkheads at ends of enclosed superstructures is to be at least 380 millimetres above the deck.

Chapter 5 Equipment

Symbols

EN : Equipment Number defined in 2.1

σ_{ALL} : Allowable stress, in N/mm^2, used for the yielding check, to be taken as the lesser of:

• $\sigma_{ALL} = 0.67\ R_{eH}$

• $\sigma_{ALL} = 0.40\ R_m$

R_{eH} : Minimum yield stress, in N/mm^2, of the material

R_m : Tensile strength, in N/mm^2, of the material.

1 General

1.1 General

1.1.1 The requirements in 2 and 3 apply to temporary mooring of a ship within or near harbour, or in a sheltered area, when the ship is awaiting a berth, the tide, etc.

Therefore, the equipment complying with the requirements in 2 and 3 is not intended for holding a ship off fully exposed coasts in rough weather or for stopping a ship which is moving or drifting.

1.1.2 The equipment complying with the requirements in 2 to 4 is intended for holding a ship in good holding ground, where the conditions are such as to avoid dragging of the anchor. In poor holding ground the holding power of the anchors is to be significantly reduced.

1.1.3 It is assumed that under normal circumstances a ship will use one bow anchor only.

2 Equipment number

2.1 Equipment number

2.1.1 General

All ships are to be provided with equipment in anchors and chain cables (or ropes according to 3.2.5), to be obtained from Table 2.1, based on their Equipment Number EN.

In general, stockless anchors are to be adopted.

For ships with EN greater than 16000, the determination of the equipment will be considered by the Society on a case by case basis.

For ships having the navigation notation coastal area or sheltered area, the equipment in anchors and chain cables may be reduced. The reduction consists of entering in Table 2.1

one line higher for ships having the navigation notation coastal area and two lines higher for ships having the navigation notation sheltered area, based on their Equipment Number EN.

For ships of special design or ships engaged in special services or on special voyages, the Society may consider equipment other than that in Table 2.1.

2.1.2 Equipment Number for ships with perpendicular superstructure front bulkhead

The Equipment Number EN is to be obtained from the following formula:

$EN = \Delta^{2/3} + 2\,h\,B + 0.1\,A$

where:

Δ : Molded displacement of the ship, in tonnes, to the summer load waterline

h : Effective height, in m, from the summer load waterline to the top of the uppermost house, to be obtained in accordance with the following formula:

$h = a + \Sigma h_n$

When calculating h, sheer and trim are to be disregarded

a : Freeboard amidships from the summer load waterline to the upper deck, in m

h_n : Height, in m, at the centreline of tier "n" of superstructures or deckhouses having a breadth greater than B/4. Where a house having a breadth greater than B/4 is above a house with a breadth of B/4 or less, the upper house is to be included and the lower ignored

A : Area, in m^2, in profile view, of the parts of the hull, superstructures and houses above the summer load waterline which are within the length L_E and also have a breadth greater than B/4

L_E : Equipment length, in m, equal to L without being taken neither less than 96% nor greater

than 97% of the total length of the summer load waterline.

Fixed screens, fixed picture windows or bulwarks 1,5 m or more in height are to be regarded as parts of houses when determining h and A. In particular, the hatched area shown in Figure 2.1 is to be included. In case of non butt-jointed picture windows, only the efficient closed areas are to be included.

The height of hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining h and A.

Figure 2.1: Ships with perpendicular front bulkhead
Effective area of bulwarks or fixed screen to be included in the Equipment Number

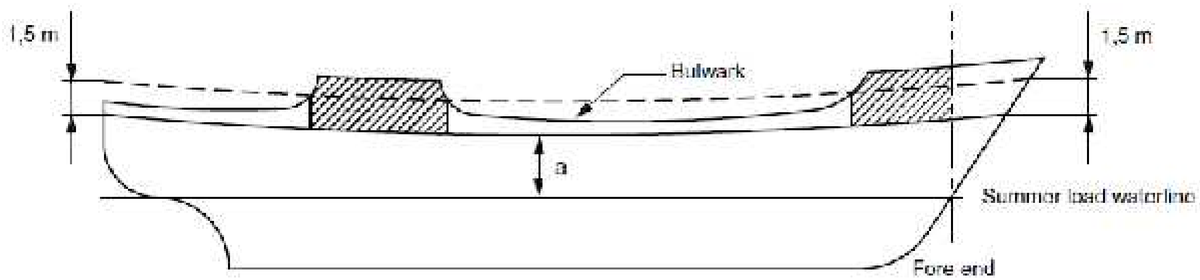


Table 2.1: Equipment

Equipment number EN; A < EN ≤ B		Stockless bower anchors		Stud link chain cables for bower anchors			
		N (1)	Mass per anchor, in kg	Total length in m	Diameter, in mm		
A	B				AC-K1	AC-K2	AC-K3
50	70	2	180	220,0	14,0	12,5	
70	90	2	240	220,0	16,0	14,0	
90	110	2	300	247,5	17,5	16,0	
110	130	2	360	247,5	19,0	17,5	
130	150	2	420	275,0	20,5	17,5	
150	175	2	480	275,0	22,0	19,0	
175	205	2	570	302,5	24,0	20,5	
205	240	3	660	302,5	26,0	22,0	20,5
240	280	3	780	330,0	28,0	24,0	22,0
280	320	3	900	357,5	30,0	26,0	24,0
320	360	3	1020	357,5	32,0	28,0	24,0
360	400	3	1140	385,0	34,0	30,0	26,0
400	450	3	1290	385,0	36,0	32,0	28,0
450	500	3	1440	412,5	38,0	34,0	30,0
500	550	3	1590	412,5	40,0	34,0	30,0
550	600	3	1740	440,0	42,0	36,0	32,0
600	660	3	1920	440,0	44,0	38,0	34,0
660	720	3	2100	440,0	46,0	40,0	36,0
720	780	3	2280	467,5	48,0	42,0	36,0
780	840	3	2460	467,5	50,0	44,0	38,0
840	910	3	2640	467,5	52,0	46,0	40,0
910	980	3	2850	495,0	54,0	48,0	42,0
980	1060	3	3060	495,0	56,0	50,0	44,0
1060	1140	3	3300	495,0	58,0	50,0	46,0
1140	1220	3	3540	522,5	60,0	52,0	46,0
1220	1300	3	3780	522,5	62,0	54,0	48,0
1300	1390	3	4050	522,5	64,0	56,0	50,0
1390	1480	3	4320	550,0	66,0	58,0	50,0
1480	1570	3	4590	550,0	68,0	60,0	52,0
1570	1670	3	4890	550,0	70,0	62,0	54,0
1670	1790	3	5250	577,5	73,0	64,0	56,0
1790	1930	3	5610	577,5	76,0	66,0	58,0
1930	2080	3	6000	577,5	78,0	68,0	60,0
2080	2230	3	6450	605,0	81,0	70,0	62,0
2230	2380	3	6900	605,0	84,0	73,0	64,0
2380	2530	3	7350	605,0	87,0	76,0	66,0
2530	2700	3	7800	632,5	90,0	78,0	68,0
2700	2870	3	8300	632,5	92,0	81,0	70,0
2870	3040	3	8700	632,5	95,0	84,0	73,0
3040	3210	3	9300	660,0	97,0	84,0	76,0
3210	3400	3	9900	660,0	100,0	87,0	78,0

Equipment number EN; A < EN ≤ B		Stockless bower anchors		Stud link chain cables for bower anchors			
		N (1)	Mass per anchor, in kg	Total length in m	Diameter, in mm		
A	B				AC-K1	AC-K2	AC-K3
3400	3600	3	10500	660,0	102,0	90,0	78,0
3600	3800	3	11100	687,5	105,0	92,0	81,0
3800	4000	3	11700	687,5	107,0	95,0	84,0
4000	4200	3	12300	687,5	111,0	97,0	87,0
4200	4400	3	12900	715,0	114,0	100,0	87,0
4400	4600	3	13500	715,0	117,0	102,0	90,0
4600	4800	3	14100	715,0	120,0	105,0	92,0
4800	5000	3	14700	742,5	122,0	107,0	95,0
5000	5200	3	15400	742,5	124,0	111,0	97,0
5200	5500	3	16100	742,5	127,0	111,0	97,0
5500	5800	3	16900	742,5	130,0	114,0	100,0
5800	6100	3	17800	742,5	132,0	117,0	102,0
6100	6500	3	18800	742,5		120,0	107,0
6500	6900	3	20000	770,0		124,0	111,0
6900	7400	3	21500	770,0		127,0	114,0
7400	7900	3	23000	770,0		132,0	117,0
7900	8400	3	24500	770,0		137,0	122,0
8400	8900	3	26000	770,0		142,0	127,0
8900	9400	3	27500	770,0		147,0	132,0
9400	10000	3	29000	770,0		152,0	132,0
10000	10700	3	31000	770,0			137,0
10700	11500	3	33000	770,0			142,0
11500	12400	3	35500	770,0			147,0
12400	13400	3	38500	770,0			152,0
13400	14600	3	42000	770,0			157,0
14600	16000	3	46000	770,0			162,0

(1) See [3.1.4].

2.1.3 Anchoring equipment for EN below 50

The Society may accept ships with low equipment number (30< EN ≤ 50), on a case-by-case basis. Anchors and stud link chain cables are to be fitted according to the values in Table 2.2.

At the discretion of the Society, reductions of the anchoring equipment may be permitted for ships having special service and/or navigation notation on a case-by-case basis.

However, the design of such equipment is to comply with the present section and the requirements.

Table 2.2: Equipment for 30 < EN ≤ 50

Stockless bower anchors		Stud link chain cables for bower anchors		
N	Mass per anchor, in kg	Total length in m	Diameter, in mm	
			AC-K1	AC-K2
2	120	192.5	12.5	11

3 Anchoring equipment

3.1 Anchors

3.1.1 General

The anchors are to be of an approved type and satisfy the testing conditions laid down in Part 2, Materials and Welding.

The scantlings of anchors are to be in compliance with 3.1.2 to 3.1.7.

Anchors are to be constructed and tested in compliance with approved plans.

3.1.2 Ordinary anchors

The required mass for each bower anchor is to be obtained from Table 2.1.

The individual mass of a main anchor may differ by ±7% from the mass required for each anchor, provided that the total mass of anchors is not less than the total mass required in Table 2.1.

The mass of the head of an ordinary stockless anchor, including pins and accessories, is to be not less than 60% of the total mass of the anchor.

Where a stock anchor is provided, the mass of the anchor, excluding the stock, is to be not less than 80% of the mass required in Table 2.1 for a stockless anchor. The mass of the stock is to be not less than 25% of the mass of the anchor without the stock but including the connecting shackle.

3.1.3 High and very high holding power anchors High Holding Power (HHP) and Very High Holding Power (VHHP) anchors, i.e. anchors for which a holding power higher than that of ordinary anchors has been proved, do not require prior adjustment or special placement on the sea bottom.

Where HHP or VHHP anchors are used as bower anchors, the mass of each anchor is to be not less than 75% or 50%, respectively, of that required for ordinary stockless bower anchors in Table 2.1.

The mass of VHHP anchors is to be, in general, less than or equal to 1500 kg.

3.1.4 Third anchor

Where three bower anchors are provided, two are to be connected to their own chain cables and positioned on board always ready for use.

The third bower anchor is intended as a spare and is not required for the purpose of classification.

3.1.5 Test for high holding power anchors approval

For approval of a HHP anchor, comparative tests are to be performed on various types of sea bottom. Such tests are to show that the holding power of the HHP anchor is at least twice the holding power of an ordinary stockless anchor of the same mass.

For approval as HHP anchors of a whole range of mass, such tests are to be carried out on anchors whose sizes are, as far as possible, representative of the full range of masses proposed. In this case, at least two anchors of different sizes are to be tested. The mass of the maximum size to be approved is to be not greater than 10 times the maximum size tested. The mass of the smallest is to be not less than 0.1 times the minimum size tested.

3.1.6 Test for very high holding power anchors approval

For approval of a VHHP anchor, comparative tests are to be performed at least on three types of sea bottom: soft mud or silt, sand or gravel and hard clay or similar compounded material. Such tests are to show that the holding power of the VHHP anchor is to be at least four times the holding power of an ordinary stockless anchor of the same mass or at least twice the holding power of a previously approved HHP anchor of the same mass.

The holding power test load is to be less than or equal to the proof load of the anchor.

For approval as VHHP anchors of a whole range of mass, such tests are to be carried out on anchors whose sizes are, as far as possible, representative of the full range of masses proposed. In this case, at least three anchors of different sizes are to be tested. relevant to the bottom, middle and top of the mass range.

3.1.7 Specification for test on high holding power and very high holding power anchors

Tests are generally to be carried out from a tug. Shore based tests may be accepted by the Society on a case-by-case basis.

Alternatively, sea trials by comparison with a previous approved anchor of the same type (HHP or VHHP) of the one to be tested may be accepted by the Society on a caseby- case basis.

For each series of sizes, the two anchors selected for testing (ordinary stockless and HHP anchors for testing HHP anchors, ordinary stockless and VHHP anchors or, when ordinary stockless anchors are not available, HHP and VHHP anchors for testing VHHP anchors) are to have the same mass.

The length of chain cable connected to each anchor, having a diameter appropriate to its mass, is to be such that the pull on the shank remains practically horizontal. For this purpose a value of the ratio between the length of the chain cable paid out and the water depth equal to 10 is considered normal. A lower value of this ratio may be accepted by the Society on a case-by-case basis.

Three tests are to be carried out for each anchor and type of sea bottom.

The pull is to be measured by dynamometer; measurements based on the RPM/bollard pull curve of tug may, however, be accepted instead of dynamometer readings.

Note is to be taken where possible of the stability of the anchor and its ease of breaking out.

3.2 Chain cables for bower anchors

3.2.1 Material

The chain cables are classified as grade AC-K1, AC-K2 or AC-K3 depending on the type of steel used and its manufacture.

The characteristics of the steel used and the method of manufacture of chain cables are to be approved by the Society for each manufacturer. The material from which chain cables are manufactured and the completed chain cables themselves are to be tested in accordance with the applicable requirements of rules.

Chain cables made of grade AC-K1 may not be used with high holding power and very high holding power anchors.

3.2.2 Scantlings of stud link chain cables The mass and geometry of stud link chain cables, including the links, are to be in compliance with the requirements in the rules.

The diameter of stud link chain cables is to be not less than the value in Table 2.1.

3.2.3 Studless link chain cables

For ships with EN less than 90, studless short link chain cables may be accepted by the Society as an alternative to stud link chain cables, provided that the equivalence in strength is based on proof load and that the steel grade of the studless chain is equivalent to the steel grade of the stud chains it replaces, as defined in 3.2.1.

3.2.4 Chain cable arrangement

Chain cables are to be made by lengths of 27,5 m each, joined together by Dee or lugless shackles.

The total length of chain cable, required in Table 2.1, is to be divided in approximately equal parts between the two anchors ready for use.

Where different arrangements are provided, they are considered by the Society on a case-by-case basis.

Where the ship may anchor in areas with current speed greater than 2,5 m/s, the Society may require a length of heavier chain cable to be fitted between the anchor and the rest of the chain in order to enhance anchor bedding.

3.2.5 Wire ropes

As an alternative to the stud link or short link chain cables mentioned, wire ropes may be used in the following cases:

- wire ropes for both the anchors, for ship length less than 30 m
- wire rope for one of the two anchors, for ship length between 30 m and 40 m.

The wire ropes above are to have a total length equal to 1,5 times the corresponding required length of stud link chain cables, obtained from Table 2.1, and a minimum breaking load equal to that given for the corresponding stud link chain cable (see 3.2.2).

A short length of chain cable is to be fitted between the wire rope and the anchor, having a length equal to 12,5m or the distance from the anchor in the stowed position to the winch, whichever is the lesser.

3.3 Attachment pieces

3.3.1 General

Where the lengths of chain cable are joined to each other by means of shackles of the ordinary Dee type, the anchor may be attached directly to the end link of the first length of

chain cable by a Dee type end shackle.

A detachable open link in two parts riveted together may be used in lieu of the ordinary Dee type end shackle; in such case the open end link with increased diameter, defined in 3.3.2, is to be omitted.

Where the various lengths of chain cable are joined by means of lugless shackles and therefore no special end and increased diameter links are provided, the anchor may be

attached to the first length of chain cable by a special pear shaped lugless end shackle or by fitting an attachment piece.

3.3.2 Scantlings

The diameters of the attachment pieces, in mm, are to be not less than the values indicated in Table 3.1.

Attachment pieces may incorporate the following items between the increased diameter stud link and the open end link:

• swivel, having diameter = 1.2 d

• increased stud link, having diameter = 1.1 d

Where different compositions are provided, they will be considered by the Society on a case-by-case basis.

Table 3.1: Diameters of attachment pieces

Attachment piece	Diameter, in mm
End shackle	1.4 d
Open end link	1.2 d
Increased stud link	1.1 d
Common stud link	d
Lugless shackle	d

Note 1:

d: Diameter, in mm, of the common link.

3.3.3 Material

Attachment pieces, joining shackles and end shackles are to be of such material and design as to provide strength equivalent to that of the attached chain cable, and are to be tested in accordance with the applicable requirements.

3.4 Hawse pipes

3.4.1 Hawse pipes are to be of substantial construction.

Their position and slope are to be arranged so as to facilitate housing and dropping of the anchors and avoid damage to the hull during these operations. The parts on which the chains bear are to be rounded to a suitable radius.

3.4.2 All mooring units and accessories, such as timbler, riding and trip stoppers are to be securely fastened to the Surveyor's satisfaction.

3.5 Windlass

3.5.1 General

The windlass is to be power driven and suitable for the size of chain cable and the mass of the anchors.

In mechanically propelled ships of less than 200 t gross tonnage, a hand-operated windlass may be fitted.

The windlass is to be fitted in a suitable position in order to ensure an easy lead of the chain cables to and through the hawse pipes. The deck in way of the windlass is to be suitably reinforced.

3.5.2 Windlass brake

A windlass brake is to be provided with sufficient capacity (Holding Load), to stop the anchor and the chain cable during all stages of mooring manoeuvres. Additionally, the

capacity (Holding Load), if the windlass brake is to be sufficient for safe stopping of anchor and chain cable when paying the chain.

Based on mooring line arrangements, the capacity (Holding Load), HL in kN, of the windlass brake is to be sufficient to withstand the loads as follows:

- If a chain stopper is not fitted, the windlass with brakes engaged and cable lifters is engaged is to be able to withstand a pull load of 80% of the breaking load of the chain, BL, in kN, without any permanent deformation of the stressed parts and without brake slip
- If a chain stopper is fitted, the windlass with brakes engaged and cable lifters disengaged is to be able to withstand a pull load of 20% of the breaking load of the chain, BL, in kN, without any permanent deformation of the stressed parts and without brake slip.

Alternatively, at the request of the interested parties, if duly justified, other values of windlass brake capacity (Holding Load) may be accepted by the Society on a case by case basis. The brake capacity (Holding Load), HL, in kN, is to be therefore verified by test and/or calculations at the satisfaction of the Society and this acceptance is to be formally documented on an annex to the Classification certificate.

Windlass brake capacity (Holding Load), HL, in kN, is to be assessed, among other performances to be reached, during workshop/facilities tests.

3.5.3 Chain stoppers

Where a chain stopper is fitted, it is to be able to withstand a pull of 80% of the breaking load of the chain.

The attention of manufacturers and designers is driven to the fact that where a chain cable stopper is fitted, the windlass brake is to comply with 3.5.2

3.5.4 Connection with deck

The windlass, its frame and the stoppers are to be efficiently bedded to the deck.

3.6 Additional requirements for windlasses located on fore deck

3.6.1 General

Additional requirements provided under this sub-article apply only to windlasses located within the forward quarter length of the ship.

These requirements apply to all ship types of sea going service of length 80 m or more, where the height of the exposed deck in way of the item is less than 0.1 L or 22 m above the summer load waterline, whichever is the lesser.

Where mooring winches are integral with the anchor windlass, they are to be considered as part of the windlass.

The strength of deck framing and hull structure supporting the windlass and its securing bolt loads as defined in 3.6.2 is to be checked according to relevant rules requirements, as applicable.

3.6.2 Loading

The following pressures and associated areas are to be applied (see Figure 3.1):

- 200 kN/m^2 normal to the shaft axis and away from the forward perpendicular, over the projected area in this direction
- 150 kN/m^2 parallel to the shaft axis and acting both inboard and outboard separately, over the multiple of f times the projected area in this direction,

where:

f = 1 + B / H, without being greater than 2.5

B : Width of windlass measured parallel to the shaft axis

H : Overall height of windlass.

Forces in the bolts, chocks and stoppers securing the windlass to the deck are to be calculated. The windlass is supported by N bolt groups, each containing one or more bolts,

see Figure 3.2.

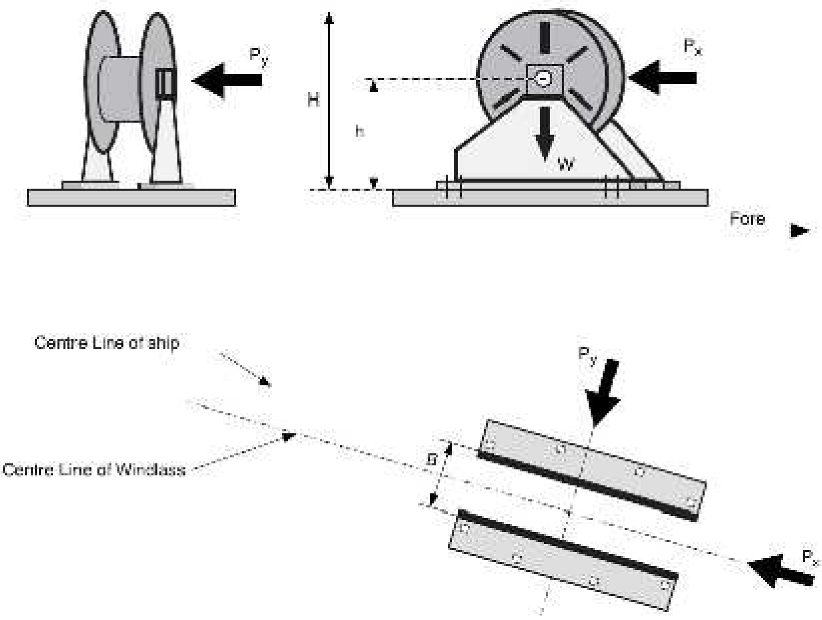
The axial force R_i in bolt group (or bolt) i, positive in tension, may be calculated from:

$R_{xi} = (P_x \, h \, x_i \, A_i) / I_x$

$R_{yi} = (P_y\ h\ y_i\ A_i) / I_y$

$R_i = R_{xi} + R_{yi} - R_{si}$

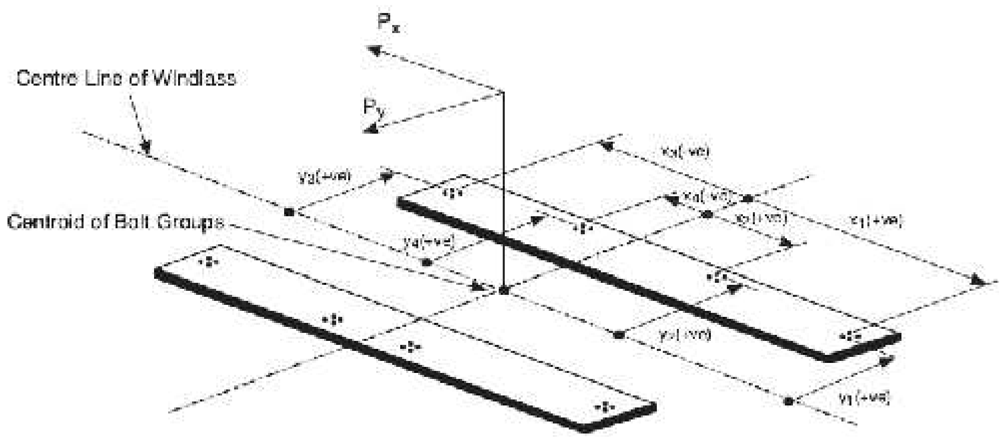
Figure 3.1: Direction of forces and weight



Note that P_y is to be examined from both inboard and outboard directions separately -see 3.6.2

The sign convention for y_i is reversed when P_y is from the opposite direction as shown.

Figure 3.2: Sign convention



Coordinates xi and yi are shown as either positive (+ve) or negative (−ve).

where:

P_x : Force, in kN, acting normal to the shaft axis

P_y : Force, in kN, acting parallel to the shaft axis, either inboard or outboard whichever gives the greater force in bolt group i

h : Shaft height above the windlass mounting, in cm

x_i, y_i : x and y coordinates of bolt group i from the centroid of all N bolt groups, positive in the direction opposite to that of the applied force, in cm

A_i : Cross sectional area of all bolts in group i, in cm^2

I_x : $\Sigma A_i x_i^2$ for N bolt groups

Iy : $\Sigma A_i y_i^2$ for N bolt groups

R_{si} : Static reaction at bolt group i, due to weight of windlass.

Shear forces F_{xi} , F_{yi} applied to the bolt group i, and the

resultant combined force Fi may be calculated from:

$F_{xi} = (P_x - \alpha g M) / N$

$F_{yi} = (P_y - \alpha g M) / N$

$Fi = (F_{xi}^2 + F_{yi}^2)^{0.5}$

where:

α : Coefficient of friction, taken equal to 0.5

M : Mass of windlass, in tonnes

g : Gravity acceleration, taken equal to 9.81 m/s^2

N : Number of bolt groups.

The design of the supporting structure are to take also into account the axial tensile and compressive forces R_{xi} , R_{yi} , R_i, and lateral forces F_{xi} , F_{yi} , F_i , calculated for bolt groups according to formulae above.

3.6.3 Strength requirements

Tensile axial stresses in the individual bolts in each bolt group i are to be calculated. The horizontal forces F_{xi} and F_{yi} are normally to be reacted by shear chocks. Where "fitted" bolts are designed to support these shear forces in one or both directions, the von Mises equivalent stresses in the individual bolts are to be calculated, and compared to the stress under proof load. Where pour-able resins are incorporated in the holding down arrangements, due account is to be taken in the calculations.

The safety factor against bolt proof strength is to be not less than 2.0.

3.7 Chain stoppers

3.7.1 A chain stopper is generally to be fitted between the windlass and the hawse pipe in order to relieve the windlass of the pull of the chain cable when the ship is at anchor. A chain stopper is to be capable of withstanding a pull of 80% of the breaking load of the chain cable. The deck at the chain stopper is to be suitably reinforced.

For the same purpose, a piece of chain cable may be used with a rigging screw capable of supporting the weight of the anchor when housed in the hawse pipe or a chain tensioner.

Such arrangements are not to be considered as chain stoppers.

3.7.2 Where the windlass is at a distance from the hawse pipes and no chain stoppers are fitted, suitable arrangements are to be provided to lead the chain cables to the windlass.

3.8 Chain locker

3.8.1 The capacity of the chain locker is to be adequate to stow all chain cable equipment and provide an easy direct lead to the windlass.

3.8.2 Where two chains are used, the chain lockers are to be divided into two compartments, each capable of housing the full length of one line.

3.8.3 The inboard ends of chain cables are to be secured to suitably reinforced attachments in the structure by means of end shackles, whether or not associated with attachment pieces.

Generally, such attachments are to be able to withstand a force not less than 15% of the breaking load of the chain cable.

In an emergency, the attachments are to be easily released from outside the chain locker.

3.8.4 Where the chain locker is arranged aft of the collision bulkhead, its boundary bulkheads are to be watertight and a drainage system is to be provided.

3.8.5 Spurling pipes and chain lockers are to be watertight up to the weather deck.

Bulkheads between separate chain lockers (see Ch.2 Sec.9 Figure 2.3, Arrangement 1) or which form a common boundary of chain lockers (see Ch.2 Sec.9 Figure 2.3, Arrangement 2), need not however be watertight.

3.8.6 Where means of access is provided, it is to be closed by a substantial cover and secured by closely spaced bolts.

3.8.7 Spurling pipes through which anchor cables are led are to be provided with permanently attached closing appliances, to minimize water ingress (for example steel plates with cutouts to accommodate chain links or canvas hoods with a lashing arrangement that maintains the cover in the secured position).

4 Emergency towing arrangements

4.1 Definitions

4.1.1 Deadweight

Deadweight is the difference, in t, between the displacement of a ship in water of a specific gravity of 1,025 t/m^3 at the summer load line corresponding to the assigned summer freeboard and the lightweight of the ship.

4.2 Application

4.2.1 The requirements of this Article apply to equipment arrangement for towing ships out of danger in emergencies such as complete mechanical breakdowns, loss of power or loss of steering capability.

The concerned ships are:

- the ships as defined in 4.2.2
- all ships when the additional class notation Emergency Towing Arrangement is assigned

4.2.2 An emergency towing arrangement is to be fitted at both ends on board of ships of 20000 t deadweight and above with one of the following service notations:

- combination carrier ESP
- oil tanker ESP
- FLS tanker
- chemical tanker ESP
- liquefied gas carrier.

4.3 Documentation

4.3.1 Documentation for approval

The following additional documentation is to be submitted to the Society for approval:

- general layout of the bow and stern towing arrangements and associated equipment
- operation manual for the bow and stern towing arrangements
- construction drawings of the bow and stern strongpoints (towing brackets or chain cable stoppers) and fairleads (towing chocks), together with material specifications and relevant calculations
- drawings of the local ship structures supporting the loads applied by strongpoints, fairleads and roller pedestals.

4.3.2 Documentation for information

The following documentation is to be submitted to the Society for information:

- specifications of chafing gears, towing pennants, pickup gears and roller fairleads
- height, in m, of the lightest seagoing ballast freeboard measured at stern towing fairlead
- deadweight, in t, of the ship at summer load line.

4.4 General

4.4.1 Scope

The emergency towing arrangements are to be so designed as to facilitate salvage and emergency towing operations on the concerned ship, primarily to reduce the risk of pollution.

4.4.2 Main characteristics

The emergency towing arrangements are, at all times, to be capable of rapid deployment in the absence of main power on the ship to be towed and easy connection to the towing ship.

To demonstrate such rapid and easy deployment, the emergency towing arrangements are to comply with the requirements in 4.12.

4.4.3 Typical layout

Figure 4.1 shows an emergency towing arrangement which may be used as reference.

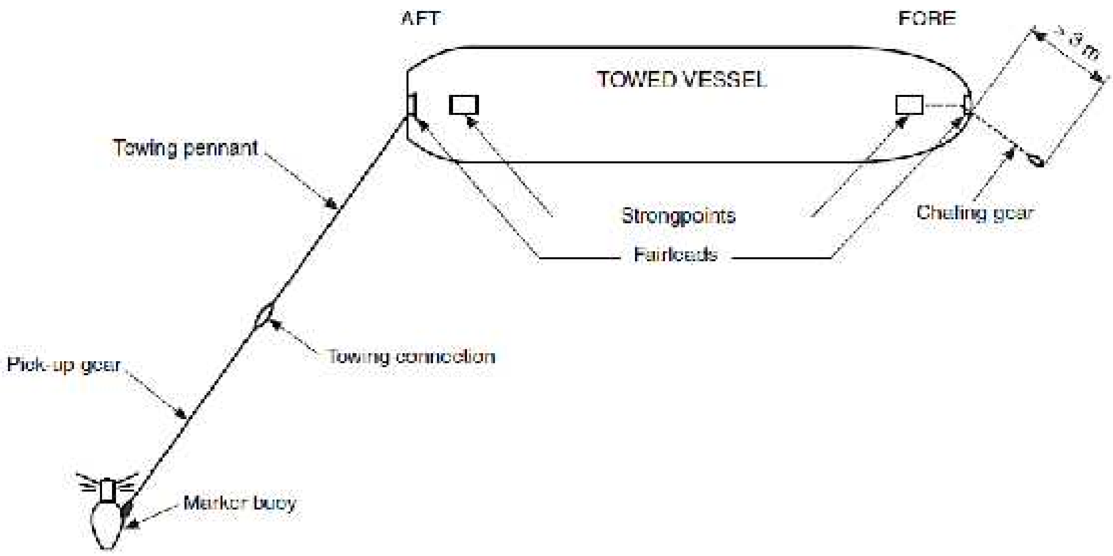
4.4.4 List of major components

The major components of the towing arrangements, their position on board and the requirements of this Article which they are to comply with are defined in Table 4.1

Table 4.1: Major components of the emergency towing arrangement

Towing component	Non pre-rigged	Pre-rigged	Reference of applicable requirements
Towing pennant	Optional	Required	4.7
Fairlead	Required	Required	4.9
Strongpoint (inboard end fasting of the towing gear)	Required	Required	4.10
Pick-up gear	Optional	Required	No requirement
Pedestal roller fairlead	Required	Depending on design	No requirement
Towing component	Forward	Afterward	Reference of Applicable requirements
Chafing gear	Required	Depending on design	4.8

Figure 4.1: Typical emergency towing arrangement



4.4.5 Inspection and maintenance

All the emergency towing arrangement components are to be inspected by ship personnel at regular intervals and maintained in good working order.

4.5 Emergency towing arrangement approval

4.5.1 General

Emergency towing arrangements of ships are to comply with the following requirements:

- they are to comply with the requirements of this item
- they are to be type approved according to the requirements in 4.13
- Certificates of inspection of materials and equipment are to be provided according to 4.13.2
- fitting on board of the emergency towing arrangements is to be witnessed by a Surveyor of the Society and a relevant Certificate is to be issued
- demonstration of the rapid deployment according to the criteria in 4.12 is to be effected for each ship and this is to be reported in the above Certificate.

4.5.2 Alternative to testing the rapid deployment for each ship

At the request of the Owner, the testing of the rapid deployment for each ship according to 4.5.1 may be waived provided that:

- the design of emergency towing arrangements of the considered ship is identical to the type approved arrangements and this is confirmed by the on board inspection required in 4.5.1
- the strong points (chain stoppers, towing brackets or equivalent fittings) are type approved (prototype tested).

In this case, an exemption certificate is to be issued.

In general, such dispensation may be granted to subsequent ships of a series of identical new buildings fitted with identical arrangements.

4.6 Safe working load (SWL) of towing pennants, chafing gears, fairleads and strong points

4.6.1 Safe working load

The safe working load (defined as one half of the ultimate strength) of towing pennants, chafing gear, fairleads and strongpoints is to be not less than that obtained, in kN, from Table 4.2.

The strength of towing pennants, chafing gear, fairleads and strongpoints is to be sufficient for all pulling angles of the towline, i.e. up to 90° from the ship's centreline to port and starboard and 30° vertical downwards.

The safe working load of other components is to be sufficient to withstand the load to which such components may be subjected during the towing operation.

Table 4.2: Safe working load

Ship deadweight DWT, in t	Safe working load,in kN
20000 ≤ DWT < 50000	1000
DWT ≥ 50000	2000

4.7 Towing pennant

4.7.1 Material

The towing pennant may be made of steel wire rope or synthetic fibre rope, which is to comply with the applicable requirements.

4.7.2 Length of towing pennant

The length l_P of the towing pennant is to be not less than that obtained, in m, from the following formula:

$l_P = 2\,H + 50$

where:

H : Lightest seagoing ballast freeboard measured, in m, at the fairlead.

4.7.3 Minimum breaking strength of towing pennants when separate chafing gear is used

Where a separate chafing gear is used, the minimum breaking strength MBS_p of towing pennants, including their terminations, is to be not less than that obtained from the following formula:

$MBS_P = 2\,\mu\,SWL$

where:

μ : Coefficient that accounts for the possible loss in strength at eye terminations, to be taken not less than 1.1

SWL: Safe working load of the towing pennants, defined in 4.6.1.

4.7.4 Minimum breaking strength of towing pennants when no separate chafing gear is used

Where no separate chafing gear is used (i.e. where the towing pennant may chafe against the fairlead during towing operation), the minimum breaking strength of the towing pennants MBS_{PC} is to be not less than that obtained, in kN,from the following formula:

$$MBS_{PC} = \phi \ MBS_P$$

where:

MBS_P : Minimum breaking strength, in kN, defined in 4.7.3

ϕ : Coefficient to be taken equal to:

$$\phi = 2\sqrt{\rho}/(2\sqrt{\rho}-1)$$

ϕ may be taken equal to 1.0 if tests carried out under a test load equal to twice the safe working load defined in 4.6.1 demonstrate that the strength of the towing pennants is satisfactory

ρ: Bending ratio (ratio between the minimum bearing surface diameter of the fairlead and the towing pennant diameter), to be taken not less than 7.

4.7.5 Towing pennant termination

For towing connection, the towing pennant is to have a hard eye-formed termination allowing connection to a standard shackle.

Socketed or ferrule-secured eye terminations of the towing pennant are to be type tested in order to demonstrate that their minimum breaking strength is not less than twice the safe working load defined in 4.6.1.

4.8 Chafing gear

4.8.1 General

Different solutions for the design of chafing gear may be used.

If a chafing chain is to be used, it is to have the characteristics defined in the following requirements.

4.8.2 Type

Chafing chains are to be stud link chains.

4.8.3 Material

In general, grade AC-K3 chain cables and associated accessories complying with the applicable requirements are to be used.

4.8.4 Chafing chain length

The chafing chain is to be long enough to ensure that the towing pennant, or the towline, remains outside the fairlead during the towing operation. A chain extending from the strongpoint to a point at least 3m beyond the fairlead complies with this requirement.

4.8.5 Minimum breaking strength

The minimum breaking strength of the stud link chafing chain and the associated links is to be not less than twice the safe working load defined in 4.6.1.

4.8.6 Diameter of the common links

The diameter of the common links of stud link chain cables is to be not less than:

• 52 mm for a safe working load, defined in 4.6.1, equal to 1000 kN

• 76 mm for a safe working load, defined in 4.6.1, equal to 2000 kN.

4.8.7 Chafing chain ends

One end of the chafing chain is to be suitable for connection to the strongpoint. Where a chain stopper is used, the inboard end of the chafing chain is to be efficiently secured in order to prevent any inadvertent loss of the chafing chain when operating the stopping device. Where the chafing chain is connected to a towing bracket, the corresponding chain end may be constructed as shown in Fig 4.2, but the inner dimension of the pear link may be taken as 5.30 d (instead of 5.75 d).

The other end of the chafing chain is to be fitted with a standard pear-shaped open link allowing connection to a standard bow shackle. A typical arrangement of this chain end is shown in Figure 4.2. Arrangements different than that shown in Fig 4.2 are considered by the Society on a case-by case basis.

4.8.8 Storing

The chafing chain is to be stored and stowed in such a way that it can be rapidly connected to the strongpoint.

4.9 Fairleads

4.9.1 General

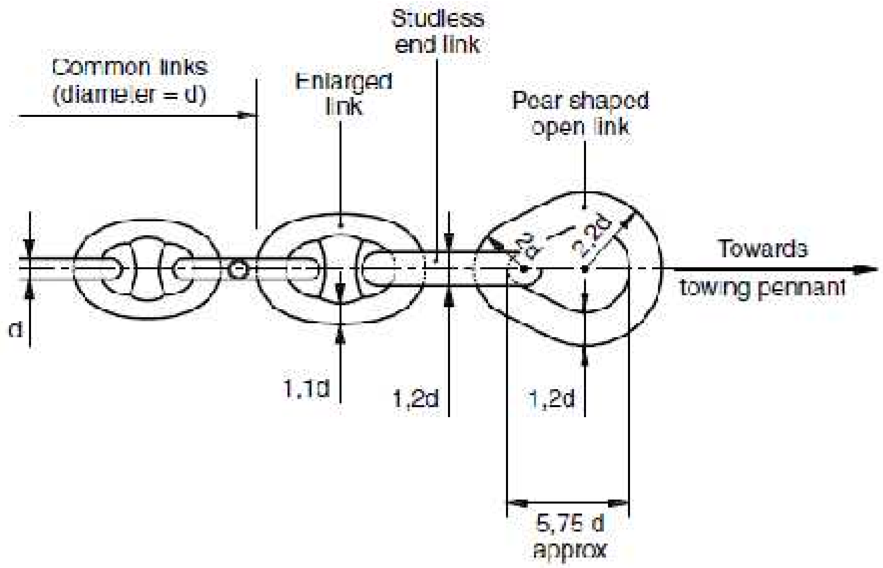
Fairleads are normally to be of a closed type (such as Panama chocks).

Fairleads are to have an opening large enough to pass the largest portion of the chafing gear, towing pennant or towline.

The corners of the opening are to be suitably rounded.

Where the fairleads are designed to pass chafing chains, the openings are to be not less than 600mm in width and 450mm in height.

Figure 4.2: Typical outboard chafing chain end



4.9.2 Material

Fairleads are to be made of fabricated steel plates or other ductile materials such as weldable forged or cast steel complying with the applicable requirements of Part 2, Materials and Welding.

4.9.3 Operating condition

The fairleads are to give adequate support for the towing pennant during towing operation, which means bending 90° to port and starboard side and 30° vertical downwards.

4.9.4 Positioning

The fairleads are to be located so as to facilitate towing from either side of the bow or stern and minimise the stress on the towing system.

The fairleads are to be located as close as possible to the deck and, in any case, in such a position that the chafing chain is approximately parallel to the deck when it is under strain between the strongpoint and the fairlead.

Furthermore, the bow and stern fairleads are normally to be located on the ship's centreline. Where it is practically impossible to fit the towing fairleads exactly on the ship's centreline, it may be acceptable to have them slightly shifted from the centreline.

4.9.5 Bending ratio

The bending ratio (ratio between the towing pennant bearing surface diameter and the towing pennant diameter) is to be not less than 7.

4.9.6 Fairlead lips

The lips of the fairlead are to be suitably faired in order to prevent the chafing chain from fouling on the lower lip when deployed or during towing.

4.9.7 Yielding check

The equivalent Von Mises stress σ_E, in N/mm^2, induced in the fairlead by a load equal to the safe working load defined in 4.6.1, is to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

Areas subjected to stress concentrations are considered by the Society on a case-by-case basis.

Where the fairleads are analysed through fine mesh finite element models, the allowable stress may be taken as 1.1 σ_{ALL}.

4.9.8 Alternative to the yielding check

The above yielding check may be waived provided that fairleads are tested with a test load equal to twice the safe working load defined in 4.6.1 and this test is witnessed by a Surveyor of the Society. In this case, the Designer is responsible for ensuring that the fairlead scantlings are sufficient to withstand such a test load.

Unless otherwise agreed by the Society, components subjected to this test load are considered as prototype items and are to be discarded.

4.10 Strongpoint

4.10.1 General

The strongpoint (inboard end fastening of the towing gear) is to be a chain cable stopper or a towing bracket or other fitting of equivalent strength and ease of connection. The strongpoint can be designed integral with the fairlead.

The strongpoint is to be type approved according to 4.13 and is to be clearly marked with its SWL.

4.10.2 Materials

The strongpoint is to be made of fabricated steel or other ductile materials such as forged or cast steel complying with the applicable requirements of Part 2, Materials and Welding.

Use of spheroidal graphite cast iron (SG iron) may be accepted for the main framing of the strongpoint provided that:

- the part concerned is not intended to be a component part of a welded assembly
- the SG iron is of ferritic structure with an elongation not less than 12%
- the yield stress at 0.2% is measured and certified
- the internal structure of the component is inspected by suitable non-destructive means.

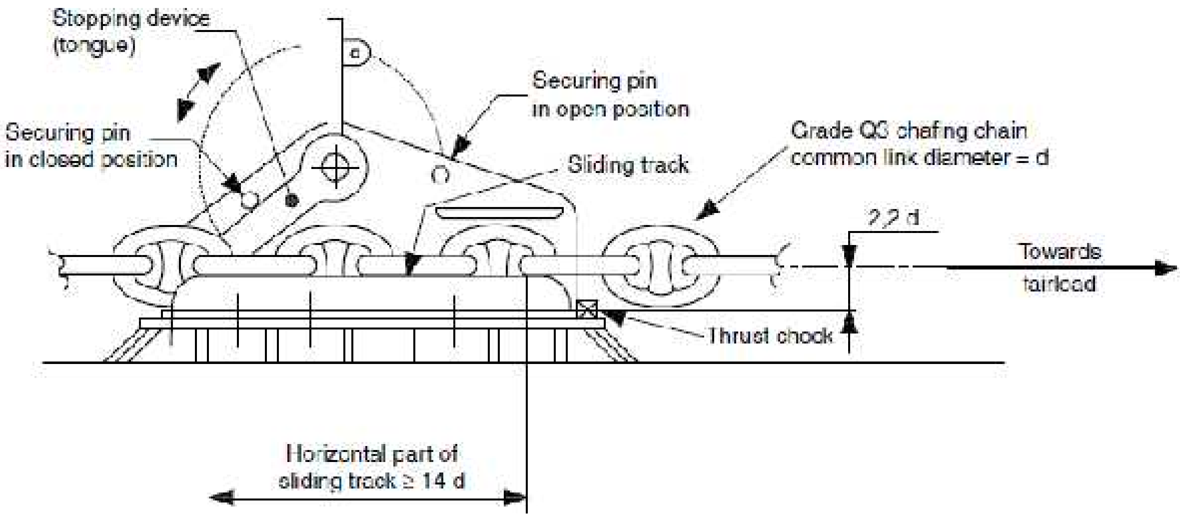
The material used for the stopping device (pawl or hinged bar) of chain stoppers and for the connecting pin of towing brackets is to have mechanical properties not less than those of grade AC-K3 chain cables.

4.10.3 Typical strongpoint arrangement Typical arrangements of chain stoppers and towing brackets are shown in Figure 4.3, which may be used as reference.

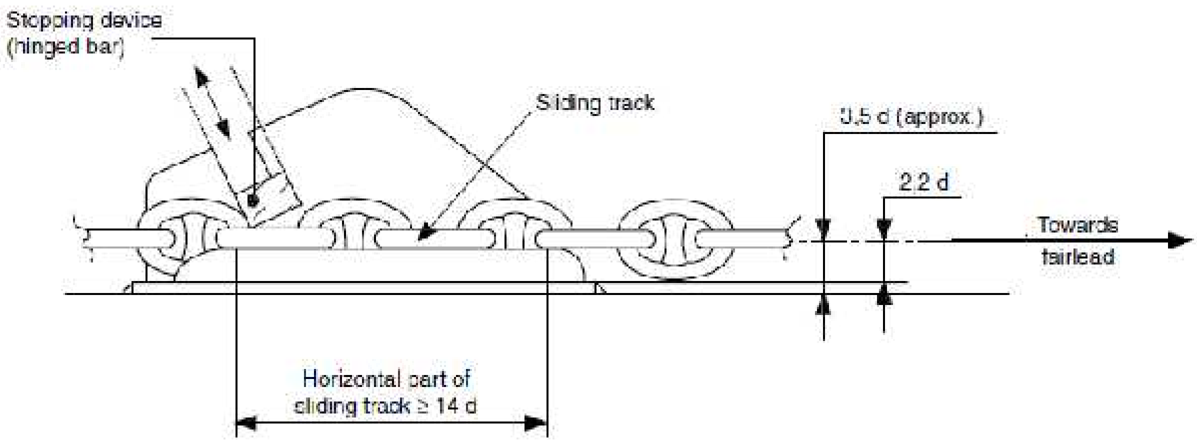
Chain stoppers may be of the hinged bar type or pawl (tongue) type or of other equivalent design.

Figure 4.3: Typical strongpoint arrangement

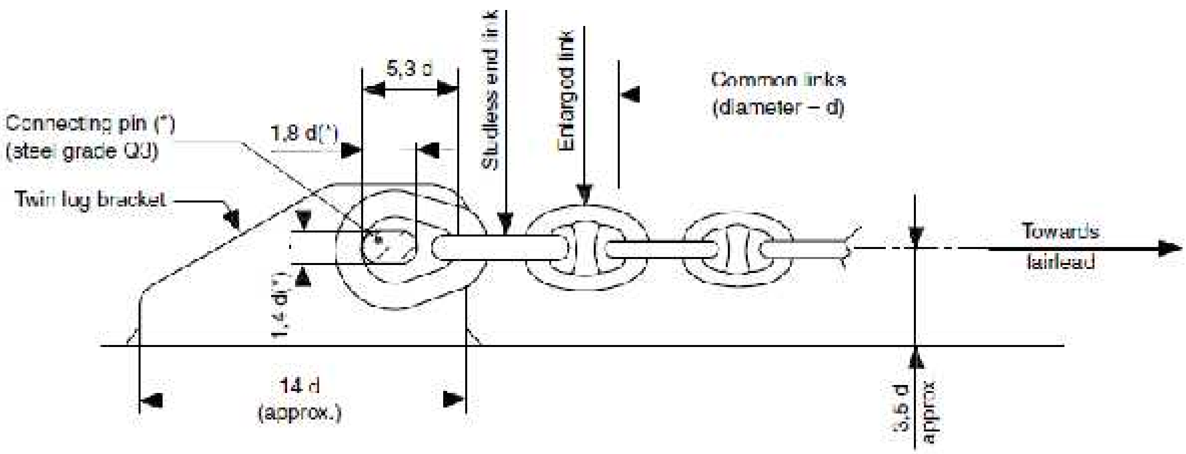
Pawl type chain stopper



Bar hinged type chain stopper



Towing bracket (*) : See 4.10.6



4.10.4 Position and operating condition

The operating conditions and the positions of the strong points are to comply with those defined in 4.9.3 and 4.9.4, respectively, for the fairleads.

4.10.5 Stopping device

The stopping device (chain engaging pawl or bar) is to be arranged, when in closed position, to prevent the chain stopper from working in the open position, in order to avoid chain cable release and allow it to pay out.

Stopping devices are to be easy and safe to operate and, in the open position, are to be properly secured.

4.10.6 Connecting pin of the towing bracket

The scantlings of the connecting pin of the towing bracket are to be not less than those of a pin of a grade AC-K3 end shackle, as shown in Figure 4.3, provided that clearance between the two side lugs of the bracket does not exceed 2.0d, where d is the chain diameter specified in 4.8.6 (see also Figure 4.2).

4.10.7 Yielding check

The equivalent Von Mises stress σ_E , in N/mm^2, induced in the strongpoint by a load equal to the safe working load defined in 4.6.1, is to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

Areas subjected to stress concentrations are considered by the Society on a case-by-case basis. Where the strongpoints are analyzed through fine mesh finite element models, the allowable stress may be taken as 1.1 σ_{ALL}.

4.10.8 Alternative to the yielding check

The above yielding check may be waived provided that strongpoints are tested with a test load equal to twice the safe working load defined in 4.6.1 and this test is witnessed by a Surveyor. In this case, the Designer is responsible for ensuring that the fairlead scantlings are sufficient to withstand such a test load.

Unless otherwise agreed by the Society, components subjected to this test load are considered as prototype items and are to be discarded.

4.10.9 Bolted connection

Where a chain stopper or a towing bracket is bolted to a seating welded to the deck, the bolts are to be relieved from shear force by means of efficient thrust chocks capable of withstanding a horizontal force equal to 1.3 times the safe working load defined in 4.6.1 within the allowable stress defined in 4.10.7.

The steel quality of bolts is to be not less than grade 8.8 as defined by ISO standard No. 898/1.

Bolts are to be pre-stressed in compliance with appropriate standards and their tightening is to be suitably checked.

4.11 Hull structures in way of fairleads or strongpoints

4.11.1 Materials and welding

The materials used for the reinforcement of the hull structure in way of the fairleads or the strongpoints are to comply with the applicable requirements.

Main welds of the strongpoints with the hull structure are to be 100% inspected by adequate non-destructive tests.

4.11.2 Yielding check of bulwark and stays

The equivalent Von Mises stress σ_E , in N/mm^2, induced in the bulwark plating and stays in way of the fairleads by a load equal to the safe working load defined in 4.6.1, for the operating condition of the fairleads defined in 4.9.3, is to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

4.11.3 Yielding check of deck structures

The equivalent Von Mises stress σ_E , in N/mm^2, induced in the deck structures in way of chain stoppers or towing brackets, including deck seatings and deck connections, by a horizontal load equal to 1,3 times the safe working load defined in 4.6.1, is to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

4.11.4 Minimum gross thickness of deck plating

The gross thickness of the deck is to be not less than:

• 12 mm for a safe working load, defined in 4.6.1, equal to 1000 kN

• 15 mm for a safe working load, defined in 4.6.1, equal to 2000 kN.

4.12 Rapid deployment of towing arrangement

4.12.1 General

To facilitate approval of towing arrangements and to ensure rapid deployment, emergency towing arrangements are to comply with the requirements of this item.

4.12.2 Marking

All components, including control devices, of the emergency towing arrangements are to be clearly marked to facilitate safe and effective use even in darkness and poor visibility.

4.12.3 Aft arrangement

The aft emergency towing arrangement is to be pre-rigged and be capable of being deployed in a controlled manner in harbour conditions in not more than 15 minutes.

The pick-up gear for the aft towing pennant is to be designed at least for manual operation by one person taking into account the absence of power and the potential for adverse environmental conditions that may prevail during such emergency towing operations.

The pick-up gear is to be protected against the weather and other adverse conditions that may prevail.

4.12.4 Forward

The forward emergency towing arrangement is to be capable of being deployed in harbour conditions in not more than 1 hour.

The forward emergency towing arrangement is to be designed at least with a means of securing a towline to the chafing gear using a suitably positioned pedestal roller to

facilitate connection of the towing pennant.

Forward emergency towing arrangements which comply with the requirements for aft emergency towing arrangements may be accepted.

4.13 Type approval

4.13.1 Type approval procedure

Emergency towing arrangements are to be type approved according to the following procedure:

- the arrangement design is to comply with the requirements of this Section
- each component of the towing arrangement is to be tested and its manufacturing is to be witnessed and certified by a Surveyor according to 4.13.2
- prototype tests are to be carried out in compliance with 4.13.3.

4.13.2 Inspection and certification

The materials and equipment are to be inspected and certified as specified in Table 4.2.

4.13.3 Prototype tests

Prototype tests are to be witnessed by a Surveyor and are to include the following:

- demonstration of the rapid deployment according to the criteria in 4.12
- load test of the strongpoints (chain stoppers, towing brackets or equivalent fittings) under a proof load equal to 1.3 times the safe working load defined in 4.6.1.

A comprehensive test report duly endorsed by the Surveyor is to be submitted to the Society for review.

Table 4.2: Material and equipment certification status

Component	Material		Equipment	
	Certificate	Reference of applicable requirements	Certificate	Reference of applicable Requirements
Towing pennant	Not applicable	4.7.1	COI (1)	4.7
Chafing chain and associated Accessories	COI (2)	4.8.3	COI (1)	4.8
Fairleads	CW	4.9.2	COI	4.9
Strongpoint: • main framing • stoppingdevice	 COI (2) COI (2)	 4.10.2 4.10.2	COI (3)	4.10
Pick-up gear: • rope • buoy • line-throwing appliance	 Not applicable Not applicable Not applicable	 - - -	 CW Not required (4) Not required (4)	Not requirement
Pedestal roller fairlead	CW	-	Not required (4)	Not requirement

(1) According to Part II, Materials and Welding.

(2) According to Part II, Materials and Welding.

(3) to be type approved.

(4) may be type approved.

Note 1:

COI: Certificate of inspection,

CW: Works’ certificate 3.1.B according to EN 10204.

5 Towing and mooring arrangement

5.1 Towline and mooring line equipment

5.1.1 Conditions of classification

The towline and the mooring lines equipment is given as a guidance but is not required as a condition of classification.

5.1.2 The equipment in towline and mooring lines (length, breaking load and number of lines) is obtained from Table 5.1, based on the ship Equipment Number EN.

5.2 Towlines and mooring lines

5.2.1 General

The breaking load given in Table 5.1 is used to determine the maximum design load applied to shipboard fittings as defined in 5.3.2.

The towlines having the characteristics defined in Table 5.1 are intended as those belonging to the ship to be towed by a tug or another ship.

5.2.2 Materials

Towlines and mooring lines may be of wire or synthetic fibre or a mixture of wire and fibre.

The breaking loads defined in Table 5.1 refer to steel wires.

Steel wires and fibre ropes are to be tested in accordance with the applicable requirements.

5.2.3 Steel wires

Steel wires are to be made of flexible galvanized steel and are to be of types defined in Table 5.2.

Where the wire is wound on the winch drum, steel wires to be used with mooring winches may be constructed with an independent metal core instead of a fibre core. In general such wires are to have not less than 186 threads in addition to the metallic core.

Table 5.1: Towline and mooring lines

Equipment number EN A < EN ≤ B		Towline (1)		Mooring lines (1)		
A	B	Minimum length, in m	Breaking load, in kN	N (2)	Length of each line, in m	Breaking load, in kN(3)
50	70	180	98,1	3	80	34
70	90	180	98,1	3	100	37
90	110	180	98,1	3	110	39
110	130	180	98,1	3	110	44
130	150	180	98,1	3	120	49
150	175	180	98,1	3	120	54
175	205	180	112	3	120	59
205	240	180	129	4	120	64
240	280	180	150	4	120	69
280	320	180	174	4	140	74
320	360	180	207	4	140	78
360	400	180	224	4	140	88
400	450	180	250	4	140	98
450	500	180	277	4	140	108
500	550	190	306	4	160	123
550	600	190	338	4	160	132
600	660	190	371	4	160	147
660	720	190	406	4	160	157
720	780	190	441	4	170	172

780	840	190	480	4	170	186
840	910	190	518	4	170	201
Equipment number EN A < EN ≤ B		Towline (1)		Mooring lines (1)		
A	B	Minimum length, in m	Breaking load, in kN	N (2)	Length of each line, in m	Breaking load, in kN(3)
910	980	190	550	4	170	216
980	1060	200	603	4	180	230
1060	1140	200	647	4	180	250
1140	1220	200	692	4	180	270
1220	1300	200	739	4	180	284
1300	1390	200	786	4	180	309
1390	1480	200	836	4	180	324
1480	1570	220	889	5	190	324
1570	1670	220	942	5	190	333
1670	1790	220	1024	5	190	353
1790	1930	220	1109	5	190	378
1930	2080	220	1168	5	190	402
2080	2230	240	1259	5	200	422
2230	2380	240	1356	5	200	451
2380	2530	240	1453	5	200	481
2530	2700	260	1471	6	200	481
2700	2870	260	1471	6	200	490
2870	3040	260	1471	6	200	500
3040	3210	280	1471	6	200	520
3210	3400	280	1471	6	200	554
3400	3600	280	1471	6	200	588
3600	3800	300	1471	6	200	612
3800	4000	300	1471	6	200	647
4000	4200	300	1471	7	200	647
4200	4400	300	1471	7	200	657
4400	4600	300	1471	7	200	667
4600	4800	300	1471	7	200	677
4800	5000	300	1471	7	200	686
5000	5200	300	1471	8	200	686
5200	5500	300	1471	8	200	696
5500	5800	300	1471	8	200	706
5800	6100	300	1471	9	200	706
6100	6500			9	200	716
6500	6900			9	200	726
6900	7400			10	200	726
7400	7900			11	200	726
7900	8400			11	200	735
8400	8900			12	200	735
8900	9400			13	200	735
9400	10000			14	200	735
10000	10700			15	200	735
10700	11500			16	200	735
11500	12400			17	200	735

12400	13400			18	200	735
13400	14600			19	200	735
14600	16000			21	200	735

(1) The towline and the mooring lines are given as a guidance, but are not required as a condition of classification.

(2) See 5.2.7.

(3) For mooring lines with breaking load above 490 kN, see 5.2.4.

Table 5.2: Steel wire composition

Breaking load B_L , in kN	Steel wire components		
	Number of threads	Ultimate tensile strength of threads, in N/mm^2	Composition of wire
$B_L < 216$	72	1420 ÷ 1570	6 strands with 7-fibre core
$216 < B_L < 490$	144	1570 ÷ 1770	6 strands with 7-fibre core
$B_L > 490$	216 or 222	1770 ÷ 1960	6 strands with 1-fibre core

5.2.4 Mooring alternative

When the breaking load of each mooring line is greater than 490kN, either a greater number of mooring lines than those required in Table 5.1 having lower strength or a lower number of mooring lines than those required in Table 5.1 having greater strength may be used, provided the total breaking load of all lines aboard the ship is greater than the value defined in Table 5.1.

In any case, the number of lines is to be not less than 6 and the breaking load of each line is to be greater than 490 kN.

5.2.5 Length of mooring lines

The length of individual mooring lines may be reduced by up to 7% of the length defined in Table 5.1, provided that the total length of mooring lines is greater than that obtained by adding the lengths of the individual lines defined in Table 5.1.

5.2.6 Synthetic fibre ropes

Where synthetic fibre ropes are adopted, their size is to be determined taking into account the type of material used and the manufacturing characteristics of the rope, as well as the different properties of such ropes.

The breaking load of synthetic fibre ropes B_{LS} is to be not less than that obtained, in kN, from the following formula:

$B_{LS} = K\, B_{L0}$

where:

B_{L0} : Breaking load, in kN, for the mooring line, defined in Table 5.1

K : Coefficient to be taken equal to:

K = 1.3 for polypropylene mooring lines

K = 1.2 for mooring lines made in other synthetic material.

Fibre rope diameters are to be not less than 20 mm.

5.2.7 Number of mooring lines for ro-ro cargo ships, ro-ro passenger ships and passenger ships

For ships with one of the service notations ro-ro cargo ship, passenger ship or ro-ro passenger ship, additional mooring lines are defined in Table 5.3, in addition to the number of mooring lines defined in Table 5.1.

5.2.8 Length of mooring lines for supply vessels For ships with the service notation supply vessel, the length of mooring lines may be reduced. The reduced length l is to be not less than that obtained, in m, from the following formula:

$l = L + 20$

Table 5.3: Additional mooring lines

A / EN	Number of additional mooring lines
0.9 < A / EN ≤ 1.1	1
1.1 < A / EN ≤ 1.2	2
1.2 < A / EN	3

Note 1: A and EN are defined in 2.1.2.

5.3 Shipboard fittings and supporting hull structures associated with towing and Mooring

5.3.1 Application

Requirements under the present sub-article apply to:

- Conventional vessels, i.e. displacement-type ships of 500 GT and above, excluding special purpose vessels,
- Shipboard fittings and supporting structures used for the mooring and normal towing operations.

Note 1: Normal towing operations mean harbour operations or escort operations.

Shipboard fittings are limited to the following components:

bollards and bitts, fairleads, stand rollers, chocks used for the mooring and similar components used for the normal towing of the vessel. Other components such as capstans,

winches, etc. are not covered by the present requirements.

Any weld or bolt or equivalent device connecting the shipboard fitting to the supporting structure is part of the shipboard fitting and subject to recognized standard applicable

to the shipboard fitting.

The strength of shipboard fittings, designed for mooring and normal towing operations which are located at bow, sides and stern, and their supporting structures, are to comply with the prescriptions of the present requirements.

The supporting hull structure of capstans, winches, etc. used for the mooring and normal towing operations is also subject to the present requirement. The term supporting hull structures is referred to that part of the ship structure on/in which the shipboard fitting is placed and which is directly submitted to the forces exerted on the shipboard fitting.

For chain stoppers also refer to 3.7.

For shipboard fittings also used for emergency towing, the requirements of 4 are also applicable.

5.3.2 Shipboard fittings design load

The design load, in kN, acting on the shipboard fittings at the attachment point of the towline and mooring line, applicable for a single post basis (i.e. no more than one turn of one cable), is to be taken equal to:

a) For harbour towing operations:

The greater of 1.25 times the intended maximum towing load and the SWL of the shipboard fitting, as indicated on the towing and mooring arrangement plan (see 5.3.6)

b) For escort towing operations:

The greater of the SWL of the shipboard fitting, as indicated on the towing and mooring arrangement plan (see 5.3.6) and the breaking load of the tow line as defined in Table 5.1, taking into account 5.3.2, Note 1

c) For mooring:

The greater of the SWL of the shipboard fitting, as indicated on the towing and mooring arrangement plan (see 5.3.6) and 1,25 times the breaking load of the mooring line as defined in Table 5.1 taking into account 5.3.2, Note 1.

Note 1: The breaking load of towline and mooring line is to be taken in Table 5.1, based on an Equipment Number calculated according to 2.1.2 with a side projected area A including maximum stacks of deck cargoes.

The design load is to be applied through the tow line and the mooring line according to the arrangement shown on the towing and mooring arrangements plan.

The acting point of the towing and mooring forces on shipboard fittings is to be taken at the attachment point of the towing line and mooring line.

The total load applied to the fittings and supporting hull structures needs not to be more than twice the design load.

5.3.3 Shipboard fittings

The selection of shipboard fittings is to be made by the shipyard in accordance with a recognised standard accepted by the Society. Whatever is the selection method of the shipboard fitting, the design load used to assess its strength and its attachment to the ship is to be in accordance with 5.3.2 .

The strength of shipboard fittings used for normal towing and mooring operation at bow, side and stern and their supporting structures are to be in accordance with the present sub-article.

5.3.4 Supporting hull structure

The arrangement and strength of supporting hull structure are to comply with:

a) Arrangement

Shipboard fittings for normal towing and mooring are to be located on longitudinals, beams and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the towing and mooring load.

Other equivalent arrangements may be accepted (for example, Panama chocks, etc.).

The arrangement of reinforced members (carling) beneath shipboard fittings is to consider any variation of direction, laterally and vertically, of the towing and mooring forces, which are to be calculated in accordance with 5.3.2.

For mooring operation, the design load applied to supporting hull structure for winches, etc. is to be 1,25 time the intended maximum brake holding load and, for capstan, 1,25 times the maximum hauling-in force.

b) Allowable stresses

When assessing the strength of supporting hull structures, the allowable stresses, not taking into account any stress concentration factor, are to be considered as follows:

• normal stress: 100% of the minimum yield stress R_{eH}

• shear stress: 60% of the minimum yield stress R_{eH}.

Note 1: Normal stress is to be considered as the sum of bending stress and axial stress, with the corresponding shearing stress acting perpendicular to the normal stress.

c) Scantling

The scantlings obtained by applying the criteria specified in the present sub article are net scantlings excluding any addition for corrosion (see 5.3.7).

5.3.5 Safe Working Load (SWL)

The following requirements on SWL, applicable for a single post basis, i.e, no more than one turn of one cable, are to be considered:

a) For towing operation:

- The SWL is not to exceed 80% of the design load defined in 5.3.2 for harbour towing operation
- The SWL is not to exceed the design load defined in 5.3.2 for escort towing operation.

For fittings used for both harbour and escort towing operations, the SWL is not to exceed the greater value.

b) For mooring operation:

- The SWL is not to exceed 80% of the design load defined in 5.3.2

The SWL of each shipboard fitting is to be marked, by weld bead or equivalent, at the place of the deck fittings used for towing and for mooring.

5.3.6 Towing and mooring arrangement plan A plan showing the towing and mooring arrangement is to be submitted to the Society for information. This plan is to define the method of use the towing and mooring lines and to include the following information for each shipboard fitting:

- location on the ship
- fitting type
- safe working load
- purpose (mooring, harbour towing, escort towing)
- manner of applying towing and mooring line (including line load, line angles etc.).

Where the arrangements and details of deck fittings and their supporting hull structures are designed based on the mooring alternative defined in 5.2.4, the arrangement of mooring lines showing number of lines together with the breaking load of each mooring line is to be clearly indicated on the plan.

5.3.7 Corrosion additions

The total corrosion addition, t_c, in mm, for both sides of the hull supporting structure is not to be less than:

- the total corrosion addition defined in Common Structural Rules for Double Hull Oil Tankers or in Common Structural Rules for Bulk Carriers, when applicable
- 2 mm for other ships.

Chapter 6 Navigation

Section 1 Visibility

1

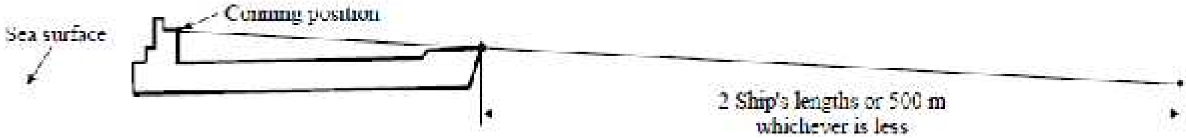
Navigation Bridge Visibility Vessels with the keel laid or in similar stage of construction on or after 1 July 1998, are to meet the following requirements with regard to the visibility from the navigation bridge, unless they are navigating solely the Great Lakes of North America and their connecting and tributary waters as far east as the lower exit of the St. Lambert Lock at Montreal in the Province of Quebec, Canada. Special consideration will be given to vessels that operate only on domestic or on short, limited, international voyages.

1.1 Field of Vision

1.1.1 Conning Position

1.1.1(a) The view of the sea surface from the conning position is not to be obscured by more than $2L_{OA}$ (Length Overall) or 500 m, whichever is less, forward of the bow to 10° on either side for all conditions of draft, trim and deck cargo under which the particular vessel is expected to operate. See Figure 1.1.

Figure 1.1



Notes:

1- A conning position is a place on the bridge with a commanding view and which is used by navigators when commanding, maneuvering and controlling a vessel.

2- Attention is drawn to flag Administrations requiring lengths of less than $2L_{OA}$.

1.1.1(b) No blind sector caused by cargo, cargo gear or other obstructions outside of the wheelhouse forward of the beam which obstructs the view of the sea surface as seen from the conning position is to exceed 10°. The total arc of blind sectors is not to exceed 20°. The clear sectors between blind sectors are to be at least 5°. However, in the view described in 1.1.1(a), each individual blind sector is not to exceed 5°.

1.1.1(c) The horizontal field of vision from the conning position is to extend over an arc of not less than 225°, that is, from right ahead to not less than 22.5° abaft the beam on either side of the vessel. Figure 1.3.

1.1.2 Bridge Wing

1.1.2(a) From each bridge wing, the horizontal field of vision is to extend over an arc of at least 225°, that is, from at least 45° on the opposite bow to right ahead and then from right ahead to right astern through 180° on the same side of the vessel. Figure1.4.

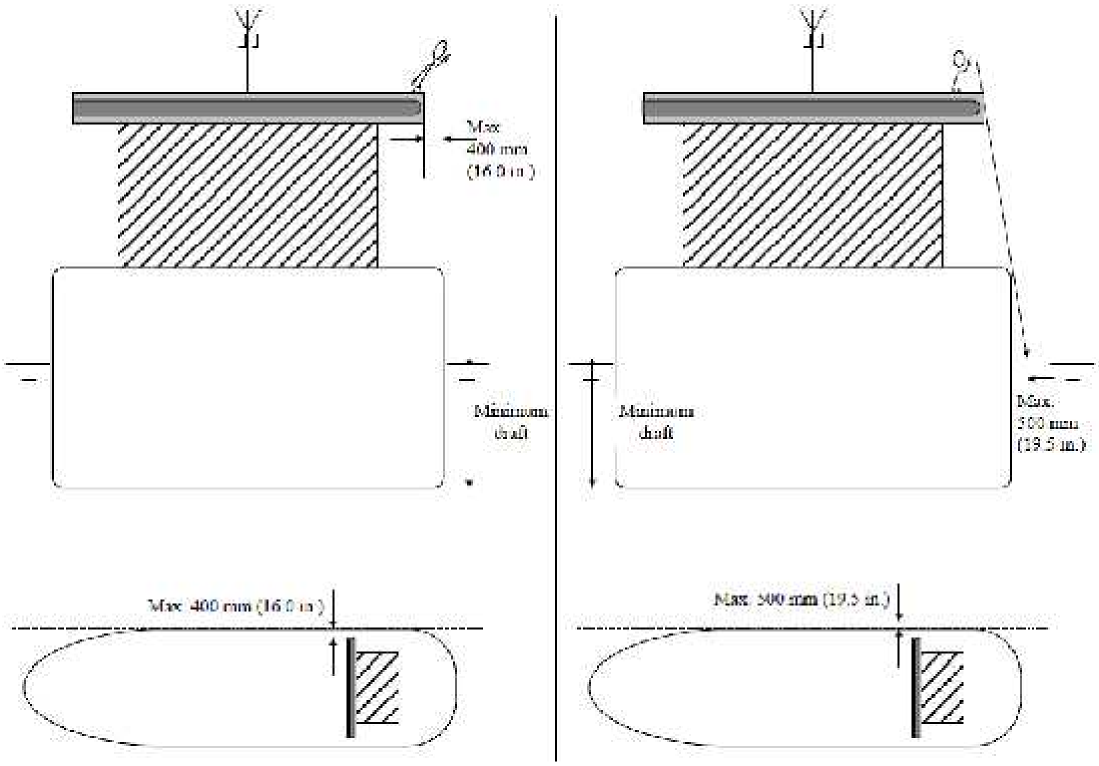
1.1.2(b) The vessel's side is to be visible from the bridge wing.

i) The requirements of 3-6-1/1.1.2 (b) are accomplished when:

- A view from the bridge wing plus a distance corresponding to a reasonable and safe distance of a seafarer leaning over the side of the bridge wing, which needs not to be more than 400 mm, to the location vertically right under the maximum beam of the ship at the lowest seagoing draft is not obscured; or
- The sea surface at the lowest seagoing draft and with a transverse distance of 500 mm and more from the maximum beam throughout the ship's length is visible from the side of the bridge wing. See Figure 1.2.

ii) For particular ship types, such as tug/tow boat, offshore supply vessel (OSV), rescue ship, work ship (e.g., floating crane ships), etc., that are designed such that, in normal operations, they come along side, or operate in close proximity to, other vessels or offshore structures at sea, 1.1.2(b) is met provided the bridge wings extend at least to a location from which the sea surface, at the lowest seagoing draft and at a transverse distance of 1500 mm from the maximum beam throughout the ship's length, is visible. If this ship type is changed to a type other than those addressed in this paragraph, then the interpretation in this paragraph would no longer apply.

Figure 1.2



1.1.3 Main Steering Position

From the main steering position, the horizontal field of vision is to extend over an arc from right ahead to at least 60° on each side of the vessel. See Figure 1.5.

Figure 1.3

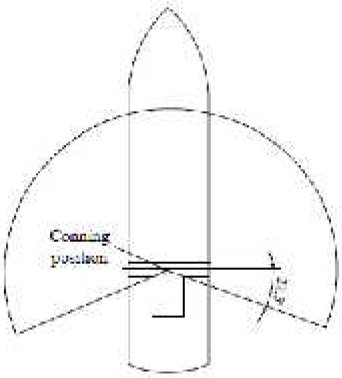


Figure 1.4

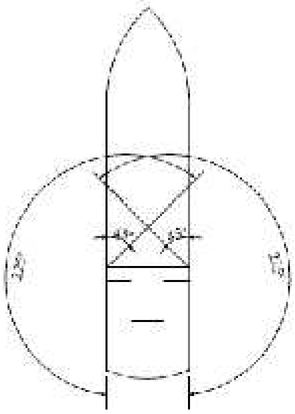
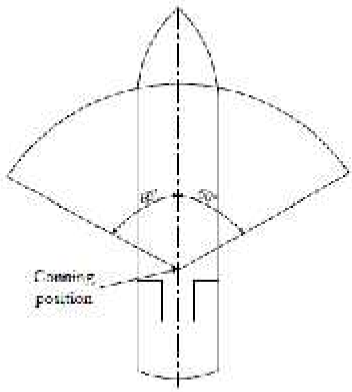


Figure 1.5



1.3 Windows and Their Arrangements

Windows and their arrangements are to meet the following requirements:

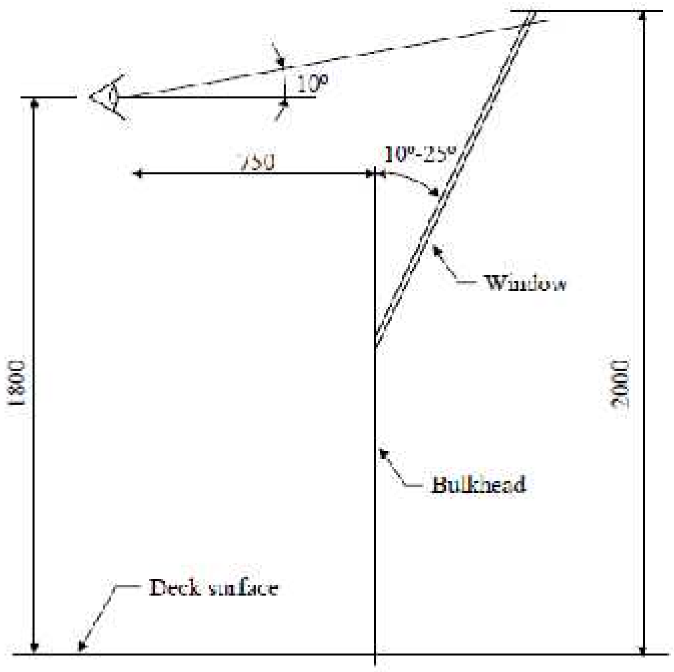
1.3.1 Framing

Framing between navigation bridge windows is to be kept to a minimum to meet the structural strength and stiffness requirements, and is not to be installed immediately in front of any workstations.

1.3.2 Inclination Angle

The bridge front windows are to be inclined from a vertical plane top out, at an angle of not less than 10° and not more than 25°, see Figure 1.6.

Figure 1.6



1.3.3 Glass

Polarized and tinted windows are not to be fitted.

1.3.4 Clear View

At all times, regardless of the weather conditions, at least two of the navigation bridge front windows are to provide a clear view, and in addition, depending on the bridge configuration, an additional number of windows are to provide a clear view. To this end, the following, or equivalent, is to be provided:

1.3.4(a) Sun Screens. Sunscreens with minimum color distortion. These sunscreens are to be readily removable and not permanently installed.

1.3.4(b) Wipers and Fresh Water Wash Systems. Heavy-duty wipers, preferably provided with an interval function, and fresh water wash systems. These wipers are to be capable of operating independently of each other.

1.3.4(c) De-icing and De-misting Systems. De-icing and de-misting systems to be provided.

1.3.4(d) Fixed Catwalk. A fixed catwalk with guardrails, fitted forward of the bridge windows, to enable manual cleaning of windows in the event of failure of the above systems.

1.3.5 Lower Edge

The height of the lower edge of the navigation bridge front windows above the bridge deck is to be kept as low as possible. In no case is the lower edge to present an obstruction to the forward view as described in this Section.

1.3.6 Upper Edge

The upper edge of the navigation bridge front windows is to allow a forward view of the horizon, for a person with a height of eye of 1800 mm above the bridge deck at the conning position, when the vessel is pitching in heavy seas. ACS, if satisfied that an 1800 mm height of eye is unreasonable and impractical, may allow reduction of the height of eye but not to less than 1600 mm. See Figure 1.5.

1.4 Unconventional Design

For vessels of unconventional design which cannot comply with the above requirements, arrangements are to be provided to the satisfaction of ACS to achieve a level of visibility that is as near as practical to those prescribed in this Section.

Chapter 7 Testing, Trials and Surveys During Construction – Hull

Section 1 Tank, Bulkhead and Rudder Tightness Testing

1 General

1.1 Application

All gravity tanks, excluding independent tanks of less than 5 m^3 in capacity, and other boundaries required to be watertight or weathertight are to be tested in accordance with this subsection and proven tight or structurally adequate as follows:

1.1.1

Gravity Tanks for their structural adequacy and tightness,

1.1.2

Watertight Boundaries Other Than Tank Boundaries for their watertightness, and

1.1.3

Weathertight Boundaries for their weathertightness.

1.2 Definitions

1.2.1

Structural Testing is a test to verify the structural adequacy of the design and the tightness of the tanks.

1.2.2

Air Testing is a test to verify the tightness of the structure by means of air pressure difference.

1.2.3

Hose Testing is a test to verify the tightness of the structure by a jet of water.

1.2.4

Hydropneumatic Testing is a combined hydrostatic and air testing wherein a tank is filled by water with air pressure applied on top.

1.2.5

Hydrostatic Testing is a test to verify the structural adequacy of the design and the tightness of the tank’s structure by means of water pressure, by filling water to the level as specified in Table 1.1.

Hydrostatic testing is the normal means for structural testing with exception as per 2.2.

2 Test Procedures

2.1 General

Tests are to be carried out in the presence of the Surveyor at a stage sufficiently close to completion, after all attachments, outfittings or penetrations which may affect the strength or tightness of the structure have been completed, and before any ceiling and cement work is applied over joints.

Specific test requirements are given in 5 and Table 1.1. For vessels or tanks of special service, additional requirements are given in Table 2.1.

For the timing of application of coating in relation to testing, see 4.

2.2 Structural Testing

Where structural testing is specified by Table 1.1 or Table 2.1, hydrostatic testing in accordance with 3.1 will be acceptable, except where practical limitations prevent it or where air testing is permitted by Note 1 to Table 1.1. Hydropneumatic testing, in accordance with 3.2, may be approved in lieu of hydrostatic testing. Structural testing may be carried out after the vessel is launched.

Tank boundaries are to be tested at least from one side. Tanks to be tested for structural adequacy (see Note 1 to Table 1.1) are to be selected so that all representative structural members are tested for the expected tension and compression.

2.3 Air Testing

Air testing is to be in accordance with 3.3.

2.4 Hose Testing

Hose testing is applied to structures not subjected to structural or air testing but required to be watertight or weathertight as specified in Table 1.1. For the details of hose testing, see 3.4. Air testing or structural testing may be accepted in lieu of hose testing.

3 Details of Testing

3.1 Hydrostatic Testing

Hydrostatic testing is to consist of a head of water to the level specified in Table 1.1.

3.2 Hydropneumatic Testing

When approved, the combined water level and air pressure used for hydropneumatic testing is to simulate the actual loading as far as practicable. The requirements and recommendations in 3.3 relative to air pressure will also apply.

3.3 Air Testing

All boundary welds, erection joints, and penetrations including pipe connections are to be examined in accordance with the approved procedure and under a pressure differential not less than 0.15 bar with a leak indicating solution.

It is recommended that the air pressure in the tank be raised to and maintained at 0.20 bar for approximately one hour, with a minimum number of personnel around the tank, before being lowered to the test pressure.

A U-tube with a height sufficient to hold a head of water corresponding to the required test pressure is to be arranged. The cross sectional area of the U-tube is to be not less than that of the pipe supplying air. In addition to the U-tube, a master gauge or other approved means is to be provided to verify the pressure.

Other effective methods of air testing, including compressed air fillet weld testing or vacuum testing, may be considered in accordance with 3.5.

3.4 Hose Testing

Hose testing is to be carried out with the pressure in the hose of at least 2 bar during test. The nozzle is to have minimum inside diameter of 12 mm and located at a distance to the joint not exceeding 1.5 m.

3.5 Other Methods of Testing

Other methods of testing may be considered upon submission of full particulars.

4 Application of Coating

4.1 Final Coating

4.1.1

Structural Testing. Final coating may be applied prior to the hydrostatic testing, provided an air test is carried out before the application of the final coating.

4.1.2

Air Testing. For all manual or semi-automatic erection welds and all fillet weld tank boundary connections including penetrations, the final coating is to be applied after air testing. For other welds, the final coating may be applied prior to air testing provided the Surveyor, after examination prior to the application of the coating, is satisfied with the weld. The Surveyor reserves a right to require air testing prior to the final coating of automatic erection welds and manual or automatic pre-erection welds.

4.1.3

Hose Testing. The final coating is to be applied after all required hose testing is completed.

4.2 Temporary Coating

Any temporary coating which may conceal defects or leaks is to be applied as specified for the final coating. This requirement applies to shop primers, other than silicate based shop primers, such as epoxy based shop primers.

Table 1.1: Testing Requirements for Tanks and Boundaries

	Structures to be Tested	*Type of Testing*	*Hydrostatic Testing Head or Pressure*	*Remarks*
1	Double Bottom Tanks	Structural (1, 2)	The greater of - to the top of overflow, or - to the bulkhead deck	
2	Double Side Tanks	Structural (1, 2)	The greater of - to the top of overflow, or - to 2.4 m above top of tank (3)	
3	Deep Tanks or Cargo Oil Tanks	Structural (1, 2)	The greatest of - to the top of overflow, - to 2.4 m above top of tank (3), or - to the top of tank(3) plus setting of any pressure relief valve	
	Fuel Oil Bunkers	Structural		
4	Ballast Holds of Bulk Carriers	Structural (1)	The greater of - to the top of overflow, or - to 0.9m above top of hatch coaming (3)	See items 12 and 13 for hatch covers.
5a	Peak Tanks	Structural	The greater of - to the top of overflow, or - to 2.4 m above top of tank (3)	After peak tank test to be carried out after installation of stern tube.
5b	Fore Peak Voids (collision bhd.)	See Note 4	See Note 4	
5c	Aft Peak Voids	Air		
6	Cofferdams	Structural (5)	The greater of - to the top of overflow, or - to 2.4 m above top of cofferdam	
7	Watertight Bulkheads	Hose (6)		
8	Watertight Doors below freeboard or bulkhead deck	Hose		See Ch.2 Sec.9/5.6 for additional test at the manufacturer.
9	Double Plate Rudder	Air		
10	Shaft Tunnel Clear of Deep Tanks	Hose		
11	Shell Doors	Hose		
12	Watertight Hatch Covers of tanks on combination carriers.	Structural (1, 2)	The greater of: - to 2.4 m above the top of hatch cover, or - setting pressure of the pressure relief valve.	At least every 2nd hatch cover is to be tested.
13	Weathertight Hatch Covers, Doors and other Closing Appliances	Hose (6)		
14 a	Chain Locker and Chain Pipe (aft of collision bulkhead)	Structural	To the top of chain pipe	
14 b	Chain Locker and Chain Pipe (fwd of collision bulkhead)	Structural (7)	To the top of chain pipe	
15	Independent Tanks	Structural	The greater of - to the top of overflow, or - to 0.9 m above top of tank	
16	Ballast Ducts	Structural	Ballast pump maximum pressure or setting of any relief valve for the ballast duct if that is less.	
17	Hawse Pipes	Hose		

Notes:

1 Provided the structural similarity of a group of tanks is recognized by ACS and a representative tank as selected by ACS is structurally tested based on the design approval, air testing in accordance with 3.3 may be accepted. In general, structural testing need not be repeated for subsequent vessels of a series of identical newbuildings. Subsequent tanks may require hydrostatic testing, if found necessary, after the structural testing.

2 All cargo segregation boundaries in oil carriers and combination carriers and tanks for segregated cargoes of pollutants are to be hydrostatically tested.

3 Top of tank is the deck forming the top of the tank, excluding hatchways. In holds for liquid cargo or ballast with large hatch covers, the top of tank is to be taken at the top of the hatch coaming.

4 Hydrostatic testing to the damaged waterline but not less than the distance to the bulkhead deck.

5 Air testing in accordance with 3.3 may be accepted, except that hydropneumatic testing may be required in consideration of the construction techniques and welding procedures employed.

6 Where hose testing is impractical due to the stage of outfitting, air test or other alternate method of testing such as close visual examination and, where necessary, nondestructive test of all joints may be considered.

7 In general, structural testing need not be repeated for subsequent vessels of a series of identical newbuildings provided air testing in accordance with 3.3 is carried out. Subsequent chain lockers may require hydrostatic testing if found necessary after the structural testing.

Table 2.1: Additional Testing Requirements for Vessels or Tanks of Special Service

	Type of Vessels or Tanks	*Structures to be Tested*	*Type of Testing*	*Hydrostatic Testing Head*	*Remarks*
1	Liquefied Gas Carriers	Ballast or Fuel Oil Tanks adjacent to or between Cargo Tank Hold Spaces	Structural	The greater of water head - to the top of overflow, or - to 2.4 m above top of tank	
2	Edible Liquid Tanks	Independent Tanks	Structural	The greater of water head - to the top of overflow, or - to 0.9 m above top of tank	
3	Chemical Carriers	Integral or Independent Tanks	Structural	The greater of water head - to 2.4 m above top of tank, or - to top of tank plus setting of any pressure relief valve	

Section 2 Trials

1 Anchor Windlass Trials

Each windlass is to be tested under working conditions after installation onboard to demonstrate satisfactory operation. Each unit is to be independently tested for braking, clutch functioning, lowering and hoisting of chain cable and anchor, proper riding of the chain over the chain lifter, proper transit of the chain through the hawse pipe and the chain pipe, and effecting proper stowage of the chain and the anchor. It is to be confirmed that anchors properly seat in the stored position and that chain stoppers function as designed if fitted. The mean hoisting speed is to be measured and verified, with each anchor and at least 82.5 m length of chain submerged and hanging free. The braking capacity is to be tested by intermittently paying out and holding the chain cable by means of the application of the brake. Where the available water depth is insufficient, the proposed test method will be specially considered.

2 Bilge System Trials

All elements of the bilge system are to be tested to demonstrate satisfactory pumping operation, including emergency suctions and all controls. Upon completion of the trials, the bilge strainers are to be opened, cleaned and closed up in good order.