Rules for Building and Classing

Marine Vessels

Part 3
Hull Construction and Equipment

January 2023

RULES FOR BUILDING AND CLASSING

MARINE VESSELS
JANUARY 2023

PART 3
HULL CONSTRUCTION AND EQUIPMENT

American Bureau of Shipping
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PART 3

Hull Construction and Equipment

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CHAPTER 1
General

SECTION 1
Definitions

1 Application

i) The following definitions of symbols and terms are to be understood (in the absence of other specifications) where they appear in the Rules.

ii) These Rules are applicable for marine vessels* having a speed length ratio $V/\sqrt{L} < 2.36 \quad (1.3)$ where L is in meters (feet) as defined in 3-1-1/3.1 and V is in knots as defined in 3-1-1/11; otherwise the ABS *Rules for Building and Classing High-Speed Craft* apply.

Note: * Marine vessels herein include these vessels formerly covered by ABS *Rules for Building and Classing Steel Vessels, ABS Rules for Building and Classing Offshore Support Vessels,* and ABS *Rules for Building and Classing Steel Vessels under 90 Meters (295 Feet) in Length.*

3 Length

3.1 Scantling Length (L) *(1 July 2020)*

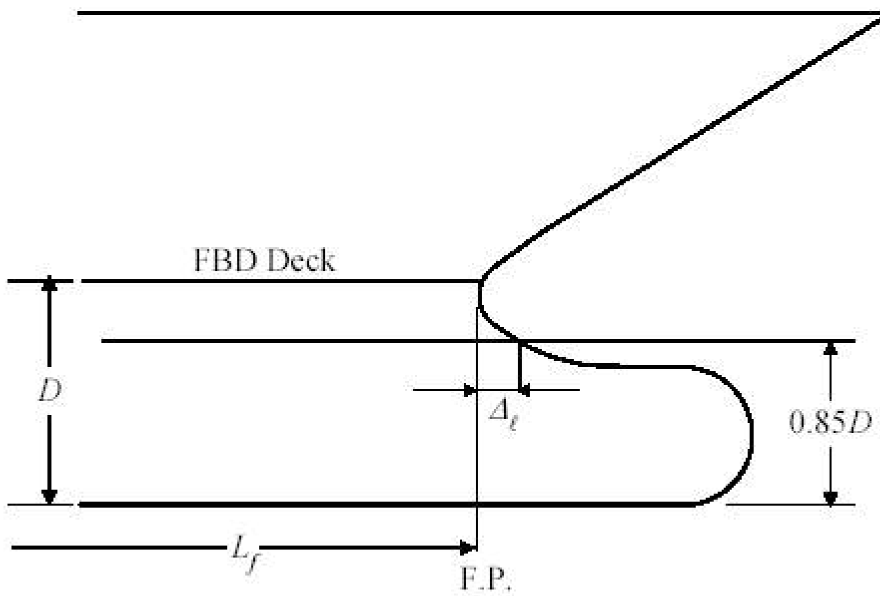
L is the distance in meters (feet) measured on the waterline at the scantling draft from the fore side of the stem to the centerline of the rudder stock. For use with these Rules, L is not to be less than 96% and need not be greater than 97% of the extreme length on the waterline at the scantling draft. The forward end of L is to coincide with the fore side of the stem on the waterline on which L is measured. In ships without rudder stock (e.g., ships fitted with azimuth thrusters), L is to be taken equal to 97% of the extreme length on the waterline at the scantling draft. In ships with an unusual stern and bow arrangement the length, L, is to be specially considered.

3.3 Freeboard Length (L_f)

L_f is the distance in meters (feet) 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 is a fair concave curve above the waterline at 85% of the least molded depth and where the aftermost point of the stem is above the waterline, the forward end of the length, L_f, is to be taken at the aftermost point of the stem above that waterline. See 3-1-1/3.3 FIGURE 1.

In ships designed with a raked keel, the waterline on which this length is measured is to be parallel to the designed waterline.

FIGURE 1



5 Breadth (B)

B is the greatest molded breadth in meters (feet).

7 Depth

7.1 Molded Depth (D)

Molded depth *(D)* is the vertical distance measured in meters (feet) at the middle of scantling length L from the molded base line to the top of the freeboard-deck beam at side.

In vessels having rounded gunwales, D is to be measured to the point of intersection of the molded lines of the deck and side shell plating. In cases where watertight bulkheads extend to a deck above the freeboard deck and are to be recorded in the *Record* as effective to that deck, D is to be measured to the bulkhead deck.

7.3 Scantling Depth D_s

Scantling depth (D_s) used with scantling requirements is the vertical distance in meters (feet) measured according to the following table as applicable:

Superstructure Arrangement		*D_s in meters (feet) Measured*	
		From	*To*
(a)	Having superstructure arrangements as described in 3-2-2/3.1, or 3-2-2/3.5, or 3-2-2/3.7	The molded base line	The uppermost continuous deck at side
(b)	Having superstructure arrangements as described in 3-2-2/3.3	The molded base line	The superstructure deck at side, or the uppermost continuous deck at side, as appropriate
(c)	All other arrangements	The molded base line	The strength deck (see 3-1-1/15.5) at side

9 Draft

9.1 Molded Draft (d)

The molded draft d, is the vertical distance in meters (feet) measured from the molded base line to the summer load line.

9.3 Scantling Draft (d_s) *(1 July 2020)*

The scantling draft d_s is the maximum draft, in meters (feet), at which the strength requirements for the scantlings of the ship are met with the following specifications:

i) d_s, is the vertical distance measured from the molded base line to the deepest load line to which the vessel is designed to operate.

ii) d_s is to be not less than that corresponding to the assigned freeboard. For offshore support vessels d_s is not be taken less than $0.67D_s$.

iii) In no case, vessel to be issued a load line certificate to operate at sea with a draft greater than that corresponding to the freeboard assigned, if that be less.

iv) The declared scantling draft is to be indicated on the Midship Section and Shell Expansion drawings.

11 Maximum Service Speed (V)

V is the maximum ahead service speed, in knots, defined as the greatest speed which the ship is designed to maintain in service at the summer load line at the maximum propeller RPM (Revolutions per Minute) and corresponding engine MCR (Maximum Continuous Rating).

13 Molded Displacement and Block Coefficient

13.1 Molded Displacement ($\varDelta$)

$\varDelta$ is the molded displacement of the vessel in metric tons (long tons), excluding appendages, taken at the summer load line.

13.3 Block Coefficient (C_b) *(1 July 2020)*

C_b is the block coefficient obtained from the following equation:

$C_b = \varDelta_s/1.025LB_{wl}d_s$ (SI & MKS units)

$C_b = 35\varDelta_s/LB_{wl}d_s$ (US units)

where

$\varDelta_s$ = molded displacement of the vessel in metric tons (long tons), excluding appendages, taken at the scantling draft d_s.

L = scantling length, as defined in 3-1-1/3.1

d_s = draft, as defined in 3-1-1/9.3

B_{wl} = the greatest molded breadth measured amidships at the scantling draft, in m (ft)

15 Decks

15.1 Freeboard Deck

The freeboard deck normally is 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. Where a vessel is designed for a special draft, considerably less than that corresponding to the least freeboard obtainable under the International Load Line Regulations, the freeboard deck, for the purpose of these Rules, may be taken as the actual lowest deck from which the draft can be obtained under those regulations.

15.3 Bulkhead Deck

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

15.5 Strength Deck

i) In general, the strength deck is the deck that forms the top of the effective hull girder at any part of its length with the following exceptions:

ii) The uppermost deck to which the side shell plating extends is considered to be the strength deck for that portion of the length, except in way of short superstructures, wherein the modified requirements for the side shell (see 3-2-2/3) and superstructure deck (see 3-2-11/1.3) are adopted. In way of such superstructures, the deck on which the superstructures are located is to be considered the strength deck.

15.7 Superstructure Deck

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

17 Weights

17.1 Deadweight (DWT)

For the purpose of these Rules, deadweight, DWT, is the difference in metric tons (long 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.

17.3 Lightship Weight

For the purpose of these Rules, lightship weight is the displacement of the vessel in metric tons (long 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. The weight of mediums on board for the fixed fire-fighting systems (e.g., freshwater, CO_2, dry chemical powder, foam concentrate, etc.) are to be included in the lightweight and lightship condition.

19 Primary Supporting Members

Structural members such as girders, transverse webs, stringers, floors and etc. that support local supporting members.

21 Local Supporting Members

Structural members that directly support the plating such as: longitudinals, beams, frames and stiffeners.

23 Deckhouse

A deckhouse is an enclosed structure above the freeboard deck having side plating set inboard of the hull's side-shell plating more than 4% of the breadth, *B*, of the vessel.

25 Gross Tonnage

25.1 International Tonnage

For the purpose of application of these Rules to vessels intended for unrestricted service [see 1-1-3/1 of the ABS *Rules for Conditions of Classification (Part 1)*], the referenced gross tonnage throughout the Rules is the measure of the internal volume of spaces within the vessel as determined in accordance with the provisions of the "International Convention on Tonnage Measurement of Ships, 1969".

25.3 National Tonnage

As an alternative to 3-1-1/25.1 above, requirements applicable on the basis of National Tonnage measurement and National Regulations will be considered for vessels whose operation is intended to be restricted exclusively to domestic service. [See 1-1-3/7 of the ABS *Rules for Conditions of Classification (Part 1)*].

27 Units

These Rules are written in three systems of units, viz., SI units, MKS units and US customary units. Each system is to be used independently of any other system.

Unless indicated otherwise, the format of presentation in these Rules of the three systems of units is as follows:

SI units (MKS units, US customary units)

PART 3

CHAPTER 1

General

SECTION 2

General Requirements

1 Material and Fabrication

1.1 Application

To use these Rules, the following are to be met:

i) The requirements of the Rules apply to vessels of all welded construction.

ii) For vessels with riveted hull construction, the applicable sections in the 1969 edition of the Rules are to be complied with.

iii) The design temperatures for unrestricted service are assumed to be not less than –10°C (14°F) for air temperature and not less than 0°C (32°F) for sea water temperature.

1.3 Material

1.3.1 Steel

These Rules are intended for vessels of welded construction using steels complying with the requirements of Chapter 1 of the ABS *Rules for Materials and Welding (Part 2)*. Use of steels other than those in Chapter 1 of the ABS *Rules for Materials and Welding (Part 2)* and the vessels' corresponding scantlings are to be specially considered.

1.3.2 Aluminum Alloys *(2023)*

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

i) Aluminum alloys for deckhouses, helicopter landing platforms, masts, ladders and hatch covers are acceptable upon approval in accordance with the requirements of Chapter 5 of the ABS *Rules for Materials and Welding (Part 2).*

ii) Connections between steel and aluminum structures are to be made by interfacing bimetallic inserts. Details of interfacing bimetallic inserts are to be in accordance with the requirements in 3-2-13/3 of the ABS *Rules for Building and Classing High Speed Craft.*

iii) Aluminum structures and components are to be fully and efficiently precluded from having direct contact with steel by approved non-wicking, non-water absorbing insulating materials, to avoid electrolytic corrosion.

1.3.3 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.

1.3.4 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 Chapter 1 of the ABS *Rules for Materials and Welding (Part 2)*, a set of plans showing the following information for each steel is to be placed aboard the vessel:

i) Material Specification

ii) Welding procedure

iii) Location and extent of application

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

3 Application of Steel Materials 150 mm (6.0 in.) and Under in Thickness *(2021)*

3.1 Selection of Material Grade *(2023)*

i) Steel materials for particular locations are not to be lower grades than those required by 3-1-2/3.3 TABLE 1 for the material class given in 3-1-2/Table 2A, 2B, or 3-1-2/3.5 TABLE 3 depending on the length (*L)* of the vessel.

ii) The provision in 3-1-2/3.1.i) is not required for vessels in length (*L*) under 61 m (200 ft). For vessels under 61 m (200 ft) in length, material is to be per 3-1-2/1.3.1. ASTM A36 steel otherwise manufactured by an ABS approved steel mill, tested and certified to the satisfaction of ABS may be used in lieu of Grade A for a thickness up to and including 12.5 mm (0.5 in.) for plate and 19 mm (0.75 in.) for sections. In addition, the dimensions for ASTM A36 steel are to comply with 2-1-1/15.

iii) When tensile stresses through the thickness (Z direction) exceed approximately 50% of the minimum specified yield stress (as defined in the applicable ABS Rules), consideration is to be given to applying Z grade steel (refer to 2-1-1/17 of the ABS *Rules for Materials and Welding (Part 2)*). Alternatives to applying Z grade may be proposed provided it is demonstrated by ultrasonic testing before and after welding that no through thickness tearing has occurred, and/or the welding preparation, weld size and bead sequence is such that damaging through thickness loads induced by weld shrinkage are avoided.

3.3 Note for Users

The attention of users is drawn to the fact that 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 1
Material Grades *(2021)*

Plate Thickness t mm (in.)	*Material Class*		
	I	*II*	*III*
$t \le 15$ $(t \le 0.60)$	A[2], AH	A, AH	A, AH
$15 < t \le 20$ $(0.60 < t \le 0.79)$	A, AH	A, AH	B, AH
$20 < t \le 25$ $(0.79 < t \le 0.98)$	A, AH	B, AH	D, DH
$25 < t \le 30$ $(0.98 < t \le 1.18)$	A, AH	D, DH	D[1], DH
$30 < t \le 35$ $(1.18 < t \le 1.38)$	B, AH	D, DH	E, EH
$35 < t \le 40$ $(1.38 < t \le 1.57)$	B, AH	D, DH	E, EH
$40 < t \le 100$ $(1.57 < t \le 4.00)$	D, DH	E, EH	E, EH
$100 < t \le 150$ $(4.00 < t \le 6.00)$[3]	E, EH	E, EH	E, EH

Notes:

1 Grade D, of these *plate* thicknesses, is to be normalized.

2 ASTM A36 steel otherwise manufactured by an ABS approved steel mill, tested and certified to the satisfaction of ABS may be used in lieu of Grade A for a thickness up to and including 12.5 mm (0.5 in.) for plate and up to and including 19 mm (0.75 in.) for sections.

3 Rolled plates over 100 mm (4 in.) thick are to be specially considered and be in accordance with 2-1-1/16.

TABLE 2A
Material Class or Grade of Structural Members for Vessels ≥ 90 m (295 ft) in Length *(1 July 2021)*

Line No.	*Structural Members*	*Within 0.4L amidships*	*Outside 0.4L amidships*
		Material Class [8] or Grade	*Material Class or Grade*
A	**Secondary**		
A1	Longitudinal bulkhead strakes, other than those belonging to the Primary category	I	A[10]/AH
A2	Deck plating exposed to weather, other than that belonging to the Primary or Special category		
A3	Side plating [12]		
B	**Primary**		
B1	Bottom plating, including keel plate	II	A[10]/AH
B2	Strength deck plating, excluding that belonging to the Special category [13]		
B3	Continuous longitudinal plating of strength members above strength deck, excluding hatch coamings [13, 14]		
B4	Uppermost strake in longitudinal bulkhead		
B5	Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank		

Line No.	*Structural Members*	*Within 0.4L amidships*	*Outside 0.4L amidships*
		Material Class (8) or Grade	*Material Class or Grade*
C	**Special**		
C1	Sheer strake at strength deck (1, 9, 13)	III	II (I outside $0.6L$ amidships)
C2	Stringer plate in strength deck (1, 9, 13)		
C3	Deck strake at longitudinal bulkhead (2, 9, 13)		
C4	Strength deck plating at outboard corners of cargo hatch openings in container carriers and other ships with similar hatch opening configurations (3, 13)		
C5	Strength deck plating at corners of cargo hatch openings in bulk carriers, ore carriers, combination carriers and other ships with similar hatch opening configurations (4, 13)		
C6	Trunk deck and inner deck plating at corners of openings for liquid and gas domes in membrane type liquefied gas carriers (4, 13)		
C7	Bilge strake (5, 6, 9)		
C8	Longitudinal hatch coamings of length greater than $0.15L$ including coaming top plate and flange(7)		
C9	End brackets and deck house transition of longitudinal cargo hatch coamings (7)		
D	**Other Categories**		
D1	Plating materials for stern frames supporting rudder and propeller boss, rudders, rudder horns, steering equipment (15), propeller nozzles, and shaft brackets	-	II(11)
D2	Strength members not referred to in A to C and D1 (17)	A(10)/AH	A(10)/AH
D3	Equipment foundations, Non-hull structure, Appurtenant structures	(16)	(16)

Notes:

1 Not to be less than grade E/EH[9] within 0.4*L* amidships in ships with length exceeding 250 m (820 ft).

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 0.6*L* 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 m (492 ft).

6 Not to be less than grade D/DH within 0.4*L* amidships in ships with length exceeding 250 m (820 ft).

7 Not to be less than grade D/DH.

8 Special consideration will be given to vessels of restricted class.

9 Single strake required to be class III or E/EH are to have breadths not less than 800 + 5*L* mm (31.5 + 0.06*L* in.), but need not exceed 1800 mm (71 in.), unless limited by the geometry of the vessel's design.

10 ASTM A36 steel otherwise manufactured by an ABS approved steel mill, tested and certified to the satisfaction of ABS may be used in lieu of Grade A for a thickness up to and including 12.5 mm (0.5 in.) for plates and up to and including 19 mm (0.75 in.) for sections.

11 For rudder and rudder body plates subjected to stress concentrations (e.g., in way of lower support or at upper part of spade rudders), class III is to be applied.

12 Single side strakes for ships exceeding 150 m (492 feet) without inner continuous longitudinal bulkheads between bottom and the single strength deck are not to be less than grade B/AH within cargo region in ships.

13 Not to be less than grade B/AH for members contributing to the longitudinal strength within 0.4*L* amidships in ships with length exceeding 150 m (492 feet) and single strength deck.

14 Not to be less than grade B/AH for inner deck plating and plating between the trunk deck and inner deck for members contributing to the longitudinal strength within 0.4L amidships in membrane type liquefied gas carriers and other similar ship types with a double deck arrangement above the strength deck and with length exceeding 150 m (492 feet). See 3-1-2/3.3 FIGURE 1.

15 Steering equipment components other than rudders, as described in Section 3-2-14.

16 ASTM A36 steel otherwise tested and certified to the satisfaction of ABS may be used in lieu of Grade A for a thickness up to and including 12.5 mm (0.5 in.) for plates and up to and including 19 mm (0.75 in.) for sections.

17 Deck plating below the strength deck at corners of cargo hatch openings immediately forward and aft of the engine room and/or deck house in container carriers and other ships with similar hatch opening configurations, is not to be less than Class I.

FIGURE 1
Typical Deck Arrangement for Membrane Type Liquefied Gas Carriers

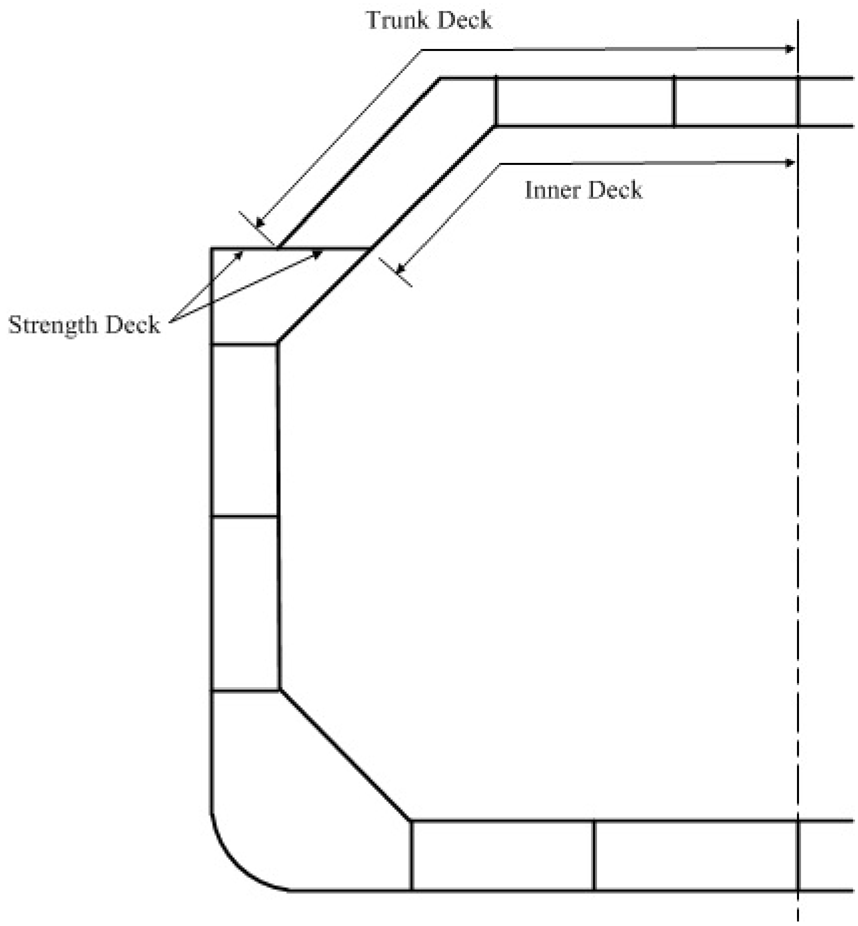


TABLE 2B
Material Class or Grade of Structural Members for Vessels 61 m (200 ft) ≤ L < 90 m (295 ft) in Length

Structural Member	*Material Class (1)*	
	Within 0.4L Amidships	*Outside 0.4L Amidships*
Shell		
Bottom plating including keel plate	II	A(4)/AH
Bilge strake	II	A(4)/AH
Side plating	I	A(4)/AH
Sheer strake at strength deck (2)	II	A(4)/AH
Decks		
Strength deck plating (3)	II	A(4)/AH
Stringer plate in strength deck (2)	II	A(4)/AH
Strength deck plating within line of hatches and exposed to weather, in general	I	A(4)/AH

Structural Member	*Material Class [1]*	
	Within 0.4L Amidships	*Outside 0.4L Amidships*
Strength deck strake on tankers at longitudinal bulkhead	II	A[4]/AH
Longitudinal Bulkheads		
Lowest strake in single bottom vessels	I	A[4]/AH
Uppermost strake including that of the top wing tank	II	A[4]/AH
Other Structures in General		
External continuous longitudinal members and bilge keels	II	A[4]/AH
Plating materials for stern frames supporting rudder and propeller boss, rudders, rudder horns, steering equipment [5], propeller nozzles, and shaft brackets	—	I
Strength members not referred to in above categories and above local structures	A[4]/AH	A[4]/AH

Notes:

1 Special consideration will be given to vessels in restricted service.

2 A radius gunwale plate may be considered to meet the requirements for both the stringer plate and the sheer strake, provided it extends suitable distances inboard and vertically. For formed material, see 2-4-1/3.13 of the ABS *Rules for Materials and Welding (Part 2).*

3 Plating at the corners of large hatch openings are to be specially considered.

4 ASTM A36 steel otherwise manufactured by an ABS approved steel mill, tested and certified to the satisfaction of ABS may be used in lieu of Grade A for a thickness up to and including 12.5 mm (0.5 in.) for plates and up to and including 19 mm (0.75 in.) for sections.

5 Steering equipment components other than rudders, as described in Section 3-2-11.

3.5 Ships Exposed to Low Air Temperatures *(1 July 2019)*

i) For ships intended to operate in areas with low air temperatures [below -10ºC (14ºF)], the materials in exposed structures are to be selected based on the design temperature t_D, to be taken as defined in 3-1-2/3.7.

ii) Materials in the various strength members above the lowest ballast water line (BWL) exposed to air (including the structural members covered by Note 5 of 3.5 TABLE 3)and materials of cargo tank boundary plating for which 3-1-2/3.9 is applicable are not to be of lower grades than those corresponding to Classes I, II and III, as given in 3-1-2/3.5 TABLE 3, depending on the categories of structural members (secondary, primary and special). For non-exposed structures (except as indicated in Note 5 of 3-1-2/3.5 TABLE 3) and structures below the lowest ballast water line, 3-1-2/3.1 applies.

iii) The material grade requirements for hull members of each class depending on thickness and design temperature are defined in 3-1-2/3.5 TABLE 4. For design temperatures t_D < –55°C (–67°F), materials are to be specially considered.

iv) Single strakes required to be of Class III or of Grade E/EH or FH are to have breadths not less than 800 + 5*L* mm (31.5 + 0.06*L* in.), maximum 1800 mm (71 in.). *L* is as defined in 3-1-1/3.1.

v) 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 3-1-2/3.1.

TABLE 3
Application of Material Classes and Grades – Structures Exposed at Low Temperatures *(1 July 2019)*

Structural Member Category	*Material Class*	
	Within 0.4L Amidships	*Outside 0.4L Amidships*
Secondary	I	I
Deck plating exposed to weather, in general		
Side plating above BWL		
Transverse bulkheads above BWL (5)		
Cargo tank boundary plating exposed to cold cargo (6)		
Primary	II	I
Strength deck plating (1)		
Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings		
Longitudinal bulkhead above BWL (5)		
Top wing tank bulkhead above BWL (5)		
Special	III	II
Sheer strake at strength deck (2)		
Stringer plate in strength deck (2)		
Deck strake at longitudinal bulkhead (3)		
Continuous longitudinal hatch coamings (4)		

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 m (820 ft).

3 In ships with breadth exceeding 70 m (230 ft) at least three deck strakes to be Class III.

4 Not to be less than Grade D/DH.

5 Applicable to plating attached to hull envelope plating exposed to low air temperature. At least one strake is to be considered in the same way as exposed plating and the strake width is to be at least 600 mm (24 in.).

6 For cargo tank boundary plating exposed to cold cargo for ships other than liquefied gas carriers, see 3-1-2/3.9.

TABLE 4
Material Grade Requirements for Classes I, II and III at Low Temperatures
Class I *(1 July 2019)*

Thickness, in mm (in.)	*–11 to –15°C (12 to 5°F)*	*–16 to –25°C (4 to –13°F)*	*–26 to –35°C (–14 to –31°F)*	*–36 to –45°C (–32 to –49°F)*	*–46 to –55°C (–50 to –68°F)*
$t \le 10$ ($t \le 0.39$)	A, AH	A, AH	B, AH	D, DH	D, DH
$10 < t \le 15$ ($0.39 < t \le 0.60$)	A, AH	B, AH	D, DH	D, DH	D, DH
$15 < t \le 20$ ($0.60 < t \le 0.79$)	A, AH	B, AH	D, DH	D, DH	E, EH
$20 < t \le 25$ ($0.79 < t \le 0.98$)	B, AH	D, DH	D, DH	D, DH	E, EH
$25 < t \le 30$ ($0.98 < t \le 1.18$)	B, AH	D, DH	D, DH	E, EH	E, EH
$30 < t \le 35$ ($1.18 < t \le 1.38$)	D, DH	D, DH	D, DH	E, EH	E, EH
$35 < t \le 45$ ($1.38 < t \le 1.80$)	D, DH	D, DH	E, EH	E, EH	-, FH
$45 < t \le 50$ ($1.80 < t \le 1.97$)	D, DH	E, EH	E, EH	-, FH	-, FH

Class II *(1 July 2019)*

Thickness, in mm (in.)	*-11 to -15°C (12 to 5°F)*	*-16 to -25°C (4 to -13°F)*	*-26 to -35°C (-14 to -31°F)*	*-36 to -45°C (-32 to -49°F)*	*-46 to -55°C (-50 to -68°F)*
$t \le 10$ ($t \le 0.39$)	A, AH	B, AH	D, DH	D, DH	E, EH
$10 < t \le 20$ ($0.39 < t \le 0.79$)	B, AH	D, DH	D, DH	E, EH	E, EH
$20 < t \le 30$ ($0.79 < t \le 1.18$)	D, DH	D, DH	E, EH	E, EH	-, FH
$30 < t \le 40$ ($1.18 < t \le 1.57$)	D, DH	E, EH	E, EH	-, FH	-, FH
$40 < t \le 45$ ($1.57 < t \le 1.80$)	E, EH	E, EH	-, FH	-, FH	-, -
$45 < t \le 50$ ($1.80 < t \le 1.97$)	E, EH	E, EH	-, FH	-, FH	-, -

Class III *(1 July 2019)*

Thickness, in mm (in.)	*-11 to -15°C (12 to 5°F)*	*-16 to -25°C (4 to -13°F)*	*-26 to -35°C (-14 to -31°F)*	*-36 to -45°C (-32 to -49°F)*	*-46 to -55°C (-50 to -68°F)*
$t \le 10$ ($t \le 0.39$)	B, AH	D, DH	D, DH	E, EH	E, EH
$10 < t \le 20$ ($0.39 < t \le 0.79$)	D, DH	D, DH	E, EH	E, EH	-, FH
$20 < t \le 25$ ($0.79 < t \le 0.98$)	D, DH	E, EH	E, EH	E, FH	-, FH
$25 < t \le 30$ ($0.98 < t \le 1.18$)	D, DH	E, EH	E, EH	-, FH	-, FH
$30 < t \le 35$ ($1.18 < t \le 1.38$)	E, EH	E, EH	-, FH	-, FH	-, -
$35 < t \le 40$ ($1.38 < t \le 1.57$)	E, EH	E, EH	-, FH	-, FH	-, -
$40 < t \le 50$ ($1.57 < t \le 1.97$)	E, EH	-, FH	-, FH	-, -	-, -

3.7 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

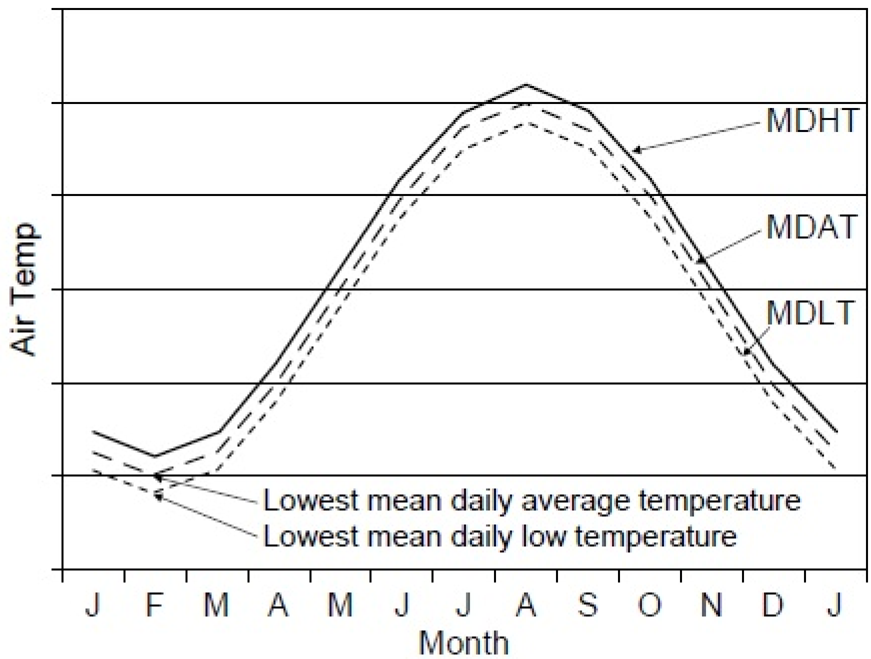
For seasonally restricted service the lowest value within the period of operation applies.

For the purpose of issuing a Polar Ship Certificate in accordance with the Polar Code, the design temperature t_D shall be no more than 13°C (23.6°F) higher than the Polar Service Temperature (PST) of the ship.

In the Polar Regions, the statistical mean over observation period is to be determined for a period of at least 10 years.

3-1-2/3.7 FIGURE 2 illustrates the temperature definition.

FIGURE 2
Commonly Used Definitions of Temperatures



MDHT = Mean Daily High (or maximum) Temperature

MDAT = Mean Daily Average Temperature

MDLT = Mean Daily Low (or minimum) Temperature

3.9 Cold Cargo for Ships Other Than Liquefied Gas Carriers *(1 July 2019)*

For ships other than liquefied gas carriers, intended to be loaded with liquid cargo having a temperature below -10°C, e.g. loading from cold onshore storage tanks during winter conditions, the material grade of cargo tank boundary plating is defined in 3-1-2/3.5 TABLE 4 based on the following:

- t_c design minimum cargo temperature in °C (°F)
- steel grade corresponding to Class I as given in 3-1-2/3.5 TABLE 3

The design minimum cargo temperature, t_c is to be specified in the loading manual.

5 Scantlings

5.1 General

i) The midship scantlings specified in these Rules are to apply throughout the midship 0.4*L* for vessels 61m (200 ft) in length and above.

ii) End scantlings are not to extend for more than 0.1*L* from each end of the vessel.

iii) Reduction in scantlings from the midship to the end scantlings is to be executed in as gradual a manner as practicable.

iv) 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.

v) It may be required that calculations be submitted in support of resistance to buckling for any part of the vessel's structure.

5.3 Rounding of Calculated Thickness

The required thickness is given by rounding the calculated plate thickness to the nearest half millimeter (or $^1/_{64}$ inch). For example:

For $10.75 \le t_{calc} < 11.25$ mm	the Rule required thickness is 11 mm
For $11.25 \le t_{calc} < 11.75$ mm	the Rule required thickness is 11.5 mm

5.5 Direct Analysis *(2023)*

A direct analysis is to be carried out:

i) When vessel specific requirements contained in Part 5A & 5B, Part 5C, or a Guide require direct analysis

ii) For vessels over 130 m (426 ft) in length with multiple continuous decks, large openings, or structural discontinuity within the midship 0.6*L*

iii) For all vessels over 150 m (492 ft) in length

The direct analysis is to cover material yielding and buckling. An assessment carried out in accordance with the ABS *Guide for 'SafeHull Dynamic Loading Approach' for Vessels* is considered acceptable. Other approaches which can be shown, through either satisfactory service experience or a review of the engineering principles, to meet the overall strength standards may also be considered acceptable. See Section 3-2-20 for guidance.

The extent of the model is to cover critical areas subject to high global stresses. The extent of the model is to be such that the imposed boundary conditions do not significantly affect the calculated stresses as the critical areas.

The Total Strength Assessment required for Specific Vessel Types per Part 5A & 5B or Part 5C is sufficient for meeting this requirement.

Unless specifically permitted, the results of the direct analysis cannot be used to reduce the basic scantlings obtained from other requirements in these Rules.

7 Proportions

To apply these Rules, vessels are generally proportioned to have:

i) $L \leq L_{\max}$

ii) $B \leq 0.2L, B \leq C_p D_s$, to the strength deck.

where

$L_{\max}$	=	305 m (1000 ft)	for offshore support vessels
	=	500 m (1640 ft)	for regular steel vessels
C_p	=	3.0	for offshore support vessels
	=	2.0	for steel vessels under 90 m (295 ft)
	=	2.5	for regular steel vessels

L, B , and D_s as defined in 3-1-1/3.1, 3-1-1/5, and 3-1-1/7.3, respectively.

Vessels that do not meet the above proportions are subject to special consideration.

9 Workmanship

The following requirements are to be complied with, as applicable:

i) All workmanship is to be of commercial marine quality and acceptable to the Surveyor.

ii) Welding is to be in accordance with the requirements of Chapter 4 or Chapter 5 of the ABS *Rules for Materials and Welding (Part 2)* and Section 3-2-19 and 3-7-3/1 of these Rules.

iii) Plates subjected to excessive furnacing are to undergo a satisfactory heat treatment before being worked into a hull.

11 Drydocking *(2021)*

Consideration is to be given to drydocking the vessel within twelve months after delivery. For vessels over 228.5 m (750 ft) in length, information indicating docking arrangements is to be submitted for information and placed onboard the vessel for guidance. See also 3-2-2/3.17 and 3-2-2/7.

13 Structural Elements and Members

13.1 General

The scantling requirements of these Rules apply to structural sections, angles, channels, plates, and bars that are used in the ship construction.

13.3 Primary Supporting Members

The section modulus of primary supporting members that support frames, beams and stiffeners, is to be in accordance with the following, as applicable:

i) The member's section modulus is to include an effective width of the attached plate with one-half of the sum of the spacing on each side of the member or 33% of the unsupported span of the member, ℓ, whichever is less.

ii) For section modulus of girders and webs along hatch openings, an effective breadth of attached plate is to be of one-half of the spacing or 16.5% of the unsupported span ℓ, whichever is less.

13.5 Local Supporting Members

13.5.1 Section Modulus

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

13.5.2 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	$15C_1C_2$

where

C_1 = 0.95 (horizontal web within a tank)

= 1.0 (all other cases)

C_2 = 1.0 (ordinary strength steel)

= 0.92 (HT32)

= 0.90 (HT36)

= 0.88 (HT40)

15 Structural Design Details

15.1 General *(1 July 2022)*

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. See 3-1-2/13.5.2 and 3-2-A4.

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 lightening holes.
- Shape and reinforcement of slots and cut-outs for internals.
- Elimination or closing of weld scallops in way of butts, "softening" of bracket toes and reducing abrupt changes of section or structural discontinuities.
- Continuity of all higher strength steel members in way of supporting members of lesser strength. Care is to be taken to provide structural continuity. Changes in scantlings are to be gradual. Strength members are not to change direction abruptly. Where major longitudinal members end at transverse structural members, tapering may be required forward or aft of the transverses. Stanchions and bulkheads are to be aligned to provide support and to minimize eccentric loading. Major appendages outside the hull and strength bulkheads in superstructures are to be aligned with major structural members within the hull.
- Major openings such as doors, large hatches, and large vent ducts are to be avoided in the sheer strake and stringer plate within the amidships three-fifths length. Corners of openings in strength structures are to have generous radii. Compensation may be required for openings.

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.

15.3 Termination of Structural Members *(1 July 2022)*

The termination of structural members is to be such that:

i) The end connections to the supporting structure are to effectively develop the bending strength and shear strength of the member being connected in such a manner as to avoid hard spots, notches and other harmful stress concentrations unless permitted elsewhere in these Rules,.

ii) 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°. The local plating in way of the sniped end is to have adequate thickness to transmit the bending strength and shear strength from the snipe end to the supporting member.

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

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

v) Bracket toes and sniped end members are to be kept within 25 mm (1.0 in.) of the adjacent member unless 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 (0.60 in.).

vi) Where a longitudinal of strength deck or shell terminates without an end attachment, it is to extend into the adjacent transversely framed structure, or stop at a local transverse member fitted at about one transverse frame space (see 3-2-5/1.5) beyond the last floor or web that supports the longitudinal.

vii) In general, the end attachments of non-load bearing members may be snipe ended. The sniped end is to be not more than 30° and kept generally within 40 mm (1.57 in.) from 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 (0.6 in.).

15.5 Fabrication *(2023)*

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 another appropriate shipbuilding and repair standard is not available, the latest version of IACS Recommendation No. 47 “Shipbuilding and repair Quality Standard” may be used. These standards are for conventional ship types and hull structures and they are not applicable to critical and highly stressed areas of the structure, which are to be reviewed and verified on an individual basis. See Appendix 5C-A1-1 "SafeHull Construction Monitoring Program".

15.7 Bolted Connections *(2021)*

Unless indicated otherwise, the structural design and fabrication of bolted connections is to meet a recognized bolting standard (AISC, API, etc.). The bolted connections, including connection type, materials and methods are to be suitable for the intended application. Workmanship of these connections is to be in accordance with 3-1-2/9 of the Rules.

17 Certification of Materials, Equipment, and Components *(2023)*

17.1 Basic Requirements

The Rules define, to varying degrees, the extent of evaluation required for materials, equipment, and their components based on the level of criticality of each of those items. There are three basic evaluation constituents:

- Design review; type/prototype testing, as applicable;
- Survey during construction and testing at the plant of manufacture; and
- Survey during installation on board the vessel and at trials.

Where design review is required by the Rules, a letter will be issued by ABS upon satisfactory review of the plans to evidence the acceptance of the design. In addition to, or independent of, design review, ABS may require survey and testing of forgings, castings, and component parts at the various manufacturers'plants, as well as survey and testing of the finished product. A certificate or report will be issued upon satisfactory completion of each survey to evidence acceptance of the forging, casting, component, or finished product. Design review, survey, and the issuance of reports or certificates constitute the certification of materials, equipment, and components.

Based on the intended service and application, some products do not require certification because they are not directly related to the scope of classification or because normal practices for their construction within the industry are considered adequate. Such products may be accepted based on the manufacturers' documentation on design and quality.

In general, surveys during installation on board the vessel and at trials are required for all items of materials, equipment, and components. This is not considered a part of the product certification process. There may be instances, however, where letters or certificates issued for items of materials, equipment, and components contain conditions which must be verified during installation, tests or trials.

17.3 Type Approval Program

Products that can be consistently manufactured to the same design and specification may be Type Approved under the ABS Type Approval Program. The ABS Type Approval Program is a voluntary option for the demonstration of the compliance of a product with the Rules or other recognized standards. It may be applied at the request of the designer or manufacturer. The ABS Type Approval Program generally covers Product Type Approval (see 1-1-4/7.7.3 of the ABS *Rules for Conditions of Classification (Part 1)*) but is also applicable for a more expeditious procedure towards Unit-Certification as specified in 1-1-4/7.7.2 of the ABS *Rules for Conditions of Classification (Part 1)*.

See the "ABS Type Approval Program" in Appendix 1-1-A3 and 1-1-A4 of the ABS *Rules for Conditions of Classification (Part 1)*.

17.5 Non-mass Produced Equipment and Components

Non-mass produced critical equipment and components, such as anchors, rudders, and similar critical items are to be individually unit certified in accordance with the procedure described in 3-1-2/17.1. However, consideration will be given to granting Type Approval to such machinery in the category of Recognized Quality System (RQS). The category of Product Quality Assurance (PQA) will not normally be available for all products, and such limitations will be indicated in 3-1-2/Table 6 through 3-1-2/Table 8. In each instance where Type Approval is granted, in addition to quality assurance and quality control assessment of the manufacturing facilities, ABS will require some degree of product specific survey during manufacture.

17.7 Details of Certification of Some Representative Products

3-1-2/Table 6 through 3-1-2/Table 8 provide abbreviated certification requirements of representative equipment and components based on the basic requirements of the Rules for equipment and components. The tables also provide the applicability of the Type Approval Program for each of these machinery items. For easy reference, the tables contain three product categories as follows:

- Hull Materials
- Equipment
- Structural Components

TABLE 5
Certification Details - Hull Materials

	Materials	*Rule Reference*
1.	Aluminum Hull Castings	3-1-2/1.3.2, 2-5-1/1.1 , 2-5-1/1.3, 2-5-10, 2-5-A3
2.	Aluminum Hull Forgings	3-1-2/1.3.2, 2-5-1/1.1 , 2-5-1/1.3, 2-5-9, 2-5-A3
3.	Aluminum Extrusions	3-1-2/1.3.2, 2-5-1/1.1 , 2-5-1/1.3, 2-5-8, 2-5-A3
4.	Aluminum Hull Materials: Sheet, Plate, and Rolled Products	3-1-2/1.3.2, 2-5-1/1.1 , 2-5-1/1.3, 2-5-7, 2-5-A3
5.	Materials for Extra High Strength Quenched and Tempered Steel	3-1-2/1.3.1, 2-1-1/1.2, 2-1-8, 2-A1-1
6.	Materials for Higher-Strength Hull Structural Steel	3-1-2/1.3.1, 2-A1-1, 2-1-3
7.	Steel Materials for Low Temperature Service	3-1-2/1.3.1, 2-1-1/1.2, 2-1-4, 2-A1-1
8.	Materials for Ordinary and Higher Strength Steels with Enhanced Corrosion Resistance Properties	3-1-2/1.3.1, 2-1-1/1.2, 2-1-7, 2-A1-1/6
9.	Materials for Ordinary-Strength Hull Structural Steel	3-1-2/1.3.1, 2-A1-1, 2-1-2
10.	Materials for H47 Hull Structural Steel	ABS *Guide for Application of Higher-Strength Hull Structural Thick Steel Plates in Container Carriers*
11.	Stainless Steel Materials for Hull Structures	5C-9-1/11.7, ABS *Requirements for Materials and Welding for Stainless Steels*
12.	Steel for Steering Equipment	3-2-14/1.3, 3-2-14/25.7, 2-1-1/1, 3-2-14/23.25
13.	Steel Hull Castings	3-1-2/1.3.1, 3-7-3/3, 2-1-1/1.2, 2-A1-1, 2-1-5, 3-2-13/13
14.	Steel Hull Forgings	3-1-2/1.3.1, 3-7-3/3, 2-1-1/1.2, 2-A1-1, 2-1-6
15.	Steel Hull Piping	3-1-2/1.3.1, 2-1-1/1.11, 2-A1-1, 2-3-12

TABLE 6
Certification Details - Equipment

	Equipment	*ABS Approval Tier*	*Rule Reference*
1.	Anchors for vessels without Ⓔ symbol	1	3-5-1/5
2.	Anchors for vessels with Ⓔ symbol	5	3-5-1/5, 2-1-1/1.1, 2-1-1/3, 2-2-1, 2-A1-1
3.	Anchor Chain for vessels without Ⓔ symbol	1	3-5-1/5
4.	Anchor Chain for vessels with Ⓔ symbol	5	3-5-1/5, 2-2-2/7.1, 2-A1-1, 2-2-2
5.	Chafing Chain	5	3-5-1/19, 2-2-2, ABS *Requirements for Certification of Offshore Mooring Chain*
6.	Chain Stopper	2	3-5-1/11
7.	Fixed Propeller Nozzles with Inner Diameter Greater than 5 meters (16.4 feet)	5	3-2-13/9
8.	Fixed Propeller Nozzles with Inner Diameter of 5 meters (16.4 feet) or Less	1	3-2-13/9

Equipment		ABS Approval Tier	Rule Reference
9.	Loading Instrument	2	3-2-A2/9.3
10.	Offshore Mooring Chain	5	3-5-1/17, 2-2-2/7.1, ABS *Requirements for Certification of Offshore Mooring Chain*
11.	Propulsion Improvement Devices (PID) as Hull Appendages	5	3-2-13/11
12.	Onboard Computers/Software for Stability Calculations	2	3-3-1/17, 3-3-A7/11.1, 3-3-A7/15, 3-3-A7/17
13.	Winches Used for Anchoring (Vessels Under 90 m (295 ft))	4/5	3-5-1/11.3, 4-1-1/5
14.	Wire Rope	1	3-5-1/5

TABLE 7
Certification Details - Structural Components

Equipment		ABS Approval Tier	Rule Reference
1.	Bollard, Fairlead and Chocks[1]	1	3-5-1/15, 3-2-7/4
2.	Doors for Access Openings	1	3-2-11/5.3
3.	Portable Industrial Module	5	3-2-A8/1.1, 7-1-17/5, ABS *Guide for Portable Accommodation Modules* - Subsection 3/5
4.	Portlights	1	3-2-17/7.5.1(a)(b), 3-2-17/9.9.1, 3-2-17/9.9.2
5.	Rudder	5	3-2-14/1.1, 3-2-14/1.3, 3-2-14/7.3, 3-2-14/17.1, 2-1-1, 6-1-4/31, 6-1-5/41, Part 2, Chapter 1
6.	Rudder Coupling Bolts and Keys	2	3-2-14/1.1, 3-2-14/1.3, Part 2, Chapter 3
7.	Rudder Pintles	5	3-2-14/1.1, 3-2-14/1.3, Part 2, Chapter 1
8.	Rudder Stock	5	3-2-14/1.1, 3-2-14/1.4, 3-2-14/7.3, Part 2, Chapter 3
9.	Rudder Bearing Materials	2	3-2-14/1.3 and Part 2, Chapter 1
10.	Structural Fire Protection	3	3-4-1/11
11.	Watertight Doors	4/5	3-2-9/1, 3-2-9/5.1, 3-2-9/5.3 3-2-9/9.11, 3-2-16/11.7, 3-2-16/17, 3-7-1/3.5 TABLE 1
12.	Weathertight Doors	1	3-2-11-3.3, 3-2-11/3.5, 3-7-1/3.5
13.	Window Glazing	1	3-2-17/9.7.1, 3-2-17/9.7.2
14.	Windows	2	3-2-17/9.5.1, 3-2-17/9.9.2, 3-2-17/9.5.2

Note:

1 When designed to an international standard

PART 3

CHAPTER 2

Hull Structures and Arrangements

CONTENTS

PART 3

CHAPTER 2

Hull Structures and Arrangements

SECTION 1

Longitudinal Strength

1 Application

Vessels to be classed for unrestricted service are to have longitudinal strength in accordance with the requirements of this Section. Vessels, however, having one or more of the following characteristics are subject to special consideration:

i)	Length:	$L > L_{max}$, where L and L_{max} are as defined in 3-1-2/7
ii)	Proportions:	not comply with 3-1-2/7.i & 3-1-2/7.ii
iii)	Block Coefficient:	$C_b < 0.6$
iv)	Vessels with large deck opening	
v)	Vessels with large flare	
vi)	Carriage of heated cargoes	
vii)	Unusual type or design	

3 Longitudinal Hull Girder Strength

3.1 Minimum Section Modulus for Vessels Under 61 m (200 ft) in Length *(2022)*

The minimum required hull girder section modulus (see 3-1-2/1.3.3), SM, at amidships, is to be determined in accordance with the following equation:

$SM = C_1 C_2 L^2 B(C_b + 0.7)$ m-cm^2 (ft-in^2)

where

C_1 For OSVs

= $0.044L + 3.75$ for $L < 61$ m

= $0.0134L + 3.75$ for $L < 200$ ft

C_1 For All other Vessels Under 61 m (200 ft) in Length

	=	$30.67 - 0.98L$	$12 \le L < 18$ m
	=	$22.40 - 0.52L$	$18 \le L < 24$ m
	=	$15.20 - 0.22L$	$24 \le L < 35$ m
	=	$11.35 - 0.11L$	$35 \le L < 45$ m
	=	6.40	$45 \le L < 61$ m
	=	$30.67 - 0.299L$	$40 \le L < 59$ ft
	=	$22.40 - 0.158L$	$59 \le L < 79$ ft
	=	$15.20 - 0.067L$	$79 \le L < 115$ ft
	=	$11.35 - 0.033L$	$115 \le L < 150$ ft
	=	6.40	$150 \le L < 200$ ft

C_2 = 0.01 (0.01, 1.44×10^{-4})

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

B = breadth of vessel, as defined in 3-1-1/5, in m (ft)

C_b = block coefficient, as defined in 3-1-1/13.3, but is not to be taken less than 0.6.

3.3 Longitudinal Strength for Vessels 61 m (200 ft) in Length and Over *(2022)*

Vessels of 61 m (200 ft) in length or greater are to comply with the following requirements.

3.3.1 Sign Convention of Bending Moment and Shear Force

The sign convention for bending moment and shear force is shown in 3-2-1/3.5.3 FIGURE 1.

3.3.2 Still-water Bending Moment and Shear Force – General

Still-water bending moment and shear force calculations, determining the bending moment and hull girder shear force values along the vessel's entire length, are to be submitted together with the distribution of lightship weights for the anticipated loaded, transitional and ballasted conditions.

For bulk carriers with notation **BC-A**, **BC-B** or **BC-C** of length 150 m (492 ft) and above, see also 5C-3-A6/5, 5C-3-3/3.1 and 5C-3-A5a for hold flooded conditions.

3.3.3 Still-water Bending Moment and Shear Force *(2022)*

3.3.3(a) Design Cargo and Ballast Loading Conditions.* The calculations are to consider the effect of bunker, fresh water and consumable stores at departure and arrival. Where their amount and disposition at any 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.

Where any ballasting/de-ballasting is intended during a voyage, calculations for the intermediate condition just before and just after ballasting and/or de-ballasting of any ballast tanks are to be submitted and, where approved, included in the loading manual for guidance.

3.3.3(b) Ballast Tanks in Cargo Loaded Conditions.* Cargo loading conditions involving partially filled peak tanks are not permitted unless the conditions indicated in 3-2-1/3.3.3(d) for partially filled tanks are complied with.

3.3.3(c) Sequential Ballast Water Exchange.* The requirements of 3-2-1/3.3.3(b) and 3-2-1/3.3.3(d) are not applicable to sequential method for ballast water exchange. However, bending moment and shear force calculations for each de-ballasting or ballasting stage in the ballast water exchange sequence are to be included in the loading manual or ballast water management plan of any vessel that intends to employ the sequential ballast water exchange method.

3.3.3(d) Ballast Tanks in Ballast Loaded Conditions.* Ballast loading conditions involving partially filled ballast tanks (peak tanks and/or other ballast tanks) are not permitted as design conditions, unless:

i) Design stress limits are satisfied for all filling levels between empty and full, and

ii) For bulk carriers, the requirements in 5C-3-A5a, as applicable, are complied with for all filling levels between empty and full.

For the purpose of compliance with the "all filling levels" requirement, calculations for full and empty conditions at each departure and arrival, and where required by 3-2-1/3.3.3, at any intermediate condition, may be accepted. The tanks intended to be partially filled are assumed to be:

- Empty
- Full
- Partially filled at intended level

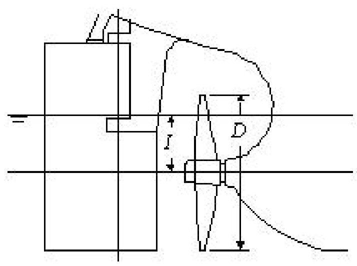
Where there are multiple tanks intended to be partially filled, all combinations of empty, full or partially filled at intended level for those tanks are subject to investigation.

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 vessel'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 vessel's length, or
- Trim by bow of 1.5% of the vessel's length, or
- Any trim that cannot maintain propeller immersion (I/D) not less than 25%, where:

I = distance from propeller centerline to the waterline

D = propeller diameter



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

3.5 Wave Loads

3.5.1 Wave Bending Moment Amidships *(2022)*

The wave bending moment, expressed in kN-m (tf-m, Ltf-ft), may be obtained from the following equations:

$$M_{ws} = -k_1 C_1 L^2 B (C_b + 0.7) \times 10^{-3} \qquad \text{Sagging Moment}$$

$$M_{wh} = +k_2 C_1 L^2 B C_b \times 10^{-3} \qquad \text{Hogging Moment}$$

where

k_1	=	110 (11.22, 1.026)	
k_2	=	190 (19.37, 1.772)	
C_1	=	$0.044L + 3.75$	$61 \le L \le 90$ m
	=	$10.75 - \left(\frac{300 - L}{100}\right)^{1.5}$	$90 < L < 300$ m
	=	10.75	$300 < L < 350$ m
	=	$10.75 - \left(\frac{L - 350}{150}\right)^{1.5}$	$350 \le L \le 500$ m
C_1	=	$0.0134L + 3.75$	$200 \le L < 295$ ft
	=	$10.75 - \left(\frac{984 - L}{328}\right)^{1.5}$	$295 \le L \le 984$ ft
	=	10.75	$984 < L < 1148$ ft
	=	$10.75 - \left(\frac{L - 1148}{492}\right)^{1.5}$	$1148 \le L \le 1640$ ft
L	=	length of vessel, as defined in 3-1-1/3.1, in m (ft)	
B	=	breadth of vessel, as defined in 3-1-1/5, in m (ft)	
C_b	=	block coefficient, as defined in 3-1-1/13.3, but is not to be taken less than 0.6	

3.5.2 Envelope Curve of Wave Bending Moment

The wave bending moment along the vessel length, L, may be obtained by multiplying the midship value by the distribution factor M, given by 3-2-1/3.5.3 FIGURE 2.

3.5.3 Wave Shear Force

The envelopes of maximum shearing forces induced by waves, F_w, as shown in 3-2-1/3.5.3 FIGURE 3 and 3-2-1/3.5.3 FIGURE 4 may be obtained from the following equations:

$$F_{wp} = +kF_1 C_1 L B (C_b + 0.7) \times 10^{-2} \qquad \text{For positive shear force}$$

$$F_{wn} = -kF_2 C_1 L B (C_b + 0.7) \times 10^{-2} \qquad \text{For negative shear force}$$

where

F_{wp}, F_{wn}	=	maximum shearing force induced by wave, in kN (tf, Ltf)
C_1	=	as defined in 3-2-1/3.5.1
L	=	length of vessel, as defined in 3-1-1/3.1, in m (ft)

B = breadth of vessel, as defined in 3-1-1/5, in m (ft)

C_b = block coefficient, as defined in 3-1-1/13.3, but is not to be taken less than 0.6

k = 30 (3.059, 0.2797)

F_1 = distribution factor, as shown in 3-2-1/3.5.3 FIGURE 3

F_2 = distribution factor, as shown in 3-2-1/3.5.3 FIGURE 4

FIGURE 1
Sign Convention

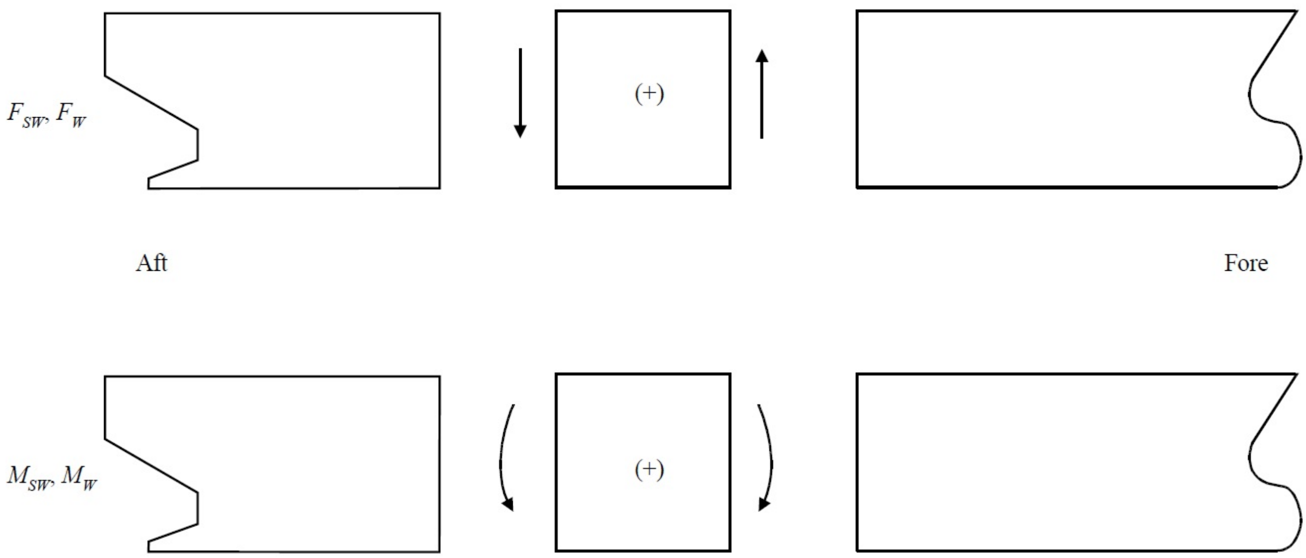


FIGURE 2
Distribution Factor M

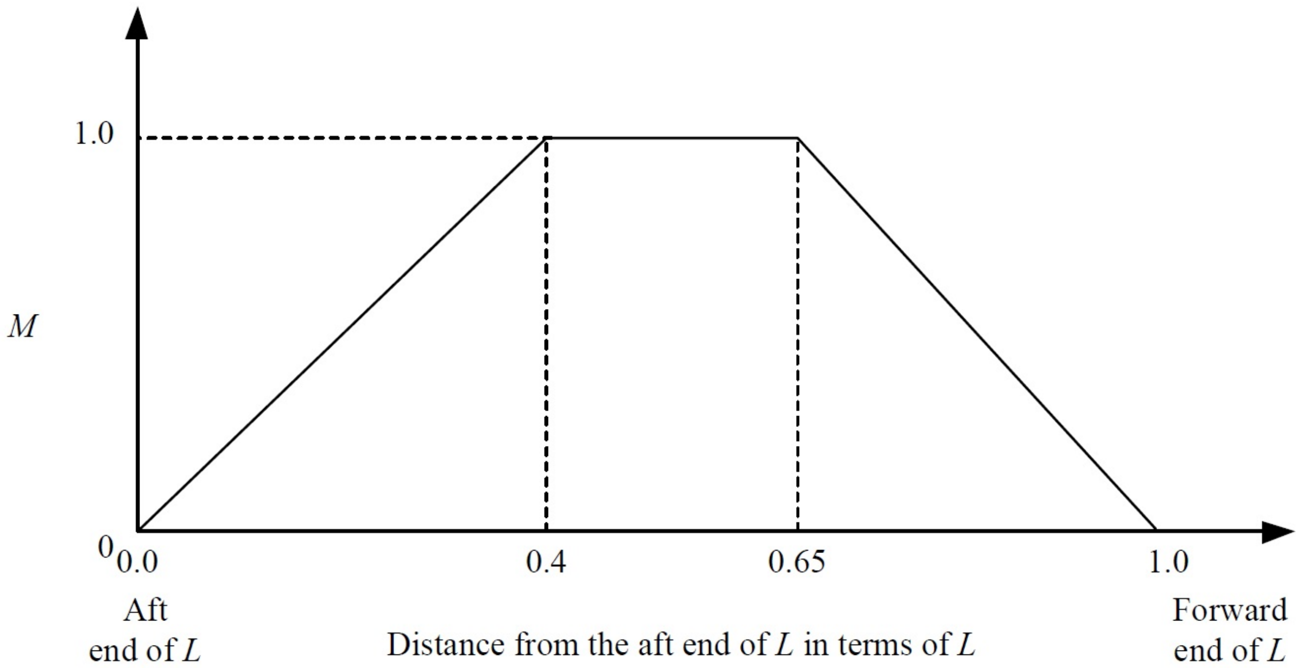


FIGURE 3
Distribution Factor F_1

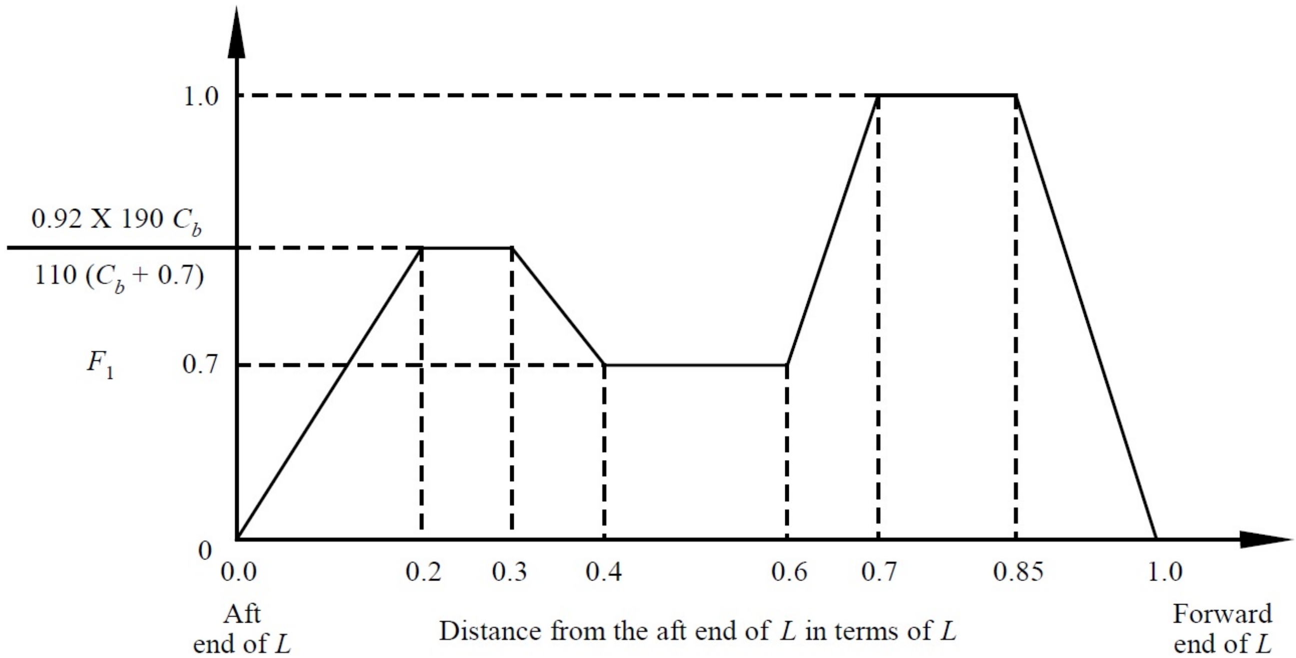
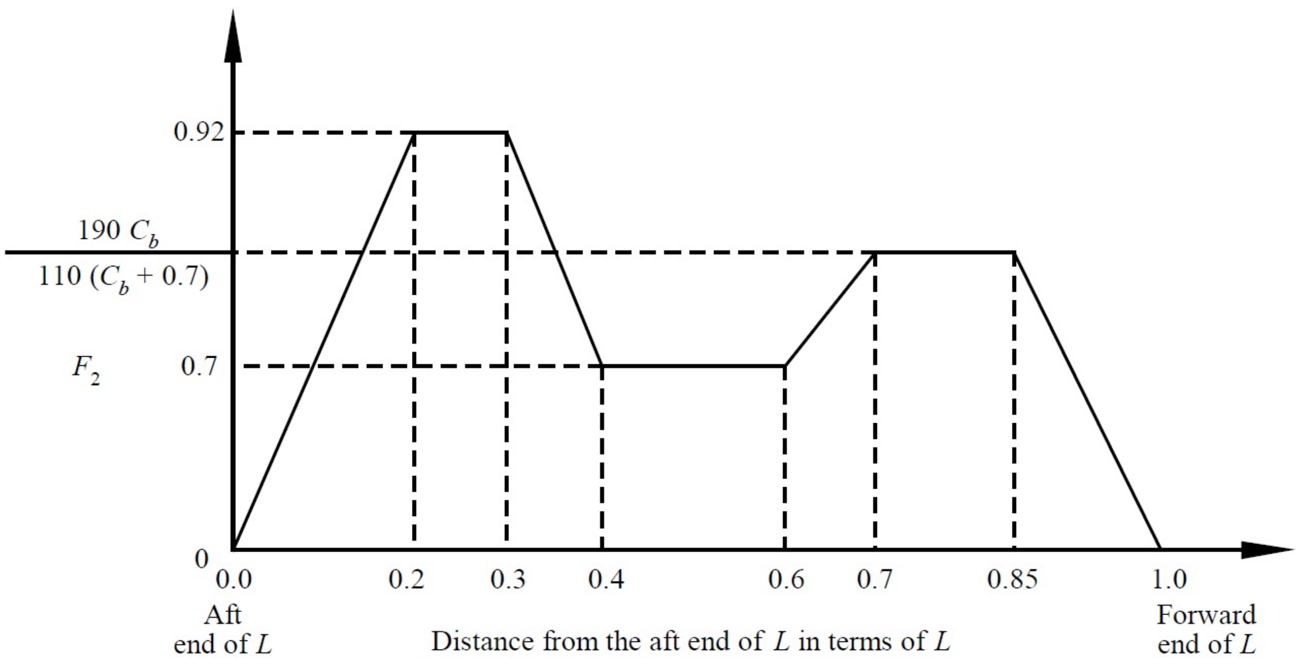


FIGURE 4
Distribution Factor F_2



3.7 Bending Strength *(2022)*

3.7.1 Hull Girder Section Modulus for Vessels 61 m (200 ft) in Length and Over *(2022)*

3.7.1(a) Section Modulus

The required hull girder section modulus for $0.4L$ amidships, is to be the greater of the values obtained from the following equation or 3-2-1/3.7.1(b):

$SM = M_t/f_p$ cm^2-m (in^2-ft)

where

M_t	=	total bending moment to be obtained as the maximum algebraic sum (see sign convention in 3-2-1/3.3.1 of still-water bending moment and wave-induced bending moment,
	=	$M_{sw} + M_w$
M_{sw}	=	still-water bending moment in accordance with 3-2-1/3.3, in kN-m (tf-m, Ltf-ft)
M_w	=	maximum wave-induced bending moment in accordance with 3-2-1/3.5.1
f_p	=	nominal permissible bending stress
	=	17.5 kN/cm^2 (1.784 tf/cm^2, 11.33 Ltf/in^2)

3.7.1(b) Minimum Section Modulus (see 3-1-2/1.3.3) (2022)

The minimum hull girder section modulus amidships is not to be less than obtained from the following equation:

$SM = C_1 C_2 L^2 B(C_b + 0.7)$ cm^2-m (in^2-ft)

where

C_1 is as defined in 3-2-1/3.5.1 and C_2, L, B, and C_b are as defined in 3-2-1/3.1

C_2 is defined in 3-2-1/3.1

3.7.1(c) Extension of Midship Section Modulus and Continuity of Structure.

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.

i) For vessels of $L \geq 90$ meters ($L \geq 295$ feet) which have longitudinal framing, the longitudinals are to be continuous within the amidships 0.4L.

Outside 0.4L amidships, the sectional area of the longitudinals may be included in the hull-girder section modulus calculations provided the longitudinals are continuous in way of deck transverses. They may be intercostal at transverse bulkheads provided the areas of the longitudinals are effectively developed at the intercostal connections by bracket areas and fillet weld throat area.

ii) For vessels of $L < 90$ meters ($L < 295$ feet) which have longitudinal framing and the hull girder strength is such that the vessel meets the requirements without including the area of the longitudinals, ordinary strength steel longitudinals need not to be continuous. However the areas of the longitudinals are to be effectively developed at intercostal connections by brackets and weld area.

Where the area of longitudinals is to be included in the section modulus calculation the longitudinals are to be continuous in way of deck transverses. They may be intercostal at transverse bulkheads provided the areas of the longitudinals are effectively developed at the intercostal connections by bracket areas and fillet weld throat area.

High strength steel longitudinals are always required to be continuous in way of ordinary strength steel transverse members.

Ordinary-strength steel longitudinals may be intercostal at watertight floors provided the throat area of the welded connections and the end bracket load paths have an area not less than the area of the longitudinals and the brackets are arranged to minimize misalignments.

iii) For all vessels, the center girder is to extend as far forward and aft as practicable. The plates are to be continuous within the amidship 0.75L. The side girders and longitudinal bulkheads are to be continuous within the amidship $0.4L$ if included in the hull girder section modulus calculation.

3.7.2 Hull Girder Moment of Inertia *(2022)*

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

$I = L \cdot SM/33.3$ cm^2-m^2 (in^2-ft^2)

where

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

SM = required hull girder section modulus, in cm^2-m (in^2-ft). See 3-2-1/3.1 for vessels under 61 m (200 ft) in length or 3-2-1/3.7.1 for vessels 61 m (200 ft) in length and over.

3.7.3 Hull Girder Strength Outside of 0.4L Amidships for Vessels 61 m (200 ft) in Length and Over *(2022)*

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 3-2-1/3.7.1(a). As a minimum, hull girder bending strength is to be checked 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, 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 3-2-1/17, in particular in regions where changes in the framing system or significant changes in the hull cross-section occur.

3.9 Shearing Strength for Vessels 61 m (200 ft) in Length and Over *(2022)*

3.9.1 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 the longitudinal bulkhead where fitted, is to be such that the nominal total shear stress f_s, as obtained from 3-2-1/3.9.2 or 3-2-1/3.9.4, are not greater than 11.0 kN/cm²(1.122 tf/cm²,7.122 Ltf/in²).

3.9.2 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:

$$f_s = (F_{sw} + F_w)m/2t_sI \qquad \mathrm{kN/cm^2(tf/cm^2, Ltf/in^2)}$$

where

I	=	moment of inertia of the hull girder at the section under consideration, in cm⁴ (in⁴)
m	=	first moment, in cm³ (in³), 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 (in.)
F_{sw}	=	hull girder shearing force in still-water, in kN (tf, Ltf)
F_w	=	F_{wp} or F_{wn}, as specified by 3-2-1/3.5.3, in kN (tf, Ltf), depending upon loading.

3.9.3 Modification of Hull girder Shearing Force Peaks

The hull girder shearing force in still water, F_{sw}, to be used for calculating side shell plate shear stress 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 (see 3-2-1/3.9 FIGURE 5).

$$F_s = F_{sw} - F_B \text{ kN (tf, Ltf)}$$

where

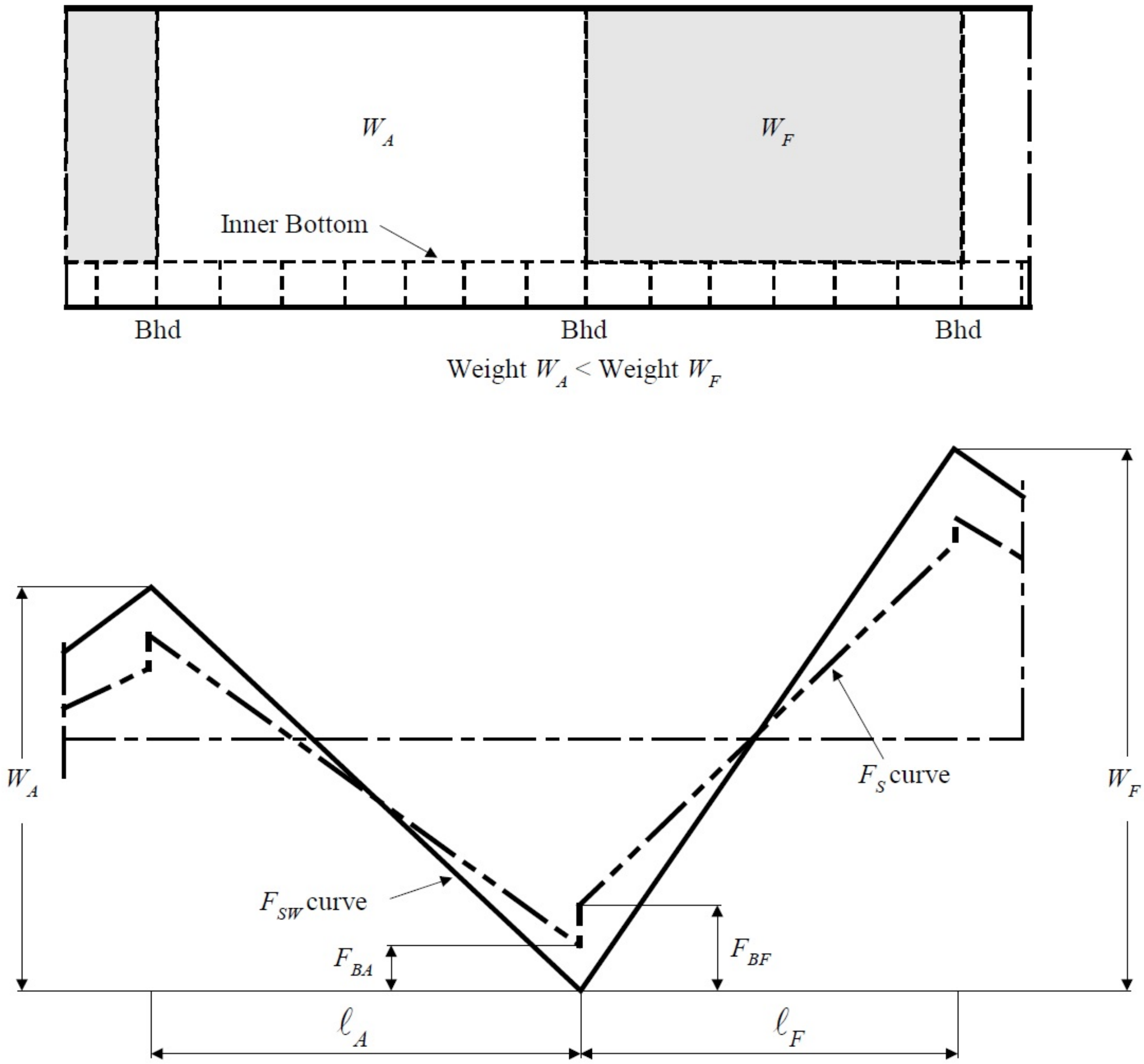
F_{sw}	=	hull girder shearing force in still water as obtained by the conventional direct integration method, in kN (tf, Ltf).
F_B	=	F_{BA} or F_{BF}, whichever is the lesser
F_{BA}	=	$(0.45 - 0.2\ell_A/b_A)W_Ab_A/B$
F_{BF}	=	$(0.45 - 0.2\ell_F/b_F)W_Fb_F/B$
W_A, W_F	=	total load (net weight or net buoyancy) in the hold immediately abaft or forward of the bulkhead in question, in kN (tf, Ltf)
ℓ_A, ℓ_F	=	length of the adjacent holds respectively, containing W_A and W_F, in m (ft)
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 (ft). For vessels having double skins with flat inner bottom, it may be measured to the inner skins.
B	=	breadth of vessel, as defined in 3-1-1/5, in m (ft)

3.9.4 Shearing Strength for Vessels with Two or Three Plane 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 still-water shear force, consideration is to be given to the effects of non-uniform athwartship distribution of loads. The method described in Appendix 3-2-A1 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 will also be considered. Some acceptable methods are shown in 5C-1-4/5 and 5C-2-A1.

FIGURE 5
Shear Force Distribution



5 Longitudinal Members of Higher-Strength Steels

The following requirements are to be satisfied:

i) Vessels where the effective longitudinal material of either or both of upper and lower flanges of the longitudinal hull girders are constructed of steel having mechanical properties greater than those of ordinary steel (see Section 2-1-2 of the ABS *Rules for Materials and Welding (Part 2)* for ordinary steels and Section 2-1-3 for higher-strength steels), they are to have longitudinal strength 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 3-2-1/5.3 and 3-2-1/5.5.

ii) Application of higher-strength material is to be continuous over the length of the vessel to locations where the stress levels are suitable for the adjacent mild-steel structure.

iii) Higher-strength steel is to be extended to suitable locations below the strength deck and above the bottom, so that the stress levels to be satisfactory for the remaining middle steel structure.

iv) Longitudinal framing members are to be continuous throughout the required extent of higher-strength steel.

5.1 Hull Girder Moment of Inertia

The hull girder moment of inertia is to be not less than required by 3-2-1/3.7.2 using the mild steel section modulus obtained from 3-2-1/3.7.1.

5.3 Hull Girder Section Modulus *(1 July 2018)*

When either the top or the bottom flange of the hull girder, or both, is constructed of higher-strength material, the section modulus *SM*, as obtained from 3-2-1/3.1 or 3-2-1/3.7 may be reduced by the factor Q.

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

where

Q = 0.78 for H32 strength steel

Q = 0.72 for H36 strength steel

Q = 0.68[(1)] for H40 strength steel

H32, H36, H40 = as specified in Section 2-1-3 of the ABS *Rules for Materials and Welding (Part 2)*

Notes:

1 The material factor for H40 may be taken as 0.66, provided that the hull structure is additionally verified for compliance with the requirements of:

- ABS *Guide for 'SafeHull-Dynamic Loading Approach' for Vessels*
- ABS *Guide for Spectral-Based Fatigue Analysis for Vessels*
- Appendix A1 of the *Guide for Application of Higher-Strength Hull Structural Thick Steel Plates in Container Carriers*

Q factors for steels having other yield points or yield strengths than listed above are to be obtained from the following formula:

$$Q = (n_y/Y)^e$$

where

n_y = 235 N/mm^2 (24 kgf/mm^2, 34000 psi)

Y = specified minimum yield strength of the material, in N/mm^2 (kgf/mm^2, psi), but is not to be taken as greater than 0.7U or 450 N/mm^2 (46 kgf/mm^2, 65000 psi), whichever is less

U = minimum tensile strength of material used, in N/mm^2 (kgf/mm^2, psi)

e = 1.0 for $Y \leq 235$ N/mm^2 (24 kgf/mm^2, 34000 psi)

= 0.75 for $Y > 235$ N/mm^2 (24 kgf/mm^2, 34000 psi)

5.5 Hull girder Shearing Force

Where the side shell or longitudinal bulkhead is constructed of higher strength material, the permissible shear stresses indicated in 3-2-1/3.9 may be increased by the factor $1/Q$. For plate panel stability see 3-2-1/17.

7 Loading Guidance

7.1 Loading Manual *(2022)*

All vessels are to be provided with a loading manual and, when fitted, a loading instrument is to be in accordance with Appendix 3-2-A2.

In addition, bulk carriers, ore carriers and combination carriers 150 m (492 ft) or more in length (L_f), are to comply with the requirements in Appendix 3-2-A3.

7.3 Allowable Stresses

7.3.1 At Sea

See 3-2-1/3.7.1 for bending stress and 3-2-1/3.9.1 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 3-2-1/5.3.

7.3.2 In Port

The allowable still water in-port stress is 13.13 kN/cm^2 (1.34 tf/cm^2, 8.5 Ltf/in^2) for bending and 10 kN/cm^2 (1.025 tf/cm^2, 6.5 Ltf/in^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 3-2-1/5.3.

9 Section Modulus Calculation

9.1 Items Included in the Calculation

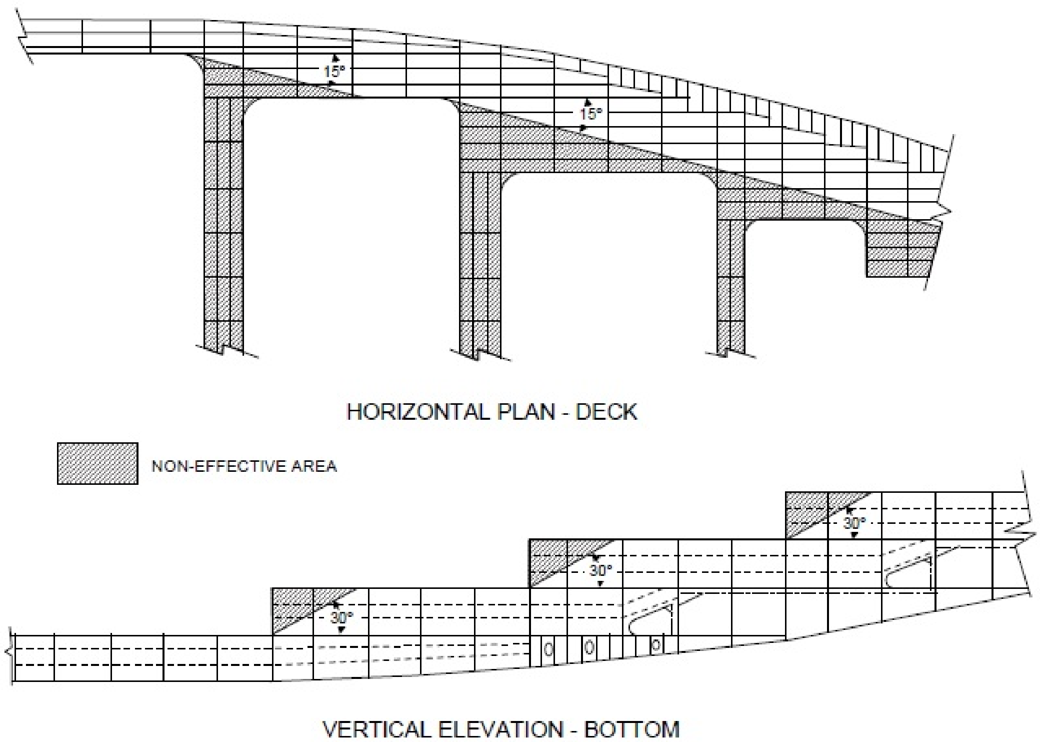
In general, the following items may be included in the calculation of the hull girder section modulus, provided that they are continuous (see 3-2-1/3.7.1(c) for details):

- Deck plating (strength deck and other effective decks)
- Shell and inner bottom plating
- Deck and bottom girders
- Plating and longitudinal stiffeners of longitudinal bulkheads. Horizontally corrugated longitudinal bulkheads can be included in the hull girder strength calculation for bending strength but not for shear strength. Vertically corrugated longitudinal bulkheads are to be excluded from the hull girder bending strength calculation but may be considered for shear strength.
- All longitudinals of deck, side, bottom and inner bottom
- Continuous longitudinal hatch coamings as described in 3-2-1/9.9.1
- Continuous longitudinal cargo rails and/or walkways as described in 3-2-1/9.7.

9.3 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 (47 in.) or 25% of the breadth or depth of the member in which it is located, whichever is less, with a maximum of 75 mm (3 in.) for scallops. The length of small isolated openings, which are not required to be deducted, is generally not to be greater than 2500 mm (100 in.). 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 3-2-1/9.3 FIGURE 6.

FIGURE 6
Effective Area of Hull Girder Members



9.5 Section Modulus to the Deck or Bottom

9.5.1 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.

9.5.2 Transition between Higher Strength Steel and Ordinary Strength Steel

Where higher strength steel is used, the section modulus for the ordinary strength steel part of the hull-girder is obtained by dividing the moment of inertia, *I*, by the vertical distance from the neutral axis to the point of transition between higher strength steel and ordinary strength steel.

9.5.3 Cargo Rails, Walkways

Where continuous cargo rails and/or walkways are fitted see 3-2-1/9.7.

9.7 Section Modulus to the Top of Cargo Rails and/or Longitudinal Side Walkways

9.7.1 Top of Cargo Rails

For continuous longitudinal cargo rails, extending throughout the amidship $0.4L$, directly welded to the deck, the section modulus to the top of the cargo rail is to be obtained by dividing the moment of inertia I by the distance from the neutral axis to the top of the cargo rail. This distance need not exceed y_t as given by the following equation, provided that y_t is not less than the distance to the molded deck line at side.

$$y_t = y(0.9 + 0.2x/B) \quad \text{m(ft)}$$

where

y	=	distance, in m (ft), from the neutral axis to the top of the continuous coaming
x	=	distance, in m (ft), from the outboard edge of the top of the continuous coaming to the centerline of the vessel
B	=	breadth of vessel, as defined in 3-1-1/5, in m (ft)

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

9.7.2 Top of Longitudinal Side Walkways

Where longitudinal side walking platforms extending throughout the amidships $0.4L$ are effectively supported by cargo rails and high side bulwarks, the longitudinal members of such structural configuration are to be included in the hull girder section modulus.

9.9 Section Modulus to the Top of Continuous Longitudinal Hatch Coamings and Above Deck Girders

9.9.1

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 3-2-15/5.9.

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 y_t as given by the following equation, provided that y_t is not less than the distance to the molded deck line at side.

$$y_t = y(0.9 + 0.2x/B) \quad \text{m(ft)}$$

where

y	=	distance, in m (ft), from the neutral axis to the top of the continuous coaming.
x	=	distance, in m (ft), 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, as defined in 3-1-1/5, in m (ft)

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.

9.9.2

The hull girder section modulus amidships to the top of the coamings is to be as required by 3-2-1/3.7.1, 3-2-1/3.7.2 and 3-2-1/9.7, but the section modulus to the deck at side, excluding the coamings, need not be determined in way of such coamings.

9.9.3

Continuous longitudinal girders on top of the strength deck are to be considered similarly. Their scantlings are also to be in accordance with Section 3-2-8.

11 Strength Decks

11.1 General

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 (see 3-2-2/3) and superstructure deck (see 3-2-11/1.3) are adopted. In way of such superstructures, the deck on which the superstructures are located is to be considered the strength deck.

11.3 Tapering of Deck Sectional Areas

In general, the tapering of deck sectional areas beyond the amidship $0.4L$, is to be in accordance with 3-2-1/3.7.1(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.

13 Effective Lower Decks

To be considered effective, and for use in calculating the hull girder section modulus the following are to be complied with:

i) Thickness of the stringer plate (excluding cutouts in way of through frames) and the deck plating is to comply with the requirements of 3-2-3/5. The sectional areas* of lower decks used in calculating the section modulus are to be obtained as described in 3-2-1/9.3.

ii) Deck sectional areas are to be adequate to meet the hull girder section modulus requirements at the location being considered where bending moment envelope curves are available;

iii) In general, where the still-water bending moment envelope curve is not submitted, or where 3-2-1/3.7.1(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.

iv) Effective lower decks are to be continuous. Where effective lower decks terminate, brackets are to be provided and are to extend forward and aft of the termination for not less than 1.0 m (3.28 ft).

Note: ** Exclude cutout in the stringer plate in way of through frames.*

15 Longitudinal Deck Structures Inboard of Lines of Openings

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.

15.1 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_o, as given below, may be used in the hull girder section modulus calculations.

$$H_o = \frac{0.62}{1 + 0.38\left(\frac{A_o}{A} + \frac{Z^2 A_o}{I}\right)}$$

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 (in^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 (in^2-ft^2)

Z = distance between the horizontal neutral axis of area A, and the centroid of area A_o, in m (ft)

A_o = 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 (in^2)

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

17 Buckling Strength for Vessels Over 61 m (200 ft) in Length

17.1 Vessels 90 Meters (295 feet) in Length and Greater

For vessels 90 meters (295 feet) in length and greater, 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, including continuous hatch coamings, cargo rails, and walkways, are to be checked against buckling. Calculations, in accordance with Appendix 3-2-A4, are to be submitted for review.

17.3 Vessels Between 61 and 90 Meters (200 and 295 Feet) in Length

For vessels between 61 meters (200 feet) and 90 meters (295 feet) in length, the deck and bottom plate panels are to be checked against buckling due to longitudinal bending. Calculations in accordance with Appendix 3-2-A4 are to be submitted for review.

17.5 Total Bending Moment

Where still water bending moments are positive (hogging) in all operating conditions, the total bending moment, M_t, is to be taken as not less than $0.9M_{ws}$ for the purpose of evaluating the structural stability of the hull girder upper flange.

Where it shows that all possible conditions of loading between lightship and full load draft result in positive (hogging) still water bending moments, such as in the case of passenger vessels, the above specified minimum total bending moment may be specially considered, provided that a statistical analysis of wave induced bending moment is carried out taking into account the effect of the hull form including bow flare.

PART 3

CHAPTER 2

Hull Structures and Arrangements

SECTION 2

Shell Plating

1 General

Shell plating is to be of not less thickness than is required for purposes of longitudinal hull girder strength; including buckling strength (as applicable), 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 3-2-10/3.1 for deep tanks.

i) For bottom shell plating bounding tanks having normal tank/air vent configurations, the head *"h"* in the formula of 3-2-10/3.1. need not be taken greater than the distance from the plate under consideration to the deck at side.

ii) 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 3-2-10/3.1.

3 Shell Plating Amidships

3.1 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 (ft), measured to the uppermost continuous deck.

3.3 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 (ft), 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.

3.5 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 (ft), measured to the uppermost continuous deck.

3.7 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 (ft), 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 3-2-3/5 TABLE 2, but substituting the frame spacing, in mm (in.), for s_b in lieu of the deck beam spacing.

3.9 Side Shell Plating

3.9.1 For Offshore Support Vessels

The minimum thickness, t, of the side shell plating throughout the amidship $0.4L$ is to be obtained from the following equations, whichever is greater:

$$t_{shell1} = (s/C_{s1})\sqrt{(L - C_{L1})(d/D_s)} + C \qquad \text{mm(in.)}$$

$$t_{shell2} = C_{s2}(L + C_{L2}) + 0.009s \qquad \text{mm(in.)}$$

where

C	=	2.5 (0.1) mm (in.)
C_{s1}	=	645 (1170) mm (in.)
C_{L1}	=	15.2 (50) m (ft)
C_{s2}	=	0.035 (0.00042) mm (in.)
C_{L2}	=	29 (95) m (ft)
s	=	spacing of transverse frames or longitudinals, in mm (in.), not greater than 610 mm (24 in.) for t_{shell2} only
L	=	length of vessel, as defined in 3-1-1/3.1, in m (ft)
d_s	=	molded draft, as defined in 3-1-1/9.3, in m (ft)
D_s	=	molded depth, in m (ft), as defined in 3-2-2/3.1 through 3-2-2/3.7

The actual ratio of d_s/D_s is to be used in the above equations, except that the ratio is not to be taken less than 0.67.

t is not to be taken less than 8.5 mm (0.33 in.) for offshore support vessels.

3.9.2 For Vessels under 90 m (295 ft) in Length

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

$$t = \frac{s\sqrt{h}}{268} + 2.5 \qquad \text{mm}$$

$$t = \frac{s\sqrt{h}}{485} + 0.10 \qquad \text{in.}$$

where

t	=	thickness, in mm (in.)
s	=	spacing of transverse frames or longitudinals, in mm (in.)

h = depth, in m (ft), as defined in 3-1-1/7, but not less than $0.1L$ or $1.18d$, whichever is greater

d = draft for scantlings, as defined in 3-1-1/9, or $0.066L$, whichever is greater

L = length of the vessel, as defined in 3-1-1/3

The side shell plating in way of hold frames of dry cargo vessels with typical bulk carrier configuration (sloping upper and lower wing tanks with a transversely framed side shell in way of the hold) is also not to be less than that obtained from the following equation:

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

$$t = 0.0218\sqrt{L} \quad \text{in.}$$

with L as defined above.

3.9.3 For All Other Steel Vessels

The minimum thickness, t, of the side shell plating throughout the amidship $0.4L$, for vessels having lengths not exceeding 427 m (1400 ft), is to be obtained from the following equations:

$$t = (s/C_{s1})\sqrt{(L - C_{L1})(d/D_s)} + C \quad \text{mm(in.)} \quad \text{for } L \le 305\ (1000)\ \text{m (ft)}$$

$$t = (s/C_{s3})\sqrt{(L - C_{L3})(d/D_s)} + C \quad \text{mm(in.)} \quad \text{for } 305\ (1000) < L \le 427\ (1400)\ \text{m (ft)}$$

where

C_{s3} = 828 (1500) mm(in.)

C_{L3} = 175 (574) m(ft)

s = spacing of transverse frames or longitudinals, in mm(in.)

d = molded draft, as defined in 3-1-1/9.1, in m(ft)

C , C_{s1}, C_{L1}, L, and D_s are as defined in 3-2-2/3.9.1.

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 3-2-2/5.1 using 610 mm (24 in.) as the frame spacing.

3.11 Side Fenders *(2022)*

Vessels under 90 m (295 ft) in length subject to impact loads during routine operations and offshore support vessels, are to comply with this section.

3.11.1 Fender* Requirements *(2022)*

i) The minimum side shell plating thickness calculated above is to be increased by 25%, unless effective permanent fenders as described in this Section are provided to protect the structure.

ii) Continuous longitudinal fenders are generally to be fitted on the side shell at cargo deck and at second deck above, if deck or platform there is fitted.

iii) The fenders are to extend from the stern to a point not less than $0.02L$ forward of the section at which the full deck's breadth starts decreasing; the area defined as an impact region.

iv) Additional fenders are to also be arranged diagonally at about 45° between the foregoing fenders, as necessary, to protect the side shell from the impact.

Note: * Fenders may be either permanent fenders constructed of steel or having exchangeable hard wood or rubber profile inserts. Carling plates or other effective means of stiffening are to be provided so that fender loads are effectively distributed to the hull structure. Steel fenders are to be efficiently welded to the shell plating with continuous fillet welds.

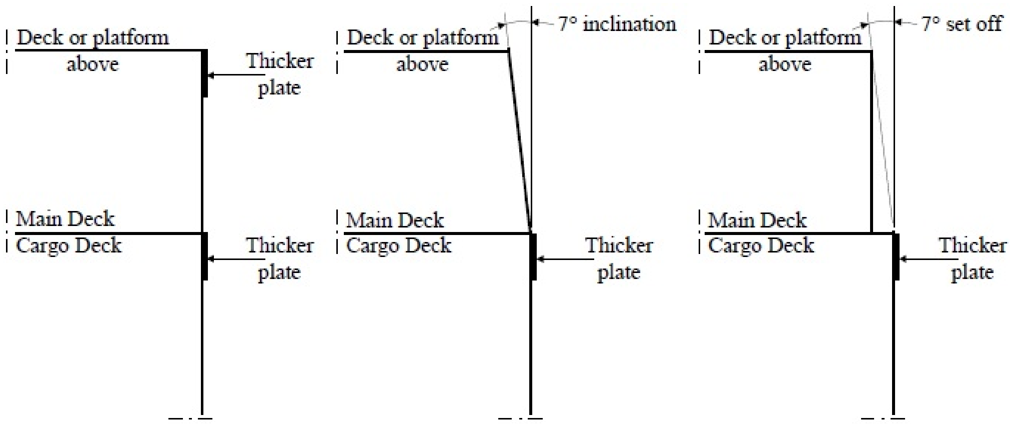
3.11.2 Alternative Requirements in Lieu of Fenders*

Note: * Requirement applies to offshore support vessels and vessels under 90 meters (295 feet) in length.

Alternatively the fenders may be omitted also if the side plating is at least twice the thickness that is required by 3-2-2/1, for a height of at least $0.01L$, along the level of the main deck/cargo deck and next deck or platform above. The upper plate may be omitted if the side shell is inclined 7° or set off 1:8 from the side's vertical (see 3-2-2/3.11.2 FIGURE 1*).

The strength of the side frames, webs and stringers in the impact region is to be increased by the factor 1.25 over the standard requirements. All side structural members in the impact region shall have end connections with brackets. Scallop welds shall not be used in connections between side frames and shell plating.

FIGURE 1*
Side Impact Plates



3.13 Sheer Strake *(2022)*

For all OSVs and other vessels greater than 90 meters (295 feet) in length, the minimum width, b, of the sheerstrake 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 $L \geq 200$ m
$b = 0.06L + 31.5$ in.	for $L < 656$ ft
$b = 71$ in.	for $L \geq 656$ ft

where

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

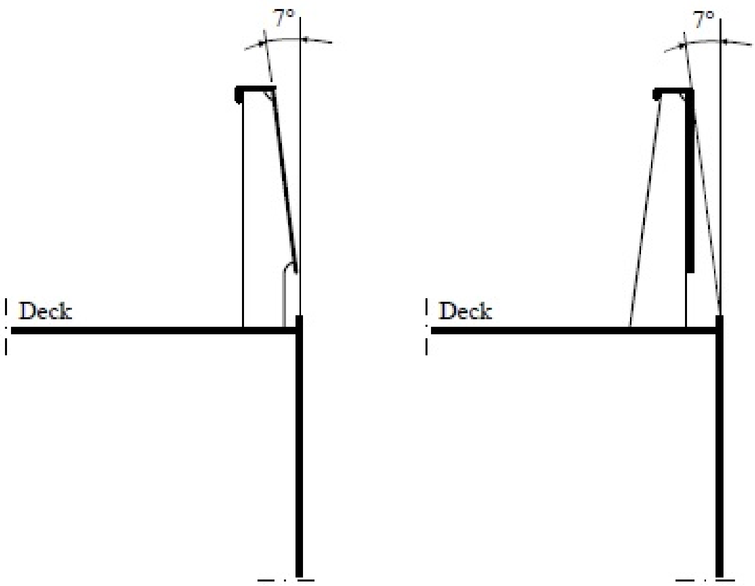
b = width of sheerstrake, in mm (in.)

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 3-2-3/5 TABLE 2 as appropriate from *Decks*-A of 3-2-3/5 TABLE 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 (0.25 in.). 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 (see 3-2-2/3.13 FIGURE 2).

Where fashion plates run into the sheer strake, the ends of the fashion plates are to be ground to form a smooth tangent with the edge of the sheer strake. Grinding should be in the longitudinal direction.

FIGURE 2
Recommended Bulwark Fitting



3.15 Bottom Shell Plating Amidships

The term "bottom plating amidships" refers to the bottom shell plating from the keel to the upper turn of the bilge or upper chine, extending over the amidships $0.4L$.

3.15.1 Bottom Shell Plating *(2022)*

The thickness, t, of the bottom plating amidships is not to be less than obtained from the following equations or the thickness determined by 3-2-2/3.15.2, whichever is greater.

Transverse Framing

$$t_{trans} = (s/519)\sqrt{(L - 19.8)(d_s/D_s)} + 2.5 \text{ mm} \qquad \text{for } L \leq 183 \text{ m}$$

$$t_{trans} = (s/940)\sqrt{(L - 65)(d_s/D_s)} + 0.1 \text{ in.} \qquad \text{for } L \leq 600 \text{ ft}$$

Longitudinal Framing

$$t_{long1} = (s/671)\sqrt{(L-18.3)(d_s/D_s)} + 2.5 \text{ mm} \quad \text{for } L \le 122 \text{ m}$$

$$t_{long2} = (s/508)\sqrt{(L-62.5)(d_s/D_s)} + 2.5 \text{ mm} \quad \text{for } 122 \le L \le 305 \text{ m}$$

$$t_{long3} = (s/661)\sqrt{(L+105)(d_s/D_s)} + 2.5 \text{ mm} \quad \text{for } 305 < L \le 427 \text{ m}$$

$$t_{long1} = (s/1215)\sqrt{(L-60)(d_s/D_s)} + 0.1 \text{ in.} \quad \text{for } L < 400 \text{ ft}$$

$$t_{long2} = (s/920)\sqrt{(L-205)(d_s/D_s)} + 0.1 \text{ in.} \quad \text{for } 400 \le L \le 1000 \text{ ft}$$

$$t_{long3} = (s/1197)\sqrt{(L+344.5)(d_s/D_s)} + 0.1 \text{ in.} \quad \text{for } 1000 < L \le 1400 \text{ ft}$$

where L, d_s, s and D_s are as defined in 3-2-2/3.9.

The actual ratio of d_s/D_s is to be used in the above equations, but it is not to be taken less than 0.67 for offshore support vessels and 0.0433 L/D_s for other steel vessels.

After all corrections have been made, the bottom shell thickness amidships is not to be less than the thickness obtained by 3-2-2/5.1 using 610 mm (24 in.) as the frame spacing.

The bottom shell plating thickness obtained from the above equations may be multiplied by the factor R_n if the following three conditions are satisfied:

i) The actual bottom hull girder section modulus SM_A is greater than required by 3-2-1/3.7.1, at least throughout 0.4L amidships,

ii) The required section modulus is based on the still-water bending moment calculations and

iii) Adequate buckling strength is maintained.

$$R_n = 1\Big/\sqrt{(f_p/\sigma_t)(1 - SM_R/SM_A) + 1}$$, but is not be taken less than 0.85 $(d/D_S \ge 0.65)$

$= 1.0$ $\quad (d/D_S \le 0.0433L/D_S)$

= by linear interpolation $\quad (0.0433L/D_S < d/D_S < 0.65)$

where

f_p = nominal permissible bending stress 17.5 kN/cm^2 (1.784 tf/cm^2, 11.33 Ltf/in^2)

σ_t = $KP_t(s/t)^2$, in kN/cm^2 (tf/cm^2, Ltf/in^2)

K = 0.5 for transverse framing and 0.34 for longitudinal framing

P_t = $(0.638H + d_s)a$ kN/cm^2 (tf/cm^2, Ltf/in^2)

a = 1.005×10^{-3} (1.025×10^{-4}, 1.984×10^{-4})

SM_R = required hull girder section modulus as per 3-2-1/3.7.1, in cm^2-m (in^2-ft)

SM_A = actual bottom hull girder section modulus, when it is greater than required by 3-2-1/3.7.1, in cm^2-m (in^2-ft)

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

H	=	wave parameter, in m (ft)	
	=	$(5.48L^2 + 16,045L)10^{-6} + 3.703$ m	$61 \le L \le 220$ m
	=	$(4.5L - 0.0071L^2 + 103)10^{-2}$ m	$220 < L \le 305$ m
	=	8.151 m	$305 < L \le 427$ m
	=	$(1.474L^2 + 16,055L)10^{-6} + 12.15$ ft	$200 \le L \le 722$ ft
	=	$(4.5L - 0.00216L^2 + 335)10^{-2}$ ft	$722 < L \le 1000$ ft
	=	26.750 ft	$1000 < L \le 1400$ ft

3.15.2 Minimum Bottom Shell Plating

The thickness, t_{bottom}, of the shell plating amidships below the upper turn of bilge or upper chine is not to be less than obtained from the following equations:

Transverse Framing

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

$t_{trmin} = s(L + 150)/(25L + 19950)$ in. for $L \le 600$ ft

where

s	=	frame spacing, in mm (in.), but is not to be less than that given in 3-2-5/1.7
L	=	length of vessel, as defined in 3-1-1/3.1, in m (ft)

Longitudinal Framing

$t_{longmin} = s(L - 18.3)/(42L + 1070)$ mm

$t_{longmin} = s(L - 60)/(42L + 3510)$ in.

where

s	=	frame spacing, in mm (in.), but is not to be less than 88% of that given in 3-2-5/1.7 or 813 mm (32 in.), whichever is less
L	=	length of vessel, as defined in 3-1-1/3.1, in m (ft)

The minimum bottom shell plating thickness obtained from the above equations may be multiplied by the factor R_b if the following three conditions are satisfied:

i) The actual bottom hull girder section modulus SM_A is greater than required by 3-2-1/3.7.1, at least throughout 0.4L amidships,

ii) The section modulus is based on the still-water bending moment calculations and

iii) Adequate buckling strength is maintained.

$R_b = \sqrt{SM_R/SM_A}$ but is not to be taken less than 0.85 $(d/D_s \geq 0.65)$

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

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

where SM_R and SM_A are as defined in 3-2-2/3.15.1.

For transverse framing, R_b is to be not less than the greater of:

- 0.85 or
- $1.2285 - L/533.55$ SI or MKS units ($1.2285 - L/1750$ for US units)

where L is as defined above, but is not to be taken as less than 122 m (400 ft).

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

3.17 Flat Keel Plate for Vessels above 90 meters (295 feet) in Length

The thickness of the flat keel plate for docking purposes is to be 1.5 mm (0.06 in.) greater than that required for the bottom shell plating at the location under consideration. This 1.5 mm (0.06 in.) increase in thickness is not required where the submitted docking plan specifies that all docking blocks are to be arranged clear of the flat keel plate. See 3-1-2/11 and 3-2-2/7.

5 Shell Plating at Ends

5.1 Minimum Shell Plating Thickness *(1 July 2021)*

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

$t = 0.0455L + 0.009s$ mm	$L < 90$ m
$t = 0.035(L + 29) + 0.009s$ mm	for $90 \leq L \leq 305$ m
$t = (11.70 + 0.009s)\sqrt{D/35}$ mm	for $305 < L \leq 427$ m
$t = 0.000545L + 0.009s$ in.	$L < 295$ ft
$t = 0.00042(L + 95) + 0.009s$ in.	for $295 \leq L \leq 1000$ ft
$t = (0.46 + 0.009s)\sqrt{D/114.8}$ in.	for $1000 < L \leq 1400$ ft

where

s = fore or aft peak frame spacing, in mm (in.) , frame spacing from the stem to $0.025L$ aft of FP is not to exceed the standard frame and cant frame spacing as per 3-2-5/1.7

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

D = molded depth, in m (ft), as defined in 3-1-1/7.1 or 35 m (114.8 ft), whichever is greater

The shell plating thickness from the stem to $0.025L$ aft of FP are to be increased by a factor of 1.25 over the standard requirements for the bow slamming/impact loads and applies to side and superstructure plating defined by 3-2-11/1.1. Additionally, structural members from the stem to $0.025L$ aft of FP are to have end connections with brackets. Scallop welds are not to be used in connections between side frames and shell plating.

For Offshore Support Vessels with unconventional bulbous bows or unconventional bow designs (such as large stem curvature, or a bulbous bow protruding the waterline), the bow impact pressures, and bow strengthening are to be calculated as per 5C-5-3/5.3.4(a) and 5C-5-6/23. For Offshore Support Vessels with unconventional large bow flare, the bowflare slamming pressures and bow strengthening are to be calculated as per 5C-5-3/11.3.1 and 5C-5-6/23.3.

5.3 Immersed Bow Plating *(1 July 2022)*

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.

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

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

$t = 0.0006(L + 66) + 0.009s$ in. for $L \leq 1000$ ft

$t = (0.64 + 0.009s)\sqrt{D/114.8}$ in. for $1000 < L \leq 1400$ ft

where

s = fore peak frame spacing, in mm (in.)

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

D = molded depth, in m (ft), as defined in 3-1-1/7.1 or 35 m (114.8 ft), whichever is greater

5.5 Bottom Forward *(2022)*

For OSVs, where the forward draft of the vessel in any of the submitted loading conditions is less than $0.04L$ m (ft), the plating on the flat of bottom forward, forward of the location given in 3-2-4/15.7 TABLE 1A is to be not less than required by the equation below.

For all other vessels of 61 m (200 ft) in length and over, 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 (ft), the plating on the flat of bottom forward, forward of the location given in 3-2-4/15.7.2 TABLE 1B is to be not less than required by the equation below.

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

$$t = 0.0026s\sqrt{\left(0.005L_1^2 - 1.3d_f^2\right)/d_f} \text{ in.}$$

where

s = frame spacing, in mm (in.)

L_1 = length of vessel, as defined in 3-1-1/3.1, in m (ft), but need not be taken greater than 214 m (702 ft)

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

d_f = heavy weather ballast draft at the forward perpendicular, in m (ft)

= $d_f \times 214/L$ m ($d_f \times 702/L$ ft), where L> 214 m (702 ft)

The required thickness of the flat of bottom forward plating is also to be in accordance with the requirements given by 3-2-2/1, 3-2-2/3.15, 3-2-2/5.1 and 3-2-2/5.3 as appropriate.

5.7 Forecastle Side Plating *(1 July 2022)*

The thickness, t, of the plating is to be not less than obtained from the following equations. Also see 3-2-11/1.1 for side plating requirements.

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

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

$t = 0.0006(L + 250) + 0.006(s - S)$ in. $\quad L < 350$ ft

$t = 0.00042(L + 505) + 0.006(s - S)$ in. $\quad L \geq 350$ ft

where

s = spacing of longitudinal or transverse frames, in mm (in.)

S = standard frame spacing, in mm (in.), given by the equation in 3-2-5/1.7, except that in way of the fore peak, the standard frame spacing is not to exceed 610 mm (24 in.)

L = length of vessel, as defined in 3-1-1/3.1, in m (ft), but need not be taken more than 305 m (1000 ft.)

5.9 Poop Side Plating *(1 July 2022)*

The thickness, t, of the plating is to be not less than obtained from the following equations. Also see 3-2-11/1.1 for side plating requirements.

$t = 0.0315(L + 150) + 0.006(s - S)$ mm $\quad L \geq 90$ m

$t = 0.0296(L + 39.5) + 0.006s$ mm $\quad L < 90$ m

$t = 0.00038(L + 493) + 0.006(s - S)$ in. $\quad L \geq 295$ ft

$t = 0.00035(L + 132.9) + 0.006s$ in. $\quad L < 295$ ft

where

s = spacing of longitudinal or transverse frames, in mm (in.)

S = standard frame spacing, in mm (in.), given by the equation in 3-2-5/1.7, except that in way of the aft peak, the standard frame spacing is not to exceed 610 mm (24 in.)

L = length of vessel, as defined in 3-1-1/3.1, in m (ft), but need not be taken more than 305 m (1000 ft)

5.11 Bow and Stern Thruster Tunnels

The thickness of the tunnel plating is not to be less than required by 3-2-2/5.1, where $s$is to be taken as the standard frame spacing given by the equation in 3-2-5/1.7, except that in way of the fore and aft peaks, the standard frame spacing is not to exceed 610 mm (24 in.), nor is the thickness to be les than obtained from the following equation:

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

$$t = 0.008d + 0.13 \quad \text{in.}$$

where

d = inside diameter of the tunnel, in mm (in.), or 968 mm (38 in.), 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, but arranged so, as to allow diver's access during underwater inspection of tunnels' interior.

5.13 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.

5.13.1 Spectacle Bossing

For OSVs:

$t = 0.084(L - 8) + 0.009s$ mm

$t = 0.001(L - 26) + 0.009s$ in.

For All Other Vessels:

$t = 0.088(L - 23) + 0.009s$ mm for $90 < L \leq 427$ m

$t = 0.00106(L - 75) + 0.009s$ in. for $295 < L \leq 1400$ ft

where

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

s = frame spacing, in mm (in.)

5.13.2 Other Plates on Stern Frame

For OSVs:

$t = 0.09(L - 5.5) + 0.009s$ mm

$t = 0.00108(L - 18) + 0.009s$ in.

For All Other Vessels:

$t = 0.094(L - 16) + 0.009s$ mm for $90 < L \leq 427$ m

$t = 0.00113(L - 53) + 0.009s$ in. for $295 < L \leq 1400$ ft

where

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

s = frame spacing, in mm (in.)

5.13.3 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 3-2-2/5.13.1.

7 Bottom Shell Plating for Special Docking Arrangement for Vessels Over 90 m in Length *(2021)*

Where it is not intended to use keel blocks when drydocking the vessel, the increase to the keel plate thickness in 3-2-2/3.17 will not be required. However, the thickness of the bottom shell plating strakes in way of the docking blocks used for drydocking the vessel is to be increased by 1.5 mm (0.06 in.). In such instances, the docking arrangement is to be indicated on the structural plans submitted for approval and on the docking plan being furnished to the vessel.

8 Moon Pools

8.1 General Arrangement

The general arrangements of the moon pool are to be in accordance with the following:

i) The opening of the moon pool should be in a suitable distance from the deck edge, cargo hatch covers, superstructure breaks and the areas of structure discontinuity.

ii) In general a pipe laying moon pool is to be located near the center of the vessel to reduce the effect from vessel motion.

iii) The corner radius of the moon pool opening is not to be less than 0.125 times of the moon pool width but need not exceed 600 mm (24 in.).

iv) Free edges of the moon pool opening are to be suitably rounded in order to protect umbilical and cables.

v) Means, such as moon pool covers, are to be provided to prevent personnel from falling into the moon pool.

vi) Transverse section through the moon pool is to be included in the hull girder longitudinal strength calculation and to be in accordance with 3-2-1/3

8.3 Moon Pool Bulkhead Scantlings

Moon pool bulkhead is designed to comply with the following:

i) Bulkhead structure is to comply with requirements for side structure. The thickness of the moon pool bulkhead plating is to be not less the thickness required by 3-2-2/1 and 3-2-2/3.9.

ii) Scantlings of moon pool bulkhead horizontal or vertical stiffeners are to be in accordance with 3-2-10/3.3 as applicable.

iii) Scantlings of moon pool bulkhead webs and girders are to be in accordance with 3-2-10/3.7 as applicable.

iv) Where the moon pool bulkhead is adjacent to liquid cargo or ballast tanks, the required plate thickness and sizes of stiffeners, webs and girders are also to comply with the deep tank requirements in 3-2-10/3.

v) Where a cofferdam is fitted, sufficient numbers of openings on the transverse or vertical webs are to be provided for inspection and maintenance.

vi) Moon pool bulkhead scantlings are to be specially considered if the bulkheads are also subject to impact loads.

9 Compensation

Compensation is to be made where necessary for openings in the shell. In general, unless otherwise specifically required, openings in the shell are to have a minimum corner radius of 0.125 times the width of the opening, but not less than 150 mm (6 in.) and need not exceed a radius of 600 mm (24 in.) in the bottom shell and side shell within 0.1D above the base line and below the gunwale and 450 mm (18 in.)

elsewhere in the side shell. Any minor openings 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.

Openings for cargo, gangway, fueling ports, etc. are to be kept well clear of discontinuities or breaks in the hull girder. Local strengthening is to be made to maintain the longitudinal and transverse strength of the hull. Where port-lights are provided in the shell plating, the locations and sizes are to be clearly indicated on the midship-section drawing submitted for approval.

11 Breaks

Side shells of 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 (0.25 in.). The side plating of the superstructure is to be increased in thickness in way of the break. The thickness of the sheer strake and the side shell plating below the sheer strake in way of the break are to be increased appropriately and are to extend well beyond the end of the superstructure in both directions 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.

12 Skeg and other Appendages *(2021)*

Vessel fitted with skegs and other permanent appendages are to comply with the following, unless otherwise specified in other sections of the Rules:

i) Thickness of the skeg plating is to be in accordance with 3-2-2/3.15, and 3-2-10/3.1 for deep tanks. The thickness of shell plating in way of an appendage is to be increased by 25%. However, this increase need not exceed 6.5 mm (0.25 in.).

ii) The stiffener section modulus is to be in accordance with 3-2-4/11.3, and 3-2-10/3.3 for deep tanks.

iii) Where a closing plate prohibits the inspection of a void space or joint that is integral to the shell plating, access ports or drain plugs are to be provided in way of this space. Access arrangements with manholes are to be provided for skegs used as deep tanks.

iv) All appendages are to be attached to shell plate using double continuous fillet welds in accordance with Section 3-2-19. Where access is not feasible, one side full penetration weld with backing is to be provided.

v) Appendage structures are to be reinforced and aligned with the internal hull structural members.

vi) In vessels where significant hydrodynamic forces act on the skeg (such as escort vessels, planing vessels, etc.), the hydrodynamic loads on the skeg and supporting hull structures are to be evaluated and submitted to ABS for review.

13 Bilge Keels

Bilge keels where fitted, are to be attached to the shell by a ground bar. In general, both the bilge keel and the ground bar are to be continuous. The connections of the bilge keel to the ground bar and the ground bar to the shell, are to be by double continuous fillet welds.

Butt welds in the bilge keel and ground bar are to be full penetration and are to be kept clear of master erection butts. Shell butts are to be flush in way of the ground bar, and the crown of the shell butt weld is to be gradually reduced until the butt weld is flush with the plate surface in way of the ground bar. The ground bar butts are to be flush in way of the bilge keel.

In general, scallops and cutouts are not to be made in the bilge keel. Where desired, a crack arresting hole, at least 25 mm (1 in.) in diameter, is to be drilled in each bilge keel butt weld as close as practicable to the fillet weld of the bilge keel to the ground bar, but not in the heat affected zone of the fillet weld.

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

Alternative arrangements of bilge keel will be specially considered subject to proven design practice and supporting calculation.

14 Bilge Plating

In general, the bilge plate is to be longitudinally stiffened. The thickness of the bilge plate is to be not less than required in 3-2-2/1 and 3-2-2/3, adjusted for spacing of the bilge longitudinals or frames and the material factors. Where girth spacing of bilge longitudinals is greater than that of the adjacent bottom plating, the spacing may be modified by the following equation in calculations of minimum required thickness.

s = $k_{r1}\, s_g$ mm (in.), but not to be taken less than the spacing of the longitudinals of the adjacent bottom plating

where

s_g = girth spacing of bilge longitudinals, in mm (in.)

k_{r1} = $(1 - 0.5s_g/R)^2$ but not less than 0.55

R = radius of bilge, in mm (in.)

Bilge keels are not to be considered as longitudinal stiffening members unless they are continuous and effectively developed.

In no case is the thickness of the bilge plate to be less than that of the adjacent bottom plating.

15 Higher-strength Materials

15.1 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 3-2-1/5.1. Calculations to show adequate provision against buckling are to be submitted. Care is to be taken 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 3-2-2/15.3 and 3-2-2/15.5.

High strength steel members are to be continuous at the intersection with members of lesser strength.

15.3 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 (in.)
t_{ms}	=	thickness, in mm (in.), of ordinary-strength steel, as required by the preceding paragraphs of this section. The requirements $t_{\min}$ in 3-2-2/3.15.2 and 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 (0.17 in.)
Q	=	as defined in 3-2-1/5.3

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

15.5 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 3-2-2/15.3

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

15.7 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.

PART 3

CHAPTER 2
Hull Structures and Arrangements

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.

3 Hull Girder Strength

3.1 Longitudinal Section Modulus Amidships

The required longitudinal hull girder section modulus amidships is obtained from the equations given in 3-2-1/3.7.1 and 3-2-1/5.5

3.3 Strength Deck

For the definition of the strength deck for calculation purposes, see 3-2-1/11.1.

3.5 Longitudinally Framed Decks

Where the beams of the strength deck and other decks are fitted longitudinally and are continuous within the 0.4*L* amidships region in accordance with Section 3-2-7, the sectional area of the longitudinals may be included in the hull girder section-modulus calculation.

Outside 0.4*L* amidships the sectional area of the longitudinals may be included in the hull-girder section - modulus calculations provided the longitudinals are continuous in way of deck transverses. They may be intercostal at transverse bulkheads provided the areas of the longitudinals are effectively developed at the intercostal connections by providing adequate areas for bracket and fillet weld throat.

For vessels with $L < 90$ meters (295 feet), the longitudinals may be non-continuous within the 0.4*L* region provided the hull girder requirements are met without including the sectional area of the longitudinals. However the areas of the longitudinals are to be effectively developed at intercostal connections by fillet weld throat areas.

Where the area of longitudinals is to be included in the section modulus calculation the longitudinals are to be continuous in way of deck transverses. They may be intercostal at transverse bulkheads provided the areas of the longitudinals are effectively developed at the intercostal connections by providing adequate areas for bracket and fillet weld throat.

3.7 Superstructure Decks

Superstructure decks which are comparatively short ($0.1L$ or less in length) or which are not designed as the strength deck (see 3-2-2/3.5 and 3-2-3/3.3) are to comply with the requirements of 3-2-11/1.3.

3.9 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 side shell or longitudinal bulkheads by means of long brackets.

Where effective decks change in level, the change is to be accomplished by a very gradually sloping section or the deck material at each level is to be effectively overlapped and thoroughly connected together by longitudinal plate diaphragms or webs, of sufficient shear area to transmit the hull girder bending forces between the two levels of strength decks.

3.11 Deck Plating

The following requirements are to be complied with:

i) 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 (0.25 in.).

ii) Requirement in 3-2-3/3.11.i) may be modified where the breaks of poop or forecastle are beyond the midship $0.6L$. The required deck area is to be maintained throughout the amidship $0.4L$ of the vessel. From $0.4L$ amidship to the ends of the vessel, the deck area contributing to the hull girder strength may be gradually reduced in accordance with 3-2-1/11.3.

iii) 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 3-2-1/11.3.

iv) Where a superstructure of or greater than $0.4L$ is located on the strength deck the superstructure deck is to be considered as the strength deck for the application of hull-girder strength requirements.

v) The required area of the strength deck plating clear of the superstructure is to be extended a suitable distance into both ends of the superstructure to ensure an effective transition of hull girder strength between the two strength decks. Where there are numerous openings in the side shell of the superstructure, such as a row of windows, the reduction in shear area of the superstructure side shell may reduce the effectiveness of the superstructure deck as a strength deck.

vi) Outside $0.6L$ the required strength deck area is to be extended into poop and forecastles by a suitable distance to provide effective structural transition of the hull-girder strength.

vii) 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 3-2-1/11.3. Where so modified, the strength deck area is to be maintained as required in the preceding requirements to provide adequate structural continuity. The thickness of the deck plating is also not to be less than given in 3-2-3/5.1.

5 Deck Scantling Details

5.1 Thickness *(2023)*

Generally, the thickness of deck plating is to be not less than obtained from the applicable equations specified in 3-2-3/5 TABLE 1. The required thickness is not to be less than 5.0 mm (0.20 in.), except for enclosed non-strength deck plating where the thickness is not to be less than 4.5 mm (0.18 in.).

Also, the plating thickness of a deck or inner bottom on which cargo is carried is to be obtained from the following equations:

$$t = \frac{s\sqrt{h}}{254} + 1.5 \quad \text{mm}$$

$$t = \frac{s\sqrt{h}}{460} + 0.06 \quad \text{in.}$$

where

t = thickness, in mm (in.)

s = beam or longitudinal spacing, in mm (in.)

p = uniform loading, in kN/m^2 (kgf/m^2, lbf/ft^2)

h = height, in m (ft), as follows:

= 3.66 m (12 ft) for an exposed deck intended to carry deck cargoes when uniform loading p does not exceed 25.66 kN/m^2 (2617 kgf/m^2, 536 lbf/ft^2)

= p/7.01 m (p/715 m, p/44.7 ft) for an exposed deck intended to carry deck cargoes when load p exceeds 25.66 kN/m^2 (2617 kgf/m^2, 536 lbf/ft^2)

= h_{cs}, in m (ft), the cargo space height at side for lower decks and/or double bottoms intended to carry cargoes when uniform loading p does not exceed 25.66 kN/m^2 (2617 kgf/m^2, 536 lbf/ft^2) and/or load density does not exceed 7.01 kN/m^3 (715 kgf/m^3, 44.7 lbf/ft^3)

= h_{cs} m (ft) or p/7.01 m (p/715 m, p/44.7 ft), whichever is greater, for lower decks and/or double bottoms intended to carry cargoes when uniform loading p exceeds 25.66 kN/m^2 (2617 kgf/m^2, 536 lbf/ft^2) and/or load density exceeds 7.01 kN/m^3 (715 kgf/m^3, 44.7 lbf/ft^3)

5.3 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 according to, 3-2-3/5 TABLE 1 appropriate to the depth D_S and the deck's stringer plate is to be connected to the shell. In no case is the plating to be less than obtained from I or J in 3-2-3/5 TABLE 1, as appropriate.

5.5 Reinforcement at Openings

5.5.1 Openings in Strength Decks

Unless otherwise specifically required, openings in the strength deck are to have a minimum corner radius of 0.125 times the width of the opening, but need not exceed 600 mm (24 in.). In other decks, the radius is to be 0.1 times the width of the opening, but need not exceed 450 mm (18 in.). Additionally, the minimum radius in way of narrow deck transverse ligaments between adjacent openings having the same width is not to be less than 150 mm (6 in.).

5.5.2 Openings in Effective Decks

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

5.5.3 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. Pillars are to extend down to the double bottom and are to be fitted in line with each other.

5.7 Platform Decks

Lower decks which are not considered to be effective for longitudinal strength are termed platform decks. The plating thickness is not to be less than obtained from equations I or J of 3-2-3/5 TABLE 1 as appropriate.

5.9 Superstructure Decks

See 3-2-11/1.3.

5.11 Decks over Tanks

For decks over tanks see 3-2-10/3.5.

5.13 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 (0.04 in.).

5.15 Retractable Tween Decks

The thickness of retractable tween deck plating is not to be less than required by equation 6 of 3-2-3/5 TABLE 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.

$SM = kchs\ell^2$ cm^3 (in^3)

where

k	=	7.8 (0.0041)
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 ($p/715$ m, $p/45$ ft)
p	=	uniform loading, in kN/m^2 (kgf/m^2, lbf/ft^2)
s	=	spacing of the beam or girder, in m (ft)
ℓ	=	unsupported length of the beam or girder, in m (ft)

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 3-2-15/11.3. The retractable decks are to be secured against movement and effectively supported by the hull structure.

5.17 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 3-2-3/5.3) is not to be less than obtained from the following equation:

$t = kKn\sqrt{CW}$ mm (in.)

where

k	=	8.05 (25.2, 1.0)
K	=	$[21.99 + 0.316(a/s)^2 - 5.328(a/s) + 2.6(a/s)(b/s) - 0.895(b/s)^2 - 7.624(b/s)]10^{-2}$, derived from the curves indicated in 3-2-3/5 FIGURE 2
n	=	1.0 for $\ell/s \geq 2.0$ and 0.85 for $\ell/s = 1.0$,
	=	$0.85 + 0.15(\ell/s - 1.0)$ for $1.0 < \ell/s < 2.0$
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 (tf, Ltf)
a	=	wheel imprint dimension, in mm (in.), parallel to the longer edge, ℓ, of the plate panel
b	=	wheel imprint dimension, in mm (in.), perpendicular to the longer edge, ℓ, of the plate panel
s	=	spacing of deck beams or deck longitudinals, in mm (in.)
ℓ	=	length of the plate panel, in mm (in.)

The strength deck plating thickness for wheel loading is not to be less than:

$t = 1.1kKn\sqrt{CW}$ mm(in.)

The platform deck plating thickness for wheel loading is not to be less than:

$t = 0.9kKn\sqrt{CW}$ mm(in.)

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, consideration is to 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, while a is to be the lesser dimension.

TABLE 1
Applicable Thickness Equations

Decks	*Minimum Thickness Equation in Table 2*
A. Strength Deck or Long Superstructure Decks Outside Line of Openings	
1. With Transverse Beams	1a and 1b(note 1)
2. With Longitudinal Beams	2a and 2b(note 1)
B. Exposed Strength Deck within Line of Openings	3(note 2)
C. Enclosed Strength Deck or Long Superstructure Decks within Line of Openings	5
D. Effective Lower Decks	
1. Second Deck:	

Decks	*Minimum Thickness Equation in Table 2*
a. D_S > 15.2 m (50 ft)	1a
b. 15.2 m (50 ft) ≥ D_S ≥ 12.8 m (42 ft)	2a
c. D_S < 12.8 m (42 ft)	3
2. Third Deck:	
a. D_S > 17.7 m (58 ft)	1a
b. 17.7 m (58 ft) ≥ D_S ≥ 13.4 m (44 ft)	2a
c. 13.4 m (44 ft) ≥D_S ≥ 9.8 m (32 ft)	3
d. D_S < 9.8 m (32 ft)	4
E. Exposed Forecastle Decks	
1. L > 122 m (400 ft)	2a
2. L≤ 122 m (400 ft)	3
F. Exposed Poop Decks	
1. L> 100 m (330 ft)	3
2. L≤ 100 m (330 ft)	5
G. Exposed Decks Above Poop/Forecastle Decks	4
H. Long Deckhouse Tops and other Enclosed Decks	5
I. Platform Decks in Enclosed Cargo Spaces	6 (note 3)
J. Enclosed decks in Accommodation spaces	7 (note 3)

Notes:

1 In small vessels where the required area for longitudinal strength is relatively small, it may be disposed in the stringer plate and in the strake alongside openings in plating of thickness not less than that 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 the 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.

FIGURE 1
Decks and Tiers Allocation

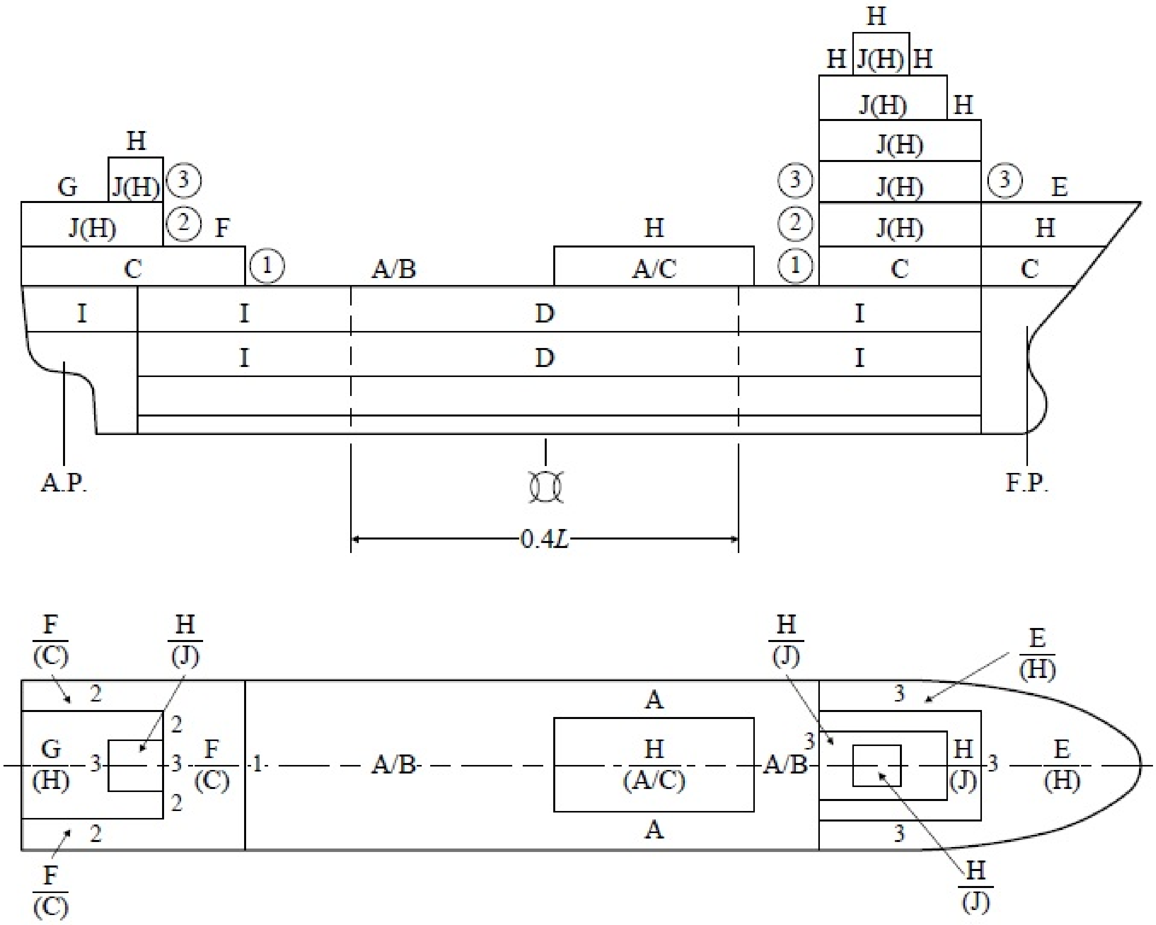


FIGURE 2
Wheel Loading Curves of "K"

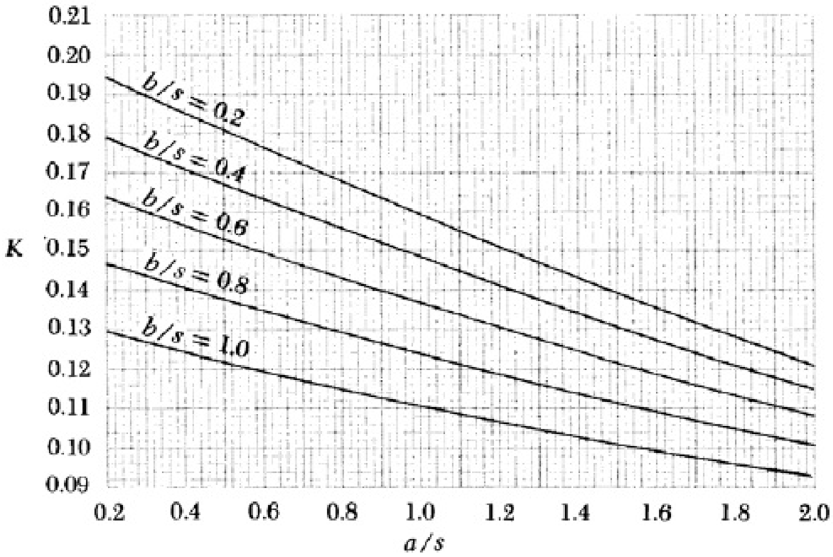


TABLE 2
Minimum Thickness Equations

Equation Number	*Equation*	
1a(notes 1, 2)	$t = 0.01s_b + 2.3$ mm	for $s_b \leq 760$ mm
	$t = 0.0066s_b + 4.9$ mm	for $s_b > 760$ mm
	$t = 0.01s_b + 0.09$ in.	for $s_b \leq 30$ in.
	$t = 0.0066s_b + 0.192$ in.	for $s_b > 30$ in.
1b(notes 1, 3)	$t = \frac{s_b(L + 45.73)}{25L + 6082}$ mm	
	$t = \frac{s_b(L + 150)}{25L + 19950}$ in.	
2a(notes 1, 2)	$t = 0.009s_b + 2.4$ mm	for $s_b \leq 760$ mm
	$t = 0.006s_b + 4.7$ mm	for $s_b > 760$ mm
	$t = 0.009s_b + 0.095$ in.	for $s_b \leq 30$ in.
	$t = 0.006s_b + 0.185$ in.	for $s_b > 30$ in.
2b(notes 1, 3)	$t = \frac{s_b(L + 48.76)}{26L + 8681}$ mm	for $L \leq 183$ m
	$t = \frac{24.38s_b}{1615.4 - 1.1L}$ mm	for $183 < L \leq 427$ m
	$t = \frac{s_b(L + 160)}{26L + 28482}$ in.	for $L \leq 600$ ft
	$t = \frac{80s_b}{5300 - 1.1L}$ in.	for $600 < L \leq 1400$ ft
3	$t = 0.01s_b + 0.9$ mm	for $s_b \leq 760$ mm
	$t = 0.0067s_b + 3.4$ mm	for $s_b > 760$ mm
	$t = 0.01s_b + 0.035$ in.	for $s_b \leq 30$ in.
	$t = 0.0067s_b + 0.134$ in.	for $s_b > 30$ in.

Equation Number	*Equation*	
4	$t = 0.01s_b + 0.25$ mm $t = 0.0043s_b + 4.6$ mm $t = 0.01s_b + 0.01$ in. $t = 0.0043s_b + 0.181$ in.	for $s_b \le 760$ mm for $s_b > 760$ mm for $s_b \le 30$ in. for $s_b > 30$ in.
5	$t = 0.009s_b + 0.8$ mm $t = 0.0039s_b + 4.3$ mm $t = 0.009s_b + 0.032$ in. $t = 0.0039s_b + 0.17$ in.	for $s_b \le 760$ mm for $s_b > 760$ mm for $s_b \le 30$ in. for $s_b > 30$ in.
6	$t = Ks_b\sqrt{h} + a$ mm (in.) but not less than 5.0 mm (0.20 in.) K = 0.00394 (0.00218) a = 1.5 mm (0.06 in.) h = tween deck height in m (ft) 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 (kgf/m^2, lbf/ft^2) and n is defined as 7.01 (715, 44.7)	
7	$t = 0.0058s_b + 1.0$ mm $t = 0.0058s_b + 0.04$ in. but not less than 4.5 mm (0.18 in.)	

L = scantling length of the vessel as defined in 3-1-1/3.1 in m (ft) s_b = spacing of deck beams, in mm (in.)

Notes:

1 Within steel superstructures or deckhouse, the plating thickness may be reduced by 1 mm (0.04 in.).

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 3-2-1/11.3. Vessels designed on still water bending moment envelope curves will be specially considered.

7 Higher-strength Material

7.1 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 taken to avoid reducing thickness of material such as might be subject to damage during normal operation. The thickness of deck plating for longitudinal 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 equations, whichever is greater:

$$t_{hts1} = (t_{ms1} - 4.3)Q + 4.3 \quad \text{mm}$$

$$t_{hts2} = (0.92/\sqrt{Q})(t_{ms2} - 4.3) + 4.3 \quad \text{mm}$$

$$t_{hts1} = (t_{ms1} - 0.17)Q + 0.17 \quad \text{in.}$$

$$t_{hts2} = (0.92/\sqrt{Q})(t_{ms2} - 0.17) + 0.17 \quad \text{in.}$$

where

t_{ms1}	=	thickness of ordinary-strength steel, in mm (in.), as required by these Rules
t_{ms2}	=	thickness of ordinary-strength steel, in mm (in.), as obtained from 3-2-3/5 TABLE 2, equation 2b
Q	=	as defined in 3-2-1/5.3, however the factor $0.92/\sqrt{Q}$ to be less than 1.0

Where the deck plating is transversely framed, or where these 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 requirements.

7.3 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:

$$t_{hts} = t_{ms}\sqrt{q} \quad \text{mm(in.)}$$

where

t_{ms}	=	thickness of ordinary-strength steel, as obtained from 3-2-3/5.17
q	=	$235/Y$ N/mm^2 ($24/Y$ kgf/mm^2, $34{,}000/Y$ lbs/in^2)
Y	=	specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, lbs/in^2), as defined in 2-1-1/13 of the ABS *Rules for Materials and Welding (Part 2)* for the higher-strength material or 0.72 of the specified minimum tensile strength, whichever is the lesser

9 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 (3 ft) 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.

The application of deck covering compositions is to be carried out with the approval of the composition manufacturers.

PART 3

CHAPTER 2

Hull Structures and Arrangements

SECTION 4

Bottom Structures

1 Double Bottoms

1.1 General *(2022)*

The following general requirements are to be complied with, as applicable:

i) Inner bottoms are to be fitted between the peaks or as near thereto as practicable in vessels of ordinary design of 500 GT or over. The depth of the double bottom measured along the center line parallel to the molded keel line is to be not less than B/20, but not less than 0.76 m (2.5 ft) and need not exceed 2 m (6.6 ft) (refer also to 3-2-4/17.5).

ii) Where, for specific reasons, the inner bottom must be omitted, the arrangements are to be clearly indicated on the plans 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.

iii) Bottom structure in way of deep tanks is to have not less strength than is required by 3-2-10/3.3 for deep tank bulkheads. The structure in way of tanks carrying heavy liquids are to be adequate for the loads imposed on them.

iv) Double bottom structures (transverse floors, longitudinal keelsons, etc.) in way of tanks carrying heavy liquid cargoes (S.G. more than 1.05), concentrated loads, or uniformly distributed loads greater than 25.66 kN/m^2 (2617 kgf/m^2, 536 lbf/ft^2) are to be evaluated for buckling strength.

v) 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.

vi) Shell longitudinals and frames in way of deep tanks are to have not less strength than is required by 3-2-10/3.3 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 3-2-10/3.3.

vii) When assessing the tank internal pressure, the head from the bottom longitudinals to two-thirds of the distance from the top of the tank to the top of overflow can be further reduced due to external pressure corresponding to $0.25d_s$ (d_s = minimum draft at light ballast condition). In addition, the modified bottom longitudinal scantlings can be applied up to the upper turn of the bilge, but not more than the required depth of the double bottom. The bottom and side longitudinals, with modified section modulus, are to meet all other Rule requirements.

1.3 Testing

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

3 Center and Side Girders

3.1 Center Girder

A center girder is to extend as far forward and aft as practicable. The plate is to be continuous within the amidship $0.75L$ and have a minimal number of cut-outs.

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.

For vessels under 90 meters (295 feet) in length, manholes may be cut in every frame space outside the midships three-quarters length; they may be cut in alternate frames spaces within the midships three-quarters length. For vessels which have a length between 61 meters (200 feet) and 90 meters (295 feet) and the length of the cargo hold is greater than $1.2B$, the thickness and depth of center girder plates are to be specially considered based on the results of a direct structural calculation."

3.1.1 General *(2022)*

The depths of center girder and side girders are to comply with the double bottom depth (see 3-2-4/1.1).

Center girder plates are to be of the thickness 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 3-2-4/3.7.

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 exceeds $0.25L$, or where the vessel is intended to carry heavy cargoes on double bottom, the thickness and depth of center girder plates are to be specially considered based on the results of a direct structural calculations.

3.1.1(a) Thickness Amidships (2022)

$$t = 0.056L + 5.5 \quad \text{mm}$$

$$t = 0.00067L + 0.22 \quad \text{in.}$$

3.1.1(b) Thickness at Ends

85% of the thickness required amidships

3.1.1(c) Depth (for Vessels other than Offshore Support Vessels) (2022)

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

$d_{DB} = 0.384B + 4.13\sqrt{d}$ in.   for $L \le 1400$ ft

where

t = thickness of plating, in mm (in.)

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

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

d = molded draft of vessel, as defined in 3-1-1/9, in m (ft)

B = breadth of vessel, as defined in 3-1-1/5, in m (ft)

3.3 Pipe Tunnels as 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.

3.5 Docking Brackets for Center Girder and Side Girders

Docking brackets are to be provided on the girders when the spacing of the floors exceeds 2.4 m (8 ft), unless calculations are submitted to verify that the girders provide 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.

3.7 Side Girders

Amidships and aft, side girders of the thickness obtained from the equation of 3-2-4/5 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 (15 ft). At the fore end, they are to be arranged as required by 3-2-4/15.5 or 3-2-4/15.7 as appropriate. Additional full or half-depth girders are to be fitted beneath the inner bottom in way of machinery and thrust seatings and beneath wide-spaced pillars. Where the bottom and inner bottom are both longitudinally framed, this requirement may be accordingly modified.

5 Solid Floors

5.1 General

Solid floors (see 3-2-4/5 FIGURE 1) of the thickness obtained from the following equations (and 3-2-4/5.5 where applicable), are to be fitted on every frame (600 mm to 800 mm) under machinery, under the outer ends of bulkhead stiffener brackets and at the forward end (see 3-2-4/15.5 or 3-2-4/15.7 as appropriate). For machinery spaces other than engine rooms and for generators installed in engine room, alternate spacing of the floors in way of machinery may be considered based on detailed structural analysis. Elsewhere, they may have a maximum spacing of 3.66 m (12 ft) in association with intermediate open floors (see 3-2-4/7), or longitudinal framing of the bottom and/or inner bottom plating. With the latter, the floors are to have stiffeners and/or brackets supporting 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 (0.55 in.), provided the buckling strength is proven adequate (see 5C-1-A2/3, 5C-3-A2/3 or 5C-5-A2/3, as appropriate, where $t_n = 12.5$ mm (0.49 in.) in FOT or 12.0 mm (0.47 in.) 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 (0.06 in.) added to their thickness after all other requirements have been satisfied.

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

$t = 0.00043L + 0.185 + c$ in. for $L \le 1400$ ft

where

t = thickness, in mm (in.), but need not exceed 14 mm (0.55 in.) when floors are fitted at every frame

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

c = 1.5 mm (0.06 in.) for floors where the bottom shell and inner bottom are longitudinally framed

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

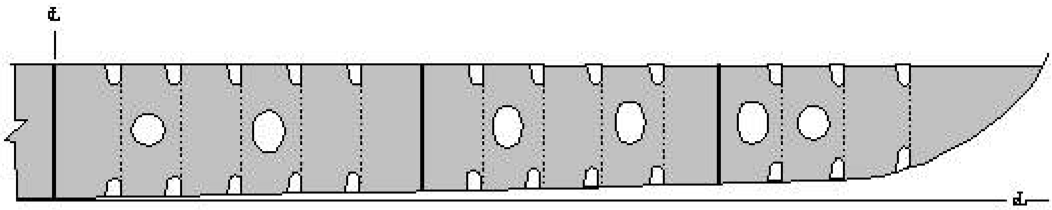
5.3 Tank-end Floors *(1997)*

Tank-end floor thickness is to be not less than required for deep tank bulkhead plating or 3-2-4/5.1, whichever is greater.

5.5 Floor Stiffeners

Stiffeners spaced not more than 1.53 m (5 ft) apart are to be fitted on every solid floor. Where the depth of the double bottom exceeds 0.915 m (3 ft), stiffeners on tank-end floors are to be of the sizes required for stiffeners on deep-tank bulkheads and their spacing is not to exceed 915 mm (36 in.). 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 3-2-4/5.1.

FIGURE 1
Double-bottom Solid Floors



7 Open Floors

7.1 General

Where solid floors are not fitted on every frame, open floors are to be fitted at each frame between the solid floors as permitted by 3-2-4/5.1.

7.3 Bottom Shell Frames and Reverse Frames

Each frame and reverse frame similar to that shown in 3-2-4/7 FIGURE 2, in association with the plating to which it is attached, is to have a section modulus SM as obtained from the following equation:

$SM = 7.8chs\ell^2$ cm^3

$SM = 0.0041chs\ell^2$ in^3

where

s = spacing of frames, in m (ft)

c = 1.0 without struts

= 0.5 with struts in accordance with 3-2-4/7.7

h = d_s or $0.67D$ in m (ft), as defined in 3-1-1/9), whichever is greater. For reverse frames without struts, the distance may be measured from the top of the inner bottom. In way of deep tanks, h is the greatest distance 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 at a distance not less than given in column (e) of 3-2-7/3.1 TABLE 2, appropriate to the vessel's length, whichever is greatest.

ℓ = the greatest distance, in m (ft), between the connecting brackets or intercostals, as shown in 3-2-4/7 FIGURE 2. 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.

7.5 Center and Side Brackets

Where fitted, center and side brackets are to overlap the frames and reverse frames for a distance equal to $0.05B$ (see 3-2-4/7 FIGURE 2); they are to be of the thickness required for solid floors in the same location (see 3-2-4/5.1 equation with $c = 0$) and are to be flanged or stiffened on their outer edges.

7.7 Struts

Struts fitted on open floor bottom structures are to comply with the following:

i) Struts are not to be of hollow sections in way of tanks;

ii) Struts are to be located at the mid-point of the spans of the bottom/inner bottom stiffeners, where fitted;

iii) Struts, in general, are not to be fitted in way where cargo is discharged by grabs, or heavy liquid cargoes are carried, or in the bottom forward slamming area;

The permissible load W_a for struts is to be determined in accordance with 3-2-8/3.1. The calculated load W is to be determined by:

$W = nphs$ kN (tf, Ltf)

where

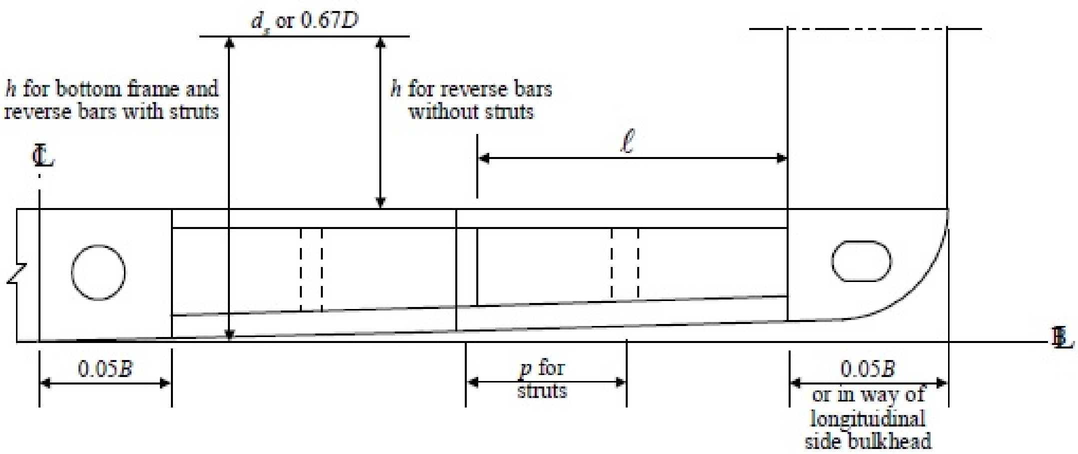
n = 10.5 (1.07, 0.03)

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

s, h are as defined in 3-2-4/7.3.

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

FIGURE 2
Double-bottom Open Floors



9 Inner-bottom Plating

9.1 Inner-bottom Plating Thickness

Inner-bottom plating thickness is not to be less than obtained from the following equation or as required by 3-2-10/3.5, or by 3-2-1/17, whichever is the greatest:

$t = 0.037L + 0.009s - c$ mm

$t = 0.000444L + 0.009s - c$ in.

where

L	=	scantling length of vessel, as defined in 3-1-1/3.1, in m (ft)	
s	=	frame spacing, in mm (in.)	
c	=	c_1	for vessels under 90 m (295 ft) in length
	=	c_2	for other steel vessels
c_1	=	–1.5 mm (–0.06 in.)	in engine space
	=	0.5 mm (0.02 in.)	elsewhere
c_2	=	0.5 mm (0.02 in.)	with transverse framing
	=	1.5 mm (0.06 in.)	with longitudinal framing

Where close ceiling, as defined in 3-2-18/1, 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 (0.08 in.), except in holds designated exclusively for the carriage of containers on the inner bottom.

9.3 Center Strakes

Center strakes are to have a thickness determined from 3-2-4/9.1. In way of pipe tunnels, an increase in the thickness of the inner bottom may be required.

9.5 Inner Bottom Plating for Vessels Intended to Use Grabs

For vessels regularly engaged in cargo handling by grabs or similar mechanical appliances, it is recommended that flush inner-bottom plating is to be adopted throughout the cargo space.

The thickness of the inner bottom plating is not to be taken less than t_{g1}, obtained from the following equation:

$$t_{g1} = (0.037L + 0.009s)\sqrt{Q} + 5.5 \text{ mm}$$

$$= (0.000444L + 0.009s)\sqrt{Q} + 0.217 \text{ in.}$$

Where

L = length of vessel, in m (ft), as defined in 3-1-1/3.1

s = spacing of inner bottom longitudinals, in mm (in.)

Q is as defined in 3-2-1/5.3.

The thickness of sloping bulkhead plating of lower wing tanks and lower stool plating of transverse bulkheads within a vertical extent of 1.5 m (5 ft) above the inner bottom is not to be taken less than t_{g1} with the actual spacing of the sloping bulkhead and stool stiffeners.

If the vessel is designed to discharge its cargo by a means other than by grabs, or similar mechanical appliances, which would negate the t_{g1} inner bottom thickness requirement, it is to be recorded in the vessel's Loading Manual that grabs, or similar mechanical appliances, are not to be used to discharge cargo.

9.6 Optional Supplementary Requirement for Vessels Intended to Use Grabs

Where the vessel is intended to use a specific weight of grab, the thickness of inner bottom plating may be obtained from the following equation:

$$t_{g2} = k_3\sqrt{W_g \cdot s \cdot Q/s_e} + 2.0 \text{ mm}$$

$$= k_3\sqrt{W_g \cdot s \cdot Q/s_e} + 0.08 \text{ in.}$$

where

k_3 = 4.56 (0.181) where W_g is in tonnes (L tons)

W_g = unladen grab weight (mass), in tonnes (L tons)

s = spacing of inner bottom longitudinals, in mm (in.)

s_e	=	1000 mm (39.37 in.)	where $W_g \le$ 20 tonnes (19.684 Ltons)
	=	$1000 + \sqrt{(k_4W_g - 312)10^3 - W_g^2/k_5}$ mm	where $W_g >$ 20 tonnes
	=	$39.37\ \ [1 + (\sqrt{k_4W_g - 31.2)10^3 - W_g^2/k_5})/1000]$ in.	where $W_g >$ 19.684 Ltons
k_4	=	1.58 (1.605)	where W_g is in tonnes (Ltons)
k_5	=	1.0 (0.969)	where W_g is in tonnes (Ltons)

Q is as defined in 3-2-1/5.3.

The unladen grab weight (mass) used in determining the inner bottom thickness, t_{g2}, is to be recorded in the vessel's Loading Manual. This does not negate the use of heavier grabs, but the owner and operators are to be made aware of the increased risk of local damage and possible early renewal of inner bottom plating if heavier grabs are used regularly to discharge cargo. The notation **GRAB [XX tonnes]** placed after the appropriate classification notation in the *Record* will signify that the vessel's inner-bottom has been designed for a specific grab weight, in metric tons.

9.7 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 3-2-3/5.17.

9.9 Under Boilers *(1 July 2020)*

Where the clear space under boilers is necessarily less than the distance required by 4-4-1/19.3, the thickness of the plating is to be increased as may be required.

9.11 In Way of Engine Bed Plates or Thrust Blocks

The thickness of the inner bottom plating is to be at least 19.0 mm (0.75 in.) in way of engine bed plates or thrust blocks which are bolted directly to the inner bottom,. 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.

For vessels of less than 90 meters (295 feet) in length, inner-bottom plating thickness is to be sufficient against the worst case scenario of the anticipated loads and vibrations.

9.13 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 3-2-4/9.1 plus 2.0 mm (0.08 in.). Where approximately horizontal, margin plates may be of the thickness required for tank-top plating at that location.

9.15 Vessels Intended to Carry Steel Coils *(2019)*

Where the vessel is intended to carry steel coils in holds, inner bottom plating thickness and section modulus, SM, of the inner bottom longitudinals are to be not less than that obtained from the following equations.

9.15.1 Inner Bottom Plating

$$t = 6.5\sqrt{\alpha\varphi W_1 Q} + 2.0 \quad \text{mm}$$

$$= 2.6\sqrt{\alpha\varphi W_1 Q} + 0.08 \quad \text{in.}$$

where

α = 1.25 (within 0.4L amidships)

= 1.25 or $1 + 0.568 k_v \alpha_o$, whichever is greater, (beyond 0.4L amidships)

α_o = acceleration factor

= $k_o\left(2.4/L^{1/2} + 34/L - 600/L^2\right)$ for L in m

= $k_o\left(4.347/L^{1/2} + 111.55/L - 6458/L^2\right)$ for L in ft

k_o = $0.86 + 0.048V - 0.47C_b$

C_b = block coefficient as defined in 3-1-1/13.3

V = 75% of the design speed, V_d, in knots. V is not to be taken less than 10 knots.V_d is defined in 3-2-14/3.

k_v = $\left[1 + 0.65(5.3 - 45/L)^2(x/L - 0.45)^2\right]^{1/2}$ for L in m

= $\left[1 + 0.65(5.3 - 147.6/L)^2(x/L - 0.45)^2\right]^{1/2}$ for L in ft

W_1 = Wmn_1/n

W = weight (mass) of one steel coil, in tonnes (L tons)

n_1 = number of tiers of steel coils

n = number of dunnages supporting one steel coil

m = parameter as given in 3-2-4/9.15.1 TABLE 1, as a function of n and ℓ/s_f

β = parameter as given in 3-2-4/9.15.1 TABLE 1, as a function of n and ℓ/s_f

ℓ = length of one steel coil, in m (ft)

s_f = floor spacing at the location being consideration, in m (ft)

φ = $\dfrac{\alpha\delta - \delta^2 - 0.25\alpha^2(1-\beta)^2}{\alpha\beta(1 + 2\alpha\delta)}$

δ = $0.5\left[\sqrt{1 + 2\alpha^2 + \alpha^4(1-\beta)^2} - 1\right]/\alpha$

α = aspect ratio of the inner bottom plating panel, (between floors and longitudinal stiffeners); α is not to be taken more than 3.0 .

Q = as defined in 3-2-1/5.5

The above equation is applicable for normal loading arrangements where steel coils are stowed on dunnage laid athwartships, with the steel coils' axes in fore-and-aft direction. Other loading arrangements of steel coils will be specially considered.

TABLE 1

n	ℓ/s_f	m	β
2	$0.83 \le \ell/s_f$	2	$0.5\ell/s_f$
2	$0.60 \le \ell/s_f < 0.83$	3	$1.2\ell/s_f$
2	$0.42 \le \ell/s_f < 0.60$	4	$1.65\ell/s_f$
2	$0.30 \le \ell/s_f < 0.42$	5	$2.35\ell/s_f$
3	$0.83 \le \ell/s_f$	3	$0.65\ell/s_f$
3	$0.65 \le \ell/s_f < 0.83$	4	$1.2\ell/s_f$
3	$0.52 \le \ell/s_f < 0.65$	5	$1.53\ell/s_f$
4	$0.83 \le \ell/s_f$	4	$0.75\ell/s_f$
4	$0.65 \le \ell/s_f < 0.83$	5	$1.2\ell/s_f$

9.15.2 Inner Bottom Longitudinals

$SM = M/f_b$ cm^3(in^3)

where

M	=	maximum bending moment at the longitudinal, in kgf-cm (lbf-in), obtained with the assumption that the longitudinal is a fixed-fixed beam at floors. The longitudinal should be loaded with concentrated loads $P = 0.8\ \alpha W n_1/n$ at the position of dunnages, where W, α, n_1, n are as defined in 3-2-4/9.15.1. The span of the longitudinal is to be defined in 3-2-4/11.3.
f_b	=	$1330/Q(18840/Q)$ for longitudinal frames (within $0.4L$ amidships)
	=	$1530/Q(21675/Q)$ for longitudinal frames (within $0.2L$ and the ends of L); between $0.3L$ and $0.2L$ from the ends of L of vessels intended to carry steel coils, f_b for inner bottom longitudinals is to be obtained by linear interpolation
Q	=	as defined in 3-2-1/5.3

11 Bottom and Inner-bottom Longitudinals

11.1 General

Bottom and inner-bottom longitudinals for vessels of more than 90 meters (295 feet) in length are to be continuous [see 3-2-1/3.7.1(c)] or attached at their ends to effectively develop their sectional area and their resistance to bending.

11.3 Bottom Longitudinals *(1 July 2021)*

Each bottom longitudinal frame similar to that shown in 3-2-4/11.3 FIGURE 3, 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:

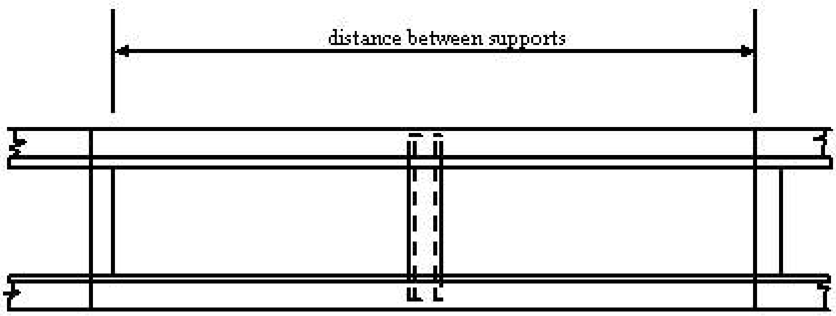
$SM = 7.8chs\ell^2$ cm^3

$SM = 0.0041chs\ell^2$ in^3

where

c	=	1.3	without struts
	=	0.715	with effective struts
h	=	for offshore support vessels, d_s or $0.67D_s$ in m (ft), as defined in 3-1-1/9, whichever is greater. In way of deep tanks, h is the greatest distance 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 at a distance not less than given in column (e) of 3-2-7/3.1 TABLE 2, appropriate to the vessel's length, whichever is greatest.	
h	=	for all other vessels, distance, in m (ft), 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 (ft)	
ℓ	=	distance, in m (ft), between the supports, but is not to be taken as less than 1.83 m (6 ft) without struts or 2.44 m (8 ft) with struts. 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 subject to above minimum.	

FIGURE 3
Longitudinal Frame



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

i) The actual bottom hull girder section modulus SM_A is greater than required by 3-2-1/3.7.1, at least throughout $0.4L$ amidships,

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

iii) Adequate buckling strength is maintained.

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

where

n = 8.278 (0.852, 5.36)

f_p = 17.5 kN/cm^2 (1.784 tf/cm^2, 11.33 Ltf/in^2)

SM_R = required hull girder section modulus required by 3-2-1/3.7.1, in cm^2-m (in^2-ft)

SM_A = actual bottom hull girder section modulus, in cm^2-m (in^2-ft)

Bottom longitudinals, with this modified section modulus, are to meet all other Rule requirements including side longitudinals in 3-2-5/3.17.

11.5 Inner-bottom Longitudinals *(1 July 2021)*

Inner-bottom longitudinals are to have values of SM at least 85% of that required in 3-2-4/11.3 for the bottom longitudinals.

For OSVs, inner-bottom longitudinals are to have values of SM at least 85% of that required for the bottom longitudinals using the deep tank h for the inner bottom, if that be greater.

12 Single Bottoms with Floors and Keelsons *(2022)*

12.1 General

For vessels under 90 m (295 ft) in length, where double bottom construction is not required by 3-2-4/1.1 or is not applied, single bottom construction is to be in accordance with 3-2-4/12 or 3-2-4/13, as may be applicable.

12.3 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 (100 ft) 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 (100 ft) in length. The keelsons are to extend as far forward and aft as practicable.

12.3.1 Center-girder Plate Thickness Amidships

$t = 0.063L + 5$ mm

$t = 0.00075L + 0.2$ in.

12.3.2 Center-girder Plates Thickness at Ends

t = 85% of center keelson thickness amidships

12.3.3 Horizontal Top-plate Area Amidships

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

$A = 0.0044L^{3/2} - 1.25$ in^2

12.3.4 Horizontal Top-Plate Area at Ends [L ≥ 30.5 m (100 ft)]

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

$A = 0.0033L^{3/2} - 0.15$ in^2

where

t = thickness of center-girder plate, in mm (in.)

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

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

12.5 Side Keelsons

Side keelsons are to be arranged so that there are not more than 2.13 m (7 ft) 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 (36 in.). 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 3-2-4/12.3, if that be less.

12.5.1 Side Keelson and Intercostal Thickness Amidships

$t = 0.063L + 4$ mm

$t = 0.00075L + 0.16$ in.

12.5.2 Side Keelson and Intercostal Thickness at Ends

t = 85% of center thickness amidships

12.5.3 Side Keelson and Intercostal, Horizontal Top Plate Area Amidships

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

$A = 0.001L^{3/2} + 2.6$ in^2

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

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

$A = 0.00065L^{3/2} + 3.1$ in^2

t, L and A are as defined in 3-2-4/12.3.

12.7 Floors

12.7.1 Section Modulus

With transverse framing, a floor as shown in 3-2-4/Figure 4 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:

$SM = 7.8chs\ell^2$ cm^3

$SM = 0.0041chs\ell^2$ in^3

where

c = 0.55

h = draft, d_s, in m (ft), as defined in section 3-1-1/9.3, but not to be less than 0.66D or 0.066L, whichever is greater.

s = floor spacing, in m (ft)

ℓ = span, in m (ft). Where brackets are fitted in accordance with 3-1-2/15.1 and are 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.

12.7.2 Depth

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

$h_f = 62.5\ell$ mm

$h_f = 0.75\ell$ in.

where

h_f = floor depth, in mm (in.)

ℓ = unsupported span of floors, in m (ft). Where brackets are fitted in accordance with 3-1-2/15.1, the length, ℓ, may be measured as permitted therein.

12.7.3 Thickness

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

$t = 0.01h_f + 3$ mm

$t = 0.01h_f + 0.12$ in.

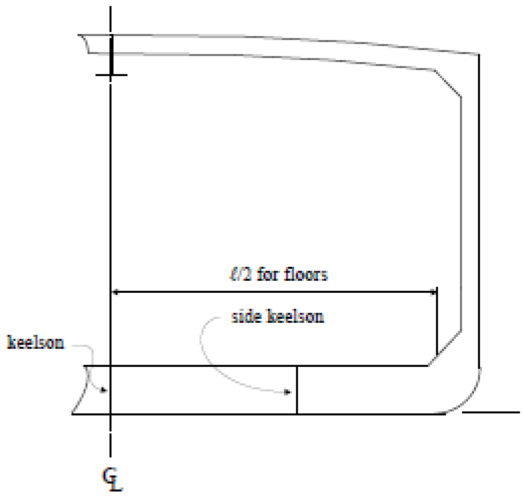
where

t = floor thickness, in mm (in.)

h_f = floor depth, in mm (in.)

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

FIGURE 4
Plate Floors



13 Single Bottoms with Longitudinal or Transverse Frames

13.1 General *(2022)*

Where longitudinal frames supported by bottom transverses or transverse frames supported by longitudinal girders and bottom transverses are proposed for a vessel not complying with SOLAS, 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 3-2-4/13.1 FIGURE 5, 3-2-4/13.1 FIGURE 6 and 3-2-4/13.1 FIGURE 7.

FIGURE 5
Round Bottom Floors with Deadrise

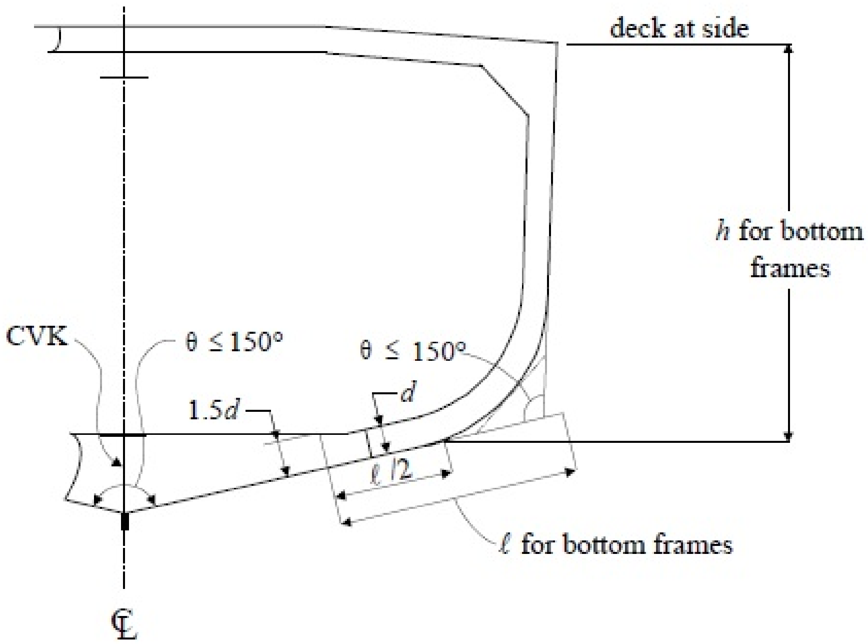


FIGURE 6
Transverse Bottom Frames with Longitudinal Side Girders

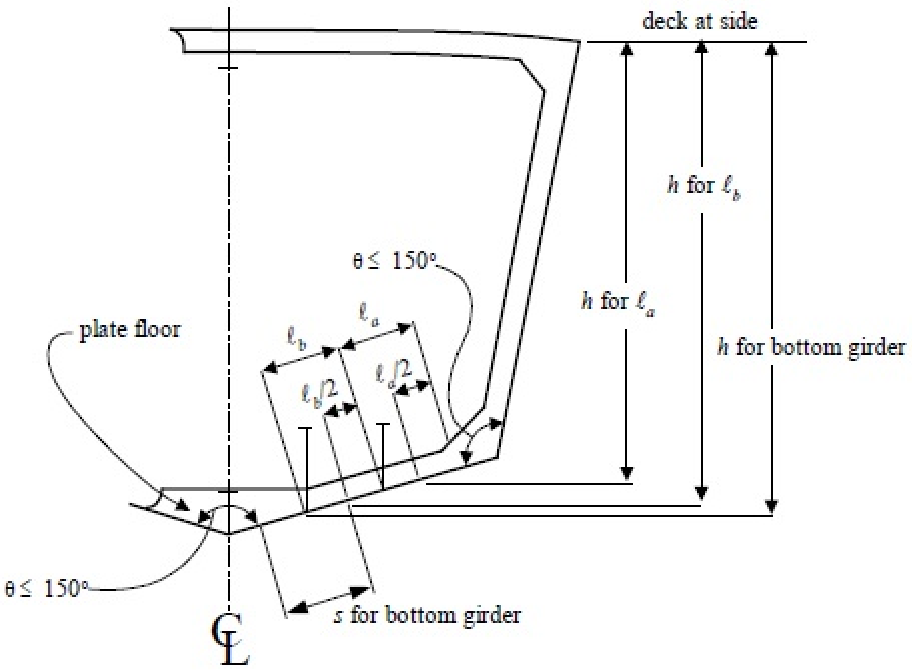
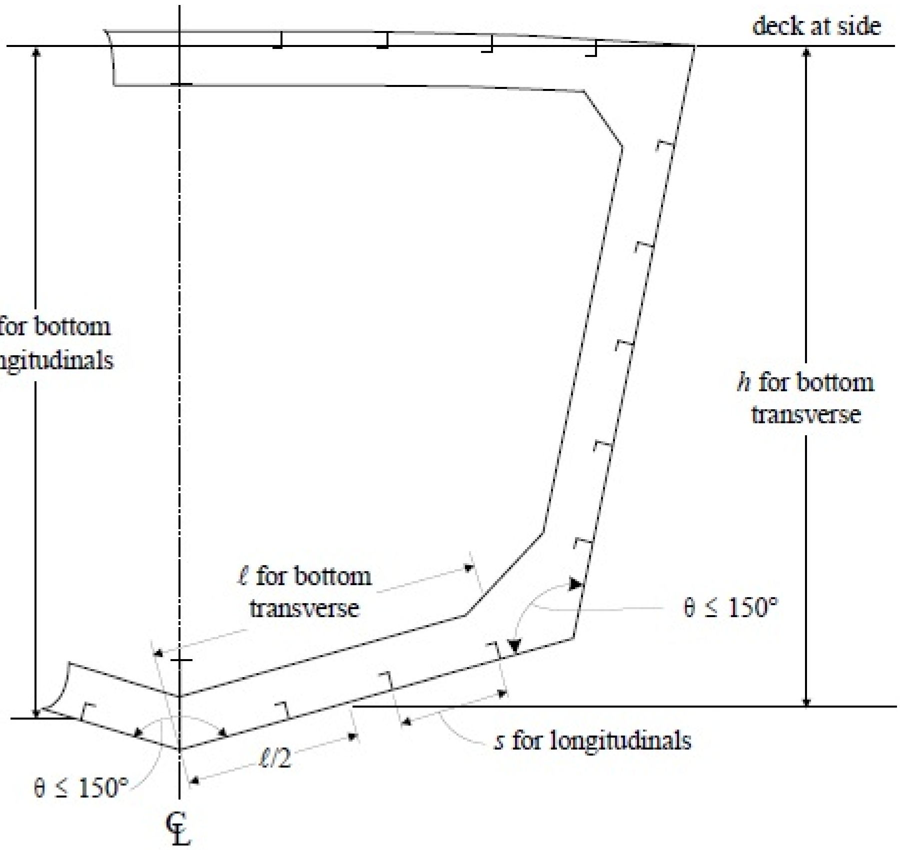


FIGURE 7
Longitudinal Frames with Transverse Webs



13.3 Bottom Girders and Transverses

13.3.1 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:

$$SM = 7.8chs\ell^2 \quad \text{cm}^3$$

$$SM = 0.0041chs\ell^2 \quad \text{in}^3$$

where

c	=	0.915
h	=	vertical distance, in m (ft), from the center of area supported to the deck at side
s	=	spacing, in m (ft)
ℓ	=	unsupported span, in m (ft).

Tripping brackets are to be fitted at intervals of about 3 m (10 ft) and stiffeners are to be fitted as may be required.

13.3.2 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:

$$h_w = 145\ell \quad \text{mm}$$

$$h_w = 1.75\ell \quad \text{in.}$$

where

h_w = girder or transverse depth, in mm (in.)

ℓ is defined in 3-2-4/13.3.1.

13.3.3 Thickness

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

$$t = 0.01h_w + 3 \quad \text{mm}$$

$$t = 0.01h_w + 0.12 \quad \text{in.}$$

where

t = floor thickness, in mm (in.)

h_w is as given in 3-2-4/13.3.2.

13.3.4 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.

13.5 Center Girder

In general, a center girder is to be fitted, complying with 3-2-4/13.3; however, alternative arrangements that provide suitable support for docking will be considered.

13.7 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:

$$SM = C_f chs\ell^2 \quad \text{cm}^3\left(\text{in}^3\right)$$

where

C_f	=	7.8 (0.0041)	for SM in cm^3 (in^3)
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 (ft)	

ℓ = unsupported span, in m (ft)

h = vertical distance, in m (ft), 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 (ft), 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 ($0.01L + 0.5$ ft) or 0.46 m (1.5 ft), whichever is greatest.

L is as defined in 3-1-1/3.

15 Fore-end Strengthening

15.1 General *(2022)*

For all OSVs and other vessels 61 m (200 ft) in length and over, where the heavy weather ballast draft forward is less than $0.04L$ m (ft), strengthening of the flat of bottom forward is to be in accordance with 3-2-4/15.3, 3-2-4/15.5, 3-2-4/15.7 and 3-2-2/5.5. Information on the heavy weather ballast draft forward used for the required fore-end strengthening is to be indicated on the shell expansion plan submitted for approval, as well as furnished to the vessel for the Master's guidance.

15.3 Extent of Strengthening

The flat of bottom forward is defined as being forward of the locations indicated in 3-2-4/Table 1A or 1B, as applicable (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 3-2-4/Table 1A or 1B.

15.5 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 3-2-4/Table 1A or 1B is to be not less than required by the following equation, nor less than required by 3-2-4/11.3.

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

$$SM = 0.0044(0.005L^2 - 1.3d_f^2)s\ell^2/d_f \quad \text{in}^3$$

where

L = length of vessel, as defined in 3-1-1/3.1, in m (ft), but need not be taken as greater than 214 m (702 ft)

d_f = heavy weather ballast draft at the forward perpendicular, in m (ft)

= $d_f \times 214/L$ m ($d_f \times 702/L$ ft), where $L > 214$ m (702 ft)

s = spacing of longitudinals, in m (ft)

ℓ = distance between floors, in m (ft)

The spacing of floors in the forward $0.25L$ is not to be greater than 3s, where s is the spacing of transverse side frames, in m (ft), or S in 3-2-5/1.7, where side shell is longitudinally framed..

15.7 Transverse Framing

15.7.1 Offshore Support Vessels

Where the heavy weather ballast draft forward is less than $0.04L$ m (ft.), 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 3-2-4/15.7 TABLE 1A does not exceed 2.44 m (8 ft) and that the spacing of alternating half and full-depth girders forward of the location in 3-2-4/15.7 TABLE 1A does not exceed 1.22 m (4 ft).

TABLE 1A
Extent of Strengthening

C_b	*Location Forward of Amidships*
$0.6 \le C_b < 0.8$	$0.25(C_b + 0.4)L$
$C_b \ge 0.8$	$0.30L$

C_b is the block coefficient as defined in 3-1-1/13.3.

Where the draft forward is 0.04L m (ft) or more, the arrangement of solid floors and side girders may be in accordance with 3-2-4/3.7 and 3-2-4/5.

15.7.2 Other Steel Vessels

Where the heavy ballast draft forward is less than 0.04L m (ft), 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 3-2-4/15.7.2 TABLE 1B does not exceed 2.13 m (7 ft) and that the spacing of alternating half and full-depth girders forward of the location in 3-2-4/15.7.2 TABLE 1B does not exceed 1.07 m (3.5 ft). Where the heavy ballast draft forward is 0.04L m (ft) or more, the arrangement of side girders and solid floors may be in accordance with 3-2-4/3.7 and 3-2-4/5.

TABLE 1B
Extent of Strengthening

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 3-1-1/13.3.

TABLE 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	

Notes:

1. d_f is the heavy ballast draft, in m (ft), at the forward perpendicular and C_b is the block coefficient at the summer load waterline, based on L as defined in 3-1-1/3.1.
2. s is the spacing of transverse side frames, or the spacing of longitudinally framed side shell.
3. For values of d_f between $0.02L$, $0.035L$ and $0.04L$ m (ft.), the floor spacing may be obtained by interpolation.

17 Higher-strength Materials

17.1 General *(2022)*

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 taken to avoid reducing thickness of material such as might be subject to damage during normal operation. Longitudinal framing members are to be of the same material as the plating they support.

Proposed applications of higher-strength material for bottom structures are to be accompanied by submission of calculations in support of adequate strength of longitudinals and plating against buckling.

17.3 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 3-2-4/9.1 or 3-2-10/3.5 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 (in.)
t_{ms}	=	thickness of mild steel, as required by 3-2-4/9.1 or 3-2-10/3.5, in mm (in.), increased where required by 3-2-4/9.1 for no ceiling
C	=	3 mm (0.12 in.)
	=	5 mm (0.20 in.) where the plating is required by 3-2-4/9.1 to be increased for no ceiling
Q	=	as defined in 3-2-1/5.3

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 3-2-4/9.5 are applicable to t_{hts}.

17.5 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 3-2-4/11.3 and 3-2-4/11.5, except that the value may be reduced by the factor Q as defined in 3-2-1/5.3.

17.7 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 3-2-4/3 or 3-2-4/5 but may be modified, as permitted, by the following equation.

$$t_{hts} = [t_{ms} - 3][Q + 2\sqrt{Q})/3] + 3 \quad \text{mm}$$

$$t_{hts} = [t_{ms} - 0.12][Q + 2\sqrt{Q})/3] + 0.12 \quad \text{in.}$$

where t_{hts}, t_{ms}, are as defined in 3-2-4/17.3 and Q is as defined in 3-2-1/5.3.

19 Structural Arrangements and Details

19.1 Structural Sea Chests *(2022)*

In addition to the requirements of 3-2-4/1 and 3-2-4/9, 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:

$$t = 0.035(L + 29) + 0.009s \quad \text{mm} \qquad \text{for} \quad 90 \le L \le 305 \quad \text{m}$$
$$t = (11.70 + 0.009s)\sqrt{D/35} \quad \text{mm} \qquad \text{for} \quad 305 < L \le 427 \quad \text{m}$$
$$t = 0.00042(L + 95) + 0.009s \quad \text{in.} \qquad \text{for} \quad 295 \le L \le 1000 \quad \text{ft}$$
$$t = (0.46 + 0.009s)\sqrt{D/114.8} \quad \text{in.} \qquad \text{for} \quad 1000 < L \le 1400 \quad \text{ft}$$

where

s	=	the maximum unsupported width of sea chest plating, in mm (in.)
L	=	length of vessel, as defined in 3-1-1/3.1, in m (ft)
D	=	molded depth, in m (ft), as defined in 3-1-1/7.1 or 35 m (114.8 ft), whichever is greater

The thickness need not exceed that required in 3-2-2/3.9 for side shell and 3-2-2/3.15 for bottom shell, as appropriate.

Where connections between shell and grating employ welding joints with lug plates instead of hinge joints, a partial or full penetration weld is required. Stiffeners attached to the shell in way of sea chest openings are to be connected at their ends.

19.3 Drainage *(1 July 2022)*

Drain wells are to be provided for draining water that may gather on the inner bottom and are to be so arranged as to comply with 4-6-4/5. For such purpose, small wells may be constructed in the double bottom, but are not to extend downward more than necessary. The vertical distance from the bottom of such a drain well to a plane coinciding with the keel line is not be less than $0.5h$ (h is the required depth of the double bottom specified in 3-2-4/1.1.i.) or 500 mm (19.7 in.), whichever is greater, or equivalent protection is to be shown by demonstrating that the ship is capable of withstanding bottom damages as specified in SOLAS II-1/Reg.9.8 or other applicable subdivision and damage stability requirements as specified in SOLAS II-1/Reg.4.2.1.2.

Other wells (e.g., for lubricating oil under main engines) may be permitted if satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with the following:

i) For a cargo vessel of 80 m (263 feet) in length and upwards or for a passenger vessel, proof of equivalent protection is to be shown by demonstrating that the vessel is capable of withstanding bottom damages as specified in SOLAS Reg. II-1/9.8 or other applicable subdivision and damage stability requirements as specified in SOLAS II-1/Reg.4.2.1.2. Alternatively, wells for lubricating oil below main engines may protrude into the double bottom below the boundary line defined by the distance h specified in 3-2-4/1.1.i. provided that the vertical distance between the well bottom and a plane coinciding with the keel line is not less than $h/2$ or 500 mm, whichever is greater.

ii) For cargo vessels of less than 80 m (263 feet) in length, the arrangements are to provide a level of safety to the satisfaction of ABS. An arrangement capable of withstanding the bottom damages as described in 3-2-4/19.3.i. may be considered to fulfill this requirement.

For oil tankers of 5,000 tonnes deadweight and above, bilge wells in a cargo pump-room may be constructed in the double bottom, provided that such wells are as small as practicable and the distance between the well bottom and the vessel's baseline measured at right angles to the vessel's baseline is not less than one-half the required depth of the double bottom specified in MARPOL Annex I/Reg.22.2.

Plating forming drain wells, except for those in the engine room, is to be at least 2.5 mm (0.10 in.) greater than is otherwise required at that location unless corrosion-resistant material is used or special protective coatings are applied. Steel striking plates or other approved arrangements are to be provided in way of sounding pipes to prevent damage by the sounding rods.

19.5 Manholes and Lightening Holes

19.5.1 Offshore Support Vessels

Manholes and lightening holes are to be cut in all non-tight /members, except in way of widely spaced pillars and those aligned with bulkheads' brackets above, to ensure accessibility and ventilation. The proposed locations and sizes of holes are to be indicated on the plans submitted for approval. Where the requirements of IMO Res.A.673(16) are to be applied, the minimum clear access opening of 600 mm × 800 mm for vertical openings and 600 mm × 600 mm for horizontal openings will be required. Manholes located in the tops of tanks are to be sufficient in size and number to secure free ventilation and provide ready access to all parts of the double bottom. It is recommended that two access manholes are being provided for each tank situated as far apart as possible. However, if this is not feasible, one of the openings for ventilation purposes may have smaller dimensions. Care is to be taken in locating the manholes to avoid the possibility of interconnection of the main subdivision compartments through the double bottom. 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.

19.5.2 Other Vessels Greater Than 90 m (295 ft) In Length

Manholes and lightening holes are to be cut in all non-tight members, except in way of widely spaced pillars, to provide 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.

19.5.3 Vessels Under 90 m (295 ft) In Length

For requirements for manholes and scuttles on vessels under 90 meters (295 feet) in length, refer to 3-2-15/21.1.

19.7 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 of liquids to the suction pipes. It is recommended that air notches to have radius of not less than 25 mm (1 in.) and drainage scallops radius of not less than 35 mm (1.4 in.).

19.9 Fixed Ballast

See 7-A1-4/25 of the ABS *Rules for Survey After Construction (Part 7)* for requirements for fixed ballast.

21 Machinery Space

21.1 General

Special attention is directed to arranging for the provision of plated through beams and such casing and pillar supports as are required to secure structural efficiency. All parts of the machinery, shafting, etc., are to be efficiently supported and the adjacent structure is to be adequately stiffened.

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. (Refer also to Section 3-2-12 and 4-3-2/7.)

21.3 Engine Foundations

21.3.1 Single Bottom Vessels (Non-SOLAS Vessel Only)

In vessels with single bottoms, the engines are to be seated on thick plates laid across the top of deep floors or upon heavy foundation girders efficiently bracketed and stiffened. Intercostal plates are to be fitted between the floors beneath the lines of bolting to distribute the weight effectively through the bottom structure to the shell. Seat plates are to be of thickness and width appropriate to the holding-down bolts and is to be effectively attached to girders and intercostals.

21.3.2 Double Bottom Vessels

On 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.

21.5 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.

21.7 Shaft Stools and Auxiliary Foundations

Shaft stools and auxiliary foundations are to be of ample strength and stiffness in proportion to the weight supported.

PART 3

CHAPTER 2
Hull Structures and Arrangements

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 3-2-5/1 FIGURE 1. The equations apply to vessels which have well-rounded lines, normal sheer and bulkhead support not less effective than that specified in Section 3-2-9. Additional stiffness will be required where bulkhead support is less effective, where sheer is excessive or where flat surface areas are 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 in the same location. Framing sections are to have sufficient thickness and depth in relation to the spans between supports.

1.3 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.

1.5 End Connections

At the ends of un-bracketed frames, both the web and the flange are to be welded to the supporting member. At bracketed end connections, continuity of strength 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 3-2-19/3 TABLE 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.

1.7 Standard and Cant Frame Spacing

The standard frame spacing, S, amidships for vessels with transverse framing, may be obtained from the following equations. 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

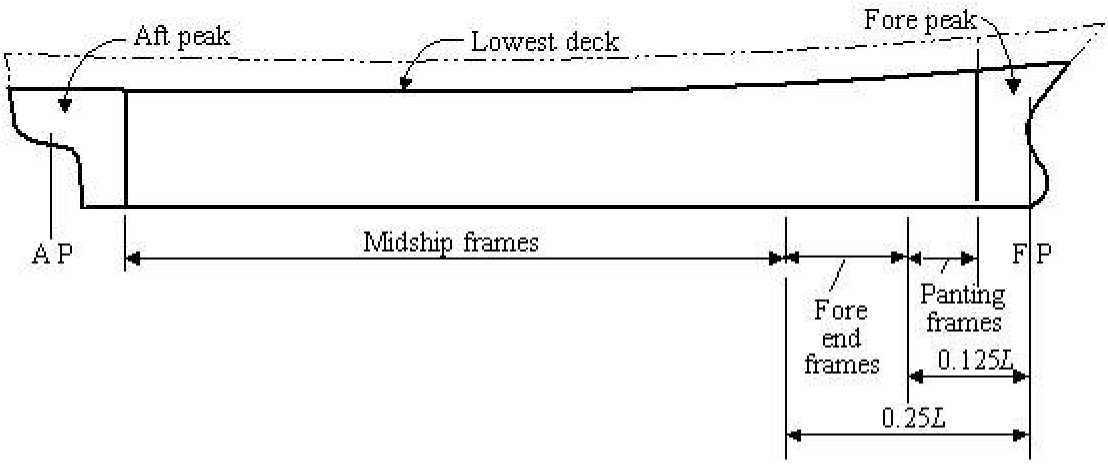
$S = 0.025L + 17.25$ in. for $L \leq 890$ ft

$S = 39.5$ in. for $890 < L \leq 1400$ ft

where

S	=	standard frame spacing, in mm (ft)
L	=	scantling length of vessel, as defined in 3-1-1/3.1, in m (ft)

FIGURE 1
Zones of Framing



3 Side Frames

3.1 Transverse Frames

3.1.1 Strength Requirement for All OSVs and Other Vessels 90 m (295 ft) in Length and Over *(2022)*

The section modulus SM (*see Note 1*) of each transverse frame located between $0.25L$ aft of the FP and the aft peak bulkhead and below the lowest deck is to be obtained from the following equation, where ℓ is the span in (ft.) as shown in 3-2-5/3.1 between the toes of brackets. The value of ℓ for use with the equation is not to be less than 2.1 m (7 ft).

$$SM = s\ell^2(h + bh_1/C_1)(C_2 + C_3/\ell^3) \quad \text{cm}^3\left(\text{in}^3\right)$$

where

C_1	=	30 (100)
C_2	=	7 (0.0037)
C_3	=	45 (0.8)
s	=	frame spacing, in m (ft)
h	=	vertical distance, in m (ft), from the middle of ℓ to the scantling draft line or 0.4ℓ whichever is greater
b	=	horizontal distance, in m (ft), from the outside of the frames to the first row of deck supports

h_1	=	$h_{FB} + h_{C1} + h_{C2} + h_{C3} + ...h_{Cn} + h_E + 0.5(h_{P1} + h_{P2} + ...h_{Pm})$ (*see Note 2*)
h_{FB}	=	vertical distance, in m (ft), from the deck at the top of the frame to the bulkhead or freeboard deck
$h_{Ci}...h_{Cn}$	=	heights of cargo spaces above the bulkhead/freeboard deck. Where the cargo load differs from 7.01 kN/m^3 (715 kgf/m^3, 44.7 lbf/ft^3) multiplied by the tween deck height in m (ft), the height of that tween deck is to be proportionately adjusted in calculating h_1.
h_E	=	3.66 m (12 ft) for an exposed deck intended to carry deck cargoes when uniform loading p does not exceed 25.66 kN/m^2 (2617 kgf/m^2, 536 lbf/ft^2)
	=	p /7.01 m (p/715 m, p/44.7 ft) for an exposed deck intended to carry deck cargoes when load p exceeds 25.66 kN/m^2 (2617 kgf/m^2, 536 lbf/ft^2)
	=	0.0 m, if the exposed deck has no cargo loads
p	=	uniform cargo load, in kN/m^2 (kgf/m^2, lbf/ft^2)
$h_{Pi}...h_{Pm}$	=	heights of accommodation spaces

In cases where there is no exposed deck intended to carry deck cargo located above the frames, the sum$h_{C1} + h_{C2} + h_{C3} + ...h_{Cn} + 0.5(h_{P1} + h_{P2} + ...h_{Pm})$ shall not be taken as less than 2.44 m (8 ft).

Notes:

1. Where a frame may be subject to special heavy vertical loads, such as may occur at the ends of deep transverse girders which in turn support deck girders, the section modulus is to be suitably increased in proportion to the extra load carried as indicated in 3-2-5/3.1.1.

2. 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 h1 is to be multiplied by the number of frame spaces between the deep transverse beams.

FIGURE 2
Side Frames

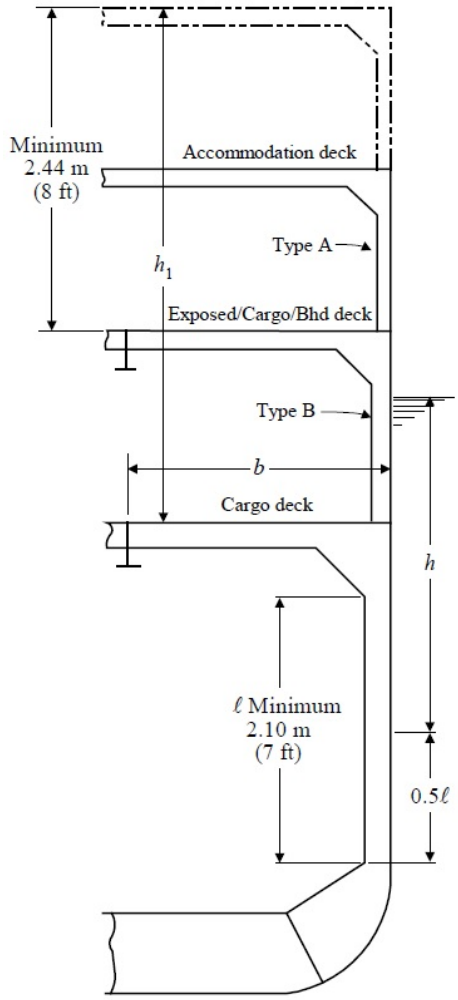


FIGURE 3
Side Frames

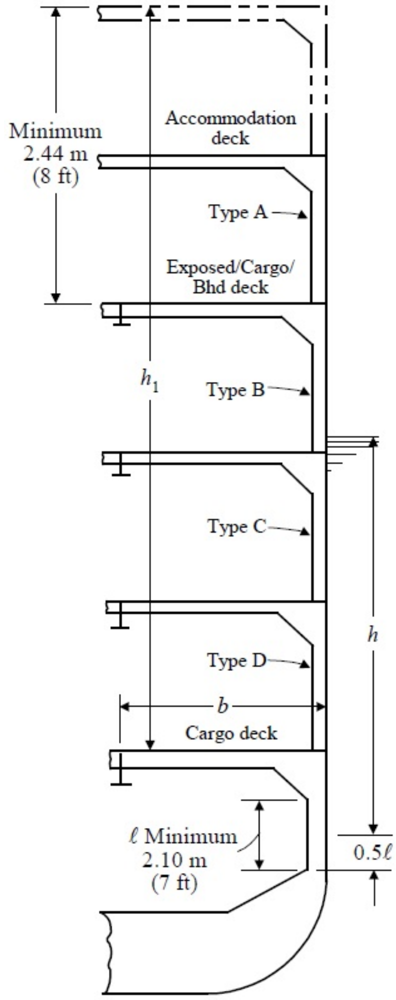
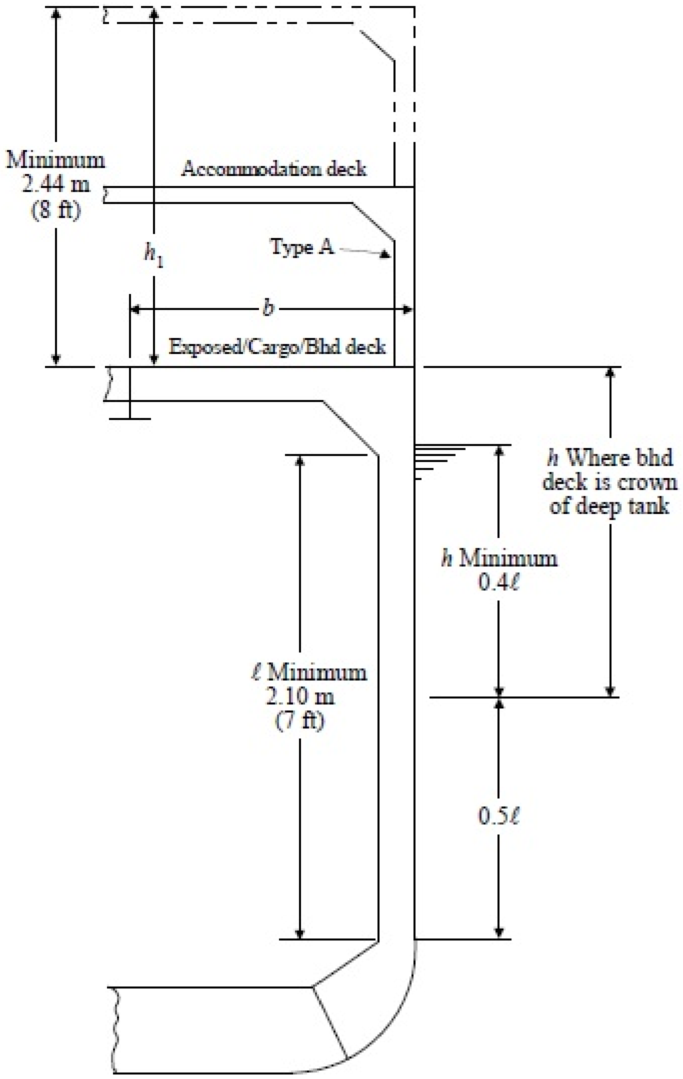


FIGURE 4
Side Frames



3.1.2 Strength Requirement for Vessels under 90 m (295 ft) in Length *(2022)*

The section modulus, SM, of each transverse side frame located between 0.25L aft of the FP and the aft peak bulkhead other than tween deck frames above the chine or upper turn of bilge, in association with the plating to which the frame is attached, is not to be less than that obtained from the following equation. See 3-2-5/Figure 5, 3-2-5/Figure 6, and 3-2-5/Figure 7.

$$SM = C_1 chs\ell^2 \quad \text{cm}^3\left(\text{in}^3\right)$$

where

C_1	=	7.8 (0.0041)	
c	=	0.915	for frames having no tween decks above
	=	$0.90 + 5.8/\ell^3 \quad (0.90 + 205/\ell^3)$	for frames having tween decks above

s = frame spacing, in m (ft)

ℓ = straight-line unsupported span, in m (ft). Where brackets are fitted in accordance with 3-1-2/5.5 and are supported by decks or inner bottoms, the length ℓ may be measured as permitted therein. Where tween decks are located above the frame, ℓ is to be taken as the length between the toes of the brackets, except where beam knees are fitted on alternate frames, ℓ is to be increased by one half the depth of the beam knees. ℓ is not to be taken less than 2.1 m (7.0 ft).

h = on frames having no tween decks above, the vertical distance, in m (ft), from the mid length of the frame to the freeboard deck at side, but not less than $0.02L + 0.46$ m ($0.02L + 1.5$ ft).

= on frames having tween decks above, the vertical distance, in m (ft), from the middle of ℓ to the load line or 0.4ℓ, whichever is greater, plus $bh_\circ/33(bh_\circ/100)$.

b = horizontal distance, in m (ft), from the outside of the frames to the first row of deck beam supports.

$h_\circ$ = vertical distance, in m (ft), from the deck at the top of the frame to the bulkhead or freeboard deck plus the height of all cargo tween deck spaces above the bulkhead or freeboard deck plus one-half the height of all passenger spaces above the bulkhead or freeboard deck, or plus 2.44 m (8 ft), if that is greater. Where the cargo load differs from 715 kgf/m^3 (45 lbf/ft^3), h1 is to be adjusted accordingly.

FIGURE 5
Transverse Side Frame

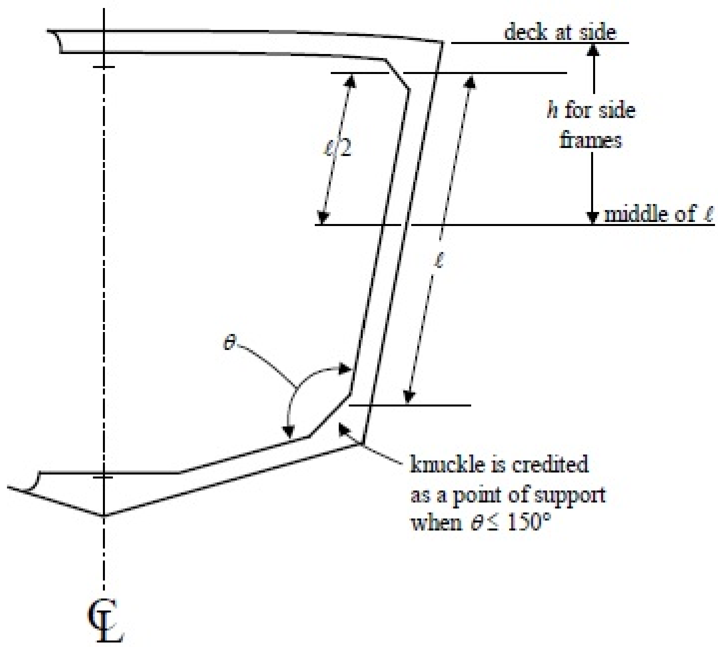


FIGURE 6
Transverse Side Frame

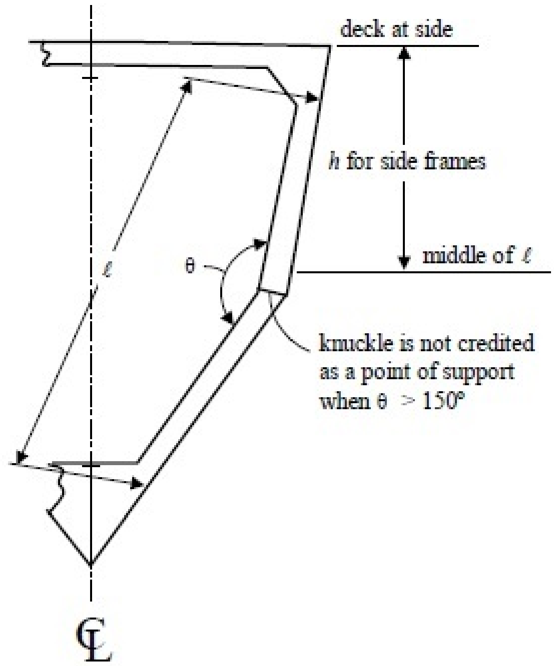
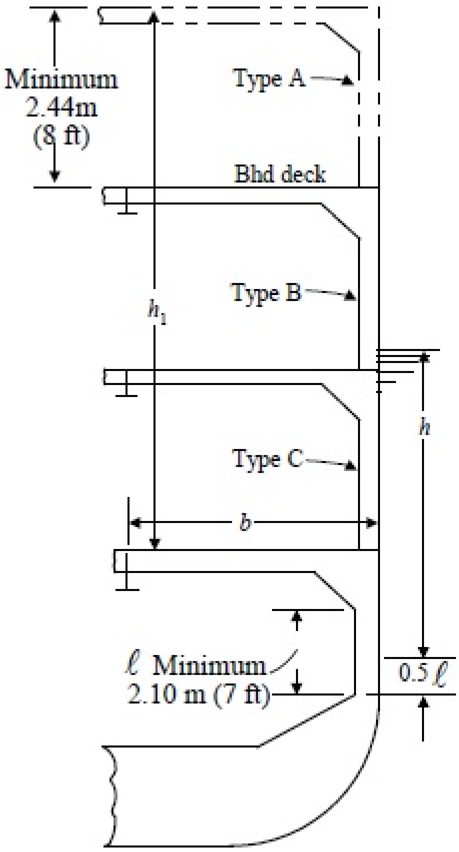


FIGURE 7
Tween Deck Frames *(2022)*



3.3 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.

3.5 Fore-end Frames

Each fore-end frame between $0.5L$ and $0.75L$ measured from the AP is to have a section modulus obtained from 3-2-5/3.1, 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 3.6 m (12 ft)

3.7 Panting Frames

Each panting frame between a point located at $0.875L$ forward of the AP and the forepeak bulkhead in vessels which have panting arrangements as per 3-2-5/3.13 is to have a section modulus as obtained from 3-2-5/3.1, where ℓ is to be the corresponding midship span plus the sheer in m (ft) at $0.125L$ from the stem. In vessels having normal sheer the other factors in 3-2-5/3.1 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 3-2-5/3.1 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.

3.9 Side Stringers

Where stringers are fitted in accordance with this paragraph, the SM of the frames in 3-2-5/3.1, 3-2-5/3.3, and 3-2-5/3.5 above may be reduced 20% where ℓ exceeds 2.75 m (9 ft) and the stringers are arranged so, that there is not more than 2.1 m (7 ft) of unbroken span at any part of the girth of the side framing. Stringers are to be at least as deep as the frames and are to have continuous face plates (see also 3-2-6/1).

3.11 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 Section 3-2-6, the section modulus of the frames is to be determined in accordance with 3-2-5/3.1, 3-2-5/3.5, and 3-2-5/3.7, but the length ℓ may be taken as the distance from the toe of the bracket to the lowest stringer plus 0.15 m (0.5 ft) but not less than 2.1 m (7 ft).

3.13 Panting Webs and Stringers

Abaft the forepeak and forward of the after peak, panting arrangements are to be provided so as to meet the effects of sheer and flatness of the hull 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 3-2-5/3.9, are to be fitted in this area in line with the stringers in the forepeak. At the after end, where due to the shape of the vessel the frames have longer unsupported span than the normal midship frames, stringers or frames of increased size may be required.

3.15 Side Frame Brackets

Brackets connecting side frames to the inner bottom margin plates are to be flanged (or edge stiffened) and of not less thickness than the frame web thickness plus 2 mm (0.08 in.) The thickness is also not to be less than required by 3-2-9/Table 1A or 1B. Where the double bottom is longitudinally framed, flanged brackets are to be fitted inside the double bottom in line with the side frame brackets and extending to the outboard inner bottom and shell longitudinals.

3.17 Longitudinal Frames

The section modulus SM of each longitudinal side frame aft of $0.25L$ from the FP and below the bulkhead deck is to be not less than obtained from the following equation:

$$SM = 7.8chs\ell^2 \quad \text{cm}^3$$

$$SM = 0.0041chs\ell^2 \quad \text{in}^3$$

where

s	=	spacing of longitudinal frames, in m (ft)	
c	=	c_1	for vessels under 90 m (295 ft) in length
	=	c_2	for other steel vessels
c_1	=	0.915	
c_2	=	0.95	
h	=	h_1	for vessels under 90 m (295 ft) in length
	=	h_2	for other steel vessels
h_1	=	vertical distance, in m (ft), from the frame to the freeboard deck at side, but not less than $0.02L + 0.46$ m ($0.02L + 1.5$ ft)	
h_2	=	above $0.5D$ from the keel, the vertical distance, in m (ft), from the longitudinal frame to the bulkhead or freeboard deck, but is not to be taken as less than 2.1 m (7.0 ft).	

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

ℓ = the unsupported span, in m (ft)

Longitudinal frames of superstructure are to comply with requirements 3-2-11/3.5

3.19 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.

5 Tween-Deck Frames Below and Above the Bulkhead Deck

5.1 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 partial bulkheads in line with the main 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, if applicable.

5.3 Transverse Tween-deck Frames

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

$$SM = (7 + 45/\ell^3)s\ell^2K \quad \text{cm}^3$$

$$SM = (0.0037 + 0.8/\ell^3)s\ell^2K \quad \text{in}^3$$

where

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

s = spacing of the frames, in m (ft)

K = factor appropriate to the length of vessel and type of tween decks, A, B, C, or D, as shown in 3-2-5/3.1 . Generally, all tween-deck frames above the bulkhead deck are Type A, except for those forward of $0.125L$ from the stem, which are to be 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 not to be less than required by 3-2-5/7.

Type A	$K = 0.022L - 0.47$	for $L \leq 427$ m
	$K = 0.022L - 1.54$	for $L \leq 1400$ ft
Type B	$K = 0.034L - 0.56$	for $L \leq 427$ m
	$K = 0.034L - 1.84$	for $L \leq 1400$ ft
Type C	$K = 0.036L - 0.09$	for $L \leq 180$ m
	$K = 0.031L + 0.83$	for $180 < L \leq 427$ m
	$K = 0.036L - 0.29$	for $L \leq 590$ ft

	$K = 0.031L + 2.8$	for $590 < L \leq 1400$ ft
Type D	$K = 0.029L + 1.78$	for $L \leq 427$ m
	$K = 0.029L + 5.84$	for $L \leq 1400$ ft

L = length of vessel, as defined in 3-1-1/3.1

When the decks above the tween-deck frames considered are carrying loads in excess of the following:

- For enclosed decks: 7.01 kN/m^3 (715 kgf/m^3, 44.7 lbf/ft^3),
- For an exposed deck: 25.66 kN/m^2 (2617 kgf/m^2, 536 lbf/ft^2)

the section modulus of the tween-deck frames is also to meet the requirements of 3-2-5/3.1.

5.5 Longitudinal Tween-deck Frame

Longitudinal tween-deck frames are to be in accordance with 3-2-5/3.17. The section modulus of each longitudinal tween-deck frame forward of $0.125L$ measured from either the stem or FP line depending on bow design, is to be not less than required by 3-2-5/5.3 for transverse frames in the same location, taking l as the unsupported span along the frame's 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 3-2-1/17 and Appendix 3-2-A4.

7 Forepeak Frames

7.1 General

Forepeak frames are to be connected to deep floors of not less thickness than that obtained from 3-2-4/5.1. for floors with transverse framing, but the thickness need not exceed 14.0 mm (0.56 in.), provided the stiffeners are not spaced more than 1.2 m (4 ft). The floors are to extend as high as necessary to give lateral stiffness to the structure and are to be stiffened on their upper edges. Care is to be taken in arranging the framing and floors such, as to avoid wide areas of unsupported plating adjacent to the stem. Angle ties are to be fitted 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, extending throughout the entire range of forward drafts, as well as above and below the maximum and minimum forward draft waterlines. In general, the frames above the lowest deck are to be as required by 3-2-5/7.3, but in vessels with large flare or varying sheers on different decks accompanied with lengthened frames; stringers and webs or more robust frames may be required in this region.

7.3 Frame Scantlings

The section modulus SM of frames is to be obtained from the following, as applicable, for three different systems of construction.

7.3.1 Beams or Struts on Every Frame without Stringer Plates

Where beams or struts are fitted on every frame in tiers of not more than 1.5 m (5 ft) 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 (ft), of the longest actual span of the peak frame from the toe of the lowest deck beam knee to the top of the floor.

$$SM = (C_1 L - C_2)(C_3 + C_4/\ell^3)\ell^2 \quad \text{cm}^3\left(\text{in}^3\right)$$

where

C_1 = 0.025 (0.085)

C_2 = 0.44 (5)

C_3 = 7 (0.0037)

C_4 = 45 (0.8)

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

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

7.3.2 Beams on Alternate Frames

In vessels where beams are fitted on alternate frames, in conjunction with flanged stringer plates of the sizes given in 3-2-6/9, are fitted in tiers at intervals of not more than 2.10 m (7 ft) apart, and the distance from the lowest tier to the top of the floor is not more than 1.83 m (6 ft), the section modulus SM of the peak frames are to be obtained from the following equation.

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

$SM = 0.021sL - 0.55$ in^3 for $L \leq 1400$ ft

where

s = frame spacing, in m (ft)

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

7.3.3 No Beams or Struts Fitted

Where no beams or struts are fitted, the section modulus of frames is not to be less than that obtained from the equation in 3-2-5/7.3.2 nor is the section modulus to be less than twice that obtained from the equation in 3-2-5/7.3.1 in association with a length ℓ as defined in 3-2-5/7.3.1.

7.3.4 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.

9 After-peak Frames

9.1 General

After-peak frames are to be efficiently connected to deep floors of not less thickness than obtained from 3-2-4/5.1 for floors with transverse framing, but need not exceed 14.0 mm (0.56 in.), 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.

9.3 Frame Scantlings

The section modulus $SM$of 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 (8 ft) between supports at any part of the girth of the frame.

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

$SM = 0.016sL - 2.2$ in^3 for $L \leq 1400$ ft

where

s	=	frame spacing, in m (ft)
L	=	length of vessel, as defined in 3-1-1/3.1, in m (ft)

9.5 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 3-2-5/9.1 and 3-2-5/9.3.

11 Vessels Subject to Impact Loads

For vessels subject to impact loads during routine operations, side frames in the impact region are to have a section modulus 25% greater than that obtained above be provided. All side structural members in the impact region are to have end connections with brackets and adequate double continuous fillet welds at the ends. Scallop welds are not to be used in connections between side frames and shell plating.

PART 3

CHAPTER 2
Hull Structures and Arrangements

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 3-2-6/3.3.2 FIGURE 1, where fitted in association with transverse or longitudinal frames of the sizes specified in 3-2-5/3.11 or 3-2-5/3.17, 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 (10 ft) apart. For webs in machinery spaces, see also 3-2-5/3.19.

Web frames and side stringers are to have not 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.

3 Web Frames

The requirements in the following Paragraphs are to be complied with, as applicable.

3.1 Hold Web Frames Amidships and Aft

3.1.1 Scope of Application

The requirement in 3-2-6/3.1.2 is intended to apply to:

i) Each web frame amidships to 0.875L forward of the aft perpendicular and aft for offshore support vessels;

ii) Each web frame amidships and aft for other steel vessels:

3.1.2 Section Modulus

Each web frame within the scope of 3-2-6/3.1.1 is to have a section modulus SM not less than obtained from the following equation:

$$SM = 4.74cs\ell^2(h + bh_1/45K) \quad \text{cm}^3$$

$$SM = 0.0025cs\ell^2(h + bh_1/150K) \quad \text{in}^3$$

where

c = 1.5

s = spacing of the web frames, in m (ft.)

ℓ = span, in m (ft), 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 3-2-6/7.1

h = vertical distance, in m (ft), from the middle of ℓ to the scantling draft line. The value of h is not to be less than 0.5ℓ

h_1 = $h_{FB} + h_{C1} + h_{C2} + h_{C3} + ...h_{Cn} + h_E + 0.5(h_{P1} + h_{P2} + ...h_{Pm})$

h_1 = vertical distance, in m (ft), 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 (8 ft), if that be greater. Where the cargo load differs from 7.04 kN/m^3 (715 kgf/m^3, 45 lbf/ft^3) multiplied by the tween-deck height in m (ft), the height of that tween-deck is to be proportionately adjusted in calculating h_1

h_{FB} = vertical distance, in m (ft), from the deck at the top of the web frame to the bulkhead or freeboard deck

$h_{Ci}...h_{Cn}$ = heights of cargo spaces above the bulkhead/freeboard deck. Where the cargo load differs from 7.01 kN/m^3 (715 kgf/m^3, 44.7 lbf/ft^3) multiplied by the tween-deck height in m (ft), the height of that tween-deck is to be proportionately adjusted in calculating h_1.

h_E = 3.66 m (12 ft) for an exposed deck intended to carry deck cargoes when uniform loading p does not exceed 25.66 kN/m^2 (2617 kgf/m^2, 536 lbf/ft^2), where p is the uniform cargo load, in KN/m^2 (kgf/m^2, lbf/ft^2)

= p /7.01 m (p/715 m, p/44.7 ft) for an exposed deck intended to carry deck cargoes when load p exceeds 25.66 kN/m^2 (2617 kgf/m^2, 536 lbf/ft^2)

= 0.0 m, if the exposed deck has no cargo loads

p = uniform cargo load, in kN/m^2(kgf/m^2,lbf/ft^2)

$h_{Pi}...h_{Pm}$ = heights of passenger spaces

In case where there is no exposed deck intended to carry deck cargo above the web frames, the sum $h_{C1} + h_{C2} + h_{C3} + ...h_{Cn} + 0.5(h_{P1} + h_{P2} + ...h_{Pm})$ shall not be taken less than 2.44 m (8 ft).

b = horizontal distance, in m (ft), 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

3.3 Hold Web Frames Forward

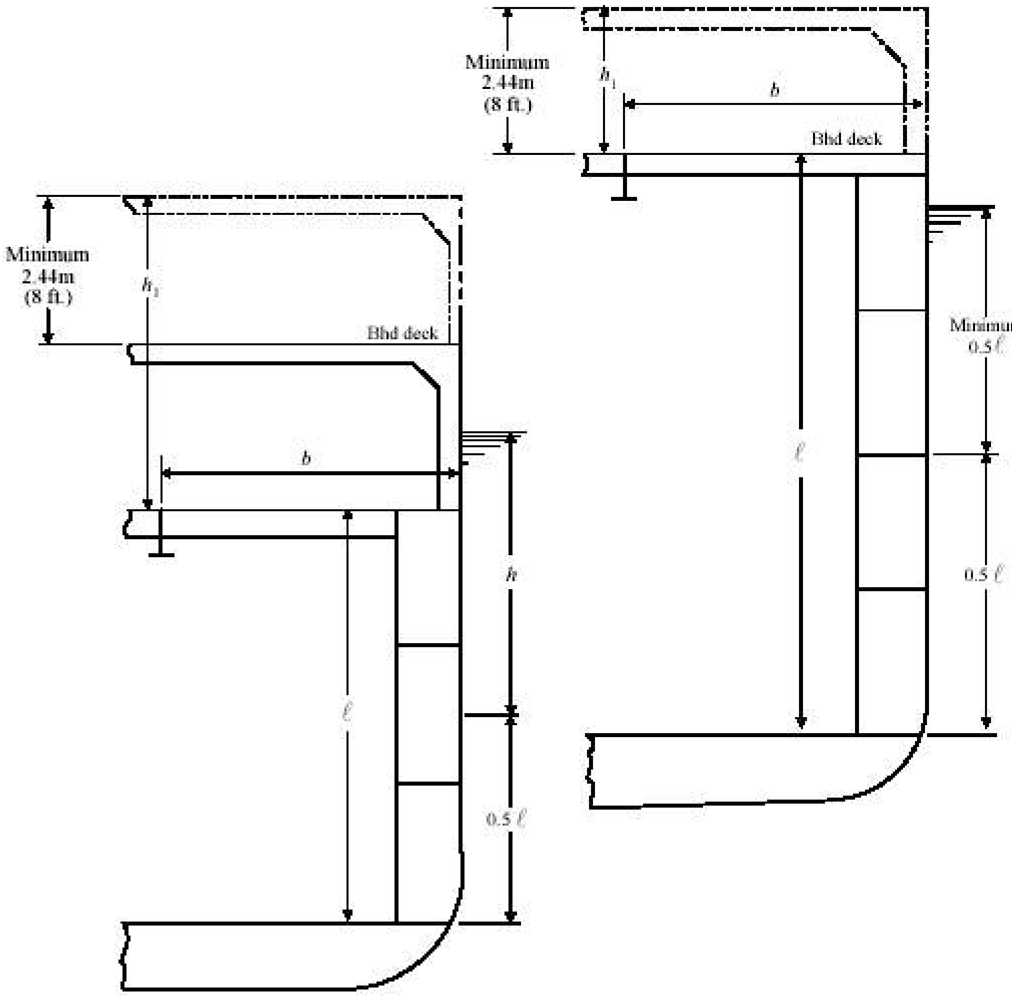
3.3.1 Offshore Support Vessels

The value of SM for the webs forward of $0.875L$ from the AP is to be increased 25%.

3.3.2 Other Steel Vessels

Hold web frames forward of the midship one-half length are to be obtained as described in 3-2-6/3.1, 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 3-2-6/3.1 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 1
Hold Web-frame Arrangements



3.5 Proportions

3.5.1 Offshore Support Vessels

Webs are to have a depth of not less than 0.125ℓ (1.5 in. per ft of span 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 for vessels 90 meters (295 feet) in length and greater or 2.5 times the depth of the slots for vessels less than 90 meters (295 feet) in length, or the slots are to be fitted with filler plates. The thickness is not to be less than 1 mm per 100 mm (0.01 in. per in.) of depth plus 3.5 mm (0.14 in.), but this need not exceed 14 mm (0.56 in.). 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 (0.06 in.) above the foregoing requirements.

3.5.2 Other Steel Vessels

Webs are to have a depth of not less than 0.125ℓ (1.5 in. per ft of span ℓ); the thickness is not to be less than 1 mm per 100 mm (0.01 in. per in.) of depth plus 3.5 mm (0.14 in.), but need not exceed 14 mm (0.56 in.). 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 (0.06 in.) above the normal requirements.

3.7 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.

3.9 Tripping Brackets

Tripping brackets are to be fitted at intervals of about 3 m (10 ft) and near the change of section. Where the breadth of the flanges on either side of the web exceeds 200 mm (8 in.), tripping brackets are to be arranged to support the flange.

3.11 Tween-deck Webs

Tween-deck webs are to be fitted below the bulkhead deck over the web frames below, to provide continuity of transverse strength above the main webs below and in machinery space.

5 Side Stringers

5.1 Hold Stringers

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

$$SM = 4.74chs\ell^2 \quad \text{cm}^3$$

$$SM = 0.0025chs\ell^2 \quad \text{in}^3$$

where

c = 1.50

= 1.85 in the forepeak for vessels 61 m (200 ft) or greater in length.

h = vertical distance, in m (ft), from the middle of s to the scantling draft line, or 1.8 m (6 ft), whichever is greater. For stringers above the lowest deck or at a similar height in relation to the design draft, h is not taken less than K as given in 3-2-5/5.3

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

ℓ = span, in m (ft), between web frames, or between web frame and bulkhead; where brackets are fitted, the length ℓ may be modified as per 3-2-6/7.1 below

5.3 Proportions

The following requirements are to be complied with:

i) Stringers are to have a depth of not less than 0.125ℓ (1.5 in. per ft of span 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.

ii) 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 and the thickness is not to be less than that determined by the equation in 3-2-6/9.1.

iii) 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 (0.06 in.) above the normal requirements.

Note: * For vessels under 90 meters (295 feet) in length, 3 times is reduced to 2.5 times.

5.5 Stiffeners

Stiffeners attached to the frame and extending 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.

5.7 Tripping Brackets

The arrangement of tripping brackets is to be in accordance with 3-2-6/3.9.

7 Structural Arrangements and Details

7.1 Brackets of Girders, Webs, and Stringers

7.1.1 Offshore Support Vessels

Where end brackets are provided, they are to have scantlings not less than shown in 3-2-9/5.5 TABLE 1A for vessels 90 meters (295 feet) or greater in length or 3-2-9/5.5 TABLE 1B for vessels less than 90 meters (295 feet) in length. The value for ℓ as defined in this Section and Sections 3-2-8, 3-2-9, and 3-2-10 may be modified in accordance with the following.

i) Where the girder, web frame or stringer is part of a continuous in -plane structure by attachment to another primary web member, the face plate on the bracket is to have the same scantlings as the face bar on the girder, web frame or stringer and the span ℓ may be measured onto the bracket by the amount of 25% of the bracket arm length

ii) Where the end bracket is welded to a girder, web or stringer, the span ℓ may be measured onto the bracket by the amount of 50% of the bracket arm length. For vessels 90 meters (295 feet) or greater in length, the face plate on the bracket is to have the same scantlings as that on the girder, web or stringer.

In such cases the fillet weld throat area at the connection of the web and bracket to the bulkhead or deck is to be not less than the area of the web and face bar of the girder, web or stringer.

7.1.2 Other Steel Vessels

Where brackets are fitted having thickness not less than the girder or web plates, the value for l, as defined in this Section, Section 3-2-8, Section 3-2-9, and Section 3-2-10, 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 (6 in.) 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.

7.2 Overlap of Brackets

7.2.1 Vessels 90 m (295 ft) or Greater in Length

For vessels 90 meters (295 feet) or greater in length, the minimum overlap of the bracket arm along the stiffener is not to be less than that shown in 3-2-9/5.5 FIGURE 3A.

Where a bracket laps a member, the width of overlap generally is to be twice the thinner plate thickness plus 25 mm (1 in.).

7.2.2 Vessels Less than 90 m (295 ft) in Length

For vessels less than 90 meters (295 feet), the minimum overlap of the bracket arm along the stiffener is not to be less than obtained from the following equation:

$$x = 1.4y + 30 \quad \text{mm}$$

$$x = 1.4y + 1.2 \quad \text{in.}$$

where

x = length of overlap along stiffener, in mm (in.)

y = depth of stiffener, in mm (in.)

Where a bracket laps a member, the width of overlap generally is to be twice the thinner plate thickness plus 25 mm (1 in.).

7.3 End Connections

The following end connection requirements are to be complied with, as applicable:

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

ii) The throat area of the welded end connections is to develop the strength of the member being attached.

iii) 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.

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

v) 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.

vi) Welding is to be in accordance with 3-2-19/3 TABLE 1.

vii) Where longitudinal frames are not continuous at bulkheads, end connections are to effectively develop their sectional area and resistance to bending.

viii) Where a structural member is terminated, structural continuity is to be maintained by suitable back-up structure, fitted in way of the end connection of frames, or the end connection is to be effectively extended by a bracket or flat bar to an adjacent beam, stiffener, etc.

9 Peak Stringers

9.1 Peak Stringer-plate Thickness *(2022)*

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

$t = C_1 L + C_2$ mm (in) for $L \leq 200$ (655) m (ft)

$t = C_3 L + C_4$ mm (in) for $200 < L \leq 427$ (1400) m (ft)

where

C_1 = 0.014 (0.00017)

C_2 = 7.2 (0.28)

C_3 = 0.007 (0.00008)

C_4 = 8.6 (0.34)

t = plate thickness, in mm (in.).

L = length of vessel, as defined in 3-1-1/3.1, in m (ft.)

9.3 Peak Stringer-plate Breadth

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

$b = C_1 L + C_2$ mm (in) for $L \leq 100$ (330) m (ft)

$b = C_3 L + C_4$ mm (in) for 100 (330) $< L \leq 427$ (1400) m (ft)

where

C_1 = 8.15 (0.098)

C_2 = 6 (0.25)

C_3 = 2.22 (0.027)

C_4 = 600 (23.5)

b = breadth of peak stringer-plate, in mm (in.)

L = length of vessel, as defined in 3-1-1/3.1, in m (ft.)

Where beams or struts are not fitted on every frame, the edge of the stringer is to be adequately stiffened by an 85 mm (31/2 in.) flange or face bar.

For vessels between 61 meters (200 feet) and 90 meters (295 feet) in length, alternative designs meeting the requirements of side stringers in 3-2-6/5 may be accepted.

11 Vessels Subject to Impact Loads

For vessels subject to impact loads during routine operations, web frames and side stringers in the impact region are to have a section modulus 25% greater than that of regular requirement. All side structural members in the impact region are to have adequate double continuous fillet weld and end connections with brackets. Scallop welds are not to be used in connections between side frames and shell plating.

PART 3

CHAPTER 2
Hull Structures and Arrangements

SECTION 7
Beams and Longitudinals

1 General

1.1 Arrangement

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

Alternatively deck longitudinals may be fitted, supported by deck transverses. Longitudinals and deck transverse are to have adequate structural stability.

1.3 Design Head

Decks are to be designed at least to the scantling heads specified in this Section, a notation indicating the restricted deck loading will be entered in the *Record*.

3 Beams and Longitudinals

3.1 Strength Requirement

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

$$SM = 7.8chs\ell^2 \quad \text{cm}^3$$

$$SM = 0.0041chs\ell^2 \quad \text{in}^3$$

where

c	=	c_1	for vessels under 90 m (295 ft) in length
	=	c_2	for other steel vessels
c_1	=	1.00	for transverse or longitudinal beams at the tops of tank, with deep tank h
	=	$1/(1.709 - 0.651k)$	for longitudinal beams of strength decks and effective lower decks
	=	0.60	for all other transverse beams
	=	0.70	for all other longitudinal beams

c_2	=	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 3-2-1/3.7.1 or 3-2-1/5.5, whichever is applicable, in cm^2- m ($in.^2$-ft.)

Y = distance, in m (ft), 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 ($in.^2$-$ft.^2$)
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 (ft.)

ℓ = distance, in m (ft), from the inner edge of the beam knee to the nearest line of girder support or between girder supports, whichever is greater. Under the top of deep tanks and in way of bulkhead recesses, the supports are to be arranged to limit the span to not exceeding 4.8 m (16 ft)

p = uniform loading, in kN/m^2 (kgf/m^2, lbf/ft^2)

h = height, in m (ft), as follows:

= 3.66 m (12 ft) for an exposed deck intended to carry deck cargoes when uniform loading p does not exceed 25.66 kN/m^2 (2617 kgf/m^2, 536 lbf/ft^2)

= p /7.01 m (p/715 m, p/44.7 ft) for an exposed deck intended to carry deck cargoes when uniform loading p exceeds 25.66 kN/m^2 (2617 kgf/m^2, 536 lbf/ft^2)

= h_{cs} , in m (ft), the cargo space height at side for lower decks and/or double bottoms intended to carry cargoes when uniform loading p does not exceed 25.66 kN/m^2 (2617 kgf/m^2, 536 lbf/ft^2) and/or load density does not exceed 7.01 kN/m^3 (715 kgf/m3, 44.7 lbf/ft^3)

= h_{cs} , in m (ft) or p/7.01 m (p/715 m, p/44.7 ft), whichever is greater, for lower decks and/or double bottoms intended to carry cargoes when uniform loading p exceeds 25.66 kN/m^2 (2617 kgf/m^2, 536 lbf/ft^2) and/or load density exceeds 7.01 kN/m^3 (715 kgf/m^3, 44.7 lbf/ft^3)

= for bulkhead recesses and tunnel flats it is the height, in m (ft), to the bulkhead deck at the centerline; where that height is less than 6.1 m (20 ft), the value of h is to be taken as 0.8 times the actual height plus 1.22 m (4 ft).

= for deep-tank tops it is not to be less than the greatest of the following distances but, the calculated section modulus is not to be less than would be required for cargo beams in the same location, if tank top supports the cargo space above:

- two-thirds of the distance from the top of the tank to the top of the overflow
- head given in column (e) of 3-2-7/3.1 TABLE 2, as appropriate to the length of the vessel,
- the height to the scantling draft line
- two-thirds of the distance from the top of the tank to the bulkhead or freeboard deck

Elsewhere, the value of h may be taken from the appropriate column of 3-2-7/3.1 TABLE 1 and 3-2-7/3.1 TABLE 2, as follows.

TABLE 1
Decks Allocation

Weather decks and decks covered only by houses:		*Column*
Freeboard decks having no decks below		a
Freeboard decks having decks below		b
Forecastle decks (first tier above freeboard deck)	See Note 1	c
Forecastle decks (second tier and higher above freeboard deck)		d
Bridge decks (first tier above freeboard deck)		c
Bridge decks (second tier and higher above freeboard deck)		d
Short bridges, with length not exceeding 0.1L (first tier above freeboard deck)		d
Poop decks (first tier above freeboard deck)		d
Poop decks (second tier and higher above freeboard deck)		e
Long superstructures forward of midship half-length (first tier above freeboard deck)		b
Long superstructures abaft midship half-length forward and forward of midship $^3/_5$ length aft (first tier above freeboard deck)		c
Long superstructures abaft midship 3/5 length (first tier above freeboard deck)		d
Superstructure decks extending forward of amidships' 0.5L (second tier above freeboard deck)		c
Superstructure decks amidships (second tier above freeboard deck)		d
Superstructure decks containing only accommodation spaces (third tier and higher above freeboard deck)		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 2	e (f)
Third and higher tiers above freeboard deck	See Note 2	f (g)

Notes:

1 See also 3-2-11/9.

2 Where decks to which the side shell does not extend and are generally used only as the shelter against weather, the value of h may be reduced as given in brackets.

3 Buckling strength of the plating and framing of all decks is to be considered where they are part of the hull girder for vessels over 61 m (200 ft) in length.

TABLE 2
Values of h for Beams

L in Meters	*a*	*b*	*c*	*d*	*e*	*f*	*g*
30	1.36	1.06	0.91	0.60	0.45	0.30	–
40	1.56	1.26	1.01	0.70	0.55	0.40	–
50	1.76	1.46	1.11	0.80	0.65	0.50	–
60	1.96	1.66	1.21	0.90	0.75	0.60	0.46
70	2.16	1.86	1.31	1.00	0.85	0.70	0.46
80	2.36	2.06	1.41	1.10	0.95	0.80	0.46
90	2.56	2.26	1.51	1.20	1.05	0.90	0.46
100	2.76	2.29	1.69	1.30	1.15	0.91	0.46
110	2.90	2.29	1.90	1.44	1.15	0.91	0.46
120	2.90	2.29	1.98	1.64	1.27	0.91	0.46
122 and above	2.90	2.29	1.98	1.68	1.30	0.91	0.46

L in Feet	*a*	*b*	*c*	*d*	*e*	*f*	*g*
100	4.50	3.50	3.00	2.00	1.50	1.00	–
125	5.00	4.00	3.25	2.25	1.75	1.25	–
150	5.50	4.50	3.50	2.50	2.00	1.50	–
175	6.00	5.00	3.75	2.75	2.25	1.75	–
200	6.50	5.50	4.00	3.00	2.50	2.00	1.50
225	7.00	6.00	4.25	3.25	2.75	2.25	1.50
250	7.50	6.50	4.50	3.50	3.00	2.50	1.50
275	8.00	7.00	4.75	3.75	3.25	2.75	1.50
300	8.50	7.50	5.00	4.00	3.50	3.00	1.50
325	9.00	7.50	5.50	4.25	3.75	3.00	1.50
350	9.50	7.50	6.00	4.50	3.75	3.00	1.50
375	9.50	7.50	6.50	5.00	4.00	3.00	1.50
400 and above	9.50	7.50	6.50	5.50	4.25	3.00	1.50

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

3.3 Deep Reinforced Beams

Deep reinforced beams are to be arranged in way of concentrated loads such as the ends of deckhouses, in way of masts, windlasses, A-frames, rollers, hooks, bollards, winches, auxiliary machinery, etc.

3.5 Beams at the Head of Web Frames

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

3.7 End Connections

At the ends of unbracketed beams or longitudinals, located inside the line of openings or near the periphery of platform decks; 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 3-2-19/3 TABLE 1 and the fillet weld throat area of the connection of the beam or longitudinal to the bracket and of the bracket to the supporting structure is to develop the strength of the beam or longitudinal.

Deck longitudinals outside the line of openings are to be continuous or bracketed at the nearest transverse bulkheads such as to effectively develop their sectional area and resistance to bending. However; non continuous longitudinals cannot be included into hull girder section modulus calculation [see also 3-2-1/3.7.1(c)].

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

4 Deck Fittings Support Structures for Vessels of More Than 500 GT *(1 July 2018)*

4.1 General *(1 July 2018)*

The strength of supporting hull structures in way of shipboard fittings used for mooring and/or towing operations as well as supporting hull structures of winches and capstans at the bow, sides and stern, are to comply with the requirements of this Section, where towing operations are defined as follows:

4.1.1 Normal Towing *(1 July 2018)*

Normal towing is the towing operations necessary for maneuvering in ports and sheltered waters associated with the normal operations of the vessel.

4.1.2 Other Towing *(1 July 2018)*

For vessels not subject to SOLAS Regulation II-1/3-4 Paragraph 1 but fitted with equipment for towing by another vessel or a tug (e.g., such as to assist the vessel in case of emergency as given in SOLAS Regulation II-1/3-4 Paragraph 2), the requirements designated as 'other towing' are to be applied to design and construction of those shipboard fittings and supporting hull structures.

The requirements of this section do not apply to design and construction of shipboard fittings and supporting hull structures used for special towing services, as follows:

- *Escort Towing.* Towing service, in particular, for laden oil tankers or LNG carriers, required in specific estuaries. Its main purpose is to control the vessel in case of failures of the propulsion or steering system. Reference should be made to local escort requirements and guidance given by, for example, the Oil Companies International Marine Forum (OCIMF).
- *Canal Transit Towing.* Towing service for vessels transiting canals (e.g., the Panama Canal). Reference should be made to local canal transit requirements.
- *Emergency Towing for Tankers.* Towing service to assist tankers in case of emergency. For the emergency towing arrangements, vessels subject to SOLAS regulation II-1/3-4 Paragraph 1 are to comply with that regulation and resolution MSC.35(63) as amended.

Shipboard fittings, such as cleats, chocks, bitts, bollards, towing pad eyes, etc., for mooring and/or towing, winches and capstans are to be located on stiffeners and/or girders, which are part of the deck construction such, as to facilitate efficient distribution of the mooring and/or towing loads. The same attention is to be paid to the structural arrangements and strength of supporting structures of the recessed bitts, if fitted.

Other arrangements may be accepted (for chocks in bulwarks, etc.) provided the strength is confirmed adequate for the intended service.

The requirements in this subsection are to be applied in conjunction with the requirements for mooring and towing equipment contained in Section 3-5-1.

4.3 Design Loads *(2022)*

Unless greater safe working load (SWL) and/or safe towing load (TOW) of shipboard fittings is specified by the applicant (see 3-2-7/4.3.3), the minimum design load to be used is the greater values obtained from 3-2-7/4.3.1 or 3-2-7/4.3.2, whichever is applicable: For shipboard fittings intended to be used for both mooring and towing services, 3-2-7/4.3.1 and 3-2-7/4.3.2 apply to mooring and towing services, respectively.

4.3.1 Mooring Operations *(1 July 2018)*

The minimum design load for shipboard fittings for mooring operations is the applicable value obtained from 3-2-7/4.3.1(a) or 3-2-7/4.3.1(b):

4.3.1(a) Mooring Line Force.

The minimum design load applied to supporting hull structures for shipboard fittings is to be 1.15 times the ship design minimum breaking load of the mooring lines according to 3-5-1/9.3 for each equipment number (EN). EN is the corresponding value used for determination of the vessel's equipment. (See Notes 1 and 2 in 3-2-7/4.3.1(b))

4.3.1(b) Mooring Winch and Capstan Force.

The minimum design load applied to supporting hull structures for winches is to be 1.25 times the intended maximum brake holding load, where the maximum brake holding load is to be assumed not less than 80% of the ship design minimum breaking load of the mooring lines according to 3-5-1/9.3. See Notes 1 and 2. For supporting hull structures of capstans, 1.25 times the maximum hauling-in force is to be taken as the design load.

Notes:

1 If not otherwise specified by Section 3-5-1, side projected area including that of deck cargoes as given by the ship nominal capacity condition is to be taken into account for selection of mooring lines and the loads applied to shipboard fittings and supporting hull structures. The nominal capacity condition is defined as the theoretical condition where the maximum possible deck cargoes are included in the ship arrangement in their respective positions. For container ships, the nominal capacity condition represents the theoretical condition where the maximum possible number of containers is included in the ship arrangement in their respective positions.

2 The increase of the line design break force for synthetic ropes according to 3-5-1/9.7 needs not to be taken into account for the loads applied to shipboard fittings and supporting hull structures.

4.3.2 Towing Operations *(1 July 2018)*

The minimum design load for shipboard fittings for towing operations is the applicable value obtained from 3-2-7/4.3.2(a) through 3-2-7/4.3.2(c), as applicable:

4.3.2(a) Normal towing operations.

1.25 times the intended maximum towing load (e.g., static bollard pull) as indicated on the towing and mooring arrangements plan.

4.3.2(b) Other towing service. *(2022)*

The ship design minimum breaking load of the tow lines according to 3-5-1/19.7 TABLE 3 for each equipment number (EN). EN is the corresponding value used for determination of the vessel's equipment. (See Notes 1 and 2)

Notes:

1 Side projected area including that of deck cargoes as given by the ship nominal capacity condition is to be taken into account for selection of towing lines and the loads applied to shipboard fittings and supporting hull structures. The nominal capacity condition is defined in 3-2-7/4.3.1(b), Note 1

2 The increase of the line design break force for synthetic ropes according to 3-5-1/9.7 needs not to be taken into account for the loads applied to shipboard fittings and supporting hull structures.

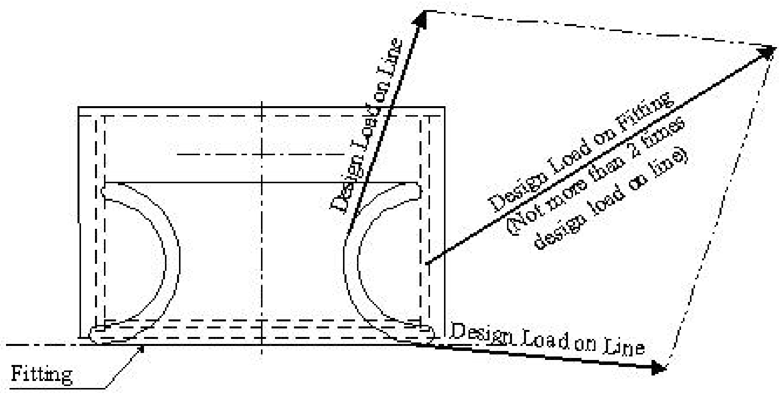
4.3.2(c) All towing operations. *(1 July 2018)*

For fittings intended to be used for, both, normal and other towing operations, the greater of the design loads according to 3-2-7/4.3.2(a) and 3-2-7/4.3.2(b).

4.3.3 Application of Design Loads *(1 July 2018)*

The design load is to be applied to fittings in all directions that may occur by taking into account the arrangement shown on the towing and mooring arrangements plan. Where the towing line takes a turn at a fitting, the total design load applied to the fitting is equal to the resultant of the design loads acting on the line, see 3-2-7/4.3.3 FIGURE 1 below. However, in no case does the design load applied to the fitting need to be greater than twice the design load on the line.

FIGURE 1
Application of Design Loads



When a specific SWL is applied for a shipboard 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 for an increased load in accordance with the appropriate SWL.design load relationship given by 3-2-7/4.3 and 3-5-1/15.3.1.

When a safe towing load, TOW, greater than that determined according to 3-5-1/15.3.2 is requested by the applicant, the design load is to be increased in accordance with the appropriate TOW/design load relationship given by 3-2-7/4.3 and 3-5-1/15.3.2.

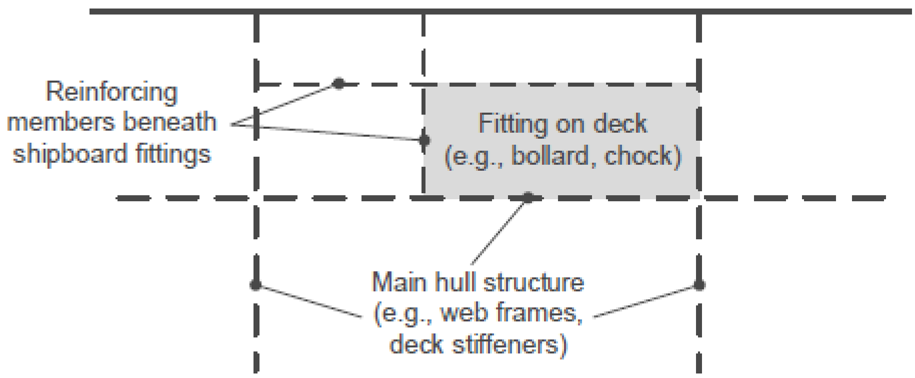
4.5 Supporting Structures

4.5.1 Arrangement and Applied Design Load *(2022)*

The design load applied to supporting hull structures for mooring operations and towing operations is to be in accordance with 3-2-7/4.3.1 and 3-2-7/4.3.2, respectively.

The arrangement of reinforced members beneath shipboard fittings, winches, and capstans is to consider any variation of direction (horizontally and vertically) of the mooring forces acting upon the shipboard fittings, see 3-2-7/4.5.1 FIGURE 2 for a sample arrangement. Proper alignment of fitting and supporting hull structure is to be verified.

FIGURE 2
Sample Arrangement *(1 July 2018)*



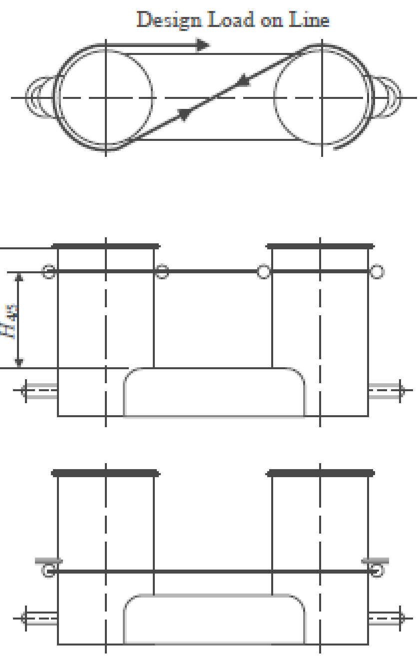
4.5.2 Line Forces *(1 July 2018)*

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

4.5.2(a) Mooring operations. (1 July 2018)

The acting point of the mooring force on shipboard fittings is to be taken at the attachment point of a mooring line or at a change in its direction. For bollards and bitts the attachment point of the mooring line is to be taken 4/5 of the tube height above the base, see a) in 3-2-7/4.5.2(a) FIGURE 3 below. If fins are fitted to the bollard tubes to keep the mooring line as low as possible, the attachment point of the mooring line may be taken at the location of the fins, see b) in 3-2-7/4.5.2(a) FIGURE 3 below.

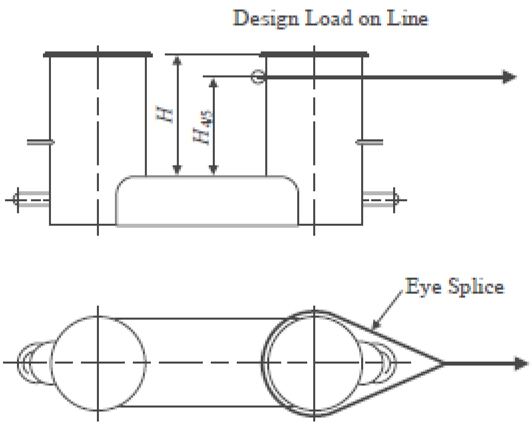
FIGURE 3
Attachment Point of Mooring Line *(1 July 2018)*



4.5.2(b) Towing operations. *(1 July 2018)*

The acting point of the towing force on shipboard fittings is to be taken at the attachment point of a towing line or at a change in its direction. For bollards and bitts the attachment point of the towing line is to be taken not less than 4/5 of the tube height above the base, see 3-2-7/4.5.2(b) FIGURE 4 below.

FIGURE 4
Attachment Point of Towing Line *(1 July 2018)*



4.5.3 Allowable stresses

Allowable stresses under the design load conditions as specified in 3-2-7/4.3 are as follows:

4.5.3(a) For strength assessment by means of beam theory or grillage analysis (2022)

- Normal stress: 100% of the specified minimum yield point of the material
- Shearing stress: 60% of the specified minimum yield point of the material

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

4.5.3(b) For strength assessment by means of finite element analysis: *(2022)*

- Von Mises stress: 100% of the specified minimum yield point of the material

For strength assessment by means of finite element analysis, the mesh is to be fine enough to represent the geometry as realistically as possible. The ratio of element length to width is not to exceed 3. Girders are to be modelled using shell or plane stress elements. Symmetric girder flanges may be modelled by beam or truss elements. The element height of girder webs is not to exceed one-third of the web height. In way of small openings in girder webs, the web thickness is to be reduced to a mean thickness over the web height. Large openings are to be modelled. Stiffeners may be modelled by using shell, plane stress, or beam elements. The mesh size of stiffeners is to be fine enough to obtain proper bending stress. If flat bars are modeled using shell or plane stress elements, dummy rod elements are to be modelled at the free edge of the flat bars and the stresses of the dummy elements are to be evaluated. Stresses are to be read from the center of the individual element. For shell elements the stresses are to be evaluated at the mid plane of the element.

4.7 Scantlings

4.7.1 Net Scantlings *(1 July 2018)*

The net minimum scantlings of the supporting hull structure are to comply with the requirements given in 3-2-7/4.5. 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 3-2-7/4.7.2 and, where applicable, the wear allowance, t_w, given in 3-2-7/4.7.3 to t_{net}.

4.7.2 Corrosion Addition *(1 July 2019)*

The total corrosion addition, t_c, is not to be less than the following values:

- For the supporting hull structure, 2.0 mm (0.08 in.).
- For pedestals and foundations on deck which are not part of a fitting according to an accepted industry standard, 2.0 mm (0.08 in.).
- For shipboard fittings not selected from an accepted industry standard, 2.0 mm (0.08 in.).

4.7.3 Wear Allowance *(1 July 2018)*

In addition to the corrosion addition given in 3-2-7/4.7.2 the wear allowance, t_w, for shipboard fittings not selected from an accepted industry standard is not to be less than 1.0 mm (0.04 in.), added to surfaces which are intended to regularly contact the line.

5 Container Loading

5.1 General

Where the vessel is to carry cargo or specialist equipment in containers intended for periodic or temporary installation on board, the exact locations of the container pads and the maximum total static load on the pads are to be indicated on the plans submitted for approval. Where the pads are not in line with the supporting structures, headers are to be provided to transmit the loads to these members. This requirement does not apply to containerized offshore supplies when carried on dedicated cargo decks.

5.3 Strength Requirements

Each member intended to support containers is to have a section modulus, SM, in cm^3 (in^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, (tf - cm, Ltf- in.).

f = permissible maximum bending stress, as given in 3-2-7/7.3 TABLE 3.

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 3-2-7/3.7. 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 3-2-7/3, 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 3-2-7/3.1 TABLE 2, is to be added to the above required section modulus.

7 Higher-strength Materials

7.1 General

In general, applications of higher-strength materials for deck longitudinals and 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.

Higher strength steel members are to be continuous in way of transverse members of ordinary strength steel or of lesser strength higher strength steel.

7.3 Longitudinals and Beams of Higher-strength Materials

Each longitudinal or 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.

$$SM_{hts} = 7.8chs\ell^2Q \quad \text{cm}^3$$

$$SM_{hts} = 0.0041chs\ell^2Q \quad \text{in}^3$$

where c, h, s and ℓ are as defined in 3-2-7/3 and Q is as defined in 3-2-1/5.3.

TABLE 3
Values of f (Ordinary-strength Steel)

	kN/cm²	*tf/cm²*	*Ltf/in²*
Effective longitudinal members	12.36	1.26	8
Transverse members and longitudinal members inside the line of openings	13.90	1.42	9

The net sectional area of the web of the member, in cm^2 (in^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, (tf, Ltf)

q = allowable average shear stress in the web, not to exceed 10.35 kN/cm^2 (1.055 tf/cm^2, 6.7 Ltf/in^2)

PART 3

CHAPTER 2

Hull Structures and Arrangements

SECTION 8

Pillars, Deck Girders and Transverses

1 General

1.1 Arrangements - General

All pillars are to be aligned vertically or, in case of misalignment, an arrangement is to be provided for transmitting their loads to the supports below. The lowest 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 those pillars.

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

Special attention is to be paid to provide support in the form of bulkheads or deep webs 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 3-2-11/9.

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 3-2-11/9.

1.3 Container Loading

Where it is intended to carry containers, the structure is to comply with 3-2-7/5.

1.5 Cargo Loading

Where it is intended to carry cargoes, the structure is to be calculated with use of head or height h, as applicable, according to 3-2-7/3.1.

3 Pillars

3.1 Permissible Load

The permissible load W_a of a pillar or strut obtained from the following equation should always be equal to or greater than the calculated load W as determined in accordance with 3-2-4/7.7, 3-2-8/3.3, 3-2-8/3.5 or 3-2-8/3.7 as appropriate.

$W_a = (k - n\ell/r)A$ kN (tf, Ltf)

where

k	=	12.09 (1.232, 7.83)	ordinary strength steel
	=	16.11 (1.643, 10.43)	HT32 strength steel
	=	18.12 (1.848, 11.73)	HT36 strength steel
	=	19.13 (1.951, 12.38)	HT40 strength steel
ℓ	=	unsupported span of the pillar or strut, in m (ft), 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 (in.)	
A	=	cross sectional area of strut, in cm^2 (in^2)	
n	=	4.44 (0.452, 0.345)	ordinary strength steel
	=	7.47 (0.762, 0.581)	HT32 strength steel
	=	9.00 (0.918, 0.699)	HT36 strength steel
	=	9.76 (0.996, 0.758)	HT40 strength steel

The foregoing equations apply where ℓ/r, with ℓ and r in the same units, is less than 130.

3.3 Calculated Load

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

$W = nbhs$ kN(tf, Ltf)

where

n	=	7.04 (0.715, 0.02)
b	=	mean breadth of the area supported, in m (ft)
s	=	mean length of the area supported, in m (ft)
h	=	height above the area supported when there is no cargo space and/or cargo carried on or above the freeboard deck, in m (ft)
	=	for pillars spaced not more than two frame spaces: the distance from the deck supported to a point located 3.80 m (12.5 ft) above the freeboard deck.
	=	for widely-spaced pillars: the distance from the deck supported to a point 2.44 m (8 ft) above the freeboard deck, except for pillars located immediately below the freeboard deck, for which the value of h is not to be less than given in 3-2-7/3.1 TABLE 2, 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 3-2-7/3 for bridge-deck beams.
	=	the height for any pillar under the first superstructure deck above the freeboard deck is not to be less than 2.44 m (8 ft).
	=	the height for any pillar is not to be less than the height given in 3-2-7/3 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 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.

Where the cargo load exceeds $h \times 7.01$ kN/m^2 the heads given above for cargo spaces below the freeboard deck are to be increased by the factor of cargo load kN/m^2/$h \times 7.01$ kN/m^2 ($h \times 44.7$ lbf/ft^2)

This adjustment to design heads may need to be included elsewhere where the implied cargo load in cargo spaces below the freeboard deck of $h \times 7.01 \quad \mathrm{kN/m^2}$ is used.

3.5 Additional Pillars

Additional 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 3-2-8/3.3.

3.7 Pillars under the Tops of Deep Tanks

Pillars under the tops of deep tanks are not to be less than required by the foregoing equation. They are to be of solid cross section (pipes and tubing not allowed) and to have not less area than cW cm^2 (in.^{2}) where W and c are obtained as follows:

$W = nbhs$ kN (tf, Ltf)

where

n	=	10.5 (1.07, 0.03)	
b	=	breadth of the area of the top of the tank supported by the pillar, in m (ft)	
s	=	length of the area of the top of the tank supported by the pillar, in m (ft)	
h	=	height, as required by 3-2-7/3.1, for beams at the top of tanks, in m (ft)	
c	=	0.1035 (1.015, 0.16)	ordinary strength steel
	=	0.0776 (0.761, 0.12)	HT32 strength steel
	=	0.069 (0.677, 0.107)	HT36 strength steel
	=	0.0655 (0.643, 0.102)	HT40 strength steel

3.9 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 a manner as to provide supports not less effective than required for stanchions or pillars.

3.11 Attachments

Widely-spaced tubular or solid section pillars are to solidly bear at top and bottom and are to be attached by partial or full penetration welds properly proportioned to 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 developed by full penetration welds.

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.

3.13 Stanchions in Double Bottoms and Under Tank Tops*

Stanchions in double bottoms and under the tops of deep tanks are to be solid in cross section. Stanchions under the tops of deep tanks are not to be less than required by 3-2-6/5.3 and 3-2-6/5.5, nor are they to have less section area than cW cm^2 (in^2) where W is to be obtained from the following equation:

$W = nbhs$ kN (tf, Ltf)

where

W	=	load, in kN (tf, Ltf)
n	=	10.5 (1.07, 0.03)
b	=	breadth, in m (ft), of the area of the top of the tank supported by the stanchion
h	=	height, in m (ft), as required by 3-2-7/3.1, for the tank-top beams
s	=	length, in m (ft), of the area of the top of the tank supported by the stanchion
c	=	0.1035 (1.015, 0.16)

Note: * This kind of structure is mostly seen for vessels under 90 meters (295 feet) in length. Requirements in this section are applied as applicable.

5 Deck Girders and Transverses

5.1 General

Girders and transverses of the sizes required by 3-2-8/5.3 through 3-2-8/5.15 are to be fitted to support the beams. In way of bulkhead recesses and the tops of tanks, they are to be arranged so, that the unsupported span of the beams does not exceed 4.8 m (16 ft). Additional girders are to be fitted under masts, king posts, deck machinery or other heavy concentrated loads. In way of deck girders or deep beams, the deck plating is to be of sufficient thickness and suitably stiffened to be considered an effective part of the girder.

5.3 Deck Girders Clear of Tanks

Each deck girder clear of tanks, similar to that shown in 3-2-8/5.3 FIGURE 1, is to have a section modulus SM as obtained from the following equation:

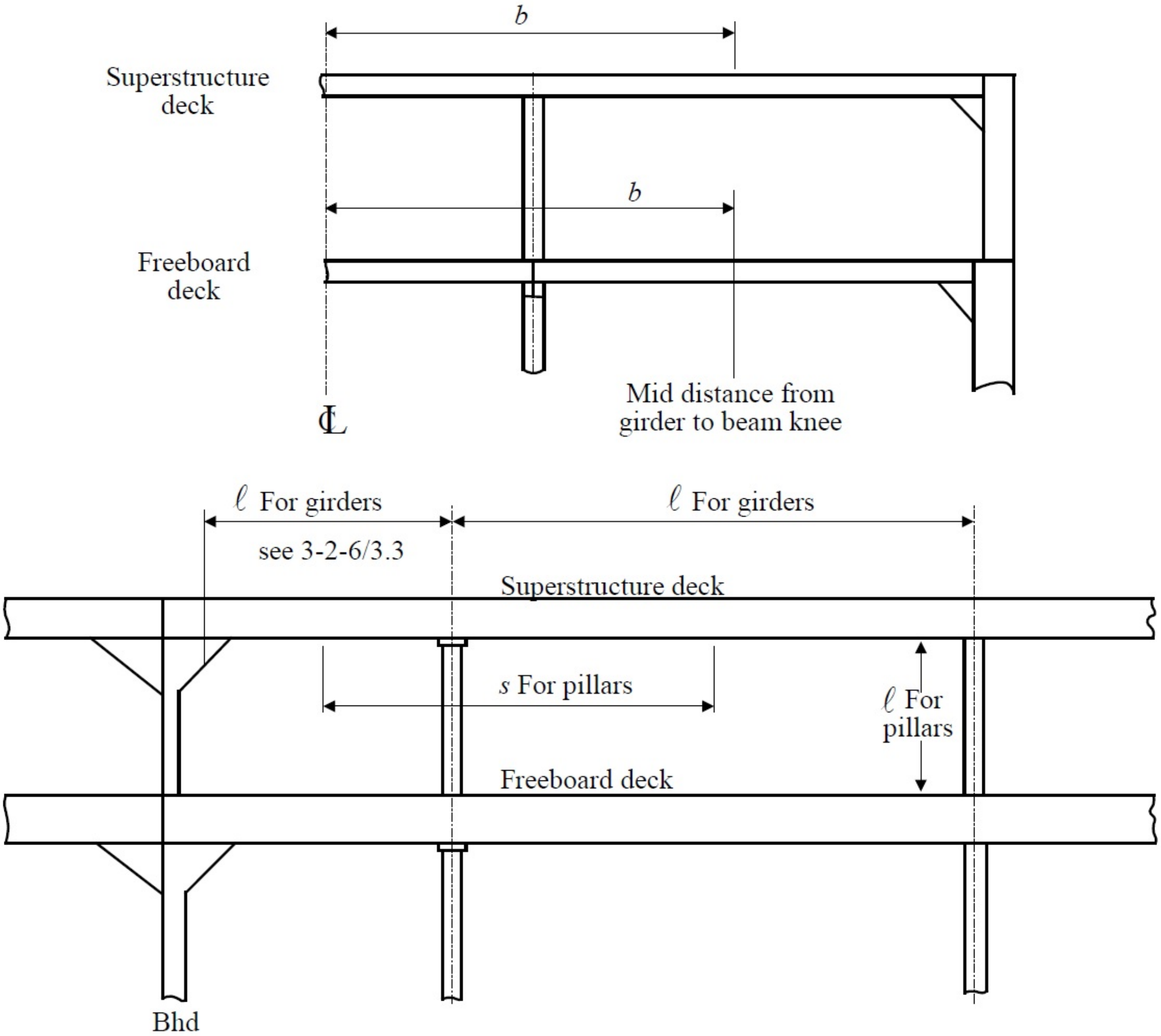
$SM = 4.74cbh\ell^2$ cm^3

$SM = 0.0025cbh\ell^2$ in^3

where

c	=	1.0
b	=	mean breadth of the area of deck supported, in m (ft)
h	=	height, as required by 3-2-7/3.1, for the beams supported, in m (ft)
ℓ	=	span between centers of supporting pillars, or between pillar and bulkhead, in m (ft). Where an effective bracket, in accordance with 3-2-6/7.1 is fitted at the bulkhead, the length ℓ may be modified.

FIGURE 1
Deck Girders and Pillars



5.5 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 3-2-8/5.3 ,where

c = 1.0

b = spacing of deck transverses, in m (ft)

h = height, as required by 3-2-7/3.1, for the beams supported, in m (ft)

ℓ = span between supporting girders or bulkheads, or between girder and side frame, in m (ft). Where an effective bracket is fitted at the side frame or bulkhead, the length ℓ may be modified. See 3-2-6/7.1.

5.7 Proportions

Girders and transverses are to have a depth of not less than 0.0583ℓ (0.7 in. per ft of span ℓ). The depth is also not to be less than 3 times the depth of the cutouts for the beams or longitudinals for vessels 90 meters (295 feet) in length and greater or 2.5 times the depth of the cutouts for the beams or longitudinals for vessels less than 90 meters (295 feet) in length, unless effective compensation is provided for the cutouts.

The thickness is not to be less than 1 mm per 100 mm (0.01 in. per in.) of depth plus 4 mm (0.16 in.). For vessels 90 meters (295 feet) in length and greater, the thickness is not to be less than 8.5 mm (0.34 in.) where the face area is 38.7 cm^2 (6 in^2) or less, 10 mm with 64.5cm^2 (0.40 in. with 10 in^2), 12.5 mm with 129 cm^2 (0.50 in. with 20 in^2) and 15 mm with 193.5 cm^2 (0.60 in. with 30 in^2) or over. The thickness for intermediate area may be obtained by interpolation.

Alternative designs with stiffness equivalent to the specified depth/length ratio and the required section modulus may be considered, provided that the calculated results are submitted for review.

5.9 Tripping Brackets

Tripping brackets are to be fitted at intervals of about 3 m (10 ft) and near any change of section. Where the breadth of the flange on either side of the web exceeds 200 mm (8 in.), 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 (16 in.).

5.11 End Attachments

The ends of deck girders and transverses are to be effectively attached by welding in which the fillet weld throat area develops the strength of the member being attached.

5.13 Deck Girders and Transverses in Tanks

Deck girders and transverses in tanks are to be obtained in the same manner as given in 3-2-8/5.3, except that the value of c is to be equal to 1.5 and the minimum depth of the girder is to be 0.0833ℓ (1 in. per ft of span ℓ). The minimum thickness, sizes and arrangements of the stiffeners, tripping brackets and end connections are to be the same as given in 3-2-8/5.7, 3-2-8/5.9, and 3-2-8/5.11.

5.15 Hatch Side Girders

Scantlings for hatch side girders supporting athwartship shifting beams or supporting hatch covers are to be obtained in the same manner as deck girders (3-2-8/5.3 through 3-2-8/5.13). Such girders along lower deck hatches at the bottom of trunks in which top covers are omitted are to be increased in proportion to the extra load which may be incurred due to loading up the trunks. The structure on which such hatch covers are seated is to be effectively supported.

Where deep coamings are fitted above a deck, such as at weather decks, the girder below deck may be modified so as to obtain a combined section modulus including the coaming and the horizontal coaming stiffener, of at least 35% greater than that required by 3-2-8/5.3.

Where hatch side girders are not continuous under deck beyond the hatchways to the nearest 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 proven 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.

7 Hatch-end Beams

7.1 Hatch-end Beam Supports

Each hatch-end beam, similar to that shown in 3-2-8/7 FIGURE 2, which is supported by a centerline pillar but without a pillar at the hatchway corner, is to have a section modulus SM not less than obtained from the following equations:

7.1.1 Where Deck Hatch-side Girders are Fitted Fore and Aft beyond the Hatchways

$$SM = K(AB + CD)h\ell \text{ cm}^3$$

$$SM = 5.267K(AB + CD)h\ell 10^{-4} \text{ in}^3$$

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

$$SM = KABh\ell \quad \text{cm}^3$$

$$SM = 5.267KABh\ell 10^{-4} \text{ in}^3$$

where

A	=	length of the hatchway, in m (ft)
B	=	distance from the centerline to the midpoint between the hatch side and the line of the toes of the beam knees, in m (ft)
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 (ft). 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 (ft)
h	=	height for the beams of the deck under consideration, as given in 3-2-7/3.1, in m (ft)
ℓ	=	distance from the toe of the beam knee to the centerline plus 0.305 m (1 ft), in m (ft)
K	=	$2.20 + 1.29(F/N)$ when $F/N \leq 0.6$
	=	$4.28 - 2.17(F/N)$ when $F/N > 0.6$
N	=	one-half the breadth of the vessel in way of the hatch-end beam, in m (ft)
F	=	distance from the side of the vessel to the hatch side girder, in m (ft)

7.3 Weather Deck Hatch-end Beams

Weather deck hatch-end beams which have deep coamings above deck throughout 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.

7.5 Depth and Thickness

The depth and thickness of hatch-end beams are to be similar to those required for deck girders by 3-2-8/5.7.

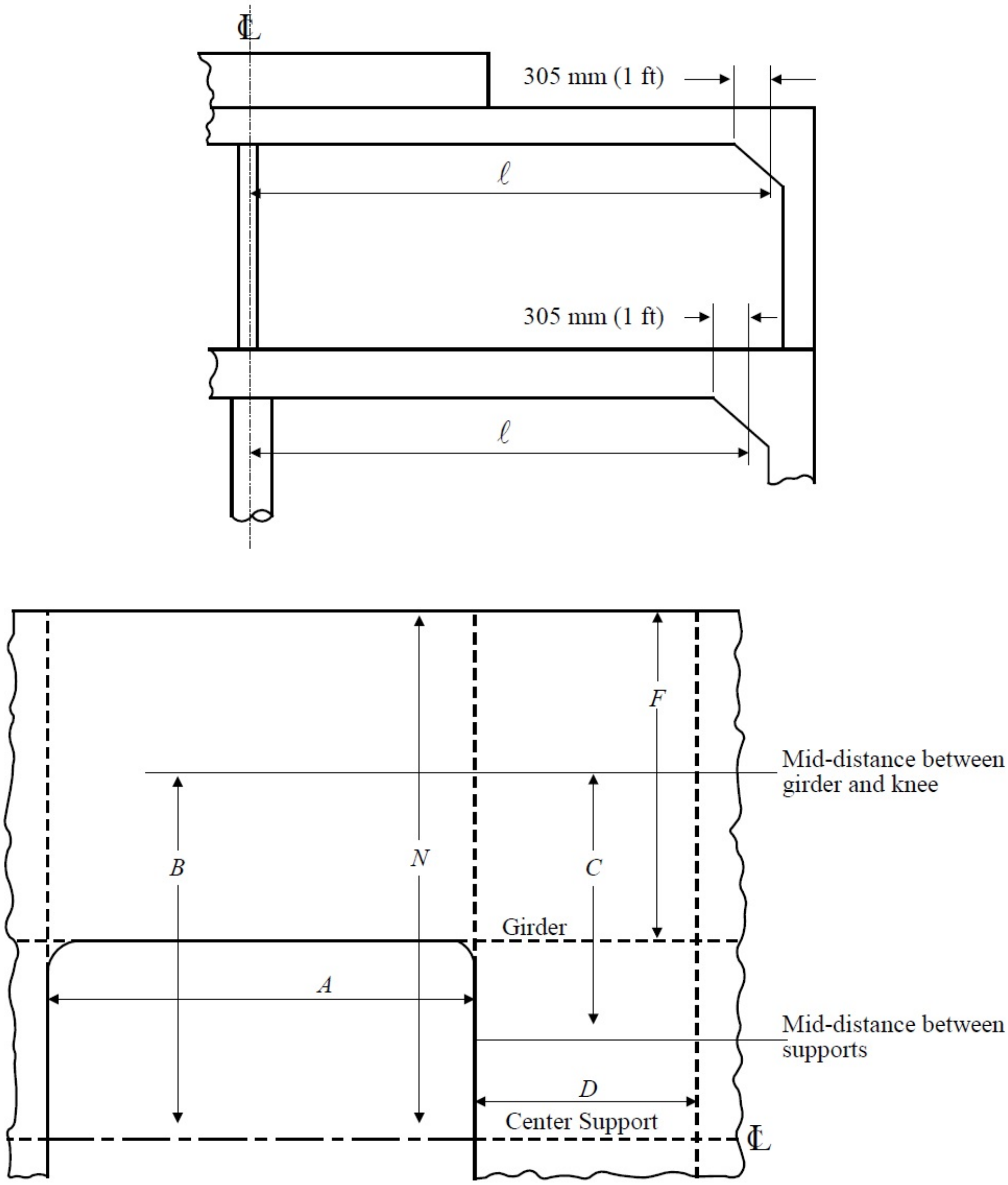
7.7 Tripping Brackets

The arrangement of tripping brackets is to be in accordance with 3-2-8/5.9.

7.9 Brackets

Brackets at the ends of hatch-end beams are to be generally as described in 3-2-6/7.1. 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 2
Hatch-end Beams



9 Higher-strength Materials

9.1 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 resistance to buckling.

Higher strength steel members are to be continuous in way of transverse members of ordinary strength steel or of lesser strength higher strength steel.

9.3 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 3-2-1/5

PART 3

CHAPTER 2

Hull Structures and Arrangements

SECTION 9

Watertight Bulkheads and Doors

1 General

1.1 Application *(1 July 2022)*

All vessels are to be provided with strength and watertight bulkheads in accordance with this Section. In all cases, the plans submitted are to clearly show the location and extent of the bulkheads. Bulkheads which are deep tank boundaries are to have scantlings which comply with Section 3-2-10.

1.3 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 3-2-15/17.3) are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity. Relaxation in the water-tightness 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. However where unavoidable, the ventilation ducting is to satisfy either watertight bulkhead requirements or watertight closing appliances are to be installed at the 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.

1.5 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 of 4-6-2/9.7.4.

1.7 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 specific type, equivalent transverse strength may be obtained by fitting partial bulkheads, deep webs or combinations of these, so as to maintain effective transverse continuity of structure.

1.9 Testing

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

1.11 Plans and Particulars to be Submitted for Watertight Doors *(1 July 2022)*

1.11.1 Door Construction

i) General Arrangement

a) Door Assembly

b) Frame Assembly

ii) Scantlings Arrangement Details

iii) Details of welded construction, as applicable

1.11.2 Door Systems and Appurtenances

i) Securing Devices

ii) Sealing Arrangements

iii) Hydraulic System Arrangements, as applicable

iv) Controls, Alarms, and Monitoring Arrangements, as applicable

1.11.3 Data

i) Prototype test procedure, measurements, and data

ii) Door Rating

a) Type

b) Class

c) Size

d) Opening Hand

e) Pressure Head

f) Fire Endurance Rating, as applicable

iii) Other limiting parameters

1.11.4 Material Specifications

The material specification or material grade for door panel, panel stiffness, door frame, tracks, gaskets and all attachments are to be specified on the drawings.

1.13 Definitions *(1 July 2022)*

1.13.1 Watertight

Capable of preventing the passage of water in any direction under a design head. The design head for any part of a structure shall be determined by reference to its location relative to the bulkhead deck or freeboard deck, as applicable, or to the most unfavorable equilibrium/intermediate waterplane, in accordance with the applicable subdivision and damage stability regulations, whichever is the greater. A watertight door is thus one that will maintain the watertight integrity of the subdivision bulkhead in which it is located.

1.13.2 Equilibrium Waterplane

The waterplane in still water when, taking account of flooding due to an assumed damage, the weight and buoyancy forces acting on a vessel are in balance. This relates to the final condition when no further flooding takes place or after cross flooding is completed.

1.13.3 Intermediate Waterplane

The waterplane in still water, which represents the instantaneous floating position of a vessel at some intermediate stage between commencement and completion of flooding when, taking account of the assumed instantaneous state of flooding, the weight and buoyancy forces acting on a vessel are in balance.

1.13.4 Sliding Door or Rolling Door

A door having a horizontal or vertical motion generally parallel to the plane of the door.

1.13.5 Hinged Door

A door having a pivoting motion about one vertical or horizontal edge.

3 Arrangement of Watertight Bulkheads

3.1 Collision Bulkhead

3.1.1 General *(2019)*

A collision bulkhead is to be fitted on all vessels. It is to be intact, without openings, except as permitted in 4-6-2/9.7.3. It is to extend at least to the freeboard deck and in general, to be in one plane, however, the bulkhead may have steps or recesses provided they are within the limits prescribed in 3-2-9/3.1.2. In the case of vessels having long superstructures at the fore end, it is to be extended weathertight to the first superstructure deck above the freeboard deck. This extension need not be fitted directly over the bulkhead below, provided that the location of the extension meets the requirements in 3-2-9/3.1.2 and the part of the deck which forms the step or recess 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 (7.5 ft) above the freeboard deck, may extend forward of the limit below. See 3-2-9/3.3 FIGURE 1B.

3.1.2 Location

The collision bulkhead is to be located at any point not less than $0.05L_r$ or 10 m (32.8 ft), whichever is less, abaft of the reference point. At no point on vessels having 500 or more gross tonnage, except as specially permitted, is it to be further than $0.08L_r$ or $0.05L_r + 3$ m (9.84 ft), whichever is greater, from the reference point.

3.1.3 Reference Point

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 (9.84 ft.). See 3-2-9/3.3 FIGURE 1A.

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 3-1-1/3.3.

3.3 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 or deep transverse webs are to extend thereto. The requirement to enclose the shaft tubes in a watertight compartment may be specially considered where such an arrangement is proven to be impracticable provided it does not increase the risk to impair the watertight integrity of the hull.

The top of the aft peak tank is to be located above the summer load waterline.

FIGURE 1A
Reference Point for Vessels with Bulbous Bow

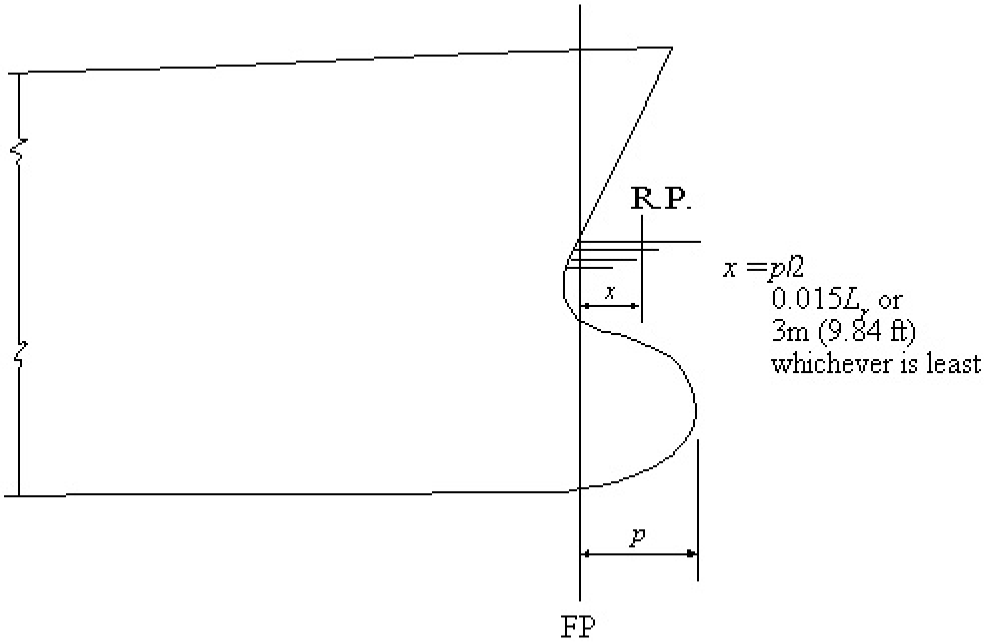
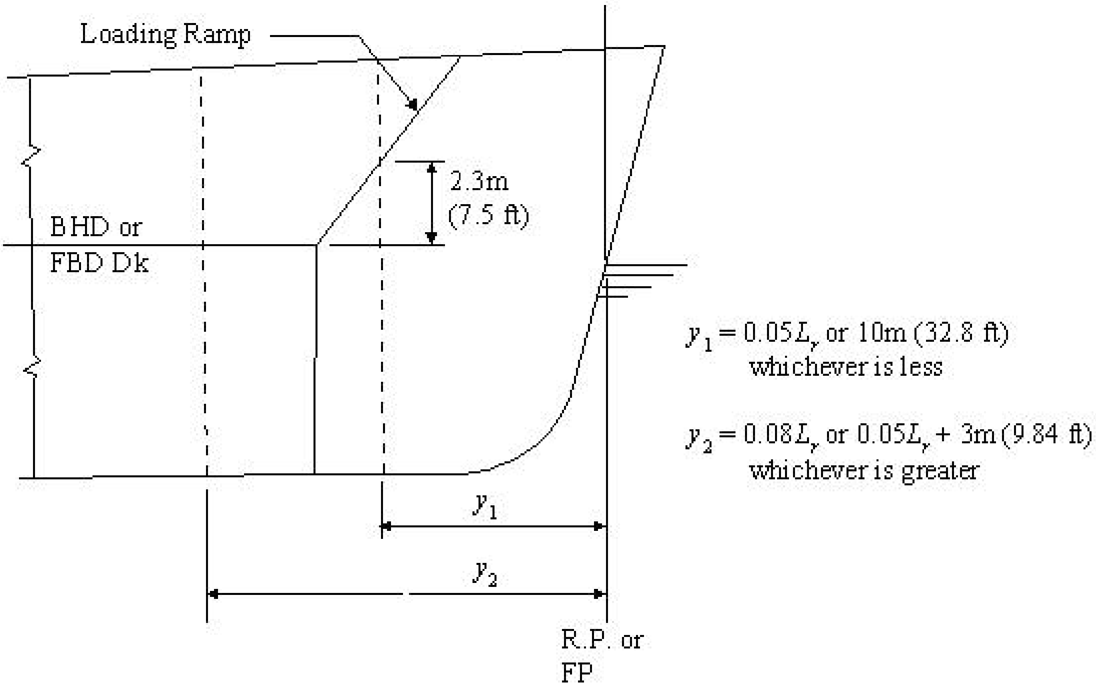


FIGURE 1B
Collision Bulkhead in Vessels with Bow Door



3.5 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. See 3-3-1/5.3.

3.7 Hold Bulkheads

3.7.1 General

In addition to the foregoing required watertight bulkheads, the number and arrangement of cargo space bulkheads are to satisfy the subdivision and damage stability requirements in 3-3-1/3.3. Review procedures for this requirement are indicated in 3-3-1/5.

3.7.2 Carriage of Water Ballast and Liquid Cargoes 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 Section 3-2-10. The hatch cover and securing devices are to be suitable for the internal loading. See 3-2-15/7.

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.

3.9 Chain Lockers

i) 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 progressive flooding into other spaces. Bulkheads between separate chain lockers not forming a part of subdivision bulkhead (see

3-2-9/3.9 FIGURE 2A below) or bulkheads which form a common boundary of chain lockers (see 3-2-9/3.9 FIGURE 2B below), need not be watertight.

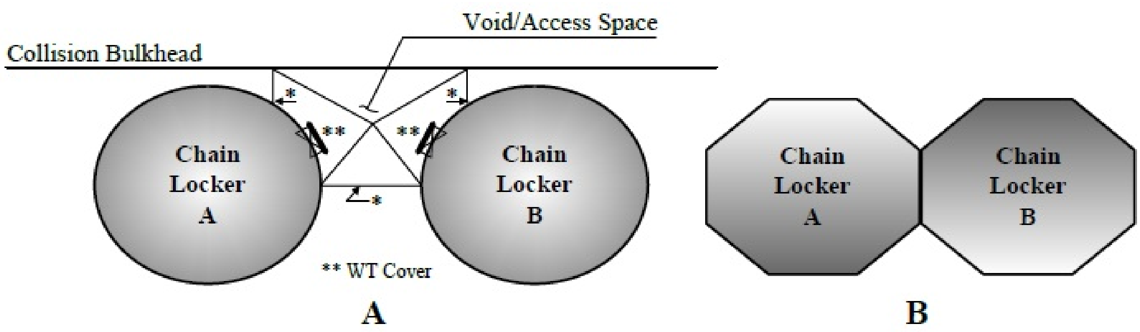
ii) Where means of access into chain lockers are provided, they are to be closed by a watertight manhole cover secured by closely spaced bolts; doors are not permitted. Closely spaced bolts mean bolt spacing not exceeding 5 times bolt nominal diameter. Doors are not permitted.

iii) 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.

iv) For closure of chain pipes, see 3-2-15/21.11.

v) The arrangements on vessels that are not subject to the International Convention on Load Lines or its Protocol may be specially considered with respect to the safety of the vessel and the requirements of the flag Administration.

FIGURE 2
Chain Lockers Arrangement



5 Construction of Watertight Bulkheads

5.1 Plating *(1 July 2022)*

Watertight bulkhead 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

$t = sk\sqrt{qh}/c + 0.06$ in. but not less than 0.24 in. or $s/200 + 0.10$ in., whichever is greater

where

t	=	thickness, in mm (in.).	
s	=	spacing of stiffeners, in mm (in.)	
k	=	$(3.075\sqrt{\alpha} - 2.077)/(\alpha + 0.272)$	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 ($24/Y$ kgf/mm^2, $34,000/Y$ lbs/in^2)	
Y	=	specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, lbs/in^2), as defined in 2-1-1/13 of the ABS *Rules for Materials and Welding (Part 2)* for the higher-strength material or 0.72 of the specified minimum tensile strength, whichever is the lesser	

h = distance from the lower edge of the plate, in m (ft), to the bulkhead deck at center, if freeboard and bulkhead decks coincide

= not less than the distance from the lower edge of the plate, in m (ft), to the designated freeboard deck at center when freeboard deck is lower than the bulkhead deck (refer to 3-1-1/15.1).

c = 254 (254, 460) for collision bulkhead below freeboard or bulkhead deck

= 290 (290, 525) for other watertight bulkhead

The plating of after-peak bulkheads below the lowest flat is not to be less than required for solid floors in the after peak space. See 3-2-5/9.

For vessels under 30.5 m (100 ft) in length, the following deductions may be made to the thicknesses obtained from the above equation for mild steel only.

L *meters*	*Deduction* *mm*	*L* *feet*	*Deduction* *in.*
24.40 to 30.50	0.25	80 to 100	0.01
21.35 to 24.40	0.50	70 to 80	0.02
18.30 to 21.35	0.75	60 to 70	0.03
Under 18.30	1.00	Under 60	0.04

In general, main non-tight transverse strength bulkhead plating is to be similar to that required for watertight bulkheads. Other non-tight strength bulkheads plating is to be not less than s/150, or 4 mm (0.16 in.), whichever is greater. The section modulus of non-watertight bulkhead stiffeners is to be not less than one-half of that required by 3-2-9/5.3.

5.3 Stiffeners *(2022)*

The following requirements are be complied with:

i) 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:

$$SM = 7.8kchs\ell^2 \quad \text{cm}^3$$

$$SM = 0.0041kchs\ell^2 \quad \text{in}^3$$

where

k = 1.00 for stiffeners on watertight bulkheads

= 1.25 for stiffeners on collision bulkheads located below the freeboard deck

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 (ft.)

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 (ft)

h = distance from the middle of ℓ, in m (ft), to the bulkhead deck at center if freeboard and bulkhead decks coincide

= not less than the distance from the middle of ℓ, in m (ft), to the designated freeboard deck at center, when freeboard deck is lower than the bulkhead deck (see 3-1-1/13.1)

= where the distance indicated above is less than 6.1 m (20 ft), h is to be taken as 0.8 times the distance plus 1.22 m (4 ft)

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

Note: For vessels under 46 meters (150 feet) in length, the above values for c may be 0.29, 0.38, 0.46 and 0.58, respectively, and h may be taken as the distance in meters or in feet from the middle of ℓ to the bulkhead deck at center in every case. For vessels between 46 and 65.5 meters (150 and 215 feet), intermediate values for c may be obtained by interpolation.

An effective bracket, for the application of the above values of c, is to have the scantlings as required by 3-2-9/5.4 and is to extend onto the stiffener for a distance at least one-eighth of the length ℓ of the stiffener.

ii) For higher-strength steel stiffeners attached to the higher-strength steel plating, its section modulus (SM_{hs}) is not to be less than obtained from the following equation, provided that all other strength criteria are satisfied:

$$SM_{hs} = Q(SM) \text{ cm}^3 \text{ (in}^3\text{)}$$

where

SM = stiffener section modulus as defined in the above;

Q = as defined in 3-2-1/5.3

5.4 Stiffener End Brackets *(1 July 2022)*

Where end brackets are provided, they are to have scantlings not less than shown in 3-2-9/5.5 TABLE 1A for vessels 90 meters (295 feet) or greater in length or 3-2-9/5.5 TABLE 1B for vessels less than 90 meters (295 feet) in length. The short arm of the bracket is to be not less than $^2/_3$ of the longer arm, as far as possible. In cases where the short arm is less than this, the effective length of the bracket is to be measured as shown in 3-2-9/5.5 FIGURE 3A.

Where the length of an effective bracket exceeds $\ell/8$, a reduction in ℓ may be taken in accordance with 3-2-9/5.5 FIGURE 3A.

5.4.1 Overlap of Brackets for Vessels 90 m (295 ft) or Greater in Length

For vessels 90 meters (295 feet) or greater in length, the minimum overlap is shown in 3-2-9/5.5 FIGURE 3A.

Where a bracket laps a member, the width of overlap generally is to be twice the thinner plate thickness plus 25 mm (1 in.).

5.4.2 Overlap of Brackets for Vessels Less than 90 m (295 ft) in Length

For vessels less than 90 meters (295 feet) in length, the minimum overlap of the bracket arm along the stiffener is not to be less than obtained from the following equation:

$x = 1.4y + 30$ mm

$x = 1.4y + 1.2$ in.

where

x = length of overlap along stiffener, in mm (in.)

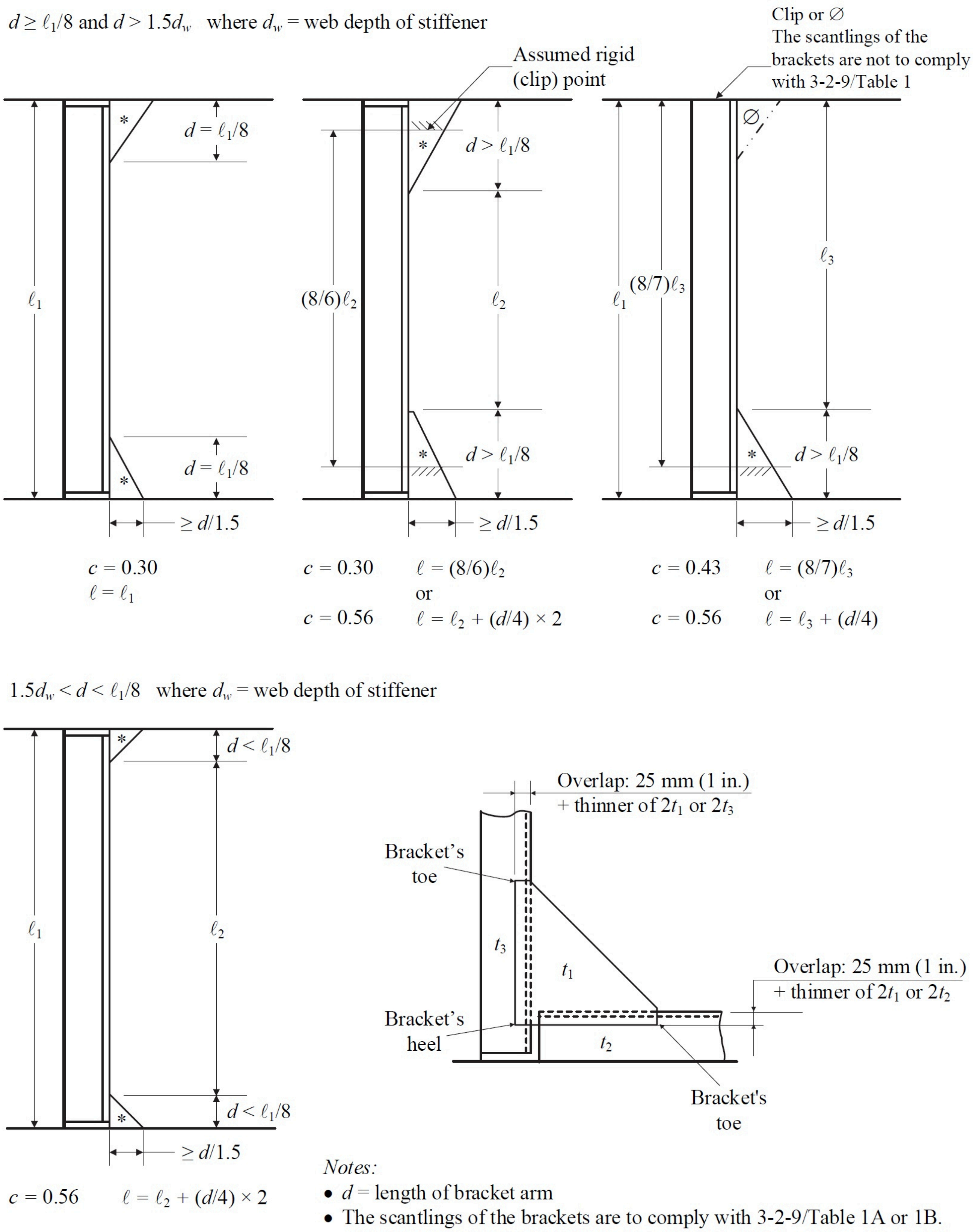
y = depth of stiffener, in mm (in.)

Where a bracket laps a member, the width of overlap generally is to be twice the thinner plate thickness plus 25 mm (1 in.).

5.5 Attachments

Lower brackets to inner bottoms are to extend over the floor adjacent to the bulkhead. Where stiffeners cross horizontal girders, they are to be attached to transmit the loads on the stiffeners effectively to the horizontal girders.

FIGURE 3A
Bracket Connections *(1 July 2022)*



Notes:

- d = length of bracket arm
- The scantlings of the brackets are to comply with 3-2-9/Table 1A or 1B.

FIGURE 3B
Flat Bar End Attachments *(1 July 2022)*

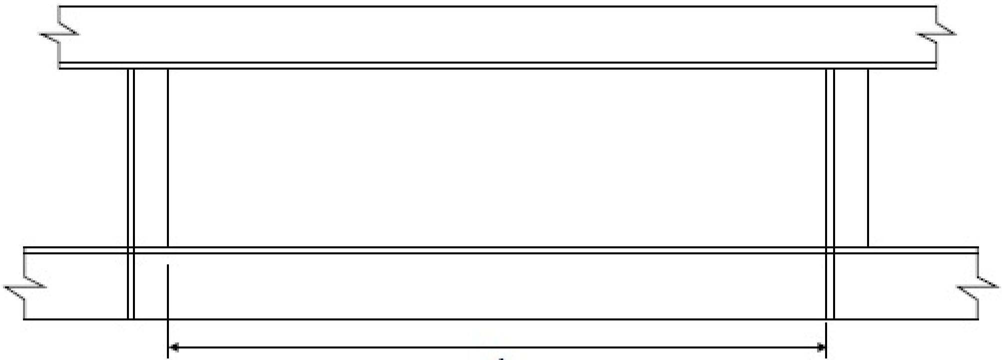


TABLE 1A
Thickness and Flanges of Brackets and Knees for Vessels ≥ 90 m (295 ft) in Length

Millimeters				*Inches*			
Depth of Longer Arm	*Thickness*		*Width of Flange*	*Depth of Longer Arm*	*Thickness*		*Width of Flange*
	Plain	*Flanged*			*Plain*	*Flanged*	
150	6.5			6.0	0.26		
175	7.0			7.5	0.28		
200	7.0	6.5	30	9.0	0.30	0.26	1 ¼
225	7.5	6.5	30	10.5	0.32	0.26	1 ¼
250	8.0	6.5	30	12.0	0.32	0.28	1 ½
275	8.0	7.0	35	13.5	0.36	0.28	1 ½
300	8.5	7.0	35	15.0	0.38	0.30	1 ¾
325	9.0	7.0	40	16.5	0.40	0.30	1 ¾
350	9.0	7.5	40	18.0	0.42	0.32	2
375	9.5	7.5	45	19.5	0.44	0.32	2
400	10.0	7.5	45	21.0	0.46	0.34	2 ¼
425	10.0	8.0	45	22.5	0.48	0.34	2 ¼
450	10.5	8.0	50	24.0	0.50	0.36	2 ½
475	11.0	8.0	50	25.5	0.52	0.36	2 ½
500	11.0	8.5	55	27.0	0.54	0.38	2 ¾
525	11.5	8.5	55	28.5	0.56	0.38	2 ¾
550	12.0	8.5	55	30.0	0.58	0.40	3
600	12.5	9.0	60	33.0		0.42	3 ¼

Millimeters				*Inches*			
Depth of Longer Arm	*Thickness*		*Width of Flange*	*Depth of Longer Arm*	*Thickness*		*Width of Flange*
	Plain	*Flanged*			*Plain*	*Flanged*	
650	13.0	9.5	65	36.0		0.44	3 ½
700	14.0	9.5	70	39.0		0.46	3 ¾
750	14.5	10.0	75	42.0		0.48	4
800		10.5	80	45.0		0.50	4 ¼
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 70% that of the arm of bracket or knee.

TABLE 1B
Thickness and Flanges of Brackets for Vessels < 90 m (295 ft) in Length

Metric

Length of Face f, mm	*Thickness, mm*		*Width of Flange, mm*
	Plain	*Flanged*	
Not exceeding 305	5.0	—	—
Over 305 to 455	6.5	5.0	38
Over 455 to 660	8.0	6.5	50
Over 660 to 915	9.5	8.0	63
Over 915 to 1370	11.0	9.5	75

Inch

Length of Face f, in.	*Thickness, in.*		*Width of Flange, in.*
	Plain	*Flanged*	
Not exceeding 12	$^{3}/_{16}$	—	—
Over 12 to 18	$^{1}/_{4}$	$^{3}/_{16}$	$1^{1}/_{2}$
Over 18 to 26	$^{5}/_{16}$	$^{1}/_{4}$	2

Length of Face f, in.	*Thickness, in.*		*Width of Flange, in.*
	Plain	*Flanged*	
Over 26 to 36	$^{3}/_{8}$	$^{5}/_{16}$	$2^{1}/_{2}$
Over 36 to 54	$^{7}/_{16}$	$^{3}/_{8}$	3

5.7 Girders and Webs

5.7.1 Strength Requirements

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

$SM = 4.74kchs\ell^2$ cm^3

$SM = 0.0025kchs\ell^2$ in^3

where

k	=	1.00	for girders and webs on watertight bulkheads
	=	1.25	for girders and webs on collision bulkheads
c	=	1.00	

h = as defined in 3-2-9/5.3, measured from the middle of s for girders and from the middle of ℓ for webs.

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

ℓ = span measured between the heels of the end attachments, in m (ft).Where brackets are fitted, the length ℓ may be modified as indicated in 3-2-6/7.1.

5.7.2 Proportions

Girders and webs are to have depths not less than 0.0832ℓ (1 in. per ft of span 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 (0.01 in. per in.) of depth plus 3 mm (0.12 in.) but need not exceed 11.5 mm (0.46 in.).

5.7.3 Tripping Brackets

Tripping brackets are to be fitted at intervals of about 3 m (10 ft), and near any change of section. Where the width of the face flange exceeds 200 mm (8 in.) on either side of the girder or web, tripping brackets are to be arranged to support the flange.

7 Construction of Corrugated Bulkheads

7.1 Plating

The plating of corrugated bulkheads is to be of the thickness required by 3-2-9/5.1 with the following modification. The spacing to be used is the greater of dimensions a or c, as indicated in 3-2-9/7.3 FIGURE 4. The angle ϕ is to be 45 degrees or more. Upper and lower stools may be provided to support the bulkheads.

7.3 Stiffeners

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

$SM = 7.8chs\ell^2$ cm^3

$SM = 0.0041chs\ell^2$ in^3

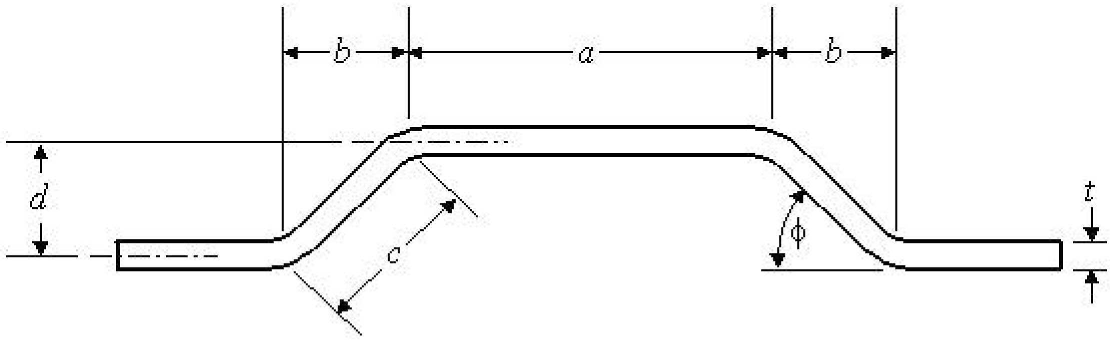
where

c	=	0.56
h	=	as defined in 3-2-9/5.3
s	=	$a + b$ (See 3-2-9/7.3 FIGURE 4)
ℓ	=	distance between supporting members, in m (ft), both for vertical and horizontal corrugations. 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 ("$2 \times b$" in 3-2-9/7.5 FIGURE 6) and trapezoidal cross section is not to exceed twice the width of the mid-segment ("$b' + b$" in 3-2-9/7.5 FIGURE 6)

The developed section modulus SM_A may be obtained from the following equation, where a, t and d are as indicated in 3-2-9/7.3 FIGURE 4.

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

FIGURE 4
Corrugated Bulkhead



7.5 End Connections *(2019)*

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 3-2-9/7.5 FIGURE 5 and 3-2-19/15.

Where no stools are fitted for the vertically corrugated bulkhead, the following requirements are to be complied with:

i) The corrugation webs are to be supported by brackets, beams, diaphragms or girders.

ii) The corrugation flanges are to be in line with the supporting floors. Scallops and cut-outs in the supporting members aligned with corrugation flanges and webs are to be closed by insert collar plates. Alternatives to closing the scallops and cut-outs may be accepted provided that adequate strength to the supporting members is verified by special review.

iii) The thickness and material properties of the floors in line with the corrugation flanges are to be at least equal to those provided for the corrugation flanges.

iv) Reinforcement may be required for access openings in supporting floors, girders, beams, and transverses.

v) Calculations or Finite Element analysis may be submitted for review to justify the design of the supporting structure in way of the connection. Finite Element Analysis shall comply with Section 3-2-20.

FIGURE 5
Corrugated Bulkhead End Connections

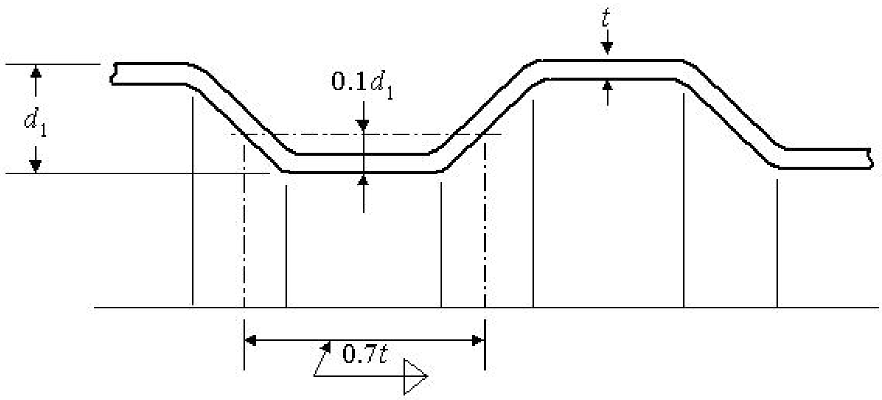
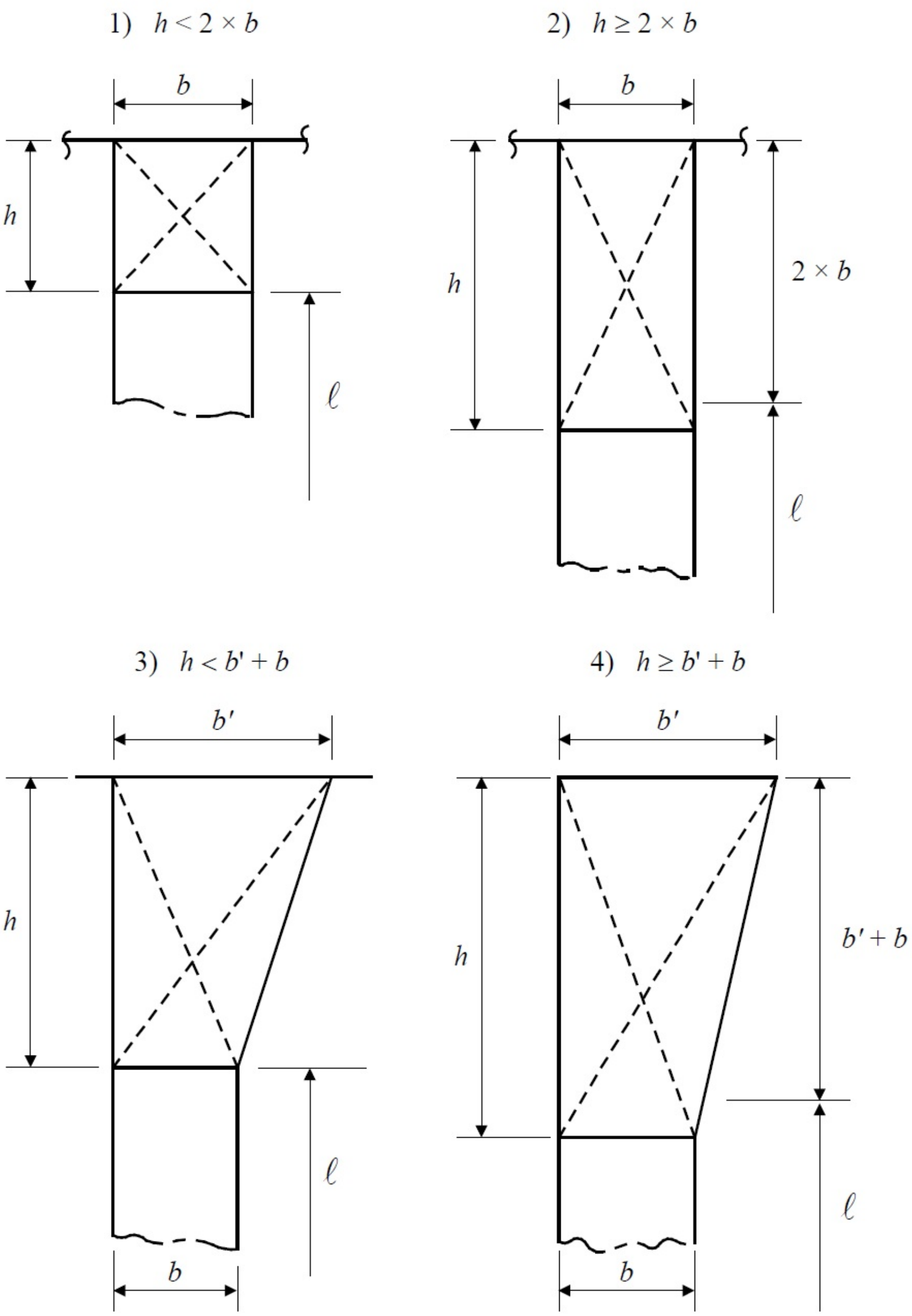


FIGURE 6
Corrugated Bulkhead Upper Stool Credit



9 Watertight Doors *(1 July 2022)*

All doors, except those which are to be permanently closed at sea, are to be capable of being opened and closed by hand (and by power, where applicable) locally from both sides of the doors, with the ship listed to either side. For passenger ships, the angle of list at which operation by hand is to be possible is 15 degrees. For cargo ships, the angle of list at which operation by hand is to be possible is 30 degrees.

For Bow, Stern and Side Shell Doors, refer to Section 3-2-16.

9.1 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. See also 4-9-8/1.3.3. 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. See also Section 4-9-7.

For vessels less than 80 m (262.4 ft) in length (L_f as defined in 3-1-1/3.3), hinged quick-acting doors, operable from both sides of the door, are permitted above a deck, the molded line of which at its lowest point at side, is at least 2.14 m (7 ft) above the deepest load line. Hinged quick-acting doors, operable from both sides, are also permitted for vessels less than 80 m (262.4 ft) in length, L_f, in way of inboard compartments that are not within the assumed extent of damage that may be applicable to the vessel.

9.3 Access Doors and Hatches Normally Closed at Sea

9.3.1 General Requirements

i) Access doors and hatches located in watertight bulkheads (see 3-2-15/17.3) and normally closed at sea may be constructed as hinged type fitted with gaskets and dogs spaced and designed so as to ensure the opening being made watertight. These closing appliances are to be provided with means of indicating locally and remotely on the bridge, whether they are open or closed. A notice is to be permanently affixed on both sides of each closing appliance to the effect that it is to be kept closed while at sea.

ii) Additionally, where a vessel is a Type B ship over 100 m (328 ft) 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 with the sinkage, heel and trim accounted for is to be below the lower edge of those doors openings 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 a hinged, quick acting type provided that the sill of such doors is above the summer load waterline.

iii) The primary securing devices of such doors are to be of a quick acting type (e.g., all door dogs are in closed/opened position simultaneously by a manually-operated single handle, central locking device or equivalent). Dogs (twist tightening handles) with wedges are not acceptable.

The requirements in the following 3-2-9/9.3.2 and 3-2-9/9.3.3 apply to offshore support vessels.

9.3.2 Additional Requirements for Steel Access Doors and Hatches in Watertight Bulkheads

Where hinged steel doors or hatches are fitted, the thickness of the plating is to be not less than required by 3-2-9/5.1 nor less than the surrounding bulkhead plating. The maximum allowable stress and deflection under the design head h and the minimum plate thickness are as follows.

Maximum allowable stress	$0.8Y$, and not exceeding the critical buckling strength in compression
Maximum allowable deflection	0.0056ℓ
Plate thickness	$0.01s$, but not less than 6 mm (0.24 in.)

where Y and s are as defined in 3-2-9/5.1.

9.3.2(a)

The effective depth of the door panel stiffeners is not to be less than 0.04ℓ. Stiffeners, whenever possible, are to be aligned with contact points of dogs/hinges All stiffeners are to be welded to the door panel edge stiffener. 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:

$SM = 7.8hs\ell^2$ cm³

$SM = 0.0041hs\ell^2$ in³

where

h	=	distance, in m (ft), from the middle of ℓ to the freeboard deck at center
s	=	spacing of the stiffeners, in m (ft)
ℓ	=	unsupported length of the stiffener, in m (ft)

9.3.2(b) Securing Arrangements.

i) Arrangement and spacing are to be determined with due attention to the water-tightness, the type and the size of the door or hatch, as well as the stiffness of the door/hatch edges between the securing devices. For hinged watertight doors and for all watertight hatch covers, the securing devices are to be of adequate strength to carry the total load on the door or cover corresponding to the head to the bulkhead deck or freeboard deck and not exceeding the stress level given in 3-2-9/9.3.3.

ii) The sealing pressure between door/hatch cover and coaming sufficient to keep water-tightness is to be maintained by the securing devices. This packing line pressure should be at least 5 N/mm² (0.51 kgf/mm², 725 lbs/in²) under the design head h applied from the opposite side to the door/hatch opening direction.

iii) The door/hatch edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices without distortion. The moment of inertia, I, of edge elements is not to be less than:

$I = c_i p \quad a^4$ cm⁴ (in⁴)

where

c_i	=	6 (58.8, 0.000218)
p	=	sealing line pressure, in N/mm derived from design head design pressure corresponding to the head to the bulkhead or freeboard deck h, plus 5 N/mm² (0.51 kgf/mm², 725 lbs/in²)
a	=	spacing, in m, of securing devices.

The seals and arrangement of the securing devices are to be such that in the secured position, with the seal compressed to the manufacturer's requirements, there is to be complete peripheral steel to steel contact between the doors and hatch cover edge structure and the bulkhead frame around the opening.

9.3.3 Strength Requirements for Aluminum Access Doors and Hatches in Watertight Bulkheads *(1 July 2022)*

Watertight access doors/hatches are to withstand the water pressure to which they may be subjected to and tested for that pressure before installing on board. Doors in the lower parts of the vessel, which may be required to be opened at sea, are to be of the sliding type. All other doors/ hatches may be constructed hinged and fitted with gaskets and dogs spaced and designed so, as to ensure that the openings may be closed watertight. The maximum allowable stress and deflection under the design head h and the minimum plate thickness are as follows.

- Maximum allowable stress — the product of the maximum stress calculated under assumed loads and the factor 4.25 is not to exceed the minimum ultimate strength of the material.
- Maximum allowable deflection — 0.0022ℓ
- Plate thickness — is not to be less in thickness than $0.9Q_o$ % of the spacing of stiffeners or $5.4Q_o$ mm ($0.22Q_o$ in.), whichever is greater.

9.3.3(a) Plating

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

For $h \leq 18 \quad m \quad (59ft)$

$$t_{al} = \frac{0.9\left(Q_o + \sqrt{Q_o}\right)}{2}\{s[(h + 6.1)/1830] + 3.05\} \quad \text{mm}$$

$$t_{al} = \frac{0.9\left(Q_o + \sqrt{Q_o}\right)}{2}\{s[(h + 20)/6000] + 0.12\} \quad \text{in.}$$

For $h > 18 \quad m \quad (59ft)$

$$t_{al} = \frac{0.9\left(Q_o + \sqrt{Q_o}\right)}{2}\{s[(h + 21.5)/3000] + 3.05\} \quad \text{mm}$$

$$t_{al} = \frac{0.9\left(Q_o + \sqrt{Q_o}\right)}{2}\{s[(h + 70.5)/9850] + 0.12\} \quad \text{in.}$$

where

t_{al}	=	thickness, in mm (in.)	
h	=	distance, in m (ft), from lower edge of the door/hatch plate to the bulkhead or freeboard deck at center	
s	=	spacing of stiffeners, in mm (in.)	
Q_o	=	material factor obtained as below:	
	=	$635/(\sigma_y + \sigma_u)$	SI Units
	=	$65/(\sigma_y + \sigma_u)$	MKS Units
	=	$92000/(\sigma_y + \sigma_u)$	US Units
σ_u	=	minimum ultimate strength of the welded aluminum alloy under consideration, in N/mm^2 (kgf/mm^2, lbs/in^2), in accordance with the table below	
σ_y	=	minimum yield strength of the welded aluminum alloy under consideration, in N/mm^2 (kgf/mm^2, lbs/in^2), in accordance with the table below	

TABLE 2
Minimum Mechanical Properties for Butt-Welded Aluminum Alloys

Alloy	*Ultimate Tensile Strength (σ_u) N/mm² (kgf/mm², lbs/in²)*	*Yield Strength (σ_y)(3) N/mm² (kgf/mm², lbs/in²)*
5083(1)	275 (28.1, 40000)	125 (12.7, 18000)
5086(1)	240 (24.6, 35000)	95 (9.85, 14000)
5454(1)	215 (21.8, 31000)	85 (8.45, 12000)
5456(1)	290 (29.5, 42000)	130 (13.4, 19000)
6061-T6(2)	165 (16.9, 24000)	105 (10.6, 15000)

Notes:

1 All tempers

2 Values when welded with 4043, 5183, 5356 or 5556 filler wire.

3 For other alloys refer to Aluminum Association's *Aluminum Construction Manual.*

9.3.3(b) Stiffeners.

Whenever possible the door panel stiffeners are to be aligned with dogs/hinges contact points. All stiffeners are to be welded to the door panel edge stiffener. The effective depth of the stiffener is to be not less than 0.065 of its unsupported length. Each stiffener, in association with the plating to which it is attached, is to have a section modulus SM as obtained from the following equations.

$$SM_{al} = 0.9Q_o(4.74hs\ell^2) \text{ cm}^3$$

$$SM_{al} = 0.9Q_o(0.00246hs\ell^2) \text{ in}^3$$

where

Q_o = material factor, as obtained in 3-2-9/9.3.3(a)

h = distance, in m (ft), from the middle of stiffener to the bulkhead or freeboard deck at center; where that distance is less than 6.1 m (20 ft), h is to be taken as 0.8 times the distance plus 1.22 m (4 ft)

s = spacing of the stiffeners, in m (ft)

ℓ = span of the stiffener, in m (ft)

9.3.3(c) Securing Arrangements.

Securing arrangement and scantlings are to be equivalent to those described in 3-2-9/9.3.2(b) above.

9.5 Doors or Ramps Dividing Large Cargo Spaces

Watertight doors or ramps (see 3-2-15/17.3) of satisfactory construction may be fitted to internally to subdivide large cargo spaces provided it is demonstrated to ABS 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 they are kept closed during navigation. The time of opening such doors or ramps in port and of closing them before the vessel leaves port a harbor is to be recorded and entered in the logbook. Doors or ramps accessible during the voyage are to be fitted with a device preventing unauthorized opening.

9.7 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 3-2-15/17.3), that are not fitted with a device preventing unauthorized opening are to be provided with a permanently affixed notice stating, that it is to be kept closed while at sea. Manholes fitted with closely bolted covers need not be so marked.

9.9 Construction *(1 July 2022)*

Watertight doors and securing devices are to be of a strength equivalent to that of the subdivision bulkheads in which they are fitted, in accordance with the preceding paragraphs. Door frames 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 door frames into consideration.

9.9.1 Fire Doors *(1 July 2022)*

Watertight doors may also serve as fire doors but need not be fire-tested if fitted on cargo ships or if fitted below the bulkhead deck on passenger ships. However, such doors fitted above the bulkhead deck on passenger ships shall be tested to the FTP Code in accordance with the fire rating of the division they are fitted in. If it is not practicable to be of self-closing type, means of indication on the bridge showing whether these doors are open or closed and a notice stating "To be kept closed at sea" can be alternative of the self-closing. Where a watertight door is located adjacent to a fire door, both doors shall be capable of independent operation, remotely if required by SOLAS ll-1/13.8.1 to 13.8.3 and from both sides of each door.

9.11 Testing and Installation of Watertight Doors *(1 July 2022)*

Watertight doors are to be fitted in accordance with all requirements relating to their mode of operation, location, provision of controls, means of indication, as required in Section 4-9-8. All watertight doors, except those which are to be permanently closed at sea, are to be capable of being opened and closed locally from both sides of the door with the ship listed to either side.

9.11.1 Materials *(1 July 2022)*

9.11.1(a) General

Materials are to comply with the requirements of Chapter 1 of the ABS *Rules for Materials and Welding (Part 2)*.

9.11.1(b) Identification of Materials

The manufacturer is to adopt a system for the identification of ingots, slabs, finished plates, shapes which will enable the material to be traced to its original heat; and the Surveyor is to be given sufficient documentation and means for verifying the traceability of the material.

9.11.1(c) Materials Containing Asbestos

Installation of materials which contain asbestos is prohibited.

9.11.2 Welded Fabrication *(1 July 2022)*

All welded fabrication is to be conducted in accordance with Section 2-4-1 of the ABS *Rules for Materials and Welding (Part 2)*.

9.11.3 Type Tests Conducted at the Plant of Manufacturer *(1 July 2022)*

Type tests are to be conducted on the first watetrtight door in the series. Doors may be considered as part of a series providing all materials, scantlings, fittings, closing devices, etc., are the same. The size range for the series is to be specified by the manufacturer and to be agreed upon by ABS. Large, medium, and small doors are to be tested and applied to the whole series.

9.11.3(a) Testing Requirements

Doors which become immersed by an equilibrium or intermediate waterplane, are to be subjected to a hydrostatic pressure test. The hydrostatic test(s) are to be conducted in accordance with a test procedure that are reviewed and approved by ABS Engineering. Hydrostatic test(s) of those doors first in a series are to be witnessed by ABS Surveyor.

For large doors intended for use in the watertight subdivision boundaries of cargo spaces, structural analysis may be accepted in lieu of pressure testing subject to ABS review. Where gasket seals are utilized for such doors, a prototype pressure test is be carried out to verify that the gasket material under the compression is capable of withstanding any deflection indicated in the structural analysis.

Doors above freeboard or bulkhead deck, which are not immersed by an equilibrium or intermediate waterplane but become intermittently immersed at angles of heel in the required range of positive stability beyond the equilibrium position, are to be hose tested.

Pressure testing requirements are as follows: the head of water used for the test shall correspond at least to the head measured from the lower edge of the door opening, at the location in which the door is to be fitted in the vessel, to:

i) The bulkhead deck or freeboard deck, as applicable, or

ii) The most unfavorable damage waterplane, if that is greater.

Testing may be carried out at the manufacturer or other shore based testing facility prior to installation in the ship.

Commentary:

Large Doors are doors that are used for vehicles or equipment. Doors used for access of personnel are not considered large for application of this requirement.

End of Commentary

9.11.3(b) Leakage Criteria

The following acceptable leakage criteria should apply as follows:

i) Doors with gaskets: No leakage

ii) Doors with metallic sealing: Max leakage 1 liter/min.

Limited leakage may be accepted for pressure tests on large doors located in cargo spaces employing gasket seals or guillotine doors located in conveyor tunnels, in accordance with the following:

Leakage rate (liter/min) = $(P + 4.572) \cdot h^3/6568$

where: P = perimeter of door opening (meters) h = test head of water (meters)

In the case of doors where the water head taken for the determination of the scantling does not exceed 6.10 m, the leakage rate may be taken equal to 0.375 liter/min if this value is greater than that calculated by the above-mentioned formula.

For doors on passenger ships which are used at sea or which become submerged by the equilibrium or intermediate waterplane, a prototype test is to be conducted, on each side of the door, to check the satisfactory closing of the door against a force equivalent to a water height of at least 1 m above the sill on the centerline of the door.

9.11.4 Tests On Board *(1 July 2022)*

All watertight doors shall be subject to a hose test in accordance with Section 3-7-1 after installation in a vessel. Hose testing is to be carried out from each side of a door unless, for a specific application, exposure to floodwater is anticipated only from one side. Where a hose test is not practicable because of possible damage to machinery, electrical equipment insulation or outfitting items, it may be replaced by means such as an ultrasonic leak test or an equivalent test.

9.11.5 Certification of Watertight Doors *(1 July 2022)*

Each watertight door required to be certified by Section 3-2-9 is:

i) To have its design approved by ABS; for which purpose, plans and data as required by 3-2-9/1.11 are to be submitted to ABS for approval, and watertight door(s) of the same type is to have been satisfactorily type tested per 3-2-9/9.11.3.

ii) To be surveyed during its construction for compliance with the design approved, along with, but not limited to, material and non-destructive tests, welded fabrication, type tests as indicated in 3-2-9/9.11, all to be carried out to the satisfaction of the Surveyor.

PART 3

CHAPTER 2

Hull Structures and Arrangements

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 Section 3-2-9.

1.3 Arrangement *(2019)*

The arrangement of all deep tanks, together with their intended content, liquid density and the height of the overflow or vent pipes, are to be clearly indicated on the tank plan submitted. Any oil tanks and all other tanks that carry flammable liquids are not to be arranged forward of the collision bulkhead. Fuel oil tanks of any volume are not to be used for ballast water. For tank protection requirements and **POT** notation refer to 4-6-4/17.

Tanks for fresh water or fuel oil, passive anti-rolling tanks or those that are not intended to be kept entirely filled in service are to have divisions or deep swashes to minimize the sloshing and dynamic stress on the structure. For fuel oil tank arrangements, see 4-6-4/13.5.

1.5 Construction *(2022)*

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 in tanks which are to be entirely filled or empty in service, may be of the scantlings required for watertight bulkheads by Section 3-2-9. 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 are kept full in service.

For additional requirements regarding high density cargo tanks, refer to 5D-1-4/5 of these Rules.

1.7 Drainage and Air Escape

Limber and air holes are to be cut in all parts of the structure so as to ensure free drainage to the suction pipes and the escape of air to the vents without entrapments. Efficient arrangements are to be made for draining the spaces above deep tanks.

1.9 Testing

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

3 Construction of Deep Tank Bulkheads and Tank Tops

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/1.05.

3.1 Plating *(2022)*

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

$t_{shmin} = (sk\sqrt{qh}/C_1) + C_2$ mm (in.) but not less than 6.5 (0.25) mm (in.) or $(s/150 + C_2)$ mm (in.), whichever is greater

where

C_1	=	254 (460)	
C_2	=	2.5 (0.10)	
t	=	thickness, in mm (in.)	
s	=	stiffener spacing, in mm (in.)	
k	=	$(3.075\sqrt{\alpha} - 2.077)/(\alpha + 0.272)$	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 ($24/Y$ kgf/mm^2, $34,000/Y$ lbs/in^{2}psi)	
Y	=	specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, lbs/in^2), as defined in 2-1-1/13 of the ABS *Rules for Materials and Welding (Part 2)*, for the higher-strength material or 0.72 of the specified minimum tensile strength, whichever is the lesser	
h	=	the greatest of the following distances, in m (ft), 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 3-2-7/3.1 TABLE 2, appropriate to the vessel's length
- the load line
- a point located at two-thirds of the distance to the bulkhead or freeboard deck
- for vessels under 90 m in length, a point located above the top of the tank, not less than the greater of $0.01L + 0.15$ m (0.5 ft), where L is as defined in 3-1-1/3, or 0.46 m (1.5 ft)

h is also not to be less than h_1 or h_0 where rupture disks or spill valves are fitted (e.g. mud tanks, methanol tanks, etc.), as obtained below:

$h_1 = \rho h_t + h_a$ m (ft)

$h_0 = (2/3)(\rho h_s + 9.95P_s)$ m (P_s in bar)

$= (2/3)(\rho h_s + 9.75P_s)$ m (P_s in kgf/cm^2)

$= (2/3)(\rho h_s + 2.25P_s)$ ft (P_s in lbf/in^2)

where

ρ	=	1.0	where the specific gravity of liquid is 1.05 or less
	=	specific gravity of liquid	where it is in excess of 1.05

(The provisions under 3-2-10/3 need not be applied in addition hereto)

h_t = head from the center of the supported area or lower edge of the plating to the deck at side or, where such is fitted, to the top of the trunk deck at side for tanks within trunk

h_a = $9.95p_v(9.75p_v, 2.25p_v)$

p_v = pressure/vacuum valve pressure setting, in bar (kgf/cm^2, lbf/in^2)

h_s = head to the spill valve or rupture disc, where fitted, in m (ft)

P_s = relieving pressure of spill valve or rupture disc, where fitted, in bar (kgf/cm^2, lbf/in^2)

3.3 Stiffeners *(1 July 2022)*

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:

$$SM = 7.8chs\ell^2 \text{ cm}^3$$

$$SM = 0.0041chs\ell^2 \text{ in}^3$$

where

c = 0.594 for stiffeners having effective bracket attachments at both ends. An effective bracket for the application of this value of c is to have scantlings not less effective than shown in 3-2-9/Table 1A or 3-2-9/Table 1B and is to extend onto the stiffener for a distance at least one-eighth of the length ℓ of the stiffener.

= 0.747 for stiffeners having effective bracket attachment at one end and supported by clip connections or by horizontal girders at the other end. An effective bracket for the application of this value of c is to have scantlings not less effective than shown in 3-2-9/Table 1A or 3-2-9/Table 1B and is to extend onto the stiffener for a distance at least one-eighth of the length ℓ of the stiffener.

= 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 (ft)

h = greatest of the following distances, in m (ft), 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 3-2-7/3.1 TABLE 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 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 (ft)

The short arm of the bracket is to be not less than $^2/_3$ of the longer arm, as far as possible. In cases where the short arm is less than this, the effective length of the bracket is to be measured as shown in 3-2-9/5.5 FIGURE 3A. Where the length of an effective bracket exceeds $\ell/8$, a reduction in ℓ may be taken in accordance with 3-2-9/5.5 FIGURE 3A.

Stiffeners are to be effectively connected to adjacent structures to avoid hard spots, notches and stress concentrations.

3.5 Tank-top Plating and Stiffeners

Tops of tanks are to have plating 1 mm (0.04 in.) thicker than would be required for vertical plating at the same level; the thickness is not to be less than required for deck plating in the tank's location. Beams, girders and pillars are to be as required by Sections 3-2-7 and 3-2-8.

3.7 Girders and Webs

3.7.1 Strength Requirements

Each girder and web which supports frames or beams in deep tanks is to have section modulus SM as required by Sections 3-2-6 and 3-2-8 or as required by this paragraph, whichever is 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.

$$SM = 4.74 c h s \ell^2 \text{ cm}^3$$

$$SM = 0.0025 c h s \ell^2 \text{ in}^3$$

where

c	=	1.50
h	=	vertical distance, in m (ft), from the middle of s for girders and from the middle of ℓ for webs to the heights as defined in 3-2-10/3.1
s	=	sum of half lengths (on each side of girder or web) of the frames or stiffeners supported, in m (ft)
ℓ	=	span measured between the heels of the end of the attachments, in m (ft). Where effective brackets are fitted, ℓ may be modified as indicated in 3-2-6/7.1.

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.

3.7.2 Proportions

Girders, except deck girders (see 3-2-8/5.13), and webs are to have depths not less than 0.145ℓ where no struts or ties are fitted, and 0.0833ℓ 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 for vessels 90 meters (295 feet) in length and greater or 2.5 times the depth of the slots for vessels less than 90 meters (295 feet) in length, unless effective compensation is provided for stiffener cutouts. The thickness is not to be less than 1% of the depth plus 3 mm (0.12 in.) but need not exceed 11.5 mm (0.46 in.).

3.7.3 Tripping Brackets

Tripping brackets are to be fitted at intervals of about 3 m (10 ft) and near the change of section. Where the width of the face flange exceeds 200 mm (8 in.) on either side of the girder or web, tripping brackets are to be arranged to support the flange.

3.9 Corrugated Bulkheads

Where corrugated bulkheads are used as deep-tank boundaries, the scantlings may be developed from 3-2-9/7. The plating thickness t and value of SM are to be as required by 3-2-10/3.1 and 3-2-10/3.3 respectively with $c = 0.90$.

3.11 Anti-rolling Tank Bulkheads

Where anti-rolling tanks are provided, the required scantlings may be calculated from the above Paragraphs 3-2-10/3.1 through 3-2-10/3.9 based on h measured to the point located above tank bottom as follows:

$h = B(0.259 + 0.966h_z/B)$ m (ft)

where

B	=	breadth of the vessel, in m (ft), as defined in 3-1-1/5
h_z	=	height of the tank at side, in m (ft)

This head is to be applied on tank structure within 0.25B from the vessel's side. For the remainder head as in 3-2-10/3.1 and 3-2-10/3.3 is to be applied.

5 Higher-strength Materials

5.1 General *(2022)*

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.

5.3 Plating

Deep-tank plating of higher-strength material is to be of not less thickness than obtained by 3-2-10/3.1.

5.5 Stiffeners *(2022)*

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

$SM_{hts} = 7.8chs\ell^2Q$ cm^3

$SM_{hts} = 0.0041chs\ell^2Q$ in^3

where c, h, s and ℓ are as defined in 3-2-10/3.1 and Q is as defined in 3-2-1/5.3.

When high strength stiffeners are fitted on mild steel plating, care should be taken to ensure that the neutral axis of the plating and stiffener combination is such as to prevent overstressing of the plating. The section modulus of the plate should meet the requirements for ordinary strength steel and the section modulus of the stiffener flange may meet high strength material requirements. The high strength stiffeners may be intersected by transverse members of lesser strength steel provided they are fitted with end connections of equivalent strength, otherwise they are to be continuous at the transverse members. Sniped ends are not permitted. The flange of the high strength member is not to be sniped, unless an end bracket providing equivalent strength is fitted. End brackets attached to the high strength stiffeners should be high strength and section modulus in way of the brackets should comply with the high strength steel

PART 3

CHAPTER 2
Hull Structures and Arrangements

SECTION 11
Superstructures, Deckhouses and Helicopter Decks

1 General Scantlings of Superstructures and Deckhouses

1.1 Side Plating *(1 July 2021)*

Side plating of superstructures within the amidships 0.4L of the vessel is to be obtained from 3-2-2/3. For superstructures and deckhouses at the after 0.1L end, the plating may be of the thickness obtained from 3-2-2/5.9 for poop side plating. For superstructures at the forward end, from the stem to 0.025L aft of FP, the plating thickness is to be obtained from 3-2-2/5.1. For deckhouses from the stem to 0.1L aft of FP and superstructures between 0.025L to 0.1L aft of FP, the plating thickness is to be obtained from 3-2-2/5.7 for forecastle plating. Between amidships 0.4L and 0.1L from each end, the thickness of the plating is to be gradually tapered. (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.)

1.3 Decks

1.3.1 Superstructures

Decks of superstructures having lengths greater than 0.1L are to comply with the requirements of 3-2-3/5. Where they are of 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 3-2-1 if they are located within the 0.4L amidships. The thickness of the plating at the forward and aft 0.1L ends is to be obtained from 3-2-3/5 TABLE 1 forecastle and poop deck plating, respectively.

1.3.2 Deckhouses

The top plating of deckhouses is to be as required by 3-2-3/5 TABLE 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 3-2-1.

1.5 Frames

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

1.7 Breaks in Continuity

Breaks in the continuity of superstructures are to be strengthened (see 3-2-2/11). The arrangements in such areas are to be clearly shown on the plans submitted for approval.

3 Exposed Bulkheads

3.1 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 Section 3-2-5 for the side frames, directly below the deck on which the house is located.

In general, the first or lowest tier is that located on the freeboard deck or the actual lower deck from which the loadline can be assigned in accordance with the ICLL. Deckhouses or superstructure situated on a deck at least one standard superstructure above the freeboard deck or the lowest exposed deck may be considered the second tier. Higher tiers are defined in a likewise manner. A standard superstructure height is that defined in the *International Convention on Load Lines, 1966.*

Special consideration may be given to the bulkhead scantlings and sills of access openings of deckhouses which do not protect any openings in the freeboard deck, in superstructure deck, in the top of a lowest tier deckhouse or which are not 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 amidships 0.4L and having lengths greater than 0.1L are to have effective longitudinal scantlings to give a hull girder section modulus throughout the superstructure or deckhouse equal to that of the main hull girder. The superstructure scantlings are to be in accordance with 3-2-11/1 and the house top and side plating of such deckhouses is to be not less than obtained from equation 5 in 3-2-3/5 TABLE 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.

3.3 Plating

3.3.1 For All Vessels

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

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

$t = s\sqrt{h}/50$ in.

where s and h are as defined in 3-2-11/3.5; when determining h, y is to be measured to the middle of the plate.

3.3.2 Minimum Thicknesses Requirements *(1 July 2021)*

For exposed bulkheads on the lowest tier of a deckhouse or superstructure and for all exposed bulkheads of deckhouses situated completely or partially on a forecastle deck, the minimum required thickness is to be as follows:

For front bulkheads of OSVs:

$t = 6.0 + 0.01L_2$ mm, but not less than 7.5 mm

$t = 0.24 + 0.00012L_2$ in., but not less than 0.3 in.

For side and end bulkheads of OSVs and lowest tier bulkheads of all other vessels:

$t = 5.0 + 0.01L_2$ mm, but not less than 6.5 mm; and not less than 6.0 mm for towing vessels less than 61 m

$t = 0.2 + 0.00012L_2$ in., but not less than 0.26 in.; and not less than 0.25 in. for towing vessels less than 200 ft

For other tier bulkheads of all vessels, the thickness is not to be less than:

$t = 4.0 + 0.01L_2$ mm, but not less than 5.0 mm

$t = 0.16 + 0.00012L_2$ in., but not less than 0.2 in.

where L_2 is defined in 3-2-11/3.5.

3.5 Stiffeners *(1 July 2022)*

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:

$SM = 3.5s\ell^2h$ cm^3

$SM = 0.00185s\ell^2h$ in^3

where

s	=	spacing of stiffeners, in m (ft.)
ℓ	=	tween deck height, in m (ft.)
h	=	$a[(bf) - y]c$, the design head, in m (ft).
	=	for unprotected front bulkheads on the lowest tier, and for all unprotected front bulkheads of a deckhouse situated completely or partially on a forecastle deck, h is not to be taken less than the following: ● 3 m (9.8 ft) for vessel length L not greater than 50 m (164 ft); ● 2.5 + L/100 m (8.2 + L/100 ft) for vessel length L greater than 50 m (164 ft) and less than 250 m (820 ft); ● 5 m (16.4 ft) for vessel length L not less than 250 m (820 ft)
	=	for all other bulkheads up to the 3rd tier, the minimum value of h is not to be less than one half the value for unprotected front bulkheads on the lowest tier. For bulkheads on the 4th tier and above, the minimum value of h is not to be less than 1.25 m (4 ft).
a	=	coefficient given in 3-2-11/3 TABLE 1
b	=	$1.0 + \left[\frac{(x/L) - 0.45}{C_b + 0.2}\right]^2$ where $x/L \le 0.45$
	=	$1.0 + 1.5\left[\frac{(x/L) - 0.45}{C_b + 0.2}\right]^2$ where $x/L > 0.45$
C_b	=	block coefficient, as defined in 3-1-1/13.3, not to be taken as less than 0.6 nor greater than 0.8. For aft end bulkheads forward of amidships C_b may be taken as 0.8.
x	=	distance, in m (ft), 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	=	length of vessel, in m (ft), but L_2 need not be taken as greater than 300 m (984 ft)
f	=	value determined from 3-2-11/3 TABLE 2, in m (ft).

y = vertical distance, in m (ft), from the summer load waterline to the midpoint of the stiffener span

c = $(0.3 + 0.7b_1/B_1)$ but is not to be taken as less than 1.0 for exposed machinery casing bulkheads. In no case is b_1/B_1 to be taken as less than 0.25.

b_1 = breadth of deckhouse at the position being considered, in m (ft)

B_1 = actual breadth of the vessel at the freeboard deck at the position being considered, in m (ft)

The stiffening is to be arranged so that mullion stiffeners are continuous between decks, with horizontal stiffeners intercostal between the mullion stiffeners. The front, end and side stiffeners are to be in alignment with the stiffeners of the deck below.

3.5.1 For Superstructures and Deckhouses Located at Forward Part of Offshore Support Vessels *(1 July 2022)*

The non-dimensional ratio of tween deck height to mullion stiffener depth is to not exceed 18 for front mullions and 30 for side mullions.

Where flat bars are used as mullion stiffeners, tripping is to be considered and flat bars are to have a depth to thickness not greater than 15.

Alternative arrangements could be acceptable providing that it can be shown equivalent in strength and stiffness to the above requirements.

3.6 Swage Bulkheads *(1 July 2020)*

Exposed bulkheads in steel superstructures and deckhouses shorter than $0.1L$ in length and whose sides are not in line with the vessel's sides may be constructed of swage panels.

Swages are triangular-shaped recesses pressed into plates to form stiffeners (see 3-2-11/Figure 1).

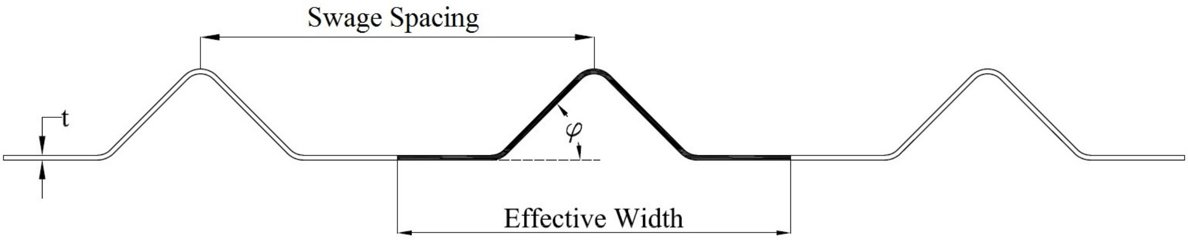
The scantlings of the exposed swage panel bulkheads of superstructures and deckhouses are to be in accordance with the following paragraphs, except that the requirements for house side swages need not exceed the requirements of Section 3-2-5 for the side frames directly below the deck on which the house is located.

The swage panel plating thickness is to satisfy the requirements in 3-2-11/3.3, where s is to be taken as the spacing of swages.

The effective width of the swage (see 3-2-11/Figure 1) is to be taken as the sum of one-half of the spacing on either side of the swage centerline. The section modulus of the swage, including the flat portion of the plates on either side of the swage within the effective width, is to satisfy the requirements in 3-2-11/3.5, where s is to be taken as the effective width of the swage. If the flat plate thickness varies, the mean flat plate thickness over the effective width is to be used.

Swages are to be oriented vertically. The swage angle, φ, is to be between 40 and 70 degrees.

FIGURE 1
Swage Panel



3.7 End Attachments

The following requirements are to be complied as applicable:

3.7.1 For Offshore Support Vessels

i) The end attachments of the stiffener webs are to be designed to prevent stress concentration.

ii) The upper and lower ends of all lowest tier bulkhead stiffeners, of all bulkhead stiffeners of the tiers on the forecastle deck and of all unprotected front bulkhead stiffeners are to be effectively attached.

iii) The end attachments are to be formed by end brackets, by welding all around flanges and webs to the deck plating or by lapping the stiffener onto the deck beam with the throat area of the weld not less than 80 % of the area of the member being attached.

iv) Where only the webs are welded on 3rd and higher tiers, the flange or face bar is to be sniped not more than 30°.

v) The upper and lower ends of all lowest tier bulkhead stiffener webs and the 2nd tier unprotected front bulkhead stiffener webs are to be efficiently welded.

Alternatively the lower ends of deckhouse stiffeners may be supported by strong vertical flat bar attached to the web frame and/or stiffener flanges (refer to 3-2-11/3.7 FIGURE 2 below) provided the structural integrity of the deck/bulkhead connection is not impaired. The vertical flat bars are to have a depth to thickness not greater than 10.

3.7.2 For Other Steel Vessels

The upper and lower ends of all lowest tier bulkhead stiffener webs and the 2nd tier unprotected front bulkhead stiffener webs are to be efficiently welded. The end attachments of stiffener web are to be supported by the deck/beams to prevent stress concentration.

The scantlings of stiffeners having other types of end connection are to be specially considered.

3.7.3 For Swage Bulkheads on All Vessels *(1 July 2020)*

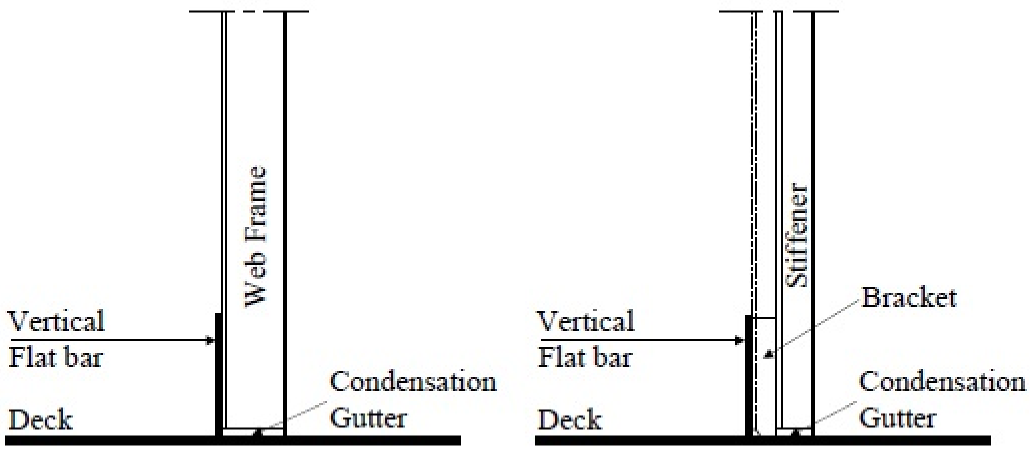
The upper and lower edges of swage panels are to be continuously welded to the deck plating. The flat plating of swage panels is to be aligned with deck girders, deck transverses, or bulkheads. The bottom ends of swages of all lowest tier bulkheads and the 2nd tier unprotected front bulkhead are to be adequately supported by underdeck stiffeners, brackets, or carlings to prevent stress concentrations.

Special attention is to be paid to connections between horizontal deck stiffeners, deck girders, or deck transverses and swage panels in order to enable effective load transfer and to minimize stress concentrations.

Large cutouts for doors, windows, pipes, and ventilation ducts are not to be positioned directly across the swages. Appropriate carlings are to be fitted at the edges of such cutouts in order to enable effective load transfer to the adjacent structure of the bulkhead.

The scantlings of swage panels having other types of end connections are to be specially considered.

FIGURE 2
Lower Ends of Deckhouse Stiffeners



3.9 Deck Steps *(1 July 2022)*

The vertical part of steps in exposed forecastle decks is to have plating of not less thickness than required for unprotected front bulkheads or aft bulkheads as applicable. The sizes of stiffeners are to be assessed on the basis of the length of the vessel, the actual height of the deck step and the arrangement of the structure.

3.11 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 1
Values of a

Bulkhead Location	*SI Units and MKS Units*	*US Units*
Unprotected front, lowest tier	$2.0 + L/120$	$2.0 + L/393.6$
Unprotected front, 2^{nd} tier	$1.0 + L/120$	$1.0 + L/393.6$
Unprotected front, 3rd tier	$0.5 + L/150$	$0.5 + L/492$
Protected front, all tiers	$0.5 + L/150$	$0.5 + L/492$
Sides, all tiers	$0.5 + L/150$	$0.5 + L/492$
Aft ends, aft of amidships, all tiers	$0.7 + (L/1000) - 0.8x/L$	$0.7 + (L/3280) - 0.8x/L$
Aft ends, forward of amidships, all tiers	$0.5 + (L/1000) - 0.4x/L$	$0.5 + (L/3280) - 0.4x/L$

TABLE 2
Values of f

Intermediate values of f may be obtained by interpolation

SI and MKS Units	
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

US Units	
L, ft	f, ft
79	4.09
130	8.34
200	13.6
250	17.0
295	19.8
300	20.1
350	22.9
400	25.5
450	27.9
500	30.1
550	31.5
600	32.6
650	33.6
700	34.4
750	35.0
800	35.5
850	35.8
900	36.1
984 and greater	36.2

Note: The above table is based on the following equations:

L	f
SI Units and MKS Units	
$L \leq 150$ 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
US Units	
$L \leq 492$ ft	$(L/10)(e^{-L/984}) - [3.28 - (L/272)^2]$
$492 < L < 984$ ft	$(L/10)(e^{-L/984})$
$L \geq 984$ ft	36.2

5 Enclosed Superstructures and Deckhouses

5.1 Openings in Bulkheads

All openings in the exposed bulkheads of enclosed superstructures and deckhouses 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 when closed the whole structure is equivalent in strength to the unpierced bulkhead.

5.3 Doors for Access Openings *(2022)*

Doors for access openings into enclosed superstructures and deckhouses are to be made either of steel, aluminum or fiber reinforced plastic (if in compliance with statutory regulations and operational requirements) and are to be permanently attached to the bulkhead. Scantlings for door panels and stiffeners or swages are to be obtained from 3-2-11/3.3 & 3.5 or 3-2-11/3.6 based on the design head of the bulkhead where the door is located. Minimum thickness requirements in 3-2-11/3.3 or 3-2-11/3.6 for exposed bulkheads are to be applied to panels of doors located on exposed bulkheads of superstructure and deckhouses at and below Position 2 and to doors located on the exposed front bulkhead at all levels. The doors are to be provided with gaskets and clamping devices, or other equivalent arrangements and the doors are to be so arranged that they can be operated from both sides of the bulkhead. Doors located above Position 2 (refer to 3-2-15/3.1) of superstructure and deckhouses are to have strength compatible to adjacent bulkheads and may be of joiner-type construction, e.g. thin gauge steel sheeting surrounding a mineral wool core, provided they are verified to be weathertight to the satisfaction of the attending Surveyor.

Superstructure and deckhouse doors located above Position 2 and located 18 m (60 ft) or higher above the deepest waterline may be accepted based on the following conditions:

i) Doors are to be capable of withstanding a wind speed of 100 knots (51.5 m/s), and

ii) The weathertightness test and securing arrangements of doors are to be to the satisfaction of the attending Surveyor.

Provided the above requirements are met, the specified minimum head pressure and thickness requirements of 3-2-11/3 may be omitted.

In the case that the superstructure/deckhouse exposed doors above Position 2 but located less than 18 m above the deepest waterline are not weathertight nor have strength compatible with adjacent bulkheads, these doors are to be considered as openings through which the progressive downflooding takes place in the damage stability calculation. If the door provides access to or protects against downflooding to a space that is considered buoyant in the stability calculations the door is to be considered a downflooding point as indicated. This will be determined on a case-by-case basis.

Marine doors rated for the same design head as the bulkhead where they are located and which are designed and built to industry standards (the current versions of ASTM F1069, JIS F 2318, and BSI Standards BSMA 39) are considered acceptable as meeting requirements in this Section

Doors are to open outwards and those in side bulkheads are to be hinged on the forward side.

5.3.1 Aluminum Doors

Aluminum doors are to have scantlings in accordance with 3-2-11/10.1. The ends of all stiffeners are to be attached to the door edge stiffeners

5.5 Sills of Access Openings *(2022)*

Except as otherwise provided in these Rules, the height of the sills of access openings in external bulkheads of enclosed superstructures and deckhouses located on and below Position 2 is to be at least 380 mm (15 in.) above the deck.

For companionway sills see 3-2-15/21.7.

5.5.1 For Vessels Under 90 Meters (295 Feet) in Length *(2022)*

For vessels under 90 meters (295 feet) in length, the height of the sills of access openings in external bulkheads of enclosed superstructures and deckhouses is to be as follows:

Position 1	*Position 2*
For vessels equal to or over 24 meters (79 feet) and under 90 meters (295 feet) in length	
380 mm (15 in.)	380 mm (15 in.)
For vessels under 24 meters (79 feet) in length [1,2]	
380 mm (15 in.)	300 mm (12 in.)

Notes:

1 Sill heights may be reduced on vessels which have freeboard in excess of the minimum geometric freeboard and/or a superstructure deck with height of deck in excess of the standard height of a superstructure.

2 For vessels with L < 24 m (79 ft), the sill height should be as indicated above, unless otherwise specifically requested by flag Administration.

5.7 Portlights

Portlights in the end bulkheads of enclosed superstructures and deckhouses are to be of substantial construction and provided with efficient inside deadlights. Also see 3-2-17/7.

5.9 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.

7 Open Superstructures

Superstructures and deckhouses with openings which do not fully comply with 3-2-11/5, are to be considered as open superstructures.

9 Forecastle Structures

Vessels subject to wave impact load over the forecastle, the following requirements are to be complied with:

i) Exposed 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.

ii) Beams and girders are to be arranged, where practicable, to limit the spans to about 3 m (10 ft).

iii) 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.

iv) Pillars are to be provided as required by 3-2-8/3.1 except that generally the diameter of pillars is not to be less than 200 mm (8 in.) for vessels possibly subjected to green water on the deck.

10 Aluminum Superstructures and Deckhouses

10.1 Scantlings

Where deckhouses are constructed of aluminum alloys, the required plate thickness and stiffener section modulus, SM, are first to be determined as required for mild steel superstructures and deckhouses, and are then to be increased by the material factor, $(235/Y_{aw})^{0.50}$ or $235/Y_{aw}$, as indicated below.

For all deck and bulkhead plating and stiffeners, the required thickness and section modulus for aluminum alloy plate and shapes are obtained from the following equations:

- Plating:

  $t_{al} = t_s(Y_s/Y_{aw})^{0.50}$ mm (in.)

- Stiffeners:

  $SM_{al} = Y_s/Y_{aw}SMs$ cm^3 (in^3)

where

t_{al}	=	minimum thickness of aluminum plate
t_s	=	required plate thickness for steel obtained from 3-2-11/1.3 and 3-2-11/3
SM_{al}	=	minimum section modulus of aluminum stiffeners
SM_s	=	minimum section modulus of steel stiffeners, as determined from 3-2-7/3 and 3-2-8/5 for deck stiffeners and 3-2-11/3.5 for bulkhead stiffeners
Y_s	=	235 N/mm^2 (24 kgf/mm^2, 34,000 lbs/in^2)
Y_{aw}	=	minimum yield strength of the welded aluminum alloy under consideration at 0.20% offset in a 254 mm (10 in.) gauge length, in N/mm^2 (kgf/mm^2, lbs/in^2), obtained from 3-2-9/9.3.3(a) TABLE 2

In addition, the aluminum stiffeners are to have a depth not less than that given below:

$d_{al} = 3SM_s \quad d_s/SM_{al}$

where

d_{al}	=	minimum required depth for aluminum stiffeners
d_s	=	minimum required depth for steel stiffeners; not to be less than 100 mm (3.94 in.) depth for fronts and 80 mm (3.15 in.) for sides and ends

10.3 Attachments *(2022)*

Stiffeners on bulkheads are to be attached to the deck plating at their upper and lower ends by welding all around and are not to be sniped. Suitable means (such as transition joints) are to be taken to avoid direct contact of faying surfaces of aluminum to steel.

11 Helicopter Decks

11.1 General

Helicopter decks, where provided, are to meet the following structural and safety requirements. Attention is to be paid to various international and governmental regulations and guides regarding the operational and design requirements for helicopters landing on ships. See also Section 1-1-5 the ABS *Rules for Conditions of Classification (Part 1)* and 4-6-4/3.9.2 and 4-6-6/9 of these Rules.

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 anticipated to use the facility is to be specified and calculations for appropriate loading conditions are to be submitted.

11.3 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 3-2-11/11.3 TABLE 3. Plastic design considerations may be applied for deck plating and stiffeners.

Scantlings of helicopter decks and supporting structures are to be such that the resulting stress in members does not exceed:

Y/F_s

where

Y = specified minimum yield point or yield strength of the material

F_s = factor of safety, as given in 3-2-11/11.3 TABLE 3

11.3.1 Overall Distributed Loading

A minimum distributed loading of 2.01 kN/m^2 (205 kgf/m^2, 42 lbf/ft^2) is to be taken over the entire helicopter deck.

11.3.2 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 (1 ft × 1 ft). 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.

11.3.3 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 (50 kgf/m^2, 10.5 lbf/ft^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.

11.3.4 Loading due to Motions of Vessel:

The structure supporting helicopter decks is to withstand the loads resulting from the motions of the vessel.

11.3.5 Special Landing Gear:

Helicopters fitted with landing gear other than wheels will be specially considered.

11.3.6 Environmental Loading

Calculations are to consider anticipated wind and wave impact loading on helicopter decks and their supporting structures.

11.3.7 Bolted Connections

Where bolted connections are used, calculations are to be carried out in accordance with a recognized standard and submitted for review. Metallic isolation arrangement is to be provided where galvanic potential exists between different materials. The degree of fixity of structural components incorporating bolted connections is to be properly considered in the helideck structural assessment. Where fully fixed connection is considered, the bolted connection is to be designed with enough stiffness to account for the full transfer of moment and prevent relative rotation of the structural components.

TABLE 3
Allowable Factors of Safety Based on Y For Helicopter Decks

Y = specified minimum yield point or yield strength of the material as defined in 2-1-1/13 of the ABS *Rules for Materials and Welding (Part 2)*

	Plating	*Beams*	*Girders, Stanchions, Truss Supports, etc. (See Note 3)*
Overall Distributed Loading	1.67	1.67	1.67
Helicopter Landing Impact Loading	*(See Note 1)* *1.00* [(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*		Beam spacing	*t*
460 mm	4.0 mm		18 in.	0.16 in.
610 mm	5.0 mm		24 in.	0.20 in.
760 mm	6.0 mm		30 in.	0.24 in.

2 Alternatively, ultimate state limit methods may be considered.

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.

4 The minimum plate thickness for materials other than steel will be specially considered.

11.5 Safety Net

The unprotected perimeter of the helicopter landing deck is to be provided with safety netting or equivalent.

11.7 Material

In general, the construction of helicopter decks is to be of steel or another material with an equivalent ability to retain structural capacity in a fire. If the helicopter deck forms the deck head of a deckhouse or superstructure, it is to be insulated to A-60 class standard. Flag concurrence is required to satisfy SOLAS Ch. II-2/18 for the aluminum construction of a helicopter deck.

Where aluminum decks are used for helicopter decks above superstructures or deckhouses, the following arrangement is considered to have the equivalent fire integrity to steel, when tested in accordance with the listed below fire test.

In addition, in order for the arrangement to be considered to have equivalent fire integrity to steel helideck, an aluminum helicopter deck which is located 1m (3.25 ft) or less above superstructure or deckhouses, a water spray system in accordance with 4-7-2/5.3.7 giving coverage to aluminum structure underneath the helicopter deck is to be provided.

11.7.1 Fire Test Procedures *(2022)*

i) Size of prototype helicopter deck is 7.6 m × 7.6 m (24.9 ft × 24.9 ft) with structural equivalence to the final product arrangement.

ii) If an aluminum gutter is incorporated in the test, the aluminum gutter should be placed at least on one side of the sample helideck panel.

iii) Testing of the helicopter deck with the proposed sealant should be done without any topcoats or painting on the helicopter deck surface.

iv) The static loads simulating actual helicopter weight are to be present on the helicopter deck.

v) An initial 284 liters (75 gallons) of fuel is to be poured over the helicopter deck area to a set fuel depth of 4-6 mm (0.16-0.24 in.). For the first 15 minutes, fuel is to be supplied at a rate of 147.6 liters per minute (39 gallons per minute) such that the deck is filled with fuel for the full 15 minutes. The depth of the fuel pool is to be limited to 4-6 mm (0.16-0.24 in.). After the first 15 minutes, no additional fuel is supplied, and the fire is allowed to burn until all fuel on the helicopter deck is consumed.

11.7.2 Fire Test Acceptance

The acceptance criteria are as follows (visual observations of the deck and sealing):

i) The helideck panel shall not collapse or be deformed between girders.

ii) The helideck panel support girders shall not collapse or be deformed.

iii) No fuel leakage shall occur in panel joints.

iv) No flames below deck or burn-through shall occur.

v) If an aluminum gutter is incorporated, no damage to the gutter is to be observed.

11.7.3 Other Arrangements of Helideck

If the aluminum helicopter deck does not meet the requirements of 3-2-11/11.7.1 and 3-2-11/11.7.2, and where the flag Administration has no specific requirements, the following conditions are to be satisfied:

i) There are to be no openings in the superstructure or deckhouse top directly below the helicopter deck.

ii) There are to be no openings in the exterior bulkheads directly below the helicopter decks.

iii) All windows/portlights in the exterior bulkheads directly below the helicopter decks are to be fitted with steel shutters.

iv) The helicopter deck is to be insulated to A-0 class if it is located 1m (3.25 ft) or less above the top of the superstructure or deckhouse top.

v) The superstructure or deckhouse top and exterior bulkhead, including penetrations, except windows/portlights, is to be constructed as A-0 class divisions.

11.9 Arrangements

The following requirements are apply to helicopter decks on offshore support vessels.

11.9.1 Size *(1 July 2020)*

In general, the helicopter deck is to be of sufficient size to contain a circle of a diameter equal to at least the rotor diameter D of the largest helicopter intended to use the facility. The helicopter deck is to have an approach/departure sector of at least 210° free of obstructions, as shown in 3-2-11/11.9.6 FIGURE 3. Objects the function of which requires that they be located on the helideck within approach/ departure sector should be limited to landing nets (where required) and certain lighting system and should not exceed the surface of the landing area by more than 0.025 m. For single main rotor helicopters, within 150° limited obstacle sector out to a distance of $0.12D$, measured from the point of origin of the limited obstacle sector, objects should not exceed a height of 0.25 m above deck. Beyond that arc, out to a distance of an additional $0.21D$, the maximum obstacle height is limited to a gradient of one unit vertically for each two units horizontally originating at a height of $0.05D$ above the level of the helideck (see 3-2-11/11.9.6 FIGURE 3)

For benign climates as determined by the coastal State, taking into account of the type of helicopter used, the conditions of wind, turbulence, sea state, water temperature and icing conditions, the helicopter deck is to be of sufficient size to contain a circle of a diameter not less than $0.83D$. The helicopter deck is to have an approach/departure sector of at least 210° free of obstructions, as shown in 3-2-11/11.9.6 FIGURE 4. Objects the function of which requires that they be located on the helideck within approach/departure sector should be limited to landing nets (where required) and certain lighting system and should not exceed the surface of the landing area by more than 0.025 m. For single main rotor helicopters, within $0.415D$ to $0.5D$ objects should not exceed a height of 0.025 m. Within 150° limited obstacle sector out to a distance of $0.12D$, measured from the point of origin of the limited obstacle sector, objects should not exceed a height of 0.05m above deck. Beyond that arc, out to a distance of an additional $0.21D$, the maximum obstacle height is limited to a gradient of one unit vertically for each two units horizontally originating at a height of $0.05D$ above the level of the helideck (see 3-2-11/11.9.6 FIGURE 4).

11.9.2 Surface

The helicopter deck is to have a skid-resistant surface.

11.9.3 Grating Type Construction

Where the helicopter deck is constructed in the form of grating, the under deck should be such that the ground effect is maintained.

11.9.4 Drainage

The helicopter deck is to have drainage facilities to prevent the collection of liquids and prevent liquids from spreading to or falling on other parts of the vessel.

11.9.5 Projections

The helicopter deck is to be free of projections except that landing lights or other essential projections may be installed around the periphery of the deck provided they do not rise more than 150 mm (6 in.) above the level of the helicopter deck.

11.9.6 Tie Downs

The helicopter deck is to have recessed tie-down points for securing a helicopter.

FIGURE 3
Helideck Obstacle Limitation Sector: Single Main Rotor Helicopter

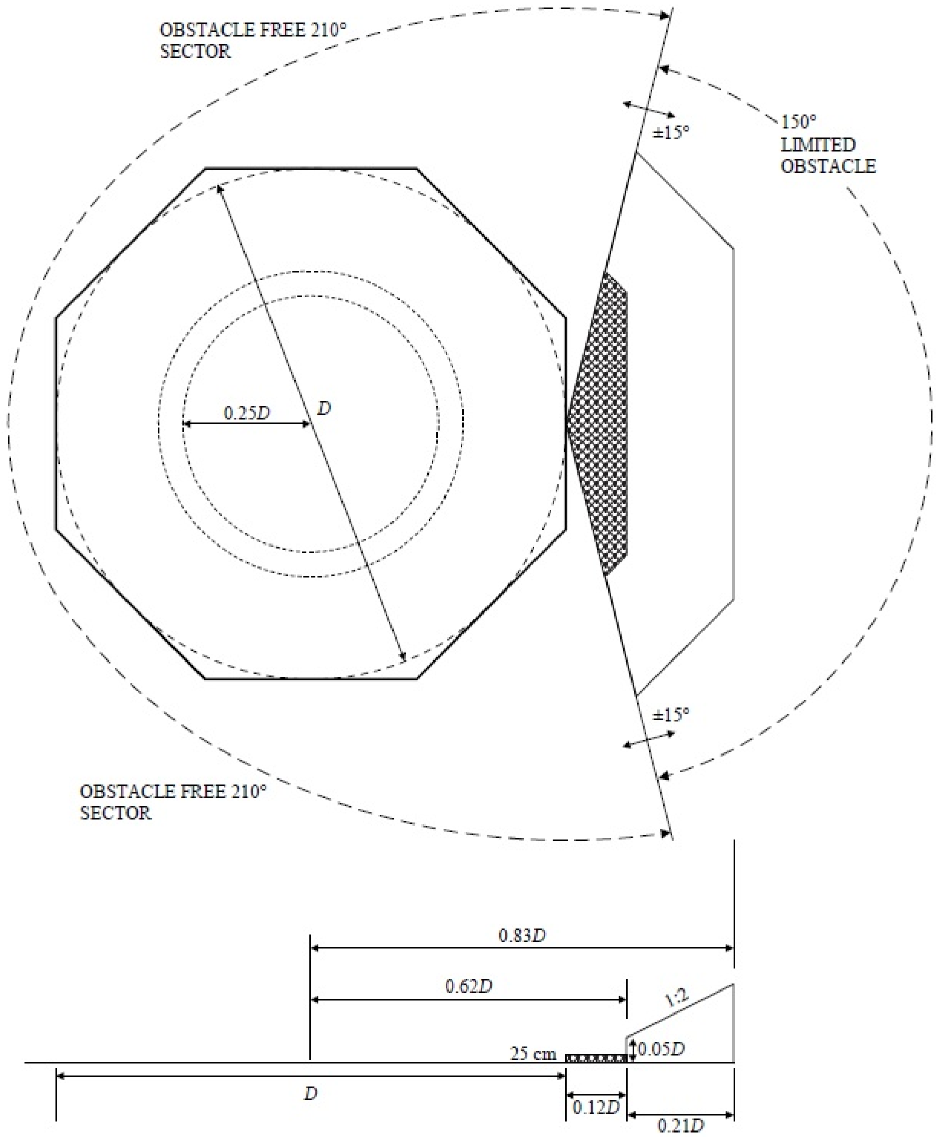
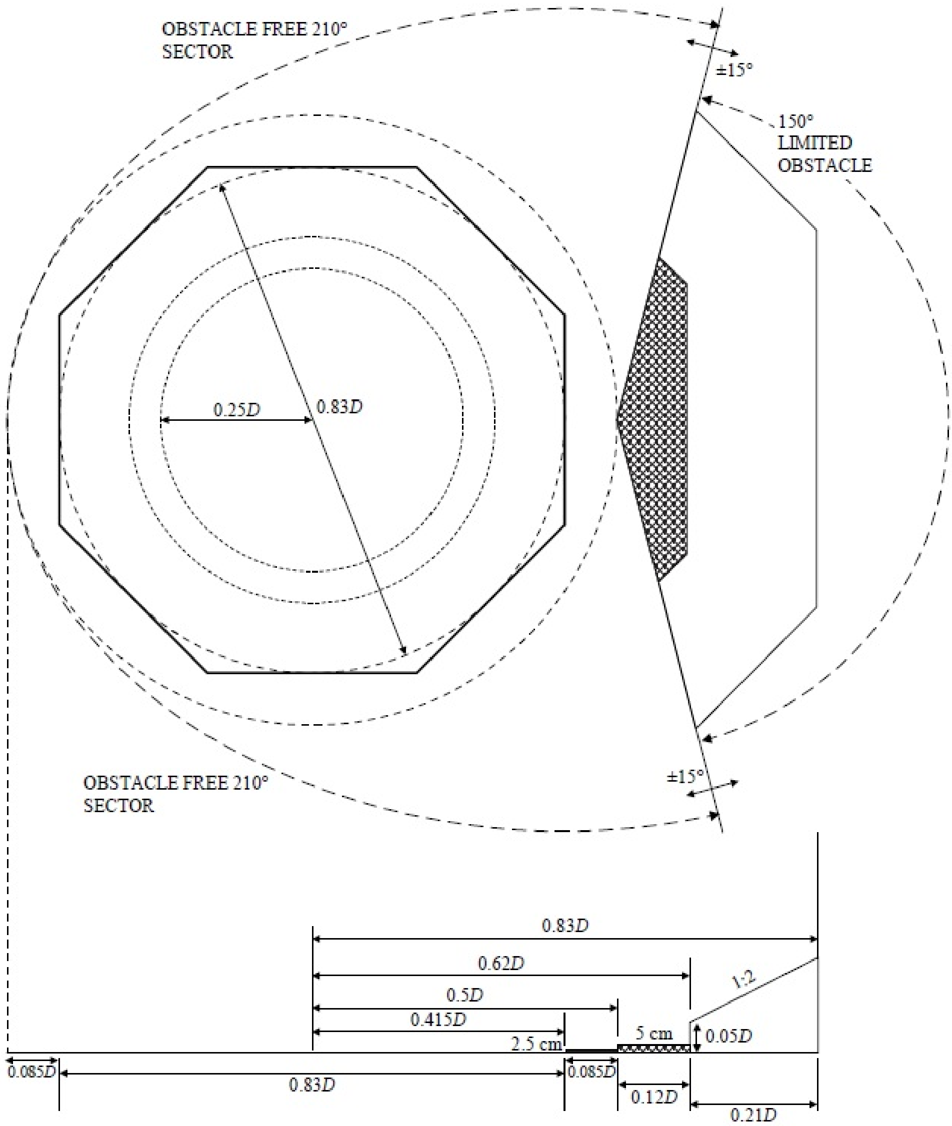


FIGURE 4
Helideck Obstacle Limitation Sector: Single Main Rotor Helicopter for Benign Climate Conditions as Accepted by the Coastal State



Note: Heights of 2.5 cm and 5 cm high shaded areas are not to scale.

11.11 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.

Aluminum access/egress platforms and stairways leading to and from the aluminum helideck are acceptable, provided the following conditions are satisfied:

i) Conditions in 3-2-11/11.7 are complied with.

ii) Acceptance from the flag Administration.

iii) The firefighting equipment, which includes the hose reel, portable fire extinguishers, fixed foam system, is to provide coverage for the access/egress platforms and stairways. The capacity of the fixed foam system is to be increased to include the additional areas of protection for the aluminum access/egress platforms and stairways

iv) Where the helideck is also used as a firefighting station, the aluminum access/egress platforms and stairways are to meet the L3 fire integrity test, or equivalent as per 3-4-A1/9 TABLE 1.

v) Where alternative means of fire protection (such as deluge system) are provided (typically along stairways or access under the helideck), and the arrangement and locations of the firefighting equipment, required in *i*) above are also available at or cover the access/egress route, the L3 performance test will not be necessary.

vi) Where the helideck is fitted with a refueling station, there is to be sufficient distance from the refueling station to at least one of the stairs, such that the aluminum stairs are not impacted by the fire at the refueling station.

In case of a fire outside the helideck area, access platforms and stairways are not to be considered part of an escape route.

11.13 Safety

11.13.1 Safety Net

For personnel protection, a safety net is to be provided around the periphery of the helicopter deck, except where structural protection exists. The net should be inclined upwards at an angle of 10° and outwards from below the edge of the helideck to a horizontal distance of 1.5 m and should not rise above the edge of the deck.

11.13.2 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.

11.13.3 Visual Aids

Coastal States may have specific requirements that must be incorporated into the design. Where the Coastal State has no requirements, the following are to be complied with:

A wind direction indicator located in an unobstructed area readily visible to helicopters approaching the helicopter deck is to be provided.

11.13.4 Markings

The helicopter deck is to be marked (see 3-2-11/11.9.6 FIGURE 3) in a contrasting color as follows:

i) The perimeter with a continuous line of 300 mm (11.811 in.) in width

ii) Vessel identification

iii) Aiming circles, taking into account deck configuration, helicopter type and operational requirements

iv) A white "**H**" 4 m high, 3 m wide, with a stroke width of 0.75 m. located at the center of the landing area

11.13.5 Lights

Each helicopter deck is to be fitted with green lights visible omni-directionally from on or above the landing area. These lights should be equally spaced at intervals of not more than 3 m (9'-10") around the perimeter of the deck.

Helicopter deck floodlights, where fitted, should be located so as to avoid glare to pilots. The arrangement and aiming of floodlights should be such that helicopter deck markings are illuminated and that shadows are kept to a minimum.

PART 3

CHAPTER 2
Hull Structures and Arrangements

SECTION 12
Machinery Space and Tunnel

1 General

1.1 Arrangement *(2019)*

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.

i) All parts of the machinery, shafting, etc., are to be efficiently supported and the adjacent structure is to be adequately stiffened.

ii) In twin-screw vessels it is necessary to make additions to the strength of the structure and the area of attachments, in proportion to the weight, power and dimensions of the machinery, especially where engines are relatively high in proportion to the width of the bed plate.

iii) 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. It is determined that the foundations for main propulsion units, reduction gears, shaft and thrust bearings, and the structure supporting those foundations are adequate in strength and rigidity, to maintain required alignment under all anticipated conditions of loading.

iv) 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. (See 4-3-2/7).

1.3 Testing of Tunnels

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

3 Machinery Foundations

3.1 Engine Foundations

3.1.1 Single Bottom Vessels

In vessels with single bottoms, the engines are to be seated on thick plates laid across the top of deep floors or upon heavy foundation girders efficiently bracketed and stiffened. Intercostal plates are to be fitted between the floors beneath the lines of bolting to distribute the weight effectively through the bottom structure to the shell. Seat plates are to be of thickness and width appropriate to the holding-down bolts and are to be effectively attached to girders and intercostals.

3.1.2 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.

3.3 Boiler Foundations *(1 July 2020)*

Boilers, if provided, 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 (refer to 3-2-4/5). Boilers are to be installed such as to provide accessibility and proper ventilation being clear of tank tops, bunker walls, etc., as required by 4-4-1/19.3. The thickness of adjacent material is to be increased where the clear space is unavoidably sparse. The available clearance is to be indicated on the plans submitted for approval.

3.5 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.

3.7 Shaft Bearing and Auxiliary Machinery Foundations

Foundations of the shaft bearings are to be strong, stiff and integrated into surrounding structure. Auxiliary machinery foundations are to be proportioned to the weight supported.

5 Tunnels and Tunnel Recesses

5.1 Plating *(2019)*

The plating of flat sides of shaft or other watertight tunnels is to be of the thickness as obtained from 3-2-9/5.1 for watertight bulkheads; but the lowest strake of the plating is to be increased 1 mm (0.04 in.). 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 (0.08 in.). Where the top of the tunnel or recess forms a part of a deck the thickness is to be less than required for the plating of watertight bulkheads at the same level plus 1 mm (0.04 in.) nor less than would be required for the deck plating in the same location. Curved plating may be of the thickness required for watertight bulkhead plating at the same level in association using stiffener spacing of 150 mm (6 in.) less than actually adopted. Crown plating in way of hatches is to be increased at least 2.5 mm (0.10 in.) or is to be protected by wood sheathing of not less than 50 mm (2 in.) thick.

5.3 Stiffeners

Stiffeners are not to be spaced more than 915 mm (36 in.) 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:

$$SM = 4.42 \quad hs\ell^2 \text{ cm}^3$$

$$SM = 0.0023 \quad hs\ell^2 \text{ in}^3$$

where

h = distance, in m (ft), from the middle of ℓ to the bulkhead deck at center

s = spacing of stiffeners, in m (ft)

ℓ = distance, in m (ft), 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.

5.5 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.

5.7 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:

$$t = 0.1345 \quad dh + 9 \text{ mm}$$

$$t = 0.000492 \quad dh + 0.36 \text{ in.}$$

where

d = diameter of the tunnel, in m (ft)

h = distance, in m (ft), 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 3-1-1/7.1, above the baseline
- a point located two-thirds of the test head above the top of the tank

PART 3

CHAPTER 2
Hull Structures and Arrangements

SECTION 13
Stems, Stern Frames, Rudder Horns, and Propeller Nozzles

1 Stems

Depending on size and design of the vessel stems may be made of bent and welded steel plates, of formed cast or forged steel, or of steel bar.

1.1 Plate Stems *(2019)*

Plate stems, where used, are not to be less in thickness than required by the following equations, in the draft change zone (between the minimum draft and the maximum draft).

t	=	$1.5 + (L/12)\sqrt{q}$ mm	$L \leq 245$ m
t	=	$1.5 + 20.5\sqrt{q}$ mm	$245 < L \leq 305$ m
t	=	$0.06 + (L/1000)\sqrt{q}$ in.	$L \leq 800$ ft
t	=	$0.06 + 0.80\sqrt{q}$ in.	$800 < L \leq 1000$ ft

where

q = $235/Y$ N/mm^2 ($24/Y$ kgf/mm^2, $34000/Y$ psi)

Y = specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2,psi), as defined in 2-1-1/13 of the ABS *Rules for Materials and Welding (Part 2)*, for the higher-strength material or 72% of the specified minimum tensile strength, whichever is the lesser.

Above and below the draft change zone, 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.

1.3 Cast or Forged Stems

Cast or forged stems of special shape are to be proportioned to provide strength at least equivalent to that of a plate stem, and all joints and connections are to be at least that effective.

1.5 Bar Stems

In general the thickness of the bar stem should also not be less than twice the adjoining shell thickness. Bar stems are to have thickness and width not less than obtained from the following equations:

$t = 0.625L + 6.35$ mm

$t = 0.0075L + 0.25$ in.

$w = 1.25L + 90$ mm

$w = 0.015L + 3.5$ in.

where

t	=	thickness, in mm (in.)
w	=	width, in mm (in.)
L	=	length of vessel, in m (ft), as defined in 3-1-1/3.1

This thickness and width is to be maintained between the keel and scantling draft line. Above the scantling draft line they may be gradually reduced until the section area at the head is 0.7 of that obtained from the above equations.

Thicknesses and widths other than given above are acceptable, provided the section moduli and moments of inertia about the longitudinal axis are not less than calculated from above, nor is proportion of *w/t* more than 5.5.

3 Stern Frames

Stern frames may be fabricated from steel plates or made of cast steel. For applicable material specifications and steel grades, see 3-1-2/1.3.1 and 3-1-2/3.3 TABLE 2A. The scantlings are to comply with 3-2-13/3.3 and 3-2-13/3.5. Stern frames of other material or construction will be specially considered.

3.1 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 (refer to 3-2-14/13.1). The thickness of the pintle housing is not to be less than 25% of the pintle diameter.

3.3 Scantlings Below the Propeller Boss

Except as modified in 3-2-13/3.5, the scantlings of stern frames of single screw vessels are to be in accordance with the following, as applicable:

3.3.1 Fabricated Stern Frame

The thickness t, width w and $tw^2\sqrt{1+(2\ell/w)^2}$ respectively for fabricated stern frames are to be not less than those given by the following equations:

$t = 0.225\sqrt{L}$ cm		$t = \sqrt{L}/20.5$ in.	
$w = 5\sqrt{L}$ cm	$L < 81$ m	$w = 1.09\sqrt{L}$ in.	$L < 265$ ft
$w = 45$ cm	$L \geq 81$ m	$w = 17.7$ in.	$L \geq 265$ ft

$$SM = tw^2\sqrt{1+(2\ell/w)^2}/6 = C_f L^{1.5}$$

where

t = thickness of side plating, in cm (in.) (See 3-2-13/3.3.1 FIGURE 1)

w = width of stern frame, in cm (in.) (See 3-2-13/3.3.1 FIGURE 1)

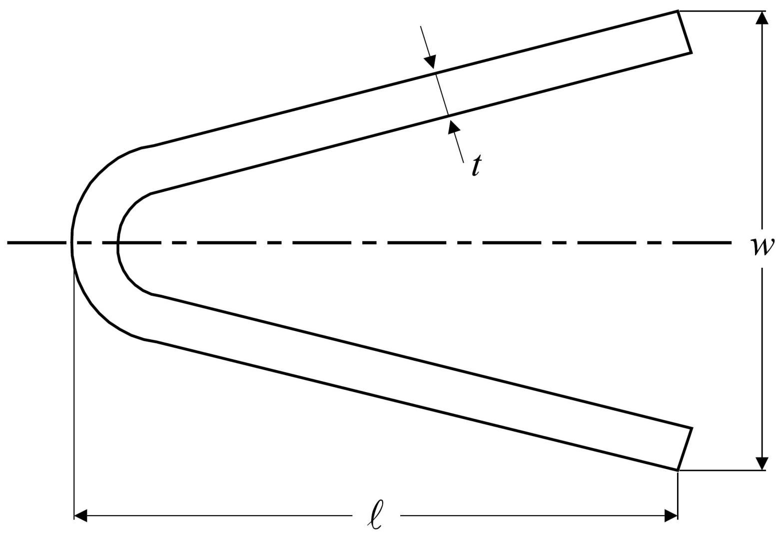
ℓ = length of stern frame, in cm (in.) (See 3-2-13/3.3.1 FIGURE 1)

L = length of vessel, in m (ft), as defined in 3-1-1/3.1

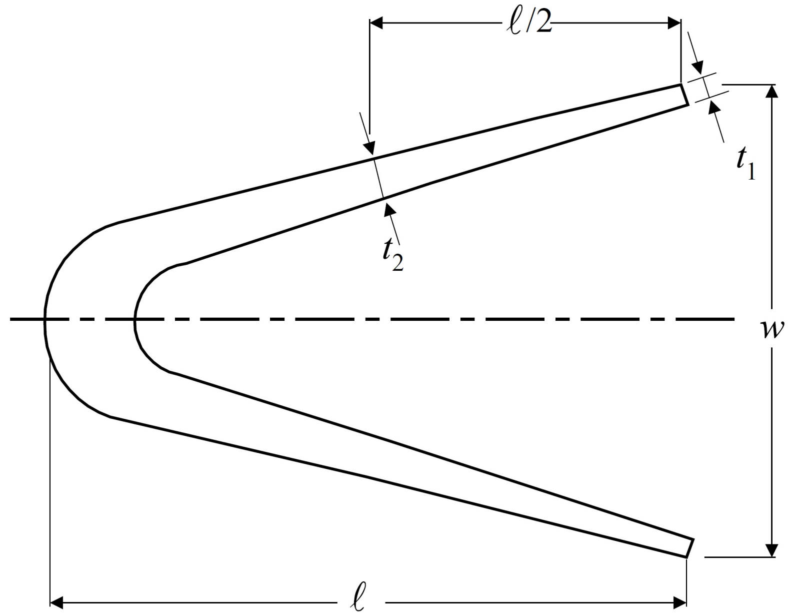
SM = section modulus about the longitudinal axis, in cm^3 (in^3)

C_f = 1.6 (1.6, 0.0164)

FIGURE 1
Stern Frame



a Fabricated



b Cast

3.3.2 Cast Stern Frame

The thicknesses t_1, t_2 and $\frac{(t_1+t_2)}{2} w^2 \sqrt{1+(2\ell/w)^2}$ 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

$t_1 = \sqrt{L}/15.3$ in. but not less than 1.0 in.

$t_2 = 1.25t_1$

$w = 5\sqrt{L}$ cm $L < 81$ m $w = 1.09\sqrt{L}$ in. $L < 265$ ft

$w = 45$ cm $L \geq 81$ m $w = 17.7$ in. $L \geq 265$ ft

$$SM = \frac{1}{24}(3t_1 + 5t_2)w^2\sqrt{1 + (2\ell/w)^2} = C_c L^{1.5} \quad Kg$$

where

w, ℓ, L = as defined in 3-2-13/3.3.1

t_1 = thickness of casting at end (See 3-2-13/3.3.1 FIGURE 1)

t_2 = thickness of casting at mid-length (See 3-2-13/3.3.1 FIGURE 1)

C_c = 1.6 (1.6, 0.0164)

K_g = q^e, cast or forged stern frame material factor

q = $235/Y$ N/mm^2 ($24/Y$ kgf/mm^2, $34000/Y$ lbs/in^2)

Y = specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, lbs/in^2) as defined in 2-1-1/13 of the ABS *Rules for Materials and Welding (Part 2)* for the higher-strength material, but is not to be taken as greater than $0.7U$ or 450 N/mm^2 (46 kgf/mm^2, 65000 lbs/in^2), whichever is lesser

U = minimum tensile strength of material used, in N/mm^2 (kgf/mm^2, lbs/in^2)

e = 1.0 for $Y \leq 235$ N/mm^2 (24 kgf/mm^2, 34000 lbs/in^2)

= 0.75 for $Y > 235$ N/mm^2 (24 kgf/mm^2, 34000 lbs/in^2)

The thickness in way of butt welding to the 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. In way of changes in section a smooth curvature or radii are to be provided.

3.3.3 Bar Sternposts

Bar sternposts without propeller bosses are to have thicknesses and widths not less than that obtained from the following equations:

$t = 0.73L + 10$ mm

$t = 0.0088L + 0.39$ in.

$b = 1.283L + 87.4$ mm

$b = 0.0154L + 3.44$ in.

where

t = thickness, in mm (in.)

b = width, in mm (in.)

L = length of vessel, in m (ft), as defined in 3-1-1/3.1

Above the bottom shell plating, sternposts may be gradually reduced until the areas at their heads are half the areas obtained from the above equations.

Thickness or width less than given above are acceptable, provided the section modulus and moment of inertia about the longitudinal axis are not less than those of a plate having the minimum thickness and width given above, and with b/t not more than 4.0.

3.5 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.

3.7 Scantlings Above the Propeller Boss

Above the propeller boss, the scantlings are to be in accordance with 3-2-13/3.3 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 0.8 of the requirements in 3-2-13/3.3, subject to the same minimum for a cast steel stern frame.

3.9 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 0.8 t or 0.8 t_1 are to be provided at suitable intervals. Where t or t_1 is reduced in accordance with 3-2-13/3.7, a proportionate reduction in the thickness of ribs or horizontal brackets may be made.

3.11 Shoe Pieces

The shoe-piece is to be sloped to avoid pressure from the keel blocks when docking and is to extend at least two frame spaces forward of the forward edge of the propeller boss.

The equivalent stress σ_e in the shoe piece at any section is not to exceed $115/K_g$ N/mm^2 ($11.7/K_g$ kgf/mm^2, $16700/K_g$ psi) and is to be obtained from the following equation:

$$\sigma_e = n\sqrt{\sigma_b^2 + 3\tau^2} \text{ N/mm}^2\text{(kgf/mm}^2\text{, lbs/in}^2\text{)(psi)}$$

where

n = 1000 (1000, 2240)

K_g = shoe-piece material factor as defined in 3-2-14/1.3

σ_b = bending stress = $0.5C_R\ell/Z_v$

C_R = rudder force, as defined in 3-2-14/3

ℓ = horizontal distance between centerline of rudder stock and the section of the stern frame shoe piece in way of the aft edge of the propeller boss, in m (in.) (see 3-2-13/3.11 FIGURE 2)

Z_v = section modulus of shoe piece about the vertical axis at the particular section under consideration, in cm^3 (in^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^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 = $k_zC_R\ell K_g$ cm^3 (in^3)

Z_y = $0.5Z_z$ cm^3 (in^3)

A_s = $k_aC_RK_g$ mm^2 (in^2)

where

Z_z = minimum required section modulus of shoe piece about the vertical axis at the particular section under consideration

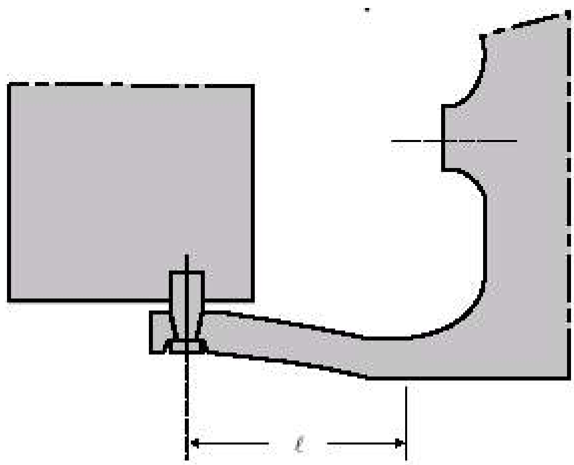
Z_y = minimum required section modulus of shoe piece about the transverse horizontal axis at the particular section under consideration

A_s = effective shear area in the transverse direction at the section of the shoe piece under consideration, in mm^2 (in^2)

k_z = 6.25 (61.3, 0.0967)

k_a = 10.4 (102, 0.161)

FIGURE 2
Shoe Piece



5 Rudder Horns

5.1 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 (12.2/K_h kgf/mm^2, 17400/K_h lbs/in^2) where σ_e is obtained from the following equation:

$\sigma_e = n\sqrt{\sigma_b^2 + 3\left(\tau^2 + \tau_T^2\right)}$ N/mm^2 (kgf/mm^2, lbs/in^2)

where

n	=	1000 (1000, 2240)
σ_b	=	bending stress = $C_R\ell_a\ell_v/(\ell_p SM)$
τ	=	shear stress due to bending = $C_R\ell_a/(\ell_p A_h)$
τ_T	=	shear stress due to torque = $0.5C_R\ell_a\ell_h/(\ell_p at)$
C_R	=	rudder force, as defined in 3-2-14/3
ℓ_a	=	vertical distance, in m (ft), from the center of the neck bearing to the centroid of A (see 3-2-13/5 FIGURE 3a)
ℓ_p	=	vertical distance, in m (ft), from the center of the neck bearing to the center of the pintle bearing (see 3-2-13/5 FIGURE 3a)
ℓ_v	=	vertical distance, in m (in.), from the center of the pintle bearing to the section of the rudder horn being considered (see 3-2-13/5 FIGURE 3a)
ℓ_h	=	horizontal distance in, mm (in.), 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 3-2-13/5 FIGURE 3a)
SM	=	section modulus of the rudder horn about the longitudinal axis, in cm^3 (in^3), 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 (in^2)
a	=	area, in mm^2 (in^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 (in.), at the section being considered
K_h	=	rudder horn material factor as defined in 3-2-14/1.3
K_h	=	K as defined in 3-2-14/1.3 for castings and forgings
	=	1.0 for ordinary strength hull steel plate
	=	Q as defined in 3-2-1/5.3 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.

$\tau = 48/K_h$ N/mm^2 (4.9/K_h kgf/mm^2, 6960/K_h lbs/in^2)

Also, the section modulus about the longitudinal horizontal axis is not to be less than given in the following equation:

$SM = n_z C_R(\ell_a/\ell_p)\ell_v K_h$ cm^3 (in^3)

n_z = 14.9 (146.4, 0.230)

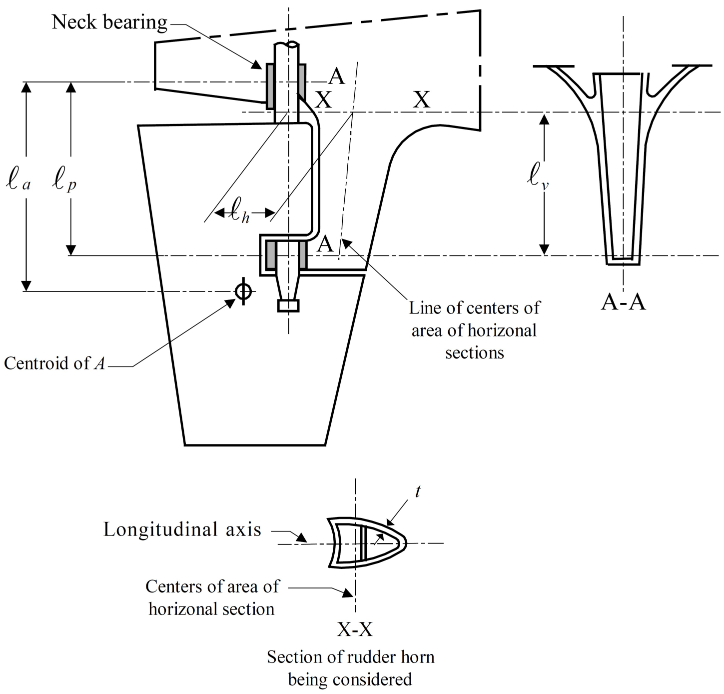
Webs extending down into the horn as far as practicable are to be fitted and effectively connected to the plate floors in the after peak. At the shell, the change in section of the horn is to be as gradual as possible. Smooth curvature or radii are to be provided at abrupt changes of section where stress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

5.3 Scantlings - Two Pintle Rudders

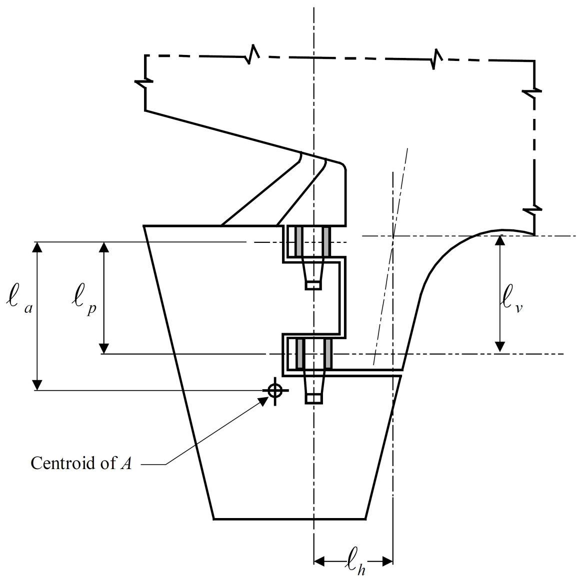
The strength of the rudder horn is to meet the requirements for single pintle horns given in 3-2-13/5.1 above, with the following modified definitions of lever arm and component stresses.

ℓ_a	=	vertical distance, in m (ft), from the center of the upper pintle to the centroid of *A* (see 3-2-13/5 FIGURE 3b)	
ℓ_p	=	vertical distance, in m (ft), from the center of the upper pintle bearing to the center of the lower pintle bearing (see 3-2-13/5 FIGURE 3b)	
ℓ_v	=	vertical distance, in m (in.), 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 3-2-13/5 FIGURE 3b)	
ℓ_h	=	horizontal distance, in mm (in.), 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 3-2-13/5 FIGURE 3b)	
σ_b	=	bending stress	
	=	$C_R\ell_a\ell_v/(\ell_p SM)$	between the upper and lower pintle gudgeons
	=	$C_R(\ell_v+\ell_a-\ell_p)/SM$	in SI or MKS units, above the upper pintle gudgeon
	=	$C_R\left[\ell_v+12(\ell_a-\ell_p)\right]/SM$	in U.S. units, above the upper pintle gudgeon
τ	=	shear stress due to bending = $C_R\ell_a/(\ell_p A_h)$ between the upper and lower pintle gudgeons	
	=	C_R/A_h above the upper gudgeon	
τ_T	=	shear stress due to torque =$0.5C_R\ell_a\ell_h/(\ell_p at)$ between the upper and lower pintle gudgeons	
	=	$0.5C_R\ell_h/(at)$ above the upper gudgeon	

FIGURE 3
Rudder Horn

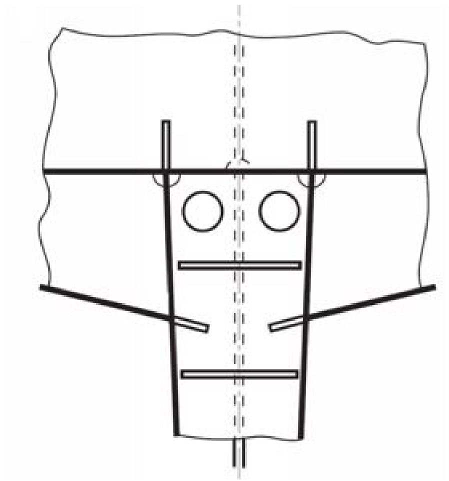


a) Single Pintle



b) Two Pintles

FIGURE 4
Connection of Rudder Horn to Aft Ship Structure



5.5 Rudder Horn Plating

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

$t = 2.4\sqrt{LK}$ mm

$t = 0.522\sqrt{LK}$ in.

Where

L	=	length of vessel, as defined in 3-1-1/3.1;
k	=	K as defined in 3-2-14/1.3 for castings
	=	1.0 for ordinary strength hull steel plate
	=	Q as defined in 3-2-1/5.3 for higher strength steel plate

5.7 Welding and Connection to Hull Structure

The following requirements are to apply:

i) The rudder horn plating is to be effectively connected to the aft ship structure (e.g., by connecting the plating to side shell and transverse/longitudinal girders) in order to achieve a proper transmission of forces, see 3-2-13/5 FIGURE 4. When the connection between the rudder horn and the hull structure is designed as a curved transition into the hull plating, special consideration should be given to the effectiveness of the rudder horn plate in bending and to the stresses in the transverse web plates

ii) Where the rudder horn does not have curved transitions into the shell plating, brackets or stringer are to be fitted internally in horn, in line with outside shell plate, as shown in 3-2-13/5 FIGURE 4.

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

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

v) Where a centerline bulkhead (wash-bulkhead) is fitted in the after peak, it is to be connected to the rudder horn.

vi) Scallops are to be avoided in way of the connection between shell plating and transverse webs in line with the aft face of the rudder horn and the webs in the rudder horn

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

5.9 Floors

Heavy plate floors are to be fitted both in way of the after face of the horn and aligned with the webs required by 3-2-13/5.1 and 3-2-13/5.3. They are to be carried up to the first deck or flat above, if possible.

5.11 Shell Plating

Heavy shell plates are to be fitted in way of the heavy plate floors required by 3-2-13/5.9. Above the heavy floors, the heavy shell plates may be gradually reduced in thickness.

5.13 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.

7 Shaft Struts

Tail-shaft (propeller-shaft) struts, where provided, may be of the V or I type. The thickness of the strut barrel or boss is to be at least one-fourth the diameter of the tail shaft. The length of the strut barrel or boss is to be adequate to accommodate the required length of propeller-end bearings. The following equations are for struts having streamlined cross-sectional shapes.

7.1 V Strut

The moment of inertia, I, and Section Modulus, SM, of each strut arm is not to be less than that obtained from the following equations:

$$I = 0.0044d^4 \text{ mm}^4 \text{ (in}^4\text{)}$$

$$SM = 0.024d^3 \text{ mm}^3 \text{ (in}^3\text{)}$$

where

d = required diameter of ABS Grade 2 tail shaft, in mm (in.)

Where the included angle is less than 45°, the foregoing scantlings are to be specially considered.

7.3 I Strut

The moment of inertia, I, and Section Modulus, SM, of the strut arm is not to be less than that obtained from the following equations:

$$I = 0.018d^4 \text{ mm}^4 \text{ (in}^4\text{)}$$

$$SM = 0.068d^3 \text{ mm}^3 \text{ (in}^3\text{)}$$

where

d = required diameter of ABS Grade 2 tail shaft, in mm (in.)

7.5 Strut Length

The length of the longer leg of a V strut or the leg of an I strut, measured from the outside perimeter of the strut barrel or boss to the outside of the shell plating, is not to exceed 10.6 times the diameter of the tail shaft. Where this length is exceeded, the width and thickness of the strut are to be increased, and the strut design will be given special consideration.

9 Propeller Nozzles

The requirements in this Subsection are applicable for propeller nozzles with inner diameter d of 5 meters (16.4 feet) or less. Nozzles of larger inner diameter are subject to special consideration, with all supporting documents and calculations to be submitted for review.

9.1 Design Pressure

The design pressure of the nozzle is to be obtained from the following:

$$p_d = 10^{-6} \cdot c \cdot \varepsilon \cdot \left(\frac{N}{A_p}\right) \quad \mathrm{N/mm^2 (kgf/mm^2, lbs/in^2)(psi)}$$

where

c = coefficient as indicated in 3-2-13/9.1 TABLE 1

ε = coefficient as indicated in 3-2-13/9 TABLE 2, but not to be taken less than 10

N = maximum shaft power, in kW (hp)

A_p = propeller disc area

= $D^2\frac{\pi}{4}$, in m^2 (ft^2)

D = propeller diameter, in m (ft)

TABLE 1
Coefficient c

Propeller Zone (see 3-2-13/5 FIGURE 4)	c		
	p_d in N/mm²	*p_d in kgf/mm²*	*p_d in lbs/in²*
2	10.0	1.02	11620
1 & 3	5.0	0.51	5810
4	3.5	0.36	4067

TABLE 2
Coefficient ε

	p_d in N/mm²	*p_d in kgf/mm²*	*p_d in lbs/in²*
ε	$21 - 0.02\left(\frac{N}{A_p}\right)$	$21 - 0.02\left(\frac{N}{A_p}\right)$	$21 - 0.16\left(\frac{N}{A_p}\right)$

9.3 Nozzle Cylinder

9.3.1 Shell Plate Thickness

The thickness of the nozzle shell plating, in mm (in.), is not to be less than:

$t = t_o + t_c$, but not to be taken less than 7.5 (0.3) mm (in.)

where

t_o = thickness obtained from the following formula:

= $c_n \cdot S_p \cdot \sqrt{P_d} \;\; K_n$ mm (in.)

c_n = coefficient as indicated in 3-2-13/9.3 TABLE 3

S_p = spacing of ring webs, in mm (in.)

p_d = nozzle design pressure in N/mm^2 (kgf/mm^2, psi), as defined in 3-2-13/5.3

t_c = corrosion allowance determined by 3-2-13/9.3 TABLE 4

K_n = nozzle material factor as defined in 3-2-14/1.3

TABLE 3
Coefficient c_n

	p_d in N/mm^2	*p_d in kgf/mm^2*	*p_d in lbs/in ^{2}*
c_n	0.158	0.495	0.0132

TABLE 4
Corrosion allowance t_c

Value of t_o	*t_c mm (in.)*		
If $t_o \le 10.0(0.4)$	1.5 (0.06)		
If $t_o > 10.0(0.4)$	the lesser of b_1, b_2		
where			
$b_1 = 3.0 \quad (0.12)$	mm (in.)		
$b_2 = \left(\frac{t_o}{\sqrt{1/K_n}} + 5\right) \times 10^{-1}$	mm or	$b_2 = \left(\frac{t_o}{\sqrt{1/K_n}} + 0.2\right) \times 10^{-1}$	in.

9.3.2 Internal Diaphragm Thickness

Thickness of nozzle internal ring web is not to be less than the required nozzle shell plating for Zone 3 (see 3-2-13/9.1 TABLE 1 and 3-2-13/9 FIGURE 5 for reference).

9.5 Nozzle Section Modulus

The minimum requirement for nozzle section modulus is obtained from the following formula:

$SM = d^2 b V_d^2 Q n$ cm^3 (in^3)

where

d = nozzle inner diameter, m (ft)

b = nozzle length, m (ft)

V_d = design speed in ahead condition, in knots, as defined in 3-2-14/3.1

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

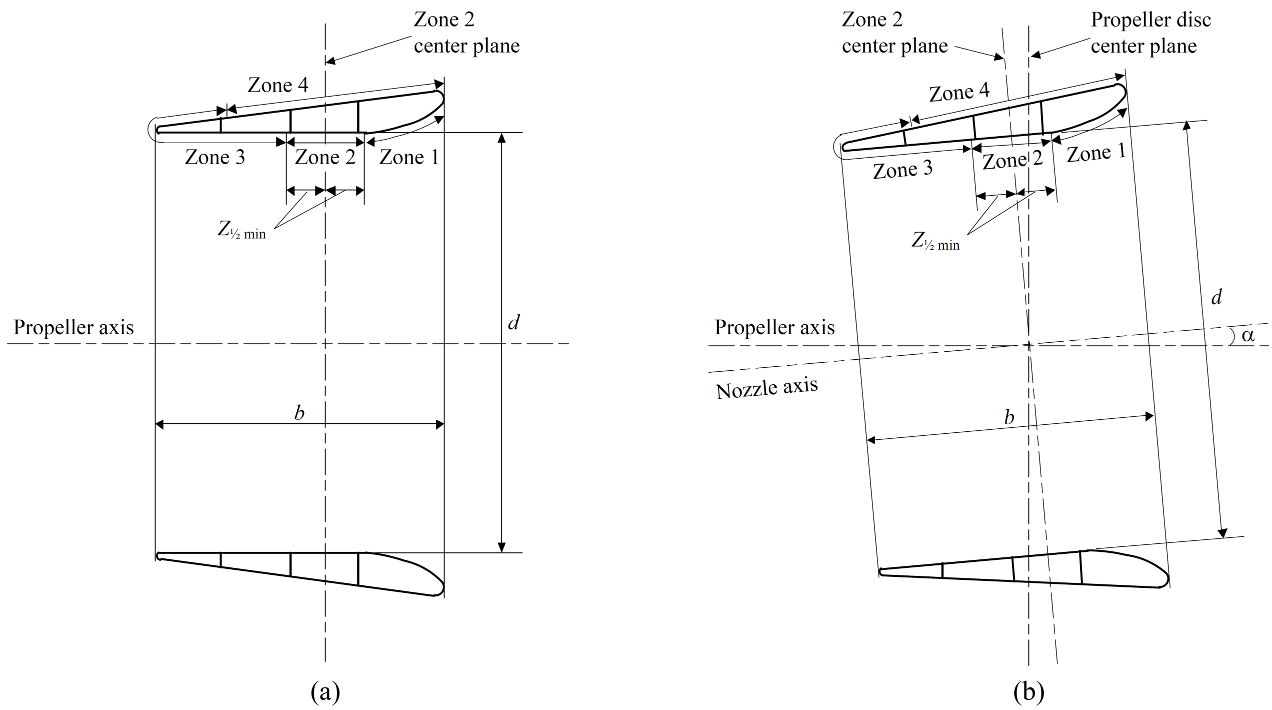
Q factor for steel having yield strength other than above is to be specially considered.

n = nozzle type coefficient

= 0.7 (0.0012) for fixed nozzles

= 1.0 (0.0017) for azimuth nozzles

FIGURE 5
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

$z_{½min}$ = The minimum length on each side of Zone 2 center plane is to be:

= $\frac{b}{8}$ where Zone 2 center plane and propeller disc center plane coincide as shown in 3-2-13/9 FIGURE 5(a);

= $\frac{b}{8}\cos\alpha + \frac{d}{2}\tan\alpha$ where α is the tilt angle between the Zone 2 and propeller disc center planes, as shown in 3-2-13/9 FIGURE 5(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

9.7 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 acceptable for the outer shell plating, provided that the nozzle ring web spacing is not greater than 350 mm (13.8 in.).

11 Propulsion Improvement Devices (PID) as Hull Appendages

11.1 Application Scope

The requirements in this Subsection are applicable for Propulsion Improvement Devices (PID) hull appendages including wake equalizing and flow separation alleviating devices (such as spoilers, wake equalizer, stern tunnels, pre-swirl fins, stators, and pre-swirl ducts) and post swirl devices (such as rudder thrust fins, post swirl stators, and rudder bulbs) that are permanently affixed to the hull structure.

11.3 Plans and Documentation *(2019)*

The following plans and details are to be submitted for approval, while the calculations are to be submitted for reference:

i) Drawings and plans covering the detailed design of the structural components, including the end connections and attachment to the hull structure;

ii) Information on material properties and welding details, such as scantlings of the welded connection and welding detail and size;

iii) Calculations to validate the design of the PID and the supporting foundations interior to the vessel. The calculations are to consider strength, fatigue and vibration, due to hydrodynamic lift and drag loads, in both the ahead and astern conditions. However, depending on the type of PID (such as rudder bulbs, etc.) the calculation may consider the strength only.

11.5 Design and Arrangement

The following requirements are to be complied with for the propulsion improvement as outlined in 3-2-13/11.1; Devices of novel concept are to be specially considered with all the related drawings and documents submitted:

i) The structural materials are to be compatible with the mechanical and chemical properties of the hull strake to which it is attached. Examples of such design considerations are to have adequate structural strength for load bearing/transferring and acceptable galvanic potential between materials to reduce the risk of galvanic corrosion.

ii) PID end connections are to have a suitable transition for the particular application and to be effectively terminated in way of internal stiffening members.

11.7 Structural End Connection

Welded end connections of device structural component to the hull are to be designed and constructed in accordance with the following:

i) Welding at the connection is to be full penetration and is to be in accordance with 2-4-1 of the ABS *Rules for Materials and Welding (Part 2)* and Section 3-2-19, as applicable

ii) Nondestructive volumetric and surface examinations are to be performed on the welds of the connection plates and the shell penetration. 100% Magnetic Testing (MT) and at least 10% Ultrasonic Testing (UT) is to be carried out on the welds of the connection plates and the shell penetration.

13 Inspection of Castings *(2021)*

The location of radiographic or other subsurface inspections of large stern-frame and rudder-horn castings is to be in accordance with 2-1-5/13.11 and Appendix 2-A6 and indicated on inspection plans, and to be agreed with the attending Surveyor. See applicable parts of Chapter 1 of the ABS *Rules for Materials and Welding (Part 2)*.

PART 3

CHAPTER 2
Hull Structures and Arrangements

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 3-2-14/3 TABLE 1A with rudder operating angle range from –35° to +35°.

ii) High-lift rudders described in 3-2-14/3 TABLE 1B, the rudder operating angle of which might be exceeding 35° on each side at maximum design speed.

iii) Other steering equipment other than rudders identified in this Section;

Rudders not covered in 3-2-14/3 TABLE 1A nor in 3-2-14/3 TABLE 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. Where direct analyses adopted to justify an alternative design are to take into consideration all relevant modes of failure, on a case by case basis. These failure modes may include, amongst others: yielding, fatigue, buckling and fracture. Possible damages caused by cavitation are also to be considered. Validation by laboratory tests or full scale tests may be required for alternative design approaches.

Rudders and other steering equipment provided on Ice Classed vessels are subject to additional requirements specified in 6-1-4/31 or 6-1-5/41 of the ABS *Marine Vessel Rules.*

1.3 Materials for Rudder, Rudder Stock and Steering Equipment

Rudder stocks, pintles, coupling bolts, keys and other steering equipment components described in this Section are to be of steel, in accordance with the requirements of Part 2, Chapter 1, 3-1-2/3.3 TABLE 2A and 3-1-2/3.3 TABLE 2B, and particularly:

i) The Surveyor need not witness material tests for coupling bolts and keys.

ii) The surfaces of rudder stocks in way of exposed bearings are to be of noncorrosive material.

iii) Material properties of dissimilar parts and components in direct contact with each other are to be submitted for review of compatibilities, such as galvanic potential.

iv) 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:

$$K = (n_y/Y)^e$$

where

n_y = 235 N/mm^2 (24 kgf/mm^2, 34000 psi)

Y = specified minimum yield strength of the material, in N/mm^2 (kgf/mm^2, psi), but is not to be taken as greater than $0.7U$ or 450 N/mm^2 (46 kgf/mm^2, 65000 psi) whichever is less

U = minimum tensile strength of material used, in N/mm^2 (kgf/mm^2, psi)

e = 1.0 for $Y \leq 235$ N/mm^2 (24 kgf/mm^2, 34000 psi)

= 0.75 for $Y > 235$ N/mm^2 (24 kgf/mm^2, 34000 psi)

1.5 Expected Torque

The torque considered necessary to operate the rudder, in accordance with 4-3-4/21.7.ii) is to be indicated on the submitted rudder or steering gear plan (see 4-3-4/1.11).

Note that the expected operating torque is not the design torque for rudder scantlings. The design torque is intended for the design of rudders and should not be directly compared with the torque expected during the sea trials or the rated torque of steering gear (see 4-3-4/1.11).

1.7 Rudders Stops

Structural rudder stops are to be fitted. Each structural stop as well as its attachment is to withstand rudder design force applied at stop's location. Where adequate positive mechanical stops are provided within the steering gear in accordance with 4-3-4/5.11, structural stops will not be required.

3 Rudder Design Force *(2022)*

Rudder force, C_R, upon which rudder scantlings are to be based, is to be obtained from equation described either in 3-2-14/3.1 or 3-2-14/3.3 as applicable. For vessels under 90 meters (295 feet) in length, where for ordinary rudders the rudder angle, φ, exceeds 35°, the rudder force, C_R, is to be increased by a factor of 1.74 sin (φ).

3.1 Rudder Blades without Cutouts *(2022)*

Where the rudder profile can be defined by a single quadrilateral, the rudder force, C_R, upon which rudder scantlings are to be based, is to be obtained from the following equation:

$$C_R = nk_Rk_ck_\ell AV_R^2 \text{ kN (tf, Ltf)}$$

where

n = 0.132 (0.0135, 0.00123)

k_R = $(b^2/A_t + 2)/3$ but not taken more than 1.33

b = mean height of rudder area, in m (ft), as determined from 3-2-14/3 FIGURE 1A

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 (ft^2)

A = total projected area of rudder blade, as illustrated in 3-2-14/3 FIGURE 1A in m^2 (ft^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 (profile type) as indicated in 3-2-14/3 TABLE 1A and 3-2-14/3 TABLE 1B. For profile types differing from those in 3-2-14/3 TABLE 1A and 3-2-14/3 TABLE 1B, k_c is subject to special consideration.

k_ℓ = coefficient as specified in 3-2-14/5 TABLE 2

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

$V_{\min}$ = $(V_d + 20)/3$

Where there are any appendages such as rudder bulb fitted on the rudder, its effective areas are to be included in the area of the rudder blade if significant.

3.3 Rudder 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 3-2-14/7.5 FIGURE 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.

The total rudder force described in 3-2-14/3.1 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:

$C_{R1} = C_R A_1/A$ kN (tf, Ltf)

$C_{R2} = C_R A_2/A$ kN (tf, Ltf)

where

C_R and A are as defined in 3-2-14/3.1.

A_1 and A_2 are as described in 3-2-14/3 FIGURE 1B.

3.5 Rudders Blades with Twisted Leading-edge

This kind of rudder has the leading edge twisted horizontally on the top and bottom of the section that is an extension of the center of the propeller shaft. For the purpose of calculating design force, twisted rudders may be distinguished in four categories:

Category	*Description*
1	The projected leading edge of twisted upper and lower blades not lineup to each other
2	The projected leading edge of twisted upper and lower blades form a straight line

Category	*Description*
3	Rudder with twisted leading-edge combined with tail edge flap or fins
4	The twisted leading edge has a smooth continuous wavy contour (no deflector) or the rudder has multiple section profile types

Design force for rudder with twisted leading edge is obtained according to the following criteria:

i) For Category 1 rudders as indicated in the above table, design force over upper and lower rudder blades are obtained from the following equations respectively:

$C_{R1} = nk_R k_c k_\ell A_1 V_R^2$ kN (tf, Ltf) for twisted upper rudder blade;

$C_{R2} = nk_R k_c k_\ell A_2 V_R^2$ kN (tf, Ltf) for twisted lower rudder blade;

$C_R = C_{R1} + C_{R2}$ kN (tf, Ltf) overall design force;

ii) For Categories 2, 3, and 4, rudder design force indicated in 3-2-14/3.1 is applicable, that is:

$C_R = nk_R k_c k_\ell A V_R^2$ kN (tf, Ltf)

where

n, k_R, k_c, k_ℓ, A and V_R are as defined in 3-2-14/3.1, (for rudder has multiple section profile types, A is the whole projected areas).

A_1 and A_2 are the projected areas of upper and lower blades separated at the deflector cross section, respectively. Where the effective projected area of rudder bulb (if present) forward of rudder leading edge is significant and needs to be counted, the proportioned bulb effective areas are added to A_1 and A_2 accordingly

Values of k_c for ahead and astern conditions are determined from one of the methods below as applicable, if the type of basic rudder profile is not provided:

a) k_c is taken from 3-2-14/3 TABLE 1A for twisted rudders of Categories 1 & 2;

b) k_c is taken from 3-2-14/3 TABLE 1B for twisted rudders of Category 3;

c) k_c is subjected to special considerations for twisted rudders of Category 4;

d) Shipyard/rudder manufacturers' submitted k_c obtained from testing data or calculations may be accepted subject to ABS review of all the supporting documents;

TABLE 1A
Coefficient k_c for Ordinary Rudders

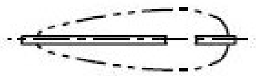
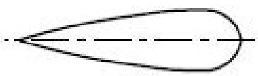
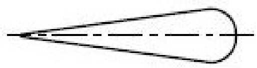
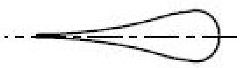
	Profile Type	k_c	
		Ahead Condition	*Astern Condition*
1	Single plate 	1.0	1.0
2	NACA - OO GÖttingen 	1.1	0.80
3	Flat side 	1.1	0.90
4	Mixed (e.g., HSVA) 	1.21	0.90
5	Hollow 	1.35	0.90
6	Twisted rudder of Cat. 1 & 2 	1.21 (if not provided)	0.90 (if not provided)

TABLE 1B
Coefficient k_c for High-lift/Performance Rudders *(2021)*

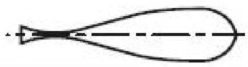
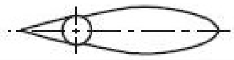
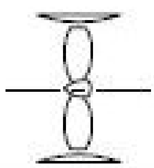
	Profile Type	k_c	
		Ahead Condition	*Astern Condition*
1	Fish tail (e.g., Schilling high-lift rudder) 	1.4	0.8
2	Flap rudder (or Twisted rudder of Cat. 3) 	1.7	1.3
3	Rudder with steering nozzle 	1.9	1.5

FIGURE 1A
Rudder Blade without Cutouts

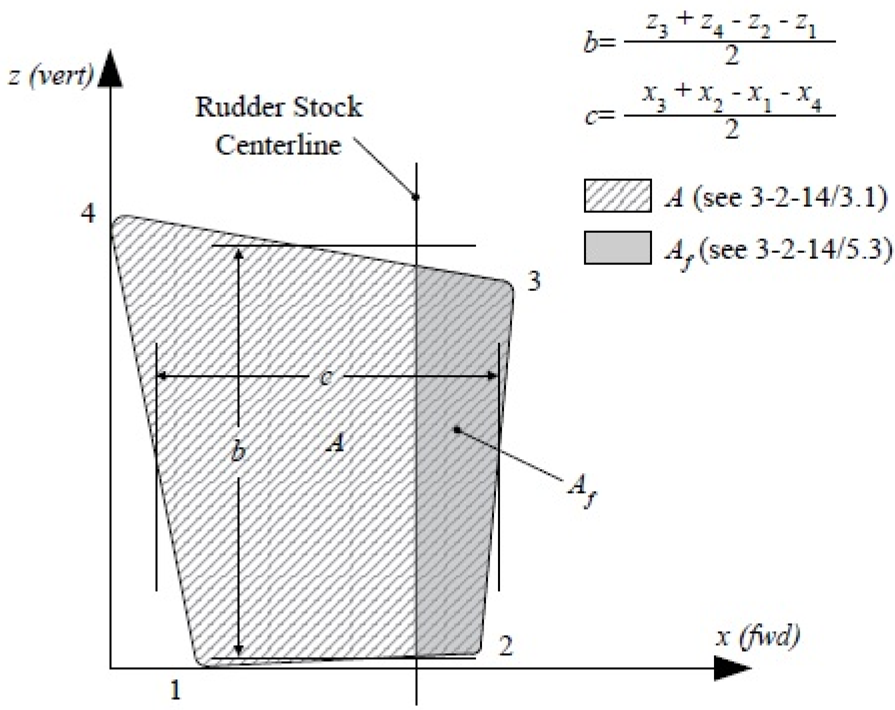
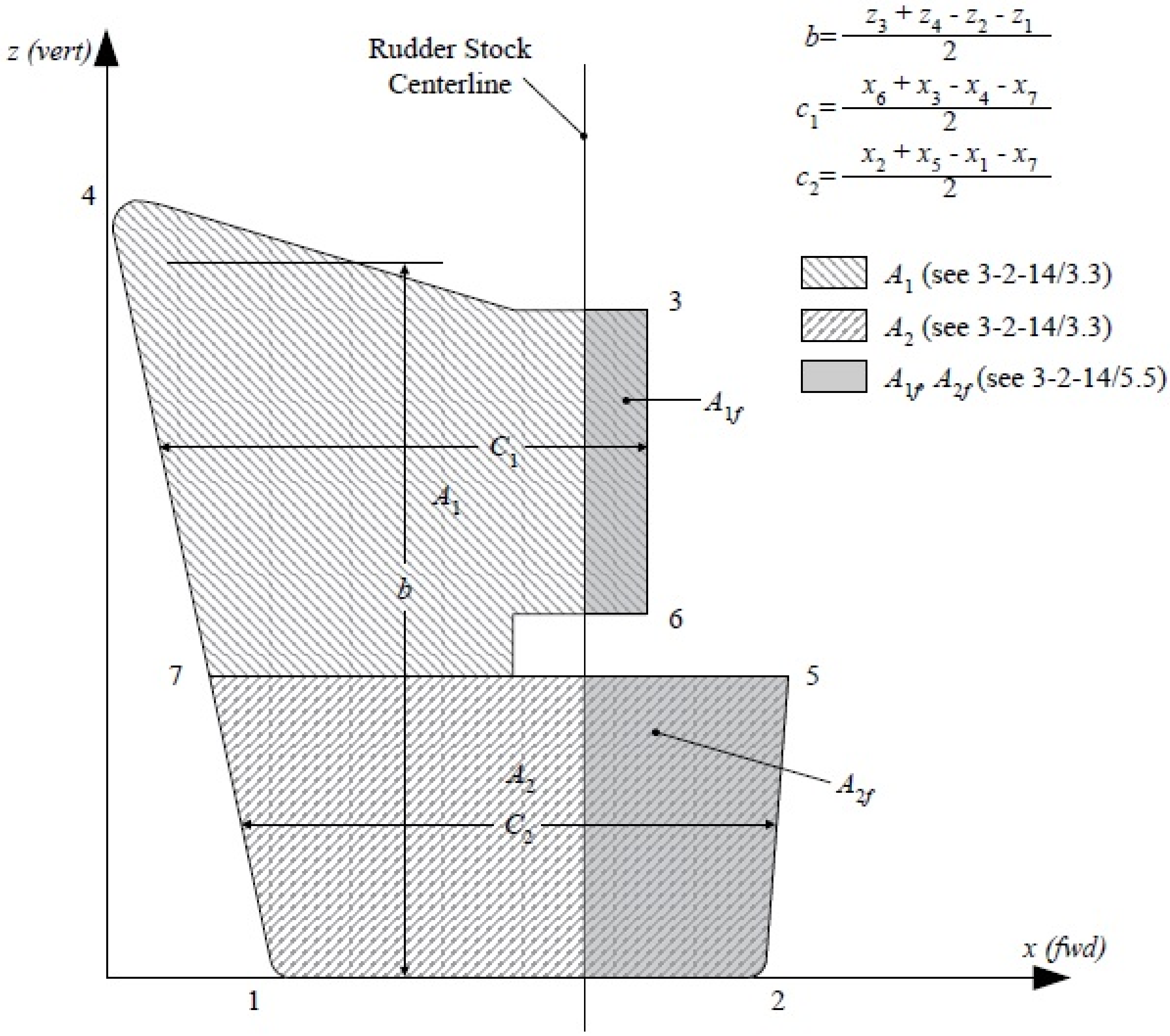


FIGURE 1B
Rudder Blade with Cutouts



5 Rudder Design Torque

5.1 General

The rudder design torque, Q_R, for rudder scantling calculations, is to be in accordance with 3-2-14/5.3 or 3-2-14/5.5 as applicable.

5.3 Rudder Blades 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 (tf-m, Ltf-ft)

where

C_R = rudder force as calculated in 3-2-14/3.1

r = $c(\alpha - k)$ but not less than $0.1c$ for ahead condition

c = mean breadth of rudder area as shown in 3-2-14/3 FIGURE 1A, in m (ft)

α = coefficient as indicated in 3-2-14/5 TABLE 3

k = A_f/A

A_f = area of rudder blade situated forward of the rudder stock centerline, in m^2 (ft^2), as shown in 3-2-14/3 FIGURE 1A

A = whole rudder area as described in 3-2-14/3.1

Where there are any appendages such as rudder bulb fitted on the rudder, effective areas are to be included in the area of the rudder blade if significant.

TABLE 2
Coefficient k_ℓ

Rudder / Propeller Layout	k_ℓ
Rudders outside propeller jet	0.8
Rudders behind a fixed propeller nozzle	1.15
Steerring nozzles and Azimuthing Thrusters	1.15
All others	1.0

TABLE 3
Coefficient α

<table>
<tr><th rowspan="2">Rudder Position or High-lift</th><th colspan="3">α</th></tr>
<tr><th>Ahead Condition</th><th colspan="2">Astern Condition</th></tr>
<tr><td>Located behind a fixed structure, such as a rudder horn</td><td>0.25</td><td colspan="2">0.55</td></tr>
<tr><td>Located where no fixed structure forward of it</td><td>0.33</td><td>0.75
(hollow profile)</td><td>0.66
(non-hollow)</td></tr>
<tr><td>High-Lift Rudders (see 3-2-14/3 TABLE 1B)</td><td>Special consideration
(0.40 if unknown)</td><td colspan="2">Special consideration</td></tr>
</table>

5.5 Rudder Blades with Cutouts

This paragraph refers to rudder blades with cutouts (semi-spade rudders) as defined in 3-2-14/3.3. 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 (tf-m, Ltf-ft)

but not to be taken less than $Q_{R\min}$ in the ahead condition

where

$Q_{R\min}$ = $0.1C_R(A_1c_1 + A_2c_2)/A$

r_1 = $c_1(\alpha - k_1)$ m (ft.)

r_2 = $c_2(\alpha - k_2)$ m (ft.)

c_1, c_2 = mean breadth of partial area A_1, A_2, from 3-2-14/3 FIGURE 1B

α = coefficient as indicated in 3-2-14/5 TABLE 3

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 3-2-14/3 TABLE 1B

$C_R, C_{R1}, C_{R2}, A_1, A_2$ are as defined in 3-2-14/3.3.

5.7 Rudders with Twisted Leading Edge

In general, rudder torque, Q_R, indicated in 3-2-14/5.3 is applicable for rudders with twisted leading edge, where C_R is obtained from 3-2-14/3.5.

5.9 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 3-2-14/1.5) or the rated torque of steering gear (see 4-3-4/1.11).

7 Rudder Stocks

7.1 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:

$$S = N_u \sqrt[3]{Q_R K_s} \text{ mm (in.)}$$

where

N_u = 42.0 (89.9, 2.39)

Q_R = total rudder torque, as defined in 3-2-14/5, in kN-m (tf-m, Ltf-ft)

K_s = material factor for upper rudder stock, as defined in 3-2-14/1.3

7.3 Lower Rudder Stocks

In determining lower rudder stock scantlings, values of rudder design force and torque calculated in 3-2-14/3 and 3-2-14/5 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 Appendix 3-2-A5.

The lower rudder stock diameter is not to be less than obtained from the following equation:

$$S_\ell = S\sqrt[6]{1 + (4/3)(M/Q_R)^2} \text{ mm (in.)}$$

where

S = upper stock required diameter from 3-2-14/7.1, in mm (in.)

M = bending moment at the section of the rudder stock considered, in kN-m (tf-m, Ltf-ft)

Q_R = rudder torque from 3-2-14/5, in kN-m (tf-m, Ltf-ft)

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 /KN/mm^2 (12.0/K kgf/mm^2, 17100/K lbs/in^2).

$\sigma_c = \sqrt{\sigma_b^2 + 3\tau^2}$ N/mm^2 (kgf/mm^2, lbs/in^2)

where

K	=	material factor as defined in 3-2-14/1.3.	
σ_b	=	$10.2 \times 10^6 M/S_\iota^3$	for SI and MKS units
	=	$270 \times 10^3 M/S_\iota^3$	for US units
τ	=	$5.1 \times 10^6 Q_R/S_\iota^3$	for SI and MKS units
	=	$135 \times 10^3 Q_R/S_\iota^3$	for US units

7.5 Rudder Trunk and Rudder Stock Sealing *(1 July 2021)*

The requirements in 3-2-14/7.5 iii), iv) and v) apply to trunk configurations which are extended below the stern frame and arranged in such a way that the trunk is stressed by forces due to rudder action.

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.

iii) *Materials.* The steel used for the rudder trunk is to be of weldable quality, with a carbon content not exceeding 0.23% on ladle analysis or a carbon equivalent (Ceq) not exceeding 0.41%. Plating materials for rudder trunks are in general not to be of lower grades than corresponding to class II as defined in 3-1-2/3.3 TABLE 1. Rudder trunks comprising of materials other than steel are to be specially considered.

iv) *Scantlings.* The scantlings of the trunk are to be such that the equivalent stress due to bending and shear does not exceed $0.35\sigma_F$, and the bending stress on welded rudder trunk is to be in compliance with the following formula:

$\sigma \le 80/k$ N/mm^2

$\sigma \le 8.17/k$ kgf/mm^2

$\sigma \le 11,600/k$ psi

where

σ = bending stress in the rudder trunk

k = K as defined in 3-2-14/1.3 for castings

	=	1.0	for ordinary strength hull steel plate
	=	Q as defined in 3-2-1/5.3	for higher strength steel plate
		k is not to be taken less than 0.7	
σ_F	=	specified minimum yield strength of the material used, in N/mm^2 (kgf/mm^2, psi)	

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

v) *Welding at the Connection to the Hull.* The weld at the connection between the rudder trunk and the shell or the bottom of the skeg is to be full penetration and fillet shoulder is to be applied in way of the weld. The fillet shoulder radius r, in mm (in.) (see 3-2-14/7.5 FIGURE 2) is to be as large as practicable and to comply with the formulae:

$$r = 0.1 S_\ell$$

without being less than:

$$r = 60 \text{ mm when } \sigma \geq 40/k \quad \text{N/mm}^2$$

$$= 60 \text{ mm when } \sigma \geq 4.09/k \quad \text{kgf/mm}^2$$

$$= 2.4 \text{ in. when } \sigma \geq 5800/k \quad \text{psi}$$

$$r = 30 \text{ mm when } \sigma < 40/k \quad \text{N/mm}^2$$

$$= 30 \text{ mm when } \sigma < 4.09/k \quad \text{kgf/mm}^2$$

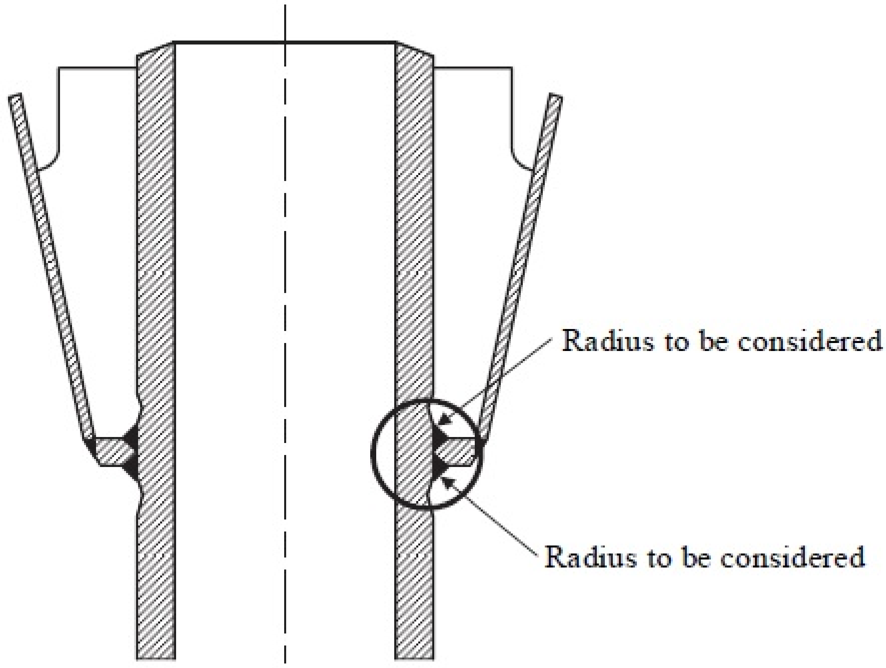
$$= 1.2 \text{ in. when } \sigma < 5800/k \quad \text{psi}$$

where

S_ℓ	=	rudder stock diameter axis defined in 3-2-14/7.3
σ	=	bending stress in the rudder trunk in N/mm^2 (kgf/mm^2, psi)
k	=	material factor as defined in 3-2-14/7.5.iv)

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

FIGURE 2
Fillet Shoulder Radius



9 Flange Couplings

9.1 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. Couplings welded to or joined with rudder stock with use of equivalent method will be subject to special consideration.

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 3-2-14/9.3 (horizontal couplings) or 3-2-14/9.5 (vertical couplings) as applicable.

9.3 Horizontal Couplings

9.3.1 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:

$$d_b = 0.62\sqrt{d_s^3 k_b/(nrK_s)} \text{ mm (in.)}$$

where

d_s = required rudder stock diameter, S (3-2-14/7.1) or S_ℓ (3-2-14/7.3) as applicable, in way of the coupling

n = total number of bolts in the horizontal coupling, but not more than eight (8)

r = mean distance of the bolt axes from the center of the bolt system, in mm (in.), (mathematical average of the bolt axes distances from the axis of the stock)

K_b = material factor for bolts, as defined in 3-2-14/1.3

K_s = material factor for stock, as defined in 3-2-14/1.3

9.3.2 Coupling Flange

Coupling flange thickness is not to be less than the greater of the following equations:

$t_f = d_{bt}\sqrt{K_f/K_b}$ mm (in.)

$t_f = 0.9 d_{bt}$ mm (in.)

where

d_{bt} = calculated bolt diameter calculated as per 3-2-14/9.3.1 based on a number of bolts, but not more than eight (8)

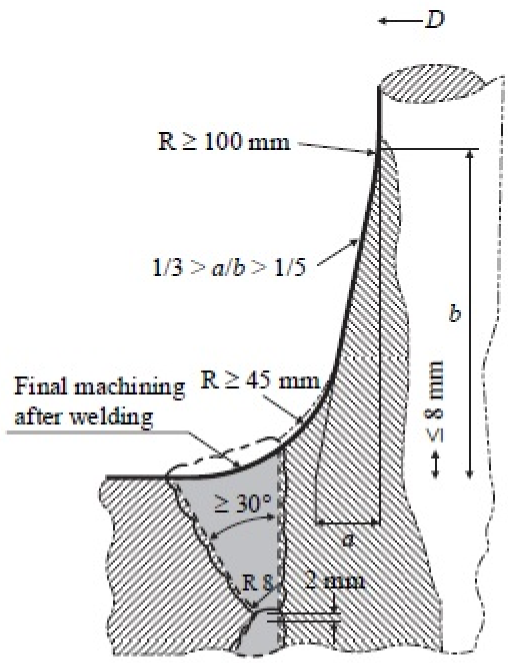
K_f = material factor for flange, as defined in 3-2-14/1.3

K_b = material factor of bolts, as defined in 3-2-14/1.3

9.3.3 Joint between Rudder Stock and Coupling Flange

The welded joint between the rudder stock and the flange is to be made in accordance with 3-2-14/9.3.3 FIGURE 3 or equivalent.

FIGURE 3
Welded Joint Between Rudder Stock and Coupling Flange



9.5 Vertical Couplings

9.5.1 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:

$$d_b = 0.81 d_s \sqrt{K_b/(nK_s)} \text{ mm (in.)}$$

where

n = total number of bolts in the vertical coupling, which is not to be less than 8

d_s, K_b, K_s as defined in 3-2-14/9.3.

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:

$$m = 0.00043 d_s^3 \quad \text{mm}^3 \text{ (in}^3\text{)}$$

where

d_s = diameter, in mm (in.), as defined in 3-2-14/9.3

9.5.2 Coupling Flange

Coupling flange thickness, t_f, is not to be less than d_b as defined in 3-2-14/9.5.1.

9.5.3 Joint between Rudder Stock and Coupling Flange

The welded joint between the rudder stock and the flange is to be made in accordance with 3-2-14/9.3.3 FIGURE 3 or equivalent.

11 Tapered Stock Couplings

11.1 Coupling Taper *(1 July 2021)*

Tapered stock couplings are to comply with the following general requirements in addition to type-specific requirements given in 3-2-14/11.3 or 3-2-14/11.5 as applicable:

i) Tapered stocks, as shown in 3-2-14/11 FIGURE 4, are to be effectively secured to the rudder casting by a nut on the end.

ii) The cone shapes are to fit exactly.

iii) The coupling length (ℓ) in the casting as shown in 3-2-14/11 FIGURE 4A is generally not to be less than 1.5 times the stock diameter (d_o) as shown in 3-2-14/11 FIGURE 4.

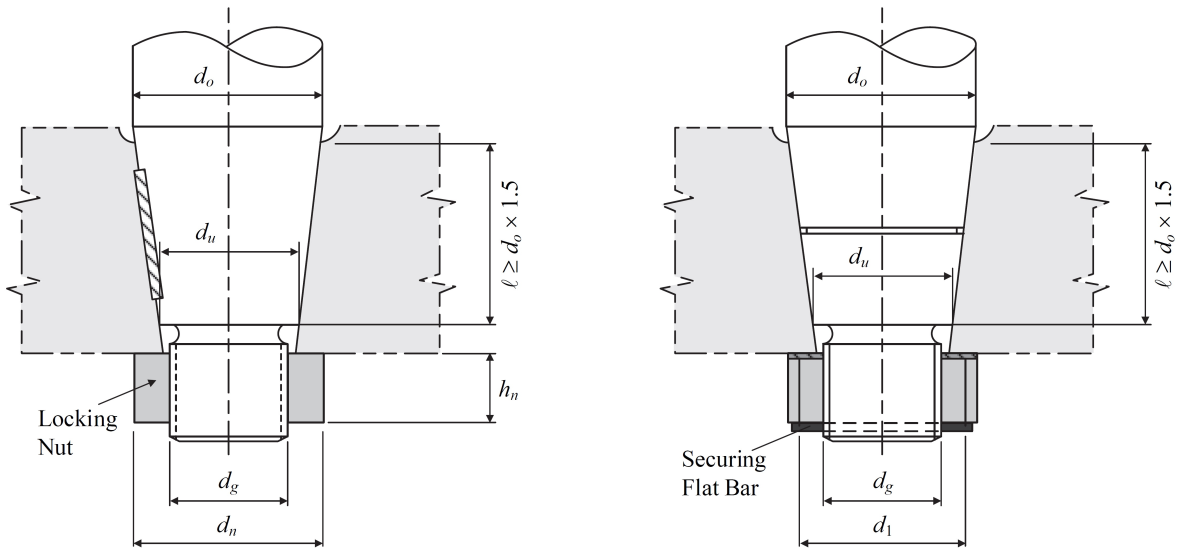
iv) The taper on diameter (c) is to be 1/12 to 1/8 for keyed taper couplings and 1/20 to 1/12 for couplings with hydraulic mounting/dismounting arrangements, as shown in the following table. The cone length (ℓ_c) is defined in 3-2-14/11 FIGURE 4A.

v) 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.

vi) Means of effective sealing are to be provided to protect against sea water ingress.

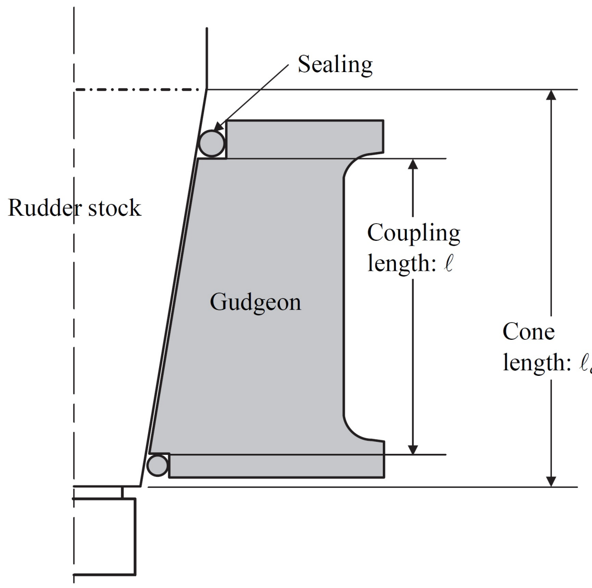
Type of Coupling Assembly	$c = \frac{d_0 - d_u}{\ell_c}$
Without hydraulic mounting/dismounting	$1/12 \le c \le 1/8$
With hydraulic mounting/dismounting	$1/20 \le c \le 1/12$

FIGURE 4
Tapered Couplings *(1 July 2021)*



a) Keyed Fitting b) Keyless Fitting

FIGURE 4A
Cone Length and Coupling Length *(1 July 2021)*



11.3 Keyed Fitting *(1 July 2021)*

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) For the couplings between stock and rudder the shear area* of the key is not to be less than:

$$a_s = \frac{17.55Q_F}{d_k\sigma_{F1}} \quad \text{cm}^2$$

$$a_s = \frac{21.06Q_F}{d_k\sigma_{F1}} \quad \text{in}^2$$

where

Q_F = design yield moment of rudder stock, in N-m (kgf-m, lbf-ft)

= $0.02664\frac{d_t^3}{k}$ N-m

= $0.002717\frac{d_t^3}{k}$ kgf-m

= $321.9838\frac{d_t^3}{k}$ lbf-ft

Where the actual rudder stock diameter d_{ta} is greater than the calculated diameter d_t, the diameter d_{ta} is to be used. However, d_{ta} applied to the above formula need not be taken greater than $1.145d_t$.

d_t = stock diameter, in mm (in.), according to 3-2-14/7.1

k = material factor for stock as given in 3-2-14/1.3

d_k = mean diameter of the conical part of the rudder stock, in mm (in.), at the key

σ_{F1} = minimum yield stress of the key material, in N/mm^2 (kgf/mm^2, psi)

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

$$a_k = \frac{5Q_F}{d_k\sigma_{F2}} \quad \text{cm}^2$$

$$a_k = \frac{6Q_F}{d_k\sigma_{F2}} \quad \text{in}^2$$

where

σ_{F2} = minimum yield stress of the key, stock or coupling material, in N/mm^2 (kgf/mm^2, psi), whichever is less.

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 0.9 of the specified minimum yield strength of the keyway material.

v) *Push up*. It is to be proved that 50% of the design yield moment is solely transmitted by friction in the cone couplings. This can be done by calculating the required push-up pressure and push-up length according to 3-2-14/11.5.iv) and 3-2-14/11.5.v) for a torsional moment $Q'_F = 0.5Q_F$.

vi) Where a key is fitted to the coupling between stock and rudder and it is considered that the entire rudder torque is transmitted by the key at the couplings, the requirement of 3-2-14/11.3v) need not be applied provided that the actual shear area and the effective surface area of the key are more than twice of that required by 3-2-14/11.3iii).

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.

11.5 Keyless Fitting *(1 July 2021)*

Hydraulic and shrink fit keyless couplings are to be fitted in accordance with the following:

i) Detailed preloading stress calculations and fitting instructions are to be submitted;

ii) 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;

iii) The upper edge of the upper main piece bore is to have a slight radius;

iv) *Push-up Pressure*. The push-up pressure is not to be less than the greater of the two following values:

$$p_{req1} = \frac{2Q_F}{d_m^2 \ell \pi \mu_o} 10^3 \quad \mathrm{N/mm^2 (kgf/mm^2)}$$

$$p_{req1} = \frac{24Q_F}{d_m^2 \ell \pi \mu_o} \quad \mathrm{psi}$$

$$p_{req2} = \frac{6M_b}{d_m \ell^2} 10^3 \quad \mathrm{N/mm^2 (kgf/mm^2)}$$

$$p_{req2} = \frac{72M_b}{d_m \ell^2} \quad \mathrm{psi}$$

where

Q_F = design yield moment of rudder stock, as defined in 3-2-14/11.3.iii)

d_m = mean cone diameter, in mm (in.)

ℓ = coupling length, in mm (in.)

μ_o = frictional coefficient, equal to 0.15

M_b = bending moment in the cone coupling (e.g., in case of spade rudders), in N-m (kgf-m, lbf-ft)

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

$$p_{perm} = \frac{0.95Y_G\left(1 - \alpha^2\right)}{\sqrt{3 + \alpha^4}} - p_b \quad \mathrm{N/mm^2 (kgf/mm^2, psi)}$$

where

p_b = $\frac{3.5M_b}{d_m\ell^2}10^3$ N/mm^2 (kg/mm^2)

p_b = $\frac{42M_b}{d_m\ell^2}$ psi

Y_G = specified minimum yield strength of the material of the gudgeon or stock, whichever is smaller, in N/mm^2 (kgf/mm^2, psi)

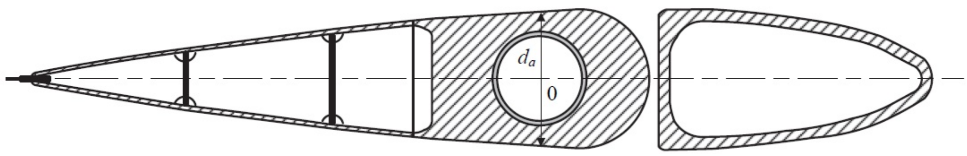
α = d_m/d_a

d_m = mean cone diameter, in mm (in.)

d_a = outer diameter of the gudgeon, in mm (in.) as shown in 3-2-14/FIGURE 4B (The least diameter is to be considered)

The outer diameter of the gudgeon in mm (in.) is not to be less than $1.25d_0$, with d_0 defined in 3-2-14/11 FIGURE 4.

FIGURE 4B
Gudgeon Outer Diameter (d_a) Measurement *(1 July 2021)*



v) *Push-up Length.* The push-up length $\Delta\ell$, in mm (in.), $\Delta\ell$ is to comply with the following formula:

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

where

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

$$\Delta\ell_2 = \frac{p_{perm}d_m}{E\left(\frac{1-\alpha^2}{2}\right)c} + \frac{0.8R_m}{c} \text{mm} \quad (\text{in.})$$

R_{tm} = mean roughness, in mm (in.) taken equal to 0.01 mm (0.0000394 in.)

c = taper on diameter according to 3-2-14/11.1.iv)

Y_G = specified minimum yield strength of the material of the gudgeon, in N/mm^2 (kgf/mm^2, psi)

E = Young's modulus of the material of the gudgeon, in N/mm^2 (kgf/mm^2, psi)

Y_G, α, and d_m are as defined in 3-2-14/11.5.iv).

Note:

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

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

The value 0.02 is a reference for the friction coefficient using oil pressure. It varies and depends on the mechanical treatment and roughness of the details to be fixed. Where due to the fitting procedure a partial push-up effect caused by the rudder weight is given, this may be taken into account when fixing the required push-up length, subject to approval.

vi) *Couplings with Special Arrangements for Mounting and Dismounting the Couplings.* Where the stock diameter exceeds 200 mm (8 in.), the press fit is recommended to be effected by a hydraulic pressure connection. In such cases the cone is to be more slender, $c \approx 1{:}12$ to $\approx 1{:}20$. In case of hydraulic pressure connections the nut is to be effectively secured against the rudder stock or the pintle. For the safe transmission of the torsional moment by the coupling between rudder stock and rudder body the push-up pressure and the push-up length are to be determined according to 3-2-14/11.5.iv) and 3-2-14/11.5.v), respectively.

vii) The locking nut is to be fitted in accordance with 3-2-14/11.7.

11.7 Locking Nut *(2022)*

Dimensions of the securing nut, as shown in 3-2-14/11 FIGURE 4, are to be proportioned in accordance with the following and the nut is to be fitted with an effective locking device.

Height

$h_n \geq 0.6 d_g$

Outer diameter of nut $d_n \geq 1.2 d_u$ or $1.5 d_g$ whichever is greater

External thread diameter $d_g \geq 0.65 d_o$

In the case of a hydraulic pressure secured nut, a securing device such as a securing flat bar is to be provided [see 3-2-14/9.1.iv]. Calculations proving the effectiveness of the securing device are to be submitted.

A securing flat bar will be regarded as an effective securing device for the nut, if its shear area, in mm^2 (in^2), is not less than:

$$A_S = \frac{P_S \cdot \sqrt{3}}{\sigma_F} \quad \text{mm}^2 \quad (\text{in}^2)$$

where

P_s = shear force, in N (kgf, lbf)

= $\frac{P_e}{2}\mu_1\left(\frac{d_1}{d_g} - 0.6\right)$

P_e = push-up force, in N (kgf, lbf), as defined in 3-2-14/11.5.v)

μ_1 = frictional coefficient between nut and rudder body, normally μ_1 = 0.3

d_1 = mean diameter of the frictional area between nut and rudder body, in mm (in.)

d_g = external thread diameter of the nut, in mm (in.)

σ_F = specified minimum yield stress of the securing flat bar material, in N/mm^2 (kgf/mm^2, psi)

13 Pintles

13.1 General *(1 July 2019)*

Generally, pintles assembled with use of a locking nut 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.

For rudders supported by shoe piece and pintle assembled without use of nut (refer to 3-2-A5/5.1 FIGURE 2), cylindrical attachment may be accepted on condition, that pintle bearing clearance allow enough space for angular inclination under associated rudder design force, to accept the connection as simple supported.

The diameter of the pintles is not to be less than obtained from the following equation.

$d_p = k_1\sqrt{BK_p}$ mm (in.)

where

k_1 = 11.1 (34.7, 1.38)

B = bearing force, in kN (tf, Ltf), from submitted direct calculation but not to be taken less than $B_{\min}$ as specified in 3-2-14/13.1 TABLE 4;

TABLE 4
Minimum Bearing Force $B_{\min}$

Pintle Type		$B_{\min}$
Conventional two pintle rudder		$0.5C_R$
3-2-A5/7.1 FIGURE 3	lower pintle	$0.5C_R$
3-2-A5/7.1 FIGURE 3	main pintle	$C_R\ell_a/\ell_p$ *
3-2-13/5 FIGURE 3	main pintle	$C_R\ell_a/\ell_p$ *
	upper pintle	$0.25C_R$

$*B_{\min} = C_R$ where $\ell_a/\ell_p \geq 1$

ℓ_a/ℓ_b as described in 3-2-13/5 FIGURE 3

K_p = material factor for the pintle, as defined in 3-2-14/1.3

For rudders on horns with two pintles, as shown in 3-2-13/5 FIGURE 3b, 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.

Threads and nuts are to be in accordance with 3-2-14/11.7.

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, where D_p is measured on the outside of the liner. The bearing pressure is to be in accordance with 3-2-14/15.1.

The thickness of the pintle housing is to be in accordance with 3-2-13/3.3.

Renewal limits are based upon pintle diameter without exceeding the following limits:

i) Spade type rudders: 6 mm.

ii) Other rudders: 7.5 mm.

Special consideration is to be given to metal bearings and unique rudder types.

13.3 Push-up Pressure and Push-up Length *(1 July 2019)*

The required push-up pressure for pintles, in N/mm² (kgf/mm², psi), is to be determined by the following formula:

$$p_{req} = \frac{0.4 B_1 d_o}{d_m^2 \ell} \quad \mathrm{N/mm^2\,(kgf/mm^2, psi)}$$

where

B_1	=	supporting force in the pintle, in N (kgf, lbf)
d_o	=	actual pintle diameter excluding the liner, in mm (in.)
d_m	=	mean cone diameter, in mm (in.)
ℓ	=	cone length, in mm (in.)

The push-up length is to be calculated similarly as in 3-2-14/11.5.v), using required push-up pressure and properties for the pintle .

15 Supporting and Anti-Lifting Arrangements

15.1 Bearings

15.1.1 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 projected area of bearing surface is not to be greater than 1.2*

ii) The projected area of the bearing surface ($A_b = d_\ell \ell_b$) is not to be less than $A_{b\min}$,

where

d_ℓ = outer diameter of the liner, in mm (in.)

ℓ_b = bearing length, in mm (in.)

$A_{b\min} = k_1 \frac{P}{p_a}$ mm²(in²)

k_1 = 1000 (2240)

P = bearing reaction force, in kN (tf, Ltf), as specified in 3-2-14/15.5 TABLE 5

p_a = allowable surface pressure as indicated in 3-2-14/15.5 TABLE 6 depending on bearing material, in N/mm² (kgf/mm², psi)

* 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.

15.1.2 Bearing Clearance

i) The clearance for metal bearings is not to be less than $d_i/1000 + 1.0$ mm ($d_i/1000 + 0.04$ in.) on the diameter, where d_i is the inner diameter of the bushing, in mm (in.).

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 (0.06 in.) on diameter*.

* Request of clearance less than 1.5 mm (0.06 in.) 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.

15.1.3 Bearing Pressure

Bearing pressure is to be accordance with 3-2-14/15.5 TABLE 6, as applicable.

15.1.4 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.

15.1.5 Liners and Bushes

i) *Rudder Stock Bearings*. Liners and bushes are to be fitted in way of bearings. The minimum thickness of liners and bushes is to be equal to:

$t_{\min} = 8$ mm (0.31 in.) for metallic materials and synthetic material

$t_{\min} = 22$ mm (0.87 in.) for lignum material

ii) *Pintle Bearings*

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

  $t = k_1\sqrt{B}$ mm (in.)

  where

  B = bearing force, in N (kgf, lbf)

  k_1 = 0.01 (0.0313, 0.000830)

  nor than the minimum thickness defined in 3-2-14/15.1.5.i).

- The bearing length L_p of the pintle is to be in accordance with 3-2-14/13.1.

15.3 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) The bearing part is to be well lubricated by dripping oil, automatic grease feeding, or a similar method.

iv) Hull structures in way of the rudder carrier are to be suitably strengthened.

15.5 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 5
Bearing Reaction Force

Bearing Type	*P , Bearing Reaction Force* *kN (tf, Ltf)*
Pintle bearings	$P = B$ as defined in 3-2-14/13
Other bearings	*Calculation of P* is to be submitted. Guidelines for calculation can be found in Appendix 3-2-A5

TABLE 6
Allowable Bearing Surface Pressure *(1 July 2021)*

Bearing Material	p_a		
	N/mm²	*kgf/mm²*	*psi*
lignum vitae	2.5	0.25	360
white metal, oil lubricated	4.5	0.46	650
synthetic material with hardness greater than 60 Shore D(1)	5.5(2)	0.56	800
steel(3) and bronze and hot-pressed bronze-graphite materials	7.0	0.71	1000
aluminum-bronzes and manganese-bronzes(4)	9.0	0.92	1290
advanced synthetic compositions incorporating solid lubricant(4)	10.0	1.02	1430

Notes:

1. Indentation hardness test at 23°C (73.4°F) and with 50% moisture, according to a recognized standard. Synthetic bearing materials to be of approved type.
2. Higher values than given in the table may be taken if they are verified by tests, but in no case more than 10 N/mm^2 (1.02 kgf/mm^2, 1450 psi).
3. Stainless and wear-resistant steel in an approved combination with stock liner.
4. Material test certificates are to be submitted to support the review.

17 Double Plate Rudder

17.1 Strength *(1 July 2021)*

Rudder section modulus and web area are to be such that stresses indicated in the following Subparagraphs are not exceeded.

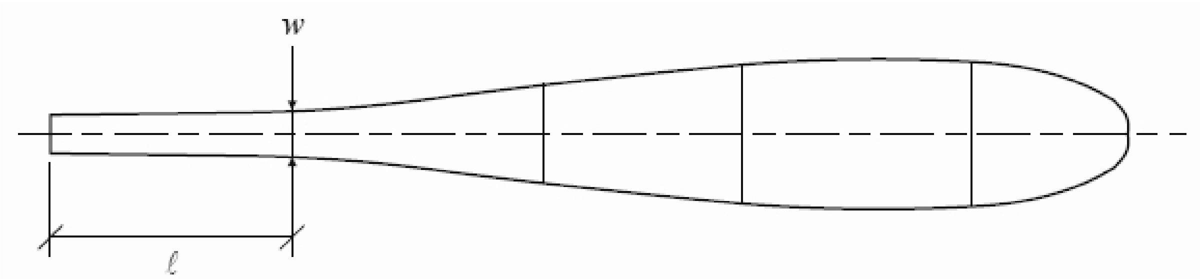
In calculating the section modulus of the rudder, the effective width of side plating is to be taken as not greater than twice the extreme athwartship dimension of the rudder in way of horizontal section being considered. Bolted cover plates on access or inspection openings to pintles or nuts are not to be considered effective in determining the section modulus of the rudder. In order for a cover plate to be considered effective, it is to be closed using a full penetration weld and confirmed suitable by non-destructive testing method. Smooth curvature or radii are to be provided at abrupt changes in section where stress concentrations occur, 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 3-2-A5.

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.

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, w, is equal or less than $^{1}/_{6}$ of the trailing edge length measured between the diaphragm and the trailing edge, ℓ, finite element vibration analysis and trailing edge vortex shedding analysis of the rudder blade are also to be submitted for review. See Figure 5.

FIGURE 5



Spade rudders with an embedded rudder trunk are to have a trailing edge with dimensions that satisfy the following requirements:

i) For a rudder trailing edge having a monotonous transition to an end with a finite thickness or diameter (see 3-2-14/17.1.i FIGURE 6), the thickness or diameter of the rounded end, t_e, is to satisfy the following requirements:

For $b \times (c_r + c_t)/2 \geq 70$ m² (753 ft²), t_e is not to exceed:

$$t_e = 43\alpha^{-0.36} c_t^{0.5} - 3.5c_t \text{ mm}$$

$$t_e = 0.93\alpha^{-0.36} c_t^{0.5} - 0.042c_t \text{ in.}$$

For $b \times (c_r + c_t)/2 < 70$ m² (753 ft²), the minimum value of t_e is to satisfy:

$$t_e = 15.2\alpha^{-0.36} V_d - 3.5c_t \text{ mm}$$

$$t_e = 0.6\alpha^{-0.36} V_d - 0.042c_t \text{ in.}$$

where

b = mean height of rudder area, as determined from 3-2-14/17.1.i FIGURE 6, in m (ft)

c_r = root chord length, as determined from 3-2-14/17.1.i FIGURE 6, in m (ft)

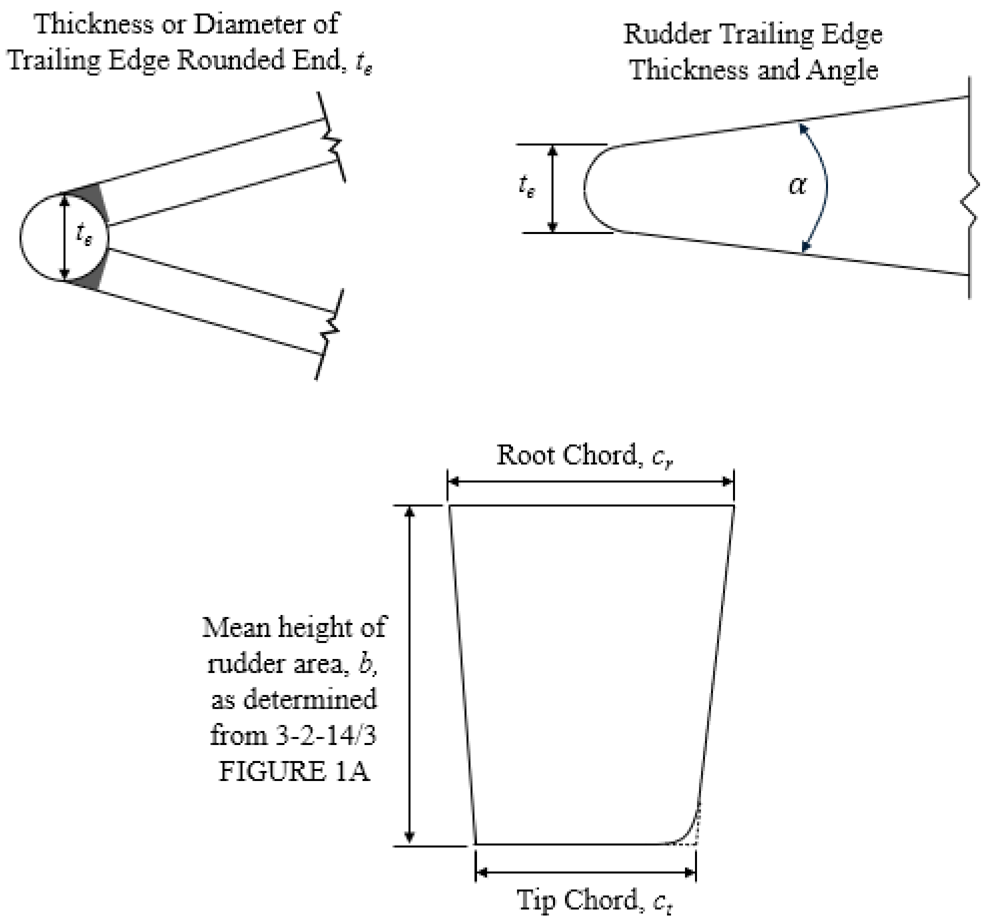
c_t = tip chord length, as determined from 3-2-14/17.1.i FIGURE 6, in m (ft)

t_e = rudder trailing edge thickness or diameter of rounded end, as determined from 3-2-14/17.1.i FIGURE 6, in mm (in.)

α = rudder trailing edge angle, as determined from 3-2-14/17.1.i FIGURE 6, in degrees

V_d = as defined in 3-2-14/3.1, in knots

FIGURE 6 *(1 July 2021)*



ii) For a rudder trailing edge with a flat splitter plate (see 3-2-14/17.1.ii FIGURE 7), the extension of the splitter plate beyond the weld to rudder, ℓ_0, is to be the same as the trailing edge thickness, as determined from3-2-14/17.1.ii FIGURE 7. The thickness of splitter plate, t_0, is to satisfy:

$t_0 \le t_e/3$, and not to be less than 20 mm (0.8 in.)

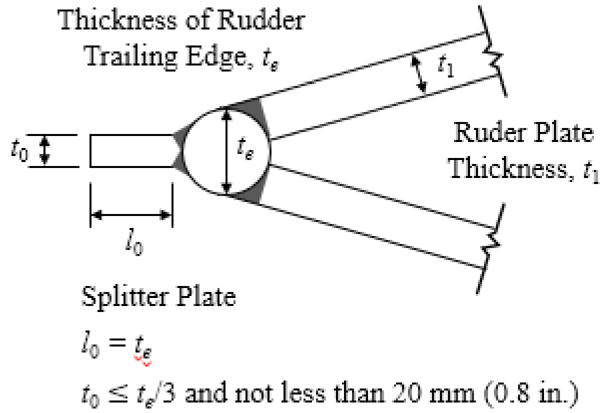
where

t_0 = thickness of splitter plate, as determined from 3-2-14/17.1.ii FIGURE 7, in mm (in.)

t_e = rudder trailing edge thickness or diameter of rounded end, as determined from 3-2-14/17.1.ii FIGURE 7, in mm (in.)

Edge serrations (i.e., a sawtooth shaped edge) may be added to the splitter plate as an extension beyond the required length, ℓ_0, to mitigate the effect of trailing edge vortex shedding.

FIGURE 7 *(1 July 2021)*



iii) For a vessel with a rudder trailing edge different from 3-2-14/17.1 i) and ii), a vibration analysis is to be carried out to verify that the natural frequencies of the rudder vibration modes that are susceptible to the adverse effect of rudder trailing edge vortex shedding are at least ±20% away from the rudder trailing edge vortex shedding frequency at the vessel speed range between $0.6V_d$ and V_d, whereV_d is the design speed as defined in 3-2-14/3.1.

For a rudder trailing edge as described in 3-2-14/17.1 i) , the trailing edge vortex shedding frequency, f_s, in Hz at a given vessel speed, V, in knots can be calculated using the following equation:

$$f_s = \frac{109 - 0.088\alpha^2}{1 + 0.0034/\left(t_e/c_t\right) - 0.14/(t_e/c_t)^{0.2}} \times \frac{V}{t_e} \qquad \text{in SI units}$$

$$f_s = \frac{4.29 - 0.0035\alpha^2}{1 + 0.0034/\left(t_e/c_t\right) - 0.14/(t_e/c_t)^{0.2}} \times \frac{V}{t_e} \qquad \text{in US customary units}$$

where t_e, c_t, and α are defined in 3-2-14/17.1 i).

Alternatively, the rudder trailing edge vortex shedding frequency can be determined through a detailed numerical analysis or a sea trial.

17.1.1 Clear of Rudder Recess Sections *(1 July 2019)*

Allowable stresses for determining the rudder strength clear of rudder recess sections (cutouts) where 3-2-14/17.1.2 applies are as follows:

Bending stress	$\sigma_b = K_\sigma/Q$	N/mm² (kgf/mm², psi)
Shear stress	$\tau = K_\tau/Q$	N/mm² (kgf/mm², psi)
Equivalent stress	$\sigma_e = \sqrt{\sigma_b{}^2 + 3\tau^2} = K_e/Q$	N/mm² (kgf/mm², psi)

where

	SI units	*MKS units*	*US units*
K_σ	110	11.2	15,900
K_τ	50	5.1	7,300
K_e	120	12.2	17,400

Q = 1.0 for ordinary strength hull steel

= as defined in 3-2-1/5.3 for higher strength steel plate

17.1.2 In Way of Rudder Recess Sections *(1 July 2019)*

Allowable stresses for determining the rudder strength in way of the recess sections (cutouts) for the rudder horn pintle on semi-spade rudders (see 3-2-14/17.1 FIGURE 8) are as follows:

Bending stress	$\sigma_b = K_\sigma$	N/mm^2 (kgf/mm^2, psi)
Shear stress	$\tau = K_\tau$	N/mm^2 (kgf/mm^2, psi)
Equivalent stress	$\sigma_e = \sqrt{{\sigma_b}^2 + 3\tau^2} = K_e$	N/mm^2 (kgf/mm^2, psi)

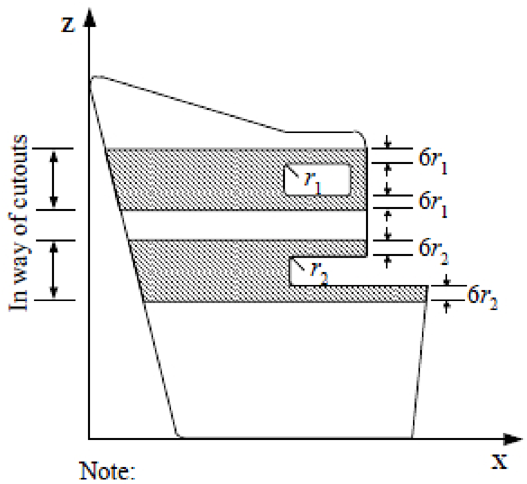
where

	SI units	*MKS units*	*US units*
K_σ	75	7.65	10,900
K_τ	50	5.1	7,300
K_e	100	10.2	14,500

Note:

The stresses in 3-2-14/17.1.2 apply equally to high tensile and ordinary steels.

FIGURE 8



Note:
r_1 = corner radius of rudder plate in way of portable bolted inspection hole
r_2 = corner radius of rudder plate

17.3 Side, Top and Bottom Plating

The thickness of the rudder side or bottom plating is to be at least 2 mm (0.08 in.) greater than that required by 3-2-10/3.1 for deep tank plating in association with a head h measured to the summer load line and not less than obtained from the following equation, whichever is greater:

$$t = 0.0055 s\beta\sqrt{k_1 d + (k_2 C_R/A)} \times \sqrt{Q} + k_3 \text{ mm (in.)}$$

where

Q	=	1.0 for ordinary strength hull steel
	=	as defined in 3-2-1/5.3 for higher strength steel plate
k_1	=	1.0 (1.0, 0.305)
k_2	=	0.1 (0.981, 10.7)
k_3	=	2.5 (2.5, 0.1)
d	=	summer loadline draft of the ship, in m (ft)
C_R	=	rudder force according to 3-2-14/3, in kN (tf, Ltf)
A	=	rudder area, in m^2 (ft^2)
β	=	$\sqrt{1.1 - 0.5(s/b)^2}$ maximum 1.0 for $b/s \geq 2.5$
s	=	smaller unsupported dimension of plating, in mm (in.)
b	=	greater unsupported dimension of plating, in mm (in.)

The rudder side plating in way of the solid part is to be of increased thickness per 3-2-14/17.7.

17.5 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 the horizontal diaphragms.

The thickness of diaphragm plates is not to be less than 70% of the required rudder side plate thickness or 8 mm (0.31 in.), whichever is greater. Openings in diaphragms are to have generous radii and the effects of openings are to be considered in the strength assessment as required in 3-2-14/17.1.

The diaphragm plating in way of the solid part is to be of increased thickness for vertical and horizontal diaphragm plates per 3-2-14/17.7.

17.7 Connections of Rudder Blade Structure with Solid Parts *(1 July 2019)*

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

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

- 10 mm (0.375 in.) for diaphragm plates welded to the solid part on which the lower pintle of a semi-spade rudder is housed and for vertical diaphragm plates welded to the solid part of the rudder stock coupling of spade rudders.
- 20 mm (0.75 in.) for other diaphragm plates.

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

Minimum section modulus of the connection with the rudder stock housing.

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

$$w_s = c_s S_\ell^3 \left(\frac{H_E - H_X}{H_E}\right)^2 \frac{Q}{K_s} 10^{-4} \quad \text{cm}^3$$

$$w_s = c_s S_\ell^3 \left(\frac{H_E - H_X}{H_E}\right)^2 \frac{Q}{K_s} 10^{-1} \quad \text{in}^3$$

where

c_s	=	coefficient, to be taken equal to:
	=	1.0 if there is no opening in the rudder plating or if such openings are closed by a full penetration welded plate
	=	1.5 if there is an opening in the considered cross-section of the rudder
S_ℓ	=	rudder stock diameter, in mm (in.)
H_E	=	vertical distance between the lower edge of the rudder blade and the upper edge of the solid part, in m (ft)
H_X	=	vertical distance between the considered cross-section and the upper edge of the solid part as indicated in 3-2-14/17.7 FIGURE 9, in m (ft)
Q	=	material factor for the rudder blade plating as given in 3-2-14/17.1
K_s	=	material factor for the rudder stock as given in 3-2-14/1.3

The actual section modulus of the cross-section of the structure of the rudder blade is to be calculated with respect to the symmetrical axis of the rudder.

The breadth of the rudder plating to be considered for the calculation of section modulus is to be not greater than:

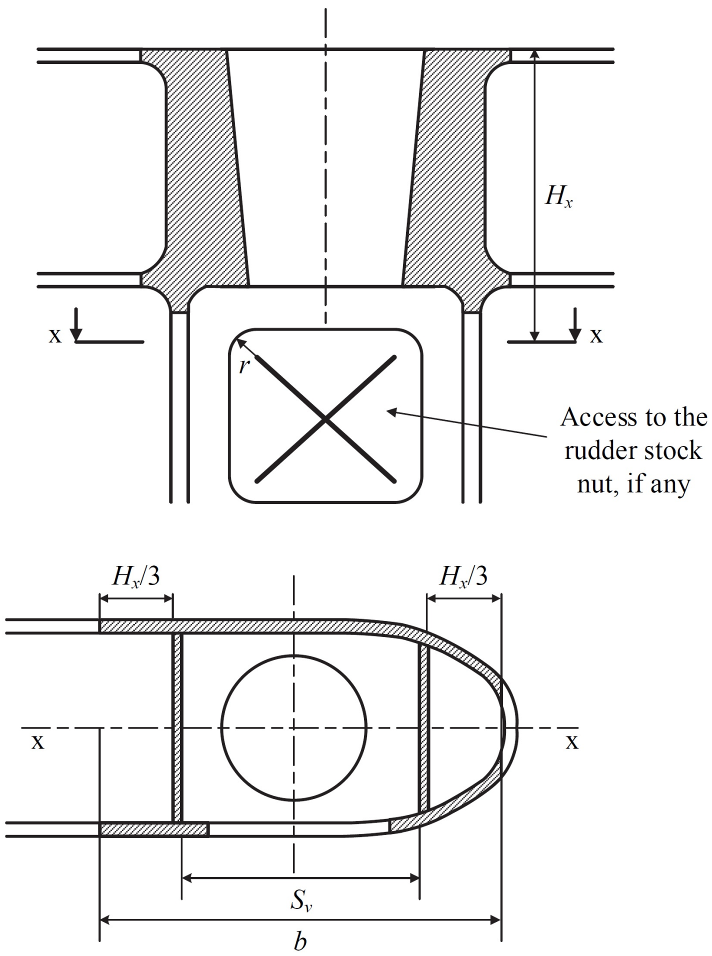
$b = s_v + 2H_X/3$ m (ft)

where

s_v	=	spacing between the two vertical diaphragm, in m (ft) (see 3-2-14/17.7 FIGURE 9)

Where openings for access to the rudder stock nut are not closed by a full penetration welded plate, they are to be deducted.

FIGURE 9
Cross-section of the Connection Between Rudder Blade Structure and Rudder Stock Housing , Example with Opening in Only One Side Shown
(1 July 2021)



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

$t_H = 1.2t$ mm (in.)

$t_H = 0.045{d_S}^2/s_H$ mm (in.)

where

t	=	defined in 3-2-14/17.3
d_S	=	diameter, in mm (in.), to be taken equal to:
	=	S_ℓ as per 3-2-14/7.3, for the solid part housing the rudder stock
	=	d_p as per 3-2-14/13.1, for the solid part housing the pintle
s_H	=	spacing between the two horizontal diaphragm plates, in mm (in.)

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

The thickness of the vertical diaphragm plates welded to the solid part where the rudder stock is housed as well as the thickness of the rudder side plating under this solid part is to be not less than the values obtained, in mm (in.), from 3-2-14/17.7 TABLE 7.

The increased thickness of vertical diaphragm plates is to extend below the solid piece at least to the next horizontal diaphragm.

TABLE 7
Thickness of Side Plating and Vertical Diaphragm Plates

Type of Rudder	*Thickness of Vertical Diaphragm Plates, in mm (in.)*		*Thickness of Rudder Plating, in mm (in.)*	
	Rudder Blade without Opening	*Rudder Blade with Opening*	*Rudder Blade without Opening*	*Area with Opening*
Rudder supported by sole piece	$1.2t$	$1.6t$	$1.2t$	$1.4t$
Semi-spade and spade rudders	$1.4t$	$2.0t$	$1.3t$	$1.6t$

t = thickness of the rudder plating, in mm (in.), as defined in 3-2-14/17.3

17.9 Welding and Design Details *(1 July 2021)*

i) Slot-welding is to be limited as far as possible. Slot welding is not to be used in areas with large in-plane stresses transversely to the slots or in way of cut-out areas of semi-spade rudders.

ii) When slot welding is applied, the length of slots is to be minimum 75 mm (3 in.) with breadth of $2t$, where$t$ is the rudder plate thickness, in mm (in.). The distance between ends of slots is not to be more than 125 mm (5 in.). The slots are to be fillet welded around the edges and filled with a suitable compound (e.g., epoxy putty). Slots are not to be filled with weld.

iii) Grove welds with structural backing/backing bar (continuous type slot weld) may be used for double-plate rudder welding. In that case, the root gap is to be between 6 to 10 mm (0.25 to 0.375 in.) and the bevel angle is to be at least 15°.

iv) In way of the rudder horn recess of semi-spade rudders the radii in the rudder plating except in way of solid part in cast steel are not to be less than 5 times the plate thickness, but in no case less than 100 mm (4 in.). Welding in side plate are to be avoided in or at the end of the radii. Edges of side plate and weld adjacent to radii are to be ground smooth.

v) Welds between plates and heavy pieces (solid parts in forged or cast steel or very thick plating) are to be made as full penetration welds. In way of highly stressed areas (e.g., cut-out of semispade rudder and upper part of spade rudder), cast or welding on ribs is to be arranged. Two sided full penetration welding is normally to be arranged. Where back welding is impossible welding is to be performed against ceramic backing bars or equivalent. Steel backing bars may be used and are to be continuously welded on one side to the heavy piece.

17.11 Watertightness

The rudder is to be watertight and is to be tested in accordance with Section 3-7-1.

19 Single Plate Rudders

19.1 Mainpiece Diameter

The mainpiece diameter is calculated according to 3-2-14/7.3. For spade rudders the lower third may be tapered down to 0.75 times stock diameter at the bottom of the rudder.

19.3 Blade Thickness

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

$$t_b = 0.0015 s V_R + 2.5 \quad \text{mm}$$

$$t_b = 0.0015 s V_R + 0.1 \quad \text{in.}$$

where

s	=	spacing of stiffening arms, in mm (in.), not to exceed 1000 mm (39 in.)
V_R	=	speed, as defined in 3-2-14/3

19.5 Arms

The thickness of the arms is not to be less than the blade thickness obtained in 3-2-14/19.3. 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:

$$SM = 0.0005 s {C_1}^2 V_R^2 Q \quad \text{cm}^3$$

$$SM = 0.0000719 s {C_1}^2 V_R^2 Q \quad \text{in}^3$$

where

C_1	=	horizontal distance from the aft edge of the rudder to the centerline of the rudder stock, in m (ft)
Q	=	1.0 for ordinary strength hull steel
	=	as defined in 3-2-1/5.3 for higher strength steel plate

s, V_R are as defined in section 3-2-14/21.3.

21 Steering Nozzles

21.1 Application Scope

Requirements in this Subsection are applicable to conventional steering nozzles, as illustrated in 3-2-14/21.3 FIGURE 10, with the following restrictions:

i) The inner diameter of 5 meters (16.4 feet) 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 Part 6, as applicable

Steering nozzles outside of the application scope are subject to special consideration with all supporting documents and calculations submitted to ABS 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

21.3 Design Force

The design force, C_R, for steering nozzles is to be obtained from the following equation:

$$C_R = nk_R k_c k_\ell A_t {V_R}^2 = C_{R1} + C_{R2} \quad \text{kN (tf, Ltf)}$$

$$C_{R1} = nk_R k_c k_\ell A_{eq} {V_R}^2 \quad \text{kN (tf, Ltf)}$$

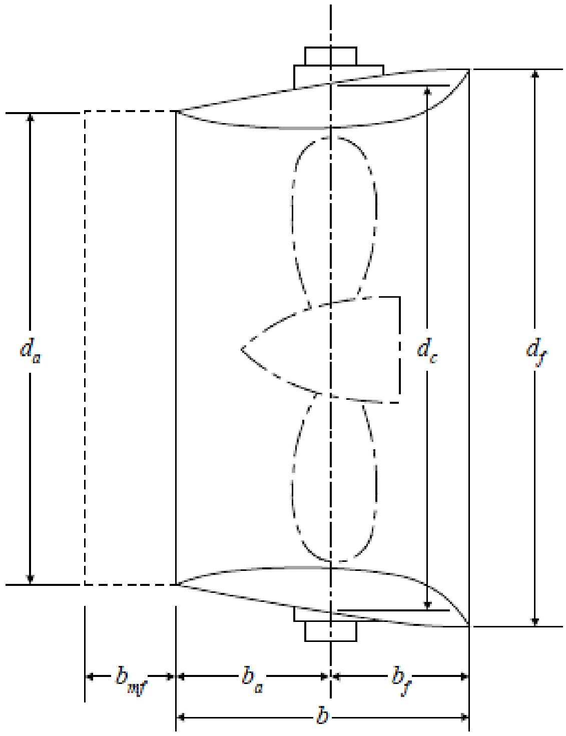
$$C_{R2} = nk_R k_c k_\ell \left(A_{po} + A_{mf}\right) {V_R}^2 \quad \text{kN (tf, Ltf)}$$

where

C_{R1}	=	Design force associated with the turning movement of the nozzle
C_{R2}	=	Design force associated with the turning movement of nozzle post, movable flap, if present
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 (ft)
	=	$0.5(d_f + d_a)$
d_f, d_a	=	fore and aft nozzle external diameters as shown in 3-2-14/21.3 FIGURE 10, in m (ft)
A_t	=	$A_{eq} + A_{po} + A_{mf}$, in m^2 (ft^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 (ft)
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 (ft^2)
k_c	=	1.9 for ahead condition
	=	1.5 for astern condition
k_ℓ	=	1.15, as specified in 3-2-14/5 TABLE 2

n, V_R are as defined in 3-2-14/3.1.

FIGURE 10
Nozzle Geometry



21.5 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 (tf-m, Ltf-ft)

where

r	=	$(\alpha - k)\ell$, but not less than 0.1ℓ for ahead condition	
ℓ	=	b	without flap, in m (ft)
	=	$b + b_{mf}$	if flap present
k	=	A_f/A	
A_f	=	$A_{eq} b_f/\ell$, in m^2 (ft^2)	
d_c	=	nozzle diameter at the section intersecting with nozzle stock axis;	

α is as defined in 3-2-14/5 TABLE 3.

A, C_R are as defined in 3-2-14/21.3.

21.7 Nozzle Stock

21.7.1 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:

$$S = N_u \sqrt[3]{Q_R K_s} \text{ mm (in.)}$$

where

N_u	=	42.0 (823.9, 2.39)
Q_R	=	as defined in 3-2-14/21.5
K_s	=	material factor for nozzle stock, as defined in 3-2-14/1.3

21.7.2 Lower Stock

In determining lower stock diameters, values of nozzle design force and torque calculated in 3-2-14/21.3 and 3-2-14/21.5 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 3-2-A5.

The lower nozzle stock diameter is not to be less than obtained from the following equation:

$$S_\ell = S \sqrt[6]{1 + 4/3(M/Q_R)^2} \text{ mm (in.)}$$

where

S	=	required upper stock diameter from 3-2-14/21.7.1, in mm (in.)
M	=	bending moment at the cross section of the nozzle stock considered, in kN-m (tf-m, Ltf-ft)
Q_R	=	design torque obtained from 3-2-14/21.5, in kN-m (tf-m, Ltf-ft)

Where there is a change in stock diameter above the neck bearing, a gradual transition is to be provided.

21.9 Design Pressure

The design pressure of the nozzle is to be obtained from the following:

p_s	=	$c_s c_m \frac{C_{R1}}{2A_{eq}}$ N/mm^2 (kgf/mm^2, psi)
c_s	=	0.001 (0.0001, 0.145)
c_m	=	as indicated in 3-2-14/21.9 TABLE 8

C_{R1}, A_{eq} as defined in 3-2-14/21.3

p_d as defined in 3-2-13/9.1

TABLE 8
Coefficient c_m

Propeller Zone (see 3-2-13/Figure 4)	c_m		
	p_s *in N/mm²*	p_s *in kgf/mm²*	p_s *in psi*
2	0.35	3.6 x 10^{-2}	4.067 x 10^{2}
1 & 3	0.5	5.1 x 10^{-2}	5.81 x 10^{2}
4	1.0	1.02 x 10^{-1}	11.62 x 10^{2}

21.11 Plate Thickness

21.11.1 Nozzle Shell

The thickness of the nozzle shell plating, in mm (in.), is not to be less than:

$t = t_o + t_c$ mm (in.), but not to be taken less than 7.5 mm (0.3 in.)

where

t_o = thickness obtained from the following formula:

= $c_n \cdot S_p \cdot \sqrt{pK_n}$ mm (in.)

c_n = coefficient as indicated in 3-2-13/9.3 TABLE 3

S_p = spacing of ring webs, in mm (in.)

p = design pressure, in N/mm² (kgf/mm², psi), as defined in 3-2-14/21.9

t_c = corrosion allowance determined by 3-2-13/9.3 TABLE 4

K_n = nozzle material factor as defined in 3-2-14/1.3

21.11.2 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 3-2-13/5 FIGURE 4.

21.11.3 Movable Flap

Nozzle movable flap plate thickness, if present, is to comply with the following:

i) For double-plate movable flap, requirements in 3-2-14/17 are to be satisfied as applicable;

ii) For single-plate movable flap, requirements in 3-2-14/19 are to be satisfied as applicable;

21.13 Section Modulus

Steering nozzle is to have a section modulus at least equal to that specified in 3-2-13/9.5, where *n* is replaced by 1.0 (0.0017).

21.15 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

21.17 Welding Requirement

Steering nozzle welding procedures are to comply with 3-2-13/9.7.

23 Azimuthal Thruster

23.1 Application Scope

23.1.1 Extent of Coverage

Requirements in this Subsection are applicable to Azimuthal Thrusters (also referred as integrated nozzle propellers), as illustrated in 3-2-14/23.7 FIGURE 11, with the following restrictions:

i) Azimuthal thrusters designed for propulsion and maneuvering

ii) The inner diameter of thruster's nozzle is of 5 meters (16.5 feet) or less, and

iii) Azimuthal thrusters of above features but provided on the vessels for Ice Class are subject to additional requirements specified in Part 6, as applicable

23.1.2 Special Review

Azimuthal thrusters outside of the above application scope are subject to special consideration with all supporting documents and calculations submitted to ABS for review. The submitted documents and calculations include, but are not limited to, the following items:

i) The drawings and plans of the thruster with indications of design operating angles and the torque considered necessary to operate the thruster at the design operating angle

ii) The calculated thruster section modulus

iii) The calculated maximum water induced pressure of the thruster under design speed (both ahead and astern conditions) and at the design operating angle, and

iv) The calculated maximum shear and bending of thruster support structure under design speed (both ahead and astern conditions) and at the design operating angle

23.3 Plans and Documents

The following structural components related plans and documents are to be submitted to ABS as applicable:

i) Overall arrangement of the thruster unit

ii) Detailed nozzle drawing with nozzle profile type indicated

iii) Detailed plans of thruster connection, bolted or welded, to the hull

iv) Nozzle strut drawings including details of the connections to the propeller gear housing and the nozzle duct

v) Material list and properties of all structure components

vi) Manufacturer specified/calculated maximum load on the unit for crash stop condition

Note: For specific requirements of machinery components, see Part 4 as applicable.

23.5 Locking Device

A locking device is to be provided to prevent the azimuthal thruster from rotating toward undesired directions in the event of accident or damage.

23.7 Design Force

The design force, C_R, for azimuthal thrusters is the maximum load for crash stop condition (3-2-14/23.1) or as obtained from the following equation, whichever is greater:

$C_R = nk_Rk_ck_\ell A{V_R}^2 = C_{R1} + C_{R2}$ kN (tf, Ltf)

$C_{R1} = nk_Rk_ck_\ell A_{eq}{V_R}^2$ kN (tf, Ltf)

$C_{R2} = nk_Rk_ck_\ell A_{tb}{V_R}^2$ kN (tf, Ltf)

where

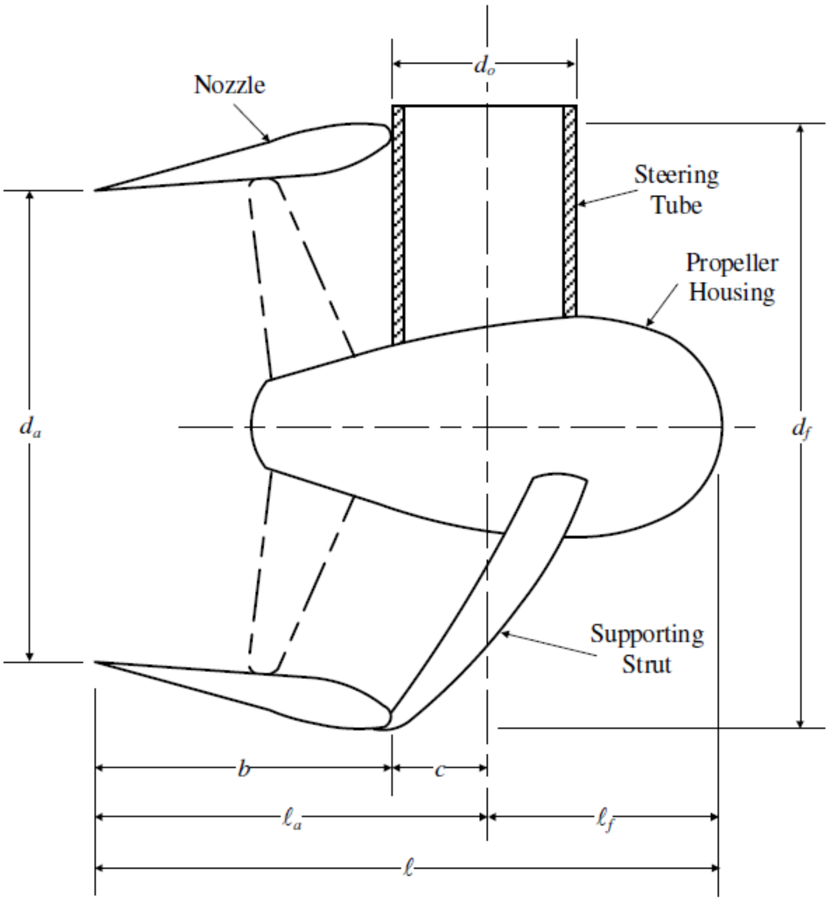
C_{R1}	=	Design force associated with the turning movement of the nozzle
C_{R2}	=	Design force associated with the turning movement of nozzle post, movable flap, if present;
k_R	=	$({d_m}^2/A + 2)/3$ but not taken more than 1.33
d_m	=	mean external diameter of the nozzle, in m (ft)
	=	$0.5(d_f + d_a)$
d_f, d_a	=	fore and aft nozzle external diameters as shown in 3-2-14/23.7 FIGURE 11(a), in m (ft)
b	=	nozzle length as shown in 3-2-14/23.7 FIGURE 11(a), in m (ft)
A	=	$A_{eq} + A_{tb}$, in m^2 (ft^2)
A_{eq}	=	equivalent nominal area of nozzle cylinder, not to be taken less than $1.35d_mb$, in m^2 (ft^2)
A_{tb}	=	effective projected areas of the azimuthal thruster components forward of the nozzle, in m^2 (ft^2)
d_o	=	outer diameter of steering tube as shown in 3-2-14/23.7 FIGURE 11(a), in m (ft)
k_c	=	1.9 for ahead condition
	=	1.5 for astern condition.
k_ℓ	=	1.15, as specified in 3-2-14/5 TABLE 2

n, V_R are as defined in 3-2-14/3.1.

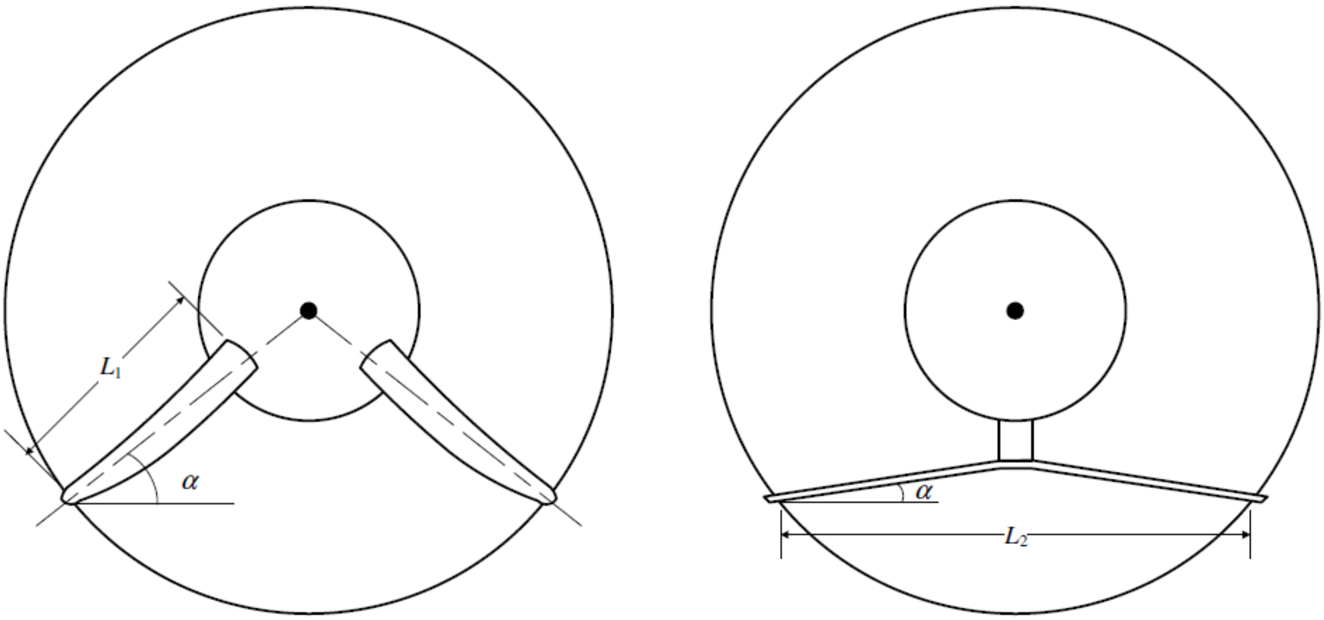
Note:

* Effective projected areas forward of the azimuthal thruster nozzle are the parts that actually contribute to generate lift force as the thruster turns. For example a torpedo shaped component, the projected profile area is to be proportionally reduced in order to be taken as the effective projected area. If this resultant effective projected area is too small to compare with the overall effective projected area, it may be discounted.

FIGURE 11
An Illustration of Azimuthal Thruster



(a) Side View



(b) Looking Aft (c)

23.9 Design Torque

Design torque, Q_R, for azimuthal thruster is to be determined from the following equation for both ahead and astern conditions:

$Q_R = C_R r$ kN-m (tf-m, Ltf-ft)

where

r	=	$(\alpha - k)\ell$, but not less than 0.1ℓ for ahead condition
ℓ	=	length of azimuthal thruster, in m (ft)
k	=	A_f / A
A_f	=	effective projected area of azimuthal thrust unit forward of steering centerline (within the extent length of ℓ_f), not to be taken less than $0.5A_{tb}$, in m^2 (ft^2)

α is as defined in 3-2-14/5 TABLE 3.

C_R and A are as defined in 3-2-14/23.7.

23.11 Design Pressure

The design pressure of the nozzle is to be obtained from the following:

$p = p_d + p_s$ N/mm^2 (kgf/mm^2, psi)

where

$$p_s = c_s c_m \frac{C_{R1}}{2A_{eq}} \quad \mathrm{N/mm^2 (kgf/mm^2, psi)}$$

p_d, c_s and c_m are as defined in 3-2-14/21.9.

C_{R1}, A_{eq} are as defined in 3-2-14/23.7.

23.13 Nozzle Scantlings

23.13.1 Nozzle Shell

The thickness of the nozzle shell plating, in mm (in.), is not to be less than the following:

$t = t_o + t_c$ mm (in.), but not to be taken less than 7.5 mm (0.3 in.)

where

t_o	=	$c_n \cdot S_p \cdot \sqrt{pK_n}$ mm (in.)
c_n	=	coefficient as indicated in 3-2-13/9.3 TABLE 3
S_p	=	nozzle ring web spacing, in mm (in.)
p	=	design pressure as defined in 3-2-14/23.11
t_c	=	corrosion allowance determined by 3-2-13/9.3 TABLE 4
K_n	=	nozzle material factor as defined in 3-2-13/9.3 TABLE 4

23.13.2 Internal Diaphragm

Thickness of nozzle internal ring webs and diaphragms are not to be less than that required by 3-2-13/9.3.2.

23.15 Steering Tube *(2020)*

The steering tube of the azimuthal thruster is to have scantlings of at least the same strength against bending moment and shear force as an equivalent stock with diameter calculated in accordance with 3-2-14/7.

where

Q_R is replaced by the design torque as defined in 3-2-14/23.9

K_s is replaced by material factor of the steering tube

M is the bending moment calculated at the section of the steering tube under consideration taking into account the Thruster Force in addition to the Design Force as defined in 3-2-14/23.7.

23.17 Section Modulus

Azimuthal thruster nozzle is to have a section modulus at least equal to that specified in 3-2-13/9.5, where n is replaced by 1.1 (0.00187).

23.19 Thruster Nozzle Top Connections

The structure where nozzle top and the steering tube are connected is to comply with the following requirements as the case may be.

23.19.1 Welded Connection

Refer to 3-2-14/23.25.2.

23.19.2 Bolted Connection *(2023)*

The following are to be complied with:

i) Flange couplings are to be supported by an ample body of metal worked out from both sides, which provide the structural continuity to bear the anticipated loads. In certain cases, stress analysis may be required to verify that the stress level within the flanges is not greater than 80% of the yield strength.

ii) Flange thickness is to comply with 3-2-14/9.3.2 or 3-2-14/9.5.2, as applicable.

iii) The coupling bolts are to be fitted bolts and are to meet the scantling requirements specified in 3-2-14/9.3.1 or 3-2-14/9.5.1, as applicable. Alternatively, a combination of holding down bolts together with shear elements may be considered, provided the holding down capacity and shearing capacity is equivalent to that of fitted bolts.

iv) Effective means are to be fitted for locking the nuts in place.

v) 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.

23.21 Nozzle Strut

23.21.1 General

i) Structural transitions of strut connected to nozzle and propeller housing are to avoid abrupt changes and the fillet radius is not to be less than 75 mm (3 in.) unless the stress in the radius area is verified to be acceptable by direct analysis.

ii) The width and thickness of strut plating are to have a gradual transition for smooth load carrying.

iii) Material properties of the nozzle strut and the structure components it is in direct contact are to be compatible [see 3-2-14/1.3.iii)].

23.21.2 Plate Thickness

The minimum plate thickness of the strut is not to be less than obtained from the following:

$$t = \sqrt{\frac{3F_{eqv}L_{eqv}}{2b_{avg}\sigma_F}}$$ mm (in.), but not to be taken less than 7.5 mm (0.3 in.)

where

F_{eqv} = equivalent load perpendicular to strut applied at ½ L, in kN (tf, Ltf)

= pA_{eqv} , where α is greater than 15° [see 3-2-14/23.7 FIGURE 11(b)]

= W_p weight of transmission shaft, gear, and bearings, in kN (tf, Ltf), where α is less than or equal to 15° [see 3-2-14/23.7 FIGURE 11(c)]

A_{eqv} = equivalent area of nozzle supporting strut, in m^2 (ft^2)

= L_1b_{avg} , as illustrated in 3-2-14/23.7 FIGURE 11(b)

= L_2b_{avg} , as illustrated in 3-2-14/23.7 FIGURE 11(c)

L_{eqv} = equivalent length of nozzle supporting strut, in m (ft)

= L_1 , as illustrated in 3-2-14/23.7 FIGURE 11(b)

= L_2 , as illustrated in 3-2-14/23.7 FIGURE 11(c)

b_{avg} = average width of nozzle strut plate, in m (ft)

σ_F = minimum yield stress of the local material, in N/mm^2 (kgf/mm^2, psi)

p is as defined in 3-2-14/23.11.

23.23 Direct Analysis

Direct calculations may be accepted in lieu of applying prescriptive formulas presented in 3-2-14/23.7 to 3-2-14/23.21, provided that the following are complied with and satisfied:

23.23.1 Additional Information to Submit

Where the design is based on direct calculations such as FEM, the full analysis is to be submitted for review including:

i) Software used;

ii) FE model;

iii) Loading conditions and load cases including but not limited to normal, heavy duty, and crash stop;

iv) Applied loads and boundary conditions;

v) Stress and deflection results, and

vi) Any other data and information associated with the analysis;

23.23.2 Acceptance Criteria

The results of analysis verify the following:

i) The maximum nominal stress is not exceed 50% of the yield strength. For the crash stop load case, the maximum local stress in the nozzle and its connection is not to exceed 80% of the yield strength;

ii) The relative radial displacement, s_{rel}, between nozzle inner shell and propeller tip is not to exceed the following:

$s_{rel} = 0.1 s_{cl}$ mm (in.)

where

s_{cl} = design clearance (the smallest distance) between nozzle inner shell and propeller tip without any loads applied

23.25 Welding and Nondestructive Testing

The following general requirements are to be complied with:

i) Welding on azimuthal thruster is to be in accordance with Section 2-4-1 of the ABS *Rules for Materials and Welding (Part 2)* and Section 3-2-19 as applicable.

ii) The required extent of NDT is to be indicated on the drawings and plans.

iii) NDT is to be performed in accordance with the ABS *Guide for Nondestructive Inspection* where applicable and any additional requirements specified by the manufacturer.

23.25.1 Nozzle Welding

i) Integrated nozzle welding details are to comply with 3-2-13/9.7.

ii) Volumetric and surface examination are to be performed on weldments of the inner and outer shell plating, as well as the internal ring web welds as appropriate.

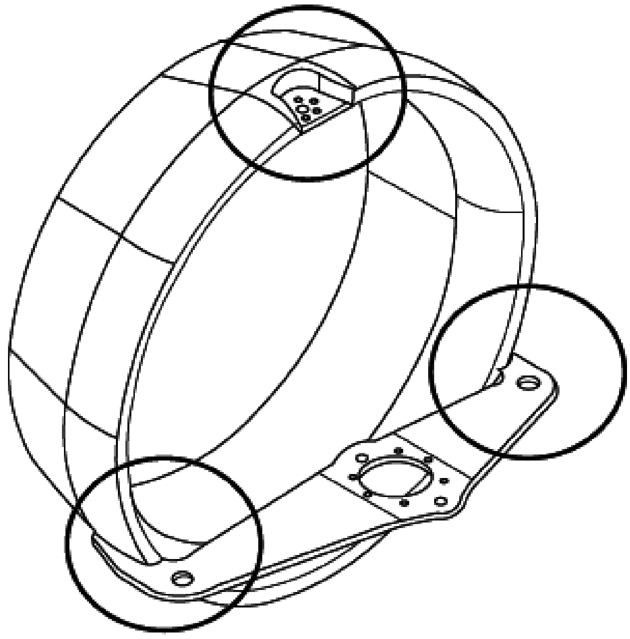
23.25.2 Connection Welding

Where the connections between nozzle and the hull/steering tube, strut and nozzle/propeller housing are welded (see figure below and 3-2-14/23.7 FIGURE 11), the following requirements are to be complied with:

i) Scantlings of the welded connection and welding type/size are to be specially considered and detailed stress analysis may be required to be submitted.

ii) Welding at the portion of the thruster assembly that penetrates the hull is to be of full penetration and in accordance with Section 2-4-1 of the ABS *Rules for Materials and Welding (Part 2)* and Section 3-2-19, as applicable.

iii) Volumetric or surface examination is to be performed on the welds of brackets and the shell penetration.



25 Azimuthing Pod

25.1 General Remarks

The requirements presented in 3-2-14/25 apply to the scantlings of the hull supports, strut, pod body, and pod fin if present. The requirements for steering unit, bearings, and other mechanical and electrical parts are offered in Part 4.

A general illustration of azimuthing pod unit is given in 3-2-14/25.1 FIGURE 12, which consists of the following parts:

i) Slewing ring

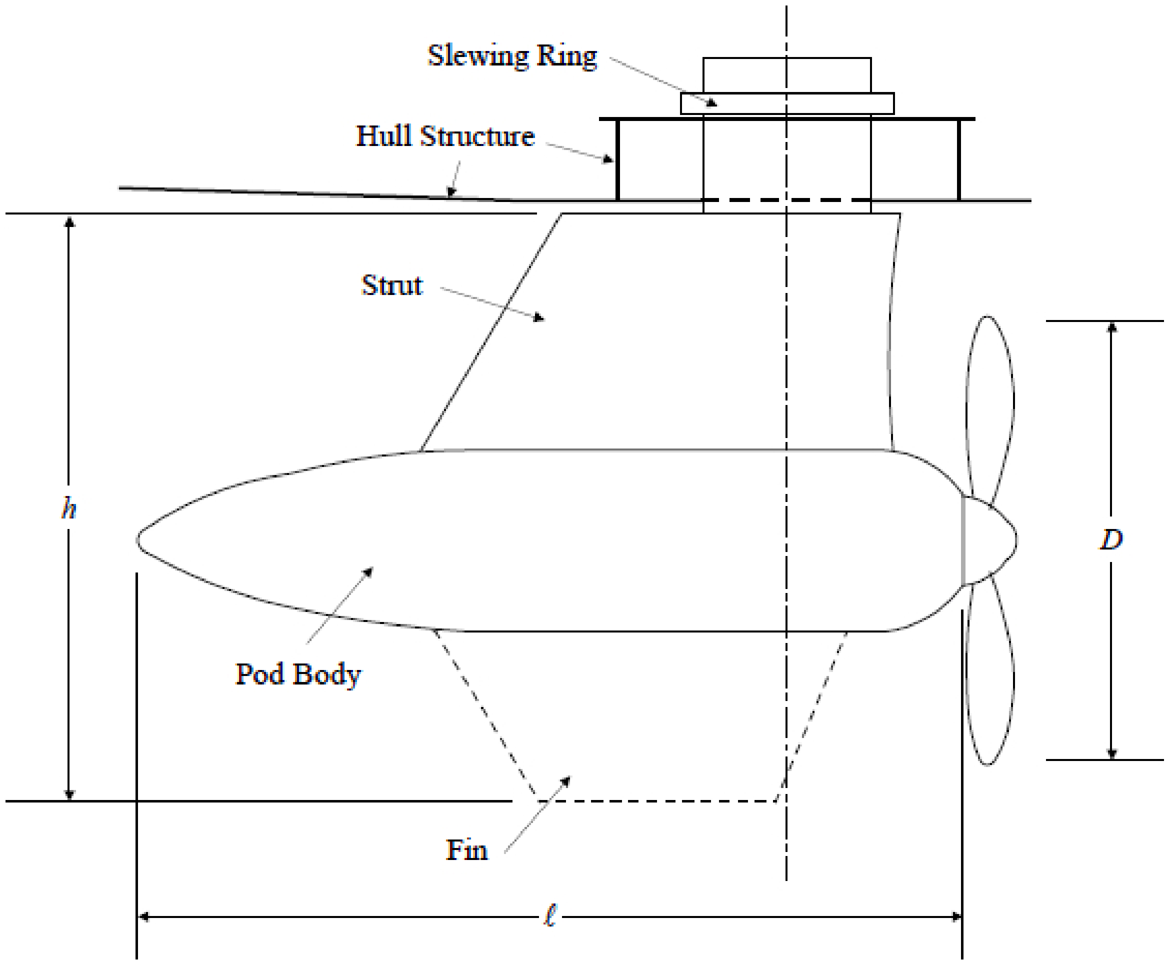
ii) Hull supporting structure

iii) Strut

iv) Pod body

v) Fin (if present)

FIGURE 12
Pod Propulsion Unit



25.3 Application Scope

Requirements hereafter apply to the azimuthing pod units with restrictions indicated below:

i) Units powered by electric propulsion motors

ii) Maximum operating angle at the design speed not to be greater than 35° on each side

iii) Units provided on Ice Classed vessels subject to additional requirements in Part 6, Chapter 1, as applicable

iv) Units of features and specifications outside the above scope are subject to special considerations provided plans and documents specified in 3-2-14/25.5 are submitted to ABS in early design stage

25.5 Plans and Documents

The following plans and documents are to be submitted to ABS:

i) System description including a block diagram showing how the various components are functionally related

ii) Ship's maneuvering capability in the specified operating conditions *iii)* Material grades, chemical and mechanical properties and welding specifications

iv) Nondestructive Testing (NDT) procedures for propulsion shaft, slewing ring bearings, gears, and couplings

v) Arrangement and scantlings in way of the pod unit and the hull supporting structure integration with the maximum loads on the structure marked

vi) Arrangements and scantlings of strut, pod body, fin (if present), and bearing mounting, also showing internal structures and assembly

vii) Drawings of detailed structural connection between structural components (i.e., bolted connections)

viii) Design loads for azimuthing pod, hull supporting structure, and propeller under all the specified design operating conditions

ix) Rated power, revolutions, and thrust

x) Power transmitted at the maximum torque condition

xi) Vibration analysis covering all operating speeds as specified in 4-3-8/1.7.3

xii) Maximum transient thrust, torque and other forces and moments experienced during all foreseeable operating modes permitted by the steering and propulsor drive control systems

xiii) Details of steering securing/locking (as specified in 3-2-14/25.9) and details of propeller shaft

xiv) Drawings of bearing arrangements with calculations of maximum bearing pressure and bearing lifetime calculation

xv) Manufacturer's limits on the seating flatness of the slewing ring

xvi) Thruster force calculations and predicted polar plots

xvii) Calculations of maximum hydrodynamic response to ship motions and accelerations, slamming, and pod/hull interaction for all the anticipated seagoing and operating conditions

xviii) Design loads for both the pod structure and propeller together with podded propulsion unit design operating modes

xix) The maximum anticipated loads calculated according to 3-2-14/25.11

xx) Fatigue analysis for local structure connections may be required

xxi) Supporting calculations for the interface between the hull structure and the podded propulsion unit (a finite element calculation would be considered an appropriate method)

xxii) Drawings of access and closing arrangements for pod unit inspection and maintenance

Note: For specific requirements of machinery components, refer to Part 4 as applicable

25.7 Material Requirements *(2023)*

Azimuthing pod units are to be of steels manufactured, tested, and certificated in accordance with ABS *Rules for Materials and Welding (Part 2)* and 3-2-14/23.25, as applicable.

Steels of specified tensile strength greater than 1040 N/mm^2 (106.1 kgf/mm^2,150,839 psi) or hardness of greater than 34 HRC are not to be used for pod fasteners at risk of coming in contacting with seawater.

Material factors for local structures/components are to be obtained according to 3-2-14/1.3.iv).

The Surveyor need not witness material tests for holding down bolts used for the attachment of the slewing ring to the hull supporting structure (slewing ring seating), coupling bolts used for joining sections of struts, and for bolts attaching the strut to the slewing bearing.The surface of the strut in way of bearings that are exposed to seawater is to be of corrosion-resistant material. Dissimilar metallic parts and components in direct contact are to be protected from galvanic corrosion. Details of the corrosion protection arrangements are to be submitted for review.

25.9 Locking Device

A locking device is to be provided and designed to meet the following:

i) To immeditaely prevent azimuthing pod from rotating beyond 35 degrees or the manufacturer's declared steering angle limit, whichever is smaller, in the event of steering system control failure during any operating mode

ii) To prevent azimuthing pod from rotating toward undesired directions in the event of accident or damage

iii) To keep each pod unit's slewing mechanism in its center (neutral) position in the event of steering system failure where more than one pod units are installed

iv) To keep the pod in position at the vessel's maneuvering speed of not less than 7 knots

25.11 Direct Analysis

The scantlings of the azimuth propulsion system and the associated hull supports are to be determined by the maximum pressure and loads obtained through direct calculations. The maximum anticipated service loads are to be determined by recognized acceptable methods, which include at least the following:

i) Gravity and buoyancy

ii) Forces of lift, drag, and thrust

iii) Maximum combined heave and pitch motions in way of hull and azimuthing pod interface

iv) Pod operates at maximum angle on each side while the ship travels at design speed

v) Maximum loads calculated for the crash stop obtained through a 180° rotation of the pod.

vi) Maximum loads calculated for the possible orientations of the system greater than the maximum angle at the relevant speed

vii) Any maneuvering conditions that are likely to give rise to high mean or vibratory loadings induced by the podded propulsion unit.

viii) Stern slamming pressure at speeds of 0 and 5 knots for all wave heights, following sea to beam sea.

ix) Rapid acceleration and deceleration maneuvers demands per the ship's operating manual.

x) The condition where the vessel travels ahead in a steady course under design oceangoing conditions while the azimuthing pod at its the maximum rated output.

Hydrodynamic analysis is to be carried out such that the structural response under the most severe load combination is not to exceed the normal operational requirements of the propulsion or steering system.

Finite element analysis is to be carried out to evaluate the structural design. The FE model developed for use with the stress criteria in 3-2-14/17.7 TABLE 7 should be discussed and agreed with ABS before analysis is commenced.

25.13 Direct Analysis Strength Criteria

The maximum stress on the strut, pod body, and hull structure obtained from the direct analysis according to 3-2-14/25.11 is to satisfy the strength checking criteria described in 3-2-14/25.13 TABLE 9.

Structure components showing localized stress concentration that is greater than the allowable stress indicated in 3-2-14/25.13 TABLE 9 may be accepted on a case by case basis, depending on the location and the scale of the localized stress, as well as the type of analysis or modeling criteria is used.

TABLE 9
Permissible Stress Level

Operating Condition	*Flow Angle*	*% of Material Yield Strength σ_F (2)*
Normal	±5°	40
Heavy Duty	±15°	60
Sea Trial	See Note 1	80
Crash/Accidental Load	0	90

Notes:

1 The smaller one of ±35° or the manufacturer's declared steering angle limit. See also 4-3-4/21.7.

2 σ_F = minimum specified yield strength of local material

25.15 Additional Requirements

The following verifications may be required by ABS on a case-by-case basis. Such a possible case where higher strength material is used so that plate thickness, structure stiffness, and connection wellness may be further verified.

25.15.1 Pod Strut

The pod strut is to have scantlings that meet the following requirements. Similar requirements also apply to the scantlings for pod fin, as applicable.

25.15.1(a) Strut Shell Plating. The plating thickness is not to be less than obtained from the following:

$$t = 0.0055 s\beta\sqrt{k_1 d_{max} + k_2 p_{max}} \times \sqrt{K} + k_3 \text{ mm (in.)}$$

where

s	=	smaller unsupported dimension of plating, in mm (in.)
β	=	$\sqrt{1.1 - 0.5(s/b)^2}$ maximum 1.0 for $b/s \geq 2.5$
b	=	greater unsupported dimension of plating, in mm (in.)
k_1	=	1.0 (1.0, 0.305)
k_2	=	0.1 (0.981, 10.7)
k_3	=	2.5 (2.5, 0.1)
d_{max}	=	vessel's maximum permissible draft in m (ft), but not be taken less than 6.1 m (20 ft)
p_{max}	=	maximum pressure obtained from direct calculation, in N/mm^2 (kgf/mm^2, psi)
K	=	plating material factor as defined in 3-2-14/1.3, as applicable
	=	1.0 for ordinary strength steel plate

25.15.1(b) Strut Strength. Strut section modulus and web area are to be such that stresses indicated in 3-2-14/25.13, as applicable, are not exceeded.

25.15.1(c) Strut Diaphragm. Strut internal diaphragms are to be fitted such that:

i) Vertical and horizontal diaphragms of strut are to be effectively attached to each other and to the shell plating. In addition, the vertical diaphragms are to be spaced approximately 1.5 times the spacing of horizontal diaphragms.

ii) The thickness of strut internal diaphragm is not to be less than 70% of the required shell plate thickness or 8 mm (0.31 in.), whichever is greater.

iii) Openings in strut diaphragms are not to exceed one half their depths.

iv) Where diaphragms are inaccessible for welding, they are to be fitted with flat bars connecting to the side plating by continuous welds or by 75 mm (3 in.) slot welds spaced at 150 mm (6 in.) centers. The slots are to be fillet welded around the edges and filled with a suitable compound.

25.15.2 Pod Body

The minimum scantlings of the pod structure are not to be less than obtained from the following.

25.15.2(a) Pod Shell Plating. The shell plate thickness of the pod body is not to be less than the greatest indicated below:

$t_1 = 2.7r\sqrt{k_1 d_{max} + k_2 p_{max}} \times \sqrt{K} + k_3$ mm (in.), or

$t_2 = sk_0\frac{\sqrt{(Kh)}}{c_f} + t_o$ mm (in.), or

$t_3 = 6.5\ (0.25)$ mm (in.), or

$t_4 = s/150 + t_o$ mm (in.)

where

r = mean radius of pod body

$k_0 = (3.075\sqrt{\alpha} - 2.077)/(\alpha + 0.272)$ for $1 \le \alpha \le 2$

$= 1.0$ for $\alpha > 2$

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

h = distances, in m (ft), from the lower edge of the plate to the summer load line;

c_f = 254 (460)

t_o = 2.5 (0.1)

k_1 , k_2, k_3, d, $p_{\max}$, K as defined in 3-2-14/25.15.1(a).

25.15.2(b) Pod Webs. The thickness of primary webs is not to be less than 70% of the adjacent shell plating or 10 mm, whichever is the greater.

25.15.2(c) Pod Stiffeners. The properties of the secondary stiffening are not to be less than obtained from 3-2-5/3.17 or 3-2-10/3.3, whichever is the greater.

25.15.3 Hull Support

Hull supporting structure, as illustrated in 3-2-14/25.15.3 FIGURE 13, in way of azimuthing pod unit is to comply with the following:

i) Hull girders connecting the slewing ring and the ordinary hull girders and floors are, in general, to be radially arranged for even transmission of loads and moments from the pod to the rest of the hull structure without unwarranted deflection.

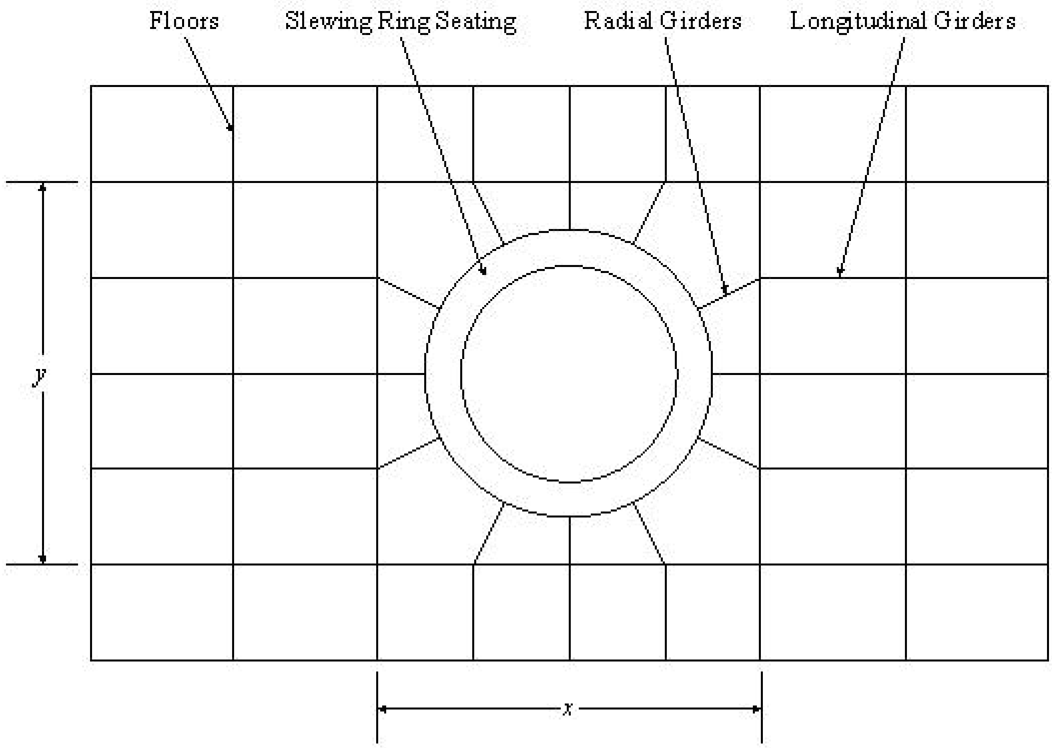
ii) Hull seating for the slew ring is to be sufficiently stiffened so that the flexure is within the manufacturer's specifications for the bearing.

iii) The minimum thickness for the girders of hull support is to be in accordance with 3-2-4/3.1, as applicable.

iv) Plate buckling of hull primary support members is to below the ideal elastic deformation limit of the material

v) Shell plating thickness in way of hull primary support structure is to be at least 50% thicker than as required for the adjacent shell plating.

FIGURE 13
Hull Supporting Structure



25.15.4 Slewing Bearing

Calculations of bearing stress are to be submitted for review and the equivalent stresses are to be lower than 80% of the yield strength of the bearing ring seating.

25.15.5 Connections *(2023)*

Where the azimuthing pod is fitted with a nozzle as illustrated in 3-2-14/23.7 FIGURE 11(c), the connections are to be evaluated according to 3-2-14/23.19.1 and/or 3-2-14/23.19.2, as applicable.

Stress calculations for the connection of the nozzle to the hull or pod body are to be submitted for review, and the equivalent stresses are to be lower than 80% of the yield strength of the bearing ring seating.

The flange connection of propeller nozzle with pod body or hull is to comply with the following:

i) The attachments (base) of flange connection are to be supported by an ample body of metal worked out from both parts that are to be coupled together.

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. Alternatively, a combination of holding down bolts together with shear elements may be considered, provided the holding down capacity and shearing capacity is equivalent to that of fitted bolts.

iv) The nuts are to be effectively locked in place.

25.15.6 Pod Web

The thickness of primary webs is not to be less than 70% of the adjacent shell plating or 10 mm (0.4 in.), whichever is the greater.

25.17 Structural Transition

The structural transitions of azimuthing pods are to avoid abrupt changes as much as practical. Structural transitions are to be smooth and gradual in way of the:

i) Strut from upper mounting with steering unit to the lower section

ii) Connection of strut and pod body with fillet radius not less than 75 mm (3 in.), in general

25.19 Service Accessibility

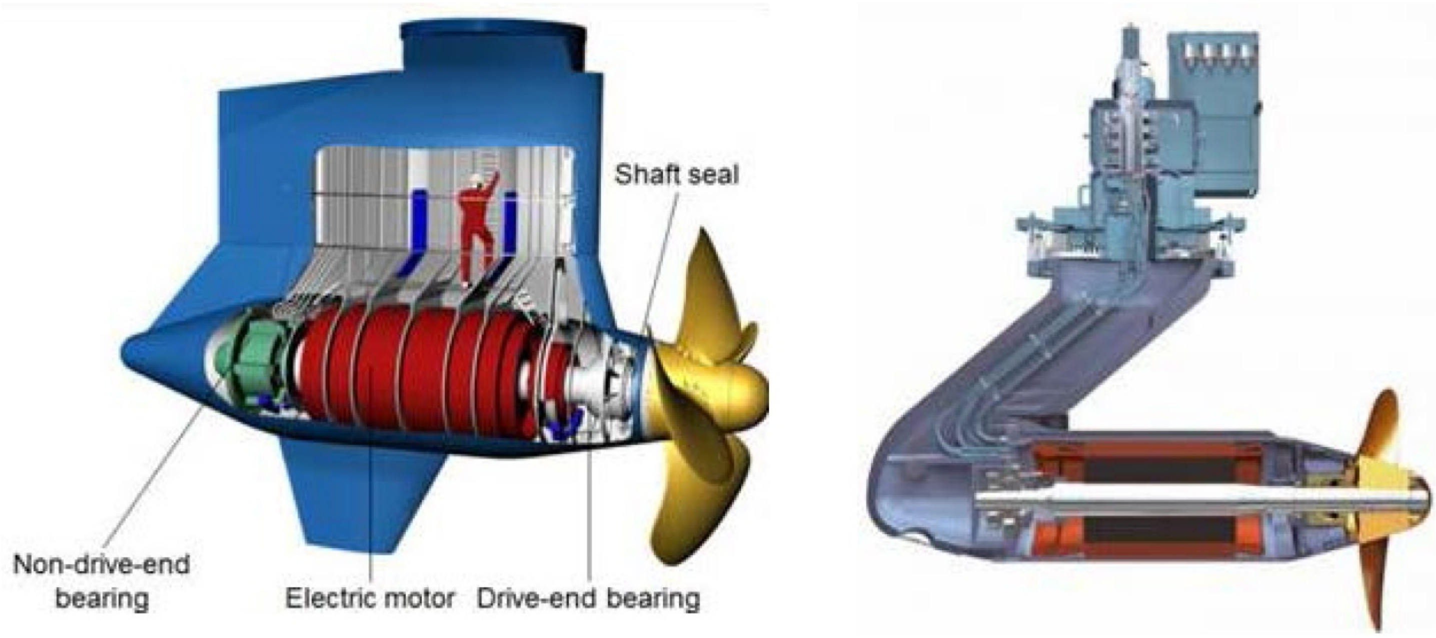
Azimuthing pod internal structures and parts including webs, frames, shafts, bearings, and seal arrangements are to be accessible for surveys and examinations in accordance with Section 3-7-1 as applicable. The design is to provide means for internal inspection as indicated in the following:

i) For units, as illustrated in 3-2-14/25.19 FIGURE 14(a) and alike, the internal structure and components are such as to allow direct access for survey and examination, or

ii) For compact version of azimuthing pods, as illustrated in 3-2-14/25.19 FIGURE 14(b) and alike, the unit is designed to be readily removable for survey or to have a sufficient number of access openings for boroscopic internal inspection.

iii) Where the design of the service access arrangement is different from those indicated in *i*) and *ii)* above, it is subject to special consideration.

FIGURE 14
Azimuthing Pod Internal Structure Access



(a) (b)

25.21 Air and Drainage Escape

Limber and air holes are to be cut in all parts of pod internal structure as required for drainage, free flow to the section pipes and the escape of air to vents.

25.23 Watertightness

Azimuthing pods are to be of watertight and are to be tested in accordance with 3-7-1/3.5.7 TABLE 1, as applicable.

25.25 Welding Requirements

Welding is to be in accordance with Section 2-4-1 of the ABS *Rules for Materials and Welding (Part 2)* and Section 3-2-19. Where inaccessible for welding inside the pod, it is recommended that webs, frames, and diaphragms be fitted with flat bars and the side plating be connected to these flat bars by continuous welds or by 75 mm (3 in.) slot welds spaced at 150 mm (6 in.) centers. The slots are to be fillet welded around the edges and filled with a suitable compound.

PART 3

CHAPTER 2
Hull Structures and Arrangements

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 requirements relate to vessels having minimum freeboards. For decks above the first deck above the freeboard deck (second and higher tiers above the freeboard deck), the heights of the coamings and the effectiveness of the closing arrangements may be modified. The arrangements and details for all hatchways are to be submitted for approval.

3 Positions and Design Pressures

3.1 Positions of Deck Openings

For the purpose of the Rules, two positions of deck openings are defined as follows.

Position 1 Upon exposed freeboard and raised quarter decks, and upon exposed superstructure decks situated forward of a point located $L_f/4$ from the forward end of L_f.

Position 2 Upon exposed superstructure decks situated abaft $L_f/4$ from the forward end of L_f and located at least one standard height of superstructure above the freeboard deck. Upon exposed superstructures decks situated forward of a point located $L_f/4$ from the forward end of L_f and located at least two standards heights of superstructure above the freeboard deck.

3.3 Vertical Weather 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. The design vertical weather pressures need not be combined with cargo loads specified in 3-2-15/9.9 and 3-2-15/9.11.

3.3.1 Cargo Hatch Covers in Position 1

For ships of 100 m (328 ft) in length and above:

$p_V = p_0 + (p_{FP} - p_0)(0.25 - x/L_f)/0.25$ kN/m² (tf/m², Ltf/ft²)

In no case is p_V to be less than p_0:

For a position 1 hatchway located at least one superstructure standard height higher than the freeboard deck:

p_V = 34.3 kN/m^2

= 3.5 tf/m^2

= 0.32 Ltf/ft^2

For ships less than 100 m (328 ft) in length:

$p_V = R\{15.8 + (L_f/N)[1 - (5/3)(x/L_f)] - 3.6x/L_f\}$ kN/m^2 (tf/m^2, Ltf/ft^2)

In no case is p_V to be less than:

p_V = $1.2897(0.15L_f + 11.6)$ kN/m^2

= $0.1316(0.15L_f + 11.6)$ tf/m^2

= $0.0121(0.0457L_f + 11.6)$ Ltf/ft^2

For a position 1 hatchway located at least one superstructure standard height higher than the freeboard deck:

p_V = $1.2897(0.15L_f + 11.6)$ kN/m^2

= $0.1316(0.15L_f + 11.6)$ tf/m^2

= $0.0121(0.0457L_f + 11.6)$ Ltf/ft^2

where

p_0 = 34.3 (3.5, 0.32) kN/m^2 (tf/m^2, Ltf/ft^2)

p_{FP} = pressure at the forward perpendicular

= $49.0 + a_V(L_f - 100)$ kN/m^2 for L_f in meters

= $5 + a_V(L_f - 100)$ tf/m^2 for L_f in meters

= $0.457 + a_V(L_f - 328)$ Ltf-ft^2 for L_f in feet

a_V = 0.0726 (0.0074, 0.000206) kN/m^3 (tf/m^3, Ltf/ft^3), for type B freeboard ships

= 0.356 (0.0363, 0.00101) kN/m^3 (tf/m^3, Ltf/ft^3), for ships with reduced freeboard

L_f = freeboard length, in m (ft), as defined in 3-1-1/3.3, but is not to be taken as greater than 340 m (1115 ft)

x = distance, in m (ft), from the mid length of the hatch cover under examination to the forward end of L_f or $0.25L_f$, whichever is less.

R = 1.0 (0.102, 0.00932)

N = 3 (3, 9.84)

3.3.2 Cargo Hatch Covers in Position 2

Where vessel's L_f is 100 m (328 ft) and greater the design pressures are as follows:

p_V = 25.51 kN/m^2

= 2.6 tf/m^2

= 0.24 Ltf/ft^2

Upon exposed superstructure deck located at least one superstructure standard height higher than the lowest Position 2 deck:

p_V = 20.60 kN/m^2

= 2.1 tf/m^2

= 0.19 Ltf/ft^2

Where vessel's L_f is less than 100 m the design pressures are as follows:

p_V = $25.5 - 0.142(100 - L_f)$ kN/m^2

= $2.6 - 0.0145(100 - L_f)$ tf/m^2

= $0.238 - 0.00041(328 - L_f)$ Ltf/ft^2

In 3-2-15/3.3.2 FIGURE 1, the positions 1 and 2 are illustrated for an example ship. Where an increased freeboard is assigned, the design pressures for hatch covers on the actual freeboard deck may be as required for a superstructure deck, provided the summer freeboard is such that the resulting draft will not be greater than that corresponding to the minimum freeboard calculated from an assumed freeboard deck situated at a distance at least equal to the standard superstructure height h_N below the actual freeboard deck, see 3-2-15/3.3.2 FIGURE 2.

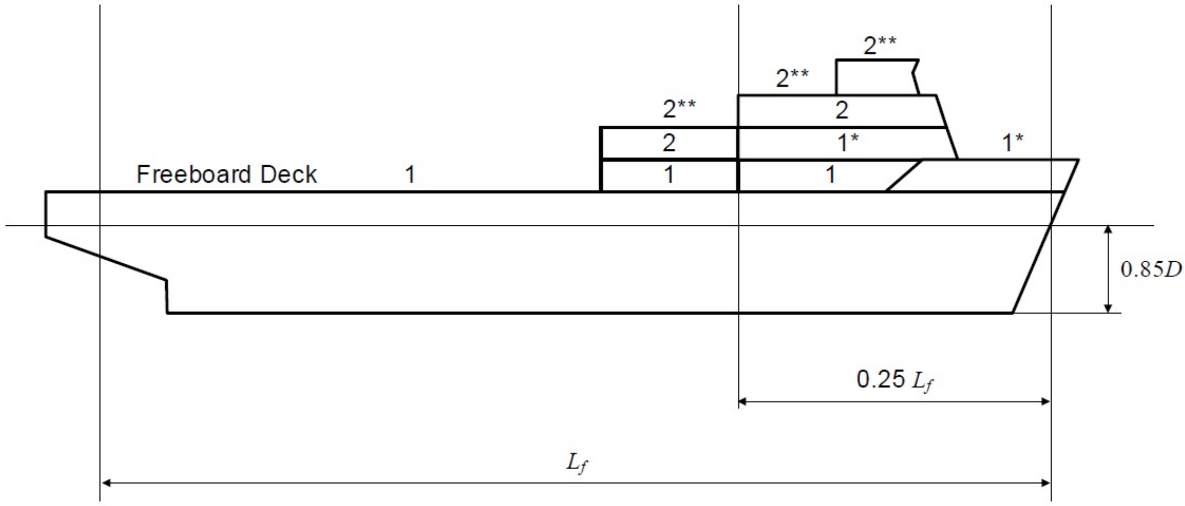
h_N = $(1.05 + 0.01L_f)$ m

where 1.8 m $\le h_N \le$ 2.3 m

h_N = $3.281(1.05 + 0.0031L_f)$ ft

where 5.91 ft $\le h_N \le$ 7.55 ft

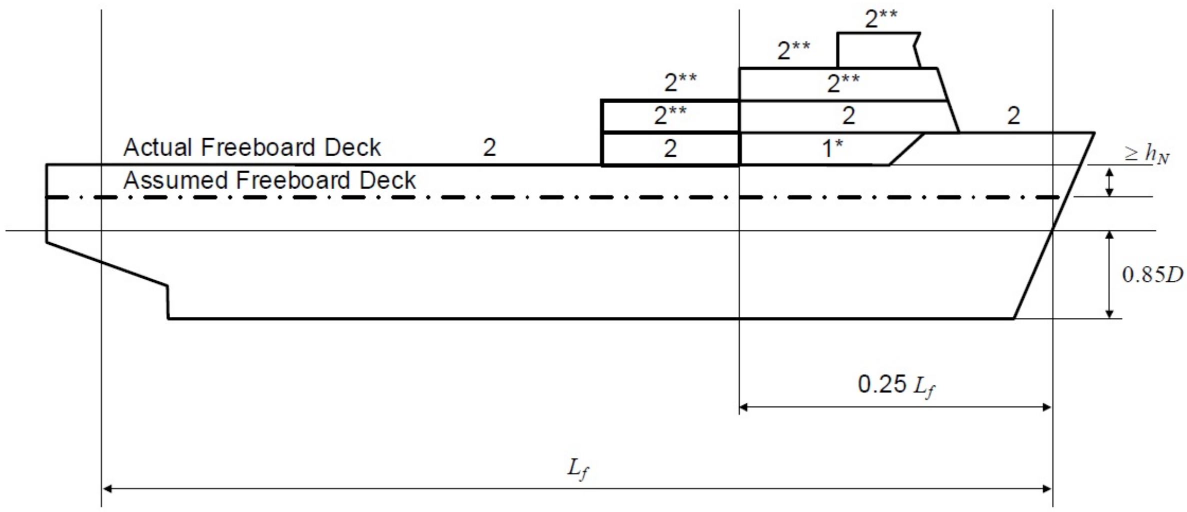
FIGURE 1
Positions 1 and 2



* reduced load upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck

** reduced load upon exposed superstructure decks of vessels with L_f > 100m (328 ft) located at least one superstructure standard height above the lowest Position 2 deck

FIGURE 2
Positions 1 and 2 for an Increased Freeboard



* reduced load upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck

** reduced load upon exposed superstructure decks of vessels with L_f > 100m (328 ft) located at least one superstructure standard height above the lowest Position 2 deck

3.5 Horizontal Design Pressures *(1 July 2018)*

The horizontal weather design pressure for determining the scantlings of outer edge girders (skirt plates) of weather deck hatch covers and of hatch coamings is:

$p_H = a_H c_H R(b_H c_L f - z)$ kNm² (tf/m², Ltf/ft²)

where

f	=	$0.04L + 4.1$	for $L < 90$ m
	=	$10.75 - \left(\frac{300 - L}{100}\right)^{1.5}$	for 90 m $\le L <$ 300 m
	=	10.75	for 300 m $\le L <$ 350 m
	=	$10.75 - \left(\frac{L - 350}{150}\right)^{1.5}$	for 350 m $\le L \le$ 500 m
	=	$0.0122L + 4.1$	for $L <$ 295 ft
	=	$10.75 - \left(\frac{300 - 0.3048L}{100}\right)^{1.5}$	for 295 ft $\le L <$ 984 ft
	=	10.75	for 984 ft $\le L <$ 1148 ft
	=	$10.75 - \left(\frac{0.3048L - 350}{150}\right)^{1.5}$	for 1148 ft $\le L \le$ 1640 ft
c_L	=	$\sqrt{0.011L}$	for $L < 90$ m
	=	1	for $L \ge 90$ m
	=	$\sqrt{0.00336L}$	for $L <$ 295 ft
	=	1	for $L \ge$ 295 ft
b_H	=	$1.0 + \left(\frac{\frac{x'}{L} - 0.45}{C_b + 0.2}\right)^2$	for $\frac{x'}{L} < 0.45$
	=	$1.0 + 1.5\left(\frac{\frac{x'}{L} - 0.45}{C_b + 0.2}\right)^2$	for $\frac{x'}{L} \ge 0.45$
a_H	=	$20 + \frac{e_H L_1}{12}$	for unprotected front coamings and hatch cover skirt plates
	=	$10 + \frac{e_H L_1}{12}$	for unprotected front coamings and hatch cover skirt plates, where the distance from the actual freeboard deck to the summer load line exceeds the minimum non-corrected tabular freeboard by at least one standard superstructure height h_N
	=	$5 + \frac{e_H L_1}{15}$	for side and protected front coamings and hatch cover skirt plates
	=	$7 + \frac{e_H L_1}{100} - 8 \cdot \frac{x'}{L}$	for aft ends of coamings and aft hatch cover skirt plates abaft amidships
	=	$5 + \frac{e_H L_1}{100} - 4 \cdot \frac{x'}{L}$	for aft ends of coamings and aft hatch cover skirt plates forward of amidships
L_1	=	L, need not be taken greater than 300 m (984 ft)	

C_b = block coefficient, as defined in 3-1-1/13.3, where $0.6 \le C_b \le 0.8$. When determining scantlings of aft ends of coamings and aft hatch cover skirt plates forward of amidships, C_b need not be taken less than 0.8.

x' = distance, in m (ft), between the transverse coaming or hatch cover skirt plate considered and aft end of the length L. When determining side coamings or side hatch cover skirt plates, the side is to be subdivided into parts of approximately equal length, not exceeding $0.15L$ each, and x' is to be taken as the distance between aft end of the length L and the center of each part considered.

z = vertical distance in m from the summer load line to the midpoint of stiffener span, or to the middle of the plate field

c_H = $0.3 + 0.7\frac{b'}{B'}$, where b'/B' is not to be taken less than 0.25

b' = breadth of coaming in m at the position considered

B' = actual maximum breadth of ship in m on the exposed weather deck at the position considered.

e_H = 1 (1, 0.3048)

R = 1 (0.102, 0.0093) , as defined in 3-2-15/3.3.1

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

The design load p_H is not to be taken less than the minimum values given in 3-2-15/3.5 TABLE 1.

TABLE 1
Minimum Design Load p_{Him}

L in m (ft)	*$p_{H\min}$ in kN/m² (tf/m², Ltf/ft²) for*	
	Unprotected Fronts	*Elsewhere*
≤ 50 (164)	30 (3.06, 0.279)	15 (1.53, 0.139)
> 50 (164) < 250 (820)	$R\left(25 + \frac{e_H L}{10}\right)$	$R\left(12.5 + \frac{e_H L}{20}\right)$
≥ 250 (820)	50 (5.1, 0.465)	25 (2.55, 0.232)

The horizontal weather design load need not be included in the direct strength calculation of the hatch cover, unless it is utilized for the design of substructures of horizontal supports according to the requirements of 3-2-15/9.23.2(c).

5 Hatchway Coamings

5.1 Height of Coamings

The height of coamings of hatchways is to be at least:

600 mm (23.5 in.) if in Position 1

450 mm (17.5 in.) 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.

5.1.1 For Vessels Under 24 Meters (79 Feet) in Length *(2022)*

The heights above deck of coamings of hatchways secured weathertight by tarpaulins and battening devices are to be at least:

450 mm (17.5 in.) if in Position 1

300 mm (12.0 in.) 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 conditions. Sealing arrangements are to be weathertight if coaming is fitted, and watertight for flush covers.

Notes:

1 Coaming heights may be reduced on vessels which have freeboard in excess of the minimum geometric freeboard and/or a superstructure deck with height of deck in excess of the standard height of a superstructure.

2 The coaming height should be as indicated above, unless otherwise specifically requested by flag Administration.

5.3 Coaming Plates *(2022)*

Where 3-2-15/9 is not applicable, coaming plates, where installed, are not to be less in thickness than that obtained from the following equation:

$$t = 0.05L + 7 \quad \text{mm}$$
$$t = 0.0006L + 0.27 \quad \text{in.}$$

where

t = thickness, in mm (in.)

L = length of vessel, in m (ft), as defined in 3-1-1/3, but need not exceed 76 m (250 ft)

5.5 Coaming Stiffening

Except as noted below, coaming stiffening is to comply with the following:

i) Horizontal stiffeners are to be fitted on coamings in Position 1 at not more than 254 mm (10 in.) below the upper edge of the coaming.*

ii) The breadth of the stiffener's web is not to be less than 175 mm (7 in.) and thickness to fulfill 3-1-2/13.5 requirements.*

iii) Brackets or stays are to be fitted from the horizontal stiffener to the deck at intervals not exceeding 3 m (10 ft).*

iv) All exposed coamings other than those in Position 1 and which are 760 mm (30 in.) or more in height are to be similarly supported.*

v) Where the height of any exposed coaming exceeds 915 mm (36 in.), the arrangement of the stiffeners and brackets or stays is to be so as to provide equivalent support and stiffness.*

vi) Where coamings are protected, the arrangement of the stiffeners and brackets or stays may be modified.

vii) 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 any weights located on hatch covers, if applicable.

Note:

* Small hatches as specified in 3-2-15/13 need not comply with these requirements. (See the strength requirements for small hatches in 3-2-15/13.1)

5.5.1 Coaming Stiffening for Vessels Under 90 Meters (295 Feet) in Length *(2022)*

The requierments of 3-2-15/5.5 may be modified as follows:

i) Horizontal stiffeners are to be fitted on coamings 450 mm (17.5 in.) or greater in height. *

ii) The breadth of the stiffener's web is not to be less than that obtained from the following equation, but need not exceed 175 mm (7 in.):*

$$b = 1.67L + 50 \quad \text{mm}$$
$$b = 0.02L + 2 \quad \text{in.}$$

where

b = breadth, in mm (in.)

L = length of vessel, in m (ft), as defined in 3-1-1/3

5.7 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.

5.9 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 3-2-1/13, they are in general to be longitudinally stiffened. The coaming thickness is to be not less than required by 3-2-3/5 TABLE 2, equation 2b, and the longitudinal stiffeners not less than required by 3-2-7/3.1 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 3-2-7/3.1 TABLE 1. Special consideration will be given to the coaming scantlings where adequate buckling strength is shown to be otherwise provided.

7 Hatchways Closed by Covers of Aluminum and Fitted with Gaskets and Clamping Devices *(1 July 2018)*

7.1 Strength of Aluminum Covers

Explosion bonding is to be used for joining aluminum to steel. Such joints are to be protected to prevent galvanic corrosion. In addition, when one or both sides of aluminum to dissimilar metal joints are exposed to the weather, sea water or wet spaces, a minimum of 0.5 mm (0.02 in.) of plastic insulation shall be installed between faying surfaces and extend beyond the edge of the joint. Non-welded oil stops and stop waters are to be a plastic insulation tape or equivalent, which would provide a corrosion resistant system. Aluminum faying surfaces exposed to the weather, sea water or other corrosive environments are to be coated to minimize crevice corrosion in way of the faying surfaces.

Aluminum covers are not allowed on cargo decks. Where weathertight covers are of aluminum alloy, the maximum allowable stress, deflection and top plate thickness under the design loads calculated according to 3-2-15/3.3, but with pressure, p, of not less than 17.17 kN/m^2 (1.75 tf/m^2, 0.16 Ltf/ft^2) for Position 1 and not less than 12.75 kN/m^2 (1.3 tf/m^2, 0.119 Ltf/ft^2) for Position 2, are as follows:

• Maximum allowable stress	the product of the maximum stress thus calculated and the factor of 4.25 is not to exceed the minimum ultimate strength of the material.
• Maximum allowable deflection	0.0028 times the span
• Top plate thickness	not less than $0.99Q_o$% of the spacing of stiffeners or $5.4Q_o$ mm ($0.22Q_o$ in.), if that be greater.

Q_o is the material factor as in 3-2-9/9.3.2, but is not to be taken less than 1.11

8 Hatchways Closed by Portable Covers and Secured Weathertight by Tarpaulins and Battening Devices

8.1 Pontoon Covers

8.1.1 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 3-2-15/3.3, 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 (0.24 in.)

where

Y = specified minimum upper yield point strength of the materials, in N/mm^2 (kgf/mm^2, psi)

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,Appendix 3-2-A6 may be used to determine required scantlings.

8.1.2 Cleats

Cleats are to be set to fit the taper of the wedges. They are to be at least 65 mm (2.5 in.) wide and spaced not more than 600 mm (23.5 in.) center to center. The cleats along each side or end are to be not more than 150 mm (6 in.) from the hatch corners.

8.1.3 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 (0.50 in.) thick at the toes.

8.1.4 Battening Bars

Battening bars are to be provided for properly securing the tarpaulins; they are to have a width of 64 mm (2.5 in.) and a thickness of not less than 9.5 mm (0.375 in.).

8.1.5 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.

8.1.6 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 (4.9 ft) in length are to be secured by at least two such securing appliances.

8.3 Wood Hatch Covers

8.3.1 Hatch Boards

Wood hatch covers on exposed hatchways are to have a finished thickness not less than 60 mm (2.375 in.), where the span is not more than 1.5 m (4.9 ft). 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.

8.3.2 Portable Beams

Where portable beams for supporting wood hatch boards are made of steel, the maximum allowable stress and deflection under the design loads in 3-2-15/3.3 are as follows.

Maximum allowable stress	$0.68Y$
Maximum allowable deflection	0.0044 times the span

where Y is as defined in 3-2-15/8.1.1.

Where the cross section of portable beams is not constant along the span, Appendix 3-2-A6 may be used to determine required beam scantlings.

8.3.3 Closing/Securing Arrangements

Closing arrangements are to be in accordance with 3-2-15/8.1.2 through 3-2-15/8.1.6.

8.3.4 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 (3 in.) 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.

8.5 Steel Hatch Covers

8.5.1 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 3-2-15/3.3 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 (0.24 in.)

where Y is as defined in 3-2-15/8.1.1.

Covers are to be assumed to be simply supported.

Portable beams are to be in accordance with 3-2-15/8.3.2.

8.5.2 Closing Arrangements

Closing arrangements are to be in accordance with 3-2-15/8.1.2 through 3-2-15/8.1.6.

8.7 Bearing Surface

The width of each bearing surface for hatchway covers is to be at least 65 mm (2.5 in.).

8.9 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.

9 Hatchways Closed by Covers of Steel Fitted with Gaskets and Clamping Devices *(1 July 2021)*

These requirements apply to all ships except bulk carriers (including self-unloading bulk carriers), ore carriers and combination carriers and are for all cargo hatch covers and coamings on exposed decks. Bulk carriers, ore carriers and combination carriers are to comply with the requirements of 5C-3-4/19.

9.1 Strength of Covers

9.1.1 Stresses

The equivalent stress σ_e in steel hatch cover structures related to the net thickness shall not exceed $0.8Y$, where Y is specified minimum upper yield point strength of the material in N/mm^2 (kgf/mm^2, psi). For design loads according to 3-2-15/3.5 and 3-2-15/9.9 to 3-2-15/9.13, the equivalent stress σ_e related to the net thickness shall not exceed $0.9Y$ when the stresses are assessed by means of FEM using plane stress or shell element

For beam element calculations and grillage analysis, the equivalent stress may be taken as follows:

$$\sigma_e = \sqrt{\sigma^2 + 3\tau^2} \text{ N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

where

σ = normal stress, in N/mm^2 (kgf/mm^2, psi)

τ = shear stress, in N/mm^2 (kgf/mm^2, psi)

For FEM calculations, the equivalent stress may be taken as follows:

$$\sigma_e = \sqrt{\sigma_x{}^2 - \sigma_x \cdot \sigma_y + \sigma_y{}^2 + 3\tau^2} \text{ N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

where

σ_x = normal stress in x-direction, in N/mm^2 (kgf/mm^2, psi)

σ_y = normal stress in y-direction, in N/mm^2 (kgf/mm^2, psi)

τ = shear stress in the x-y plane, in N/mm^2 (kgf/mm^2, psi)

Indices x and y are coordinates of a two-dimensional Cartesian system in the plane of the considered structural element.

In case of FEM calculations using shell or plane strain elements, the stresses are to be read from the center of the individual element. It is to be observed that, in particular, at flanges of unsymmetrical girders, the evaluation of stress from element center may lead to non-conservative results. Thus, a sufficiently fine mesh is to be applied in these cases or, the stress at the element edges shall not exceed the allowable stress. Where shell elements are used, the stresses are to be evaluated at the mid plane of the element.

The value for cargo hatch covers for bulk carriers, ore carriers and combination carriers is given in 5C-3-4/19.3.1(a).

9.1.2 Deflection

The maximum vertical deflection of primary supporting members due to the vertical design load according to 3-2-15/3.3 is:

$$\delta_{v\max} = 0.0056\ell_g$$

where

ℓ_g = greatest span of primary supporting members

Where hatch covers are arranged for carrying containers and mixed stowage is allowed (i.e., a 40-foot container stowed on top of two 20-foot containers, particular attention should be paid to the deflections of hatch covers. Further the possible contact of deflected hatch covers within hold cargo has to be observed.

9.1.3 Material

Hatch covers and coamings are to be made of material in accordance with 3-1-2/3.3 TABLE 1 applying Class I requirements for top plate, bottom plate and primary supporting members.

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.

9.1.4 General Requirements

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

The spacing of primary supporting members parallel to the direction of secondary stiffeners is not to exceed $^1/_3$ of the span of primary supporting members. When strength calculation is carried out by FE analysis using plane strain or shell elements, this requirement can be waived.

Secondary stiffeners of hatch coamings are to be continuous over the breadth and length of hatch coamings.

9.1.5 Net Scantling Approach

Unless otherwise quoted, the thicknesses t of the following sections are net thicknesses.

The net thicknesses are the member thicknesses necessary to obtain the minimum net scantlings required by 3-2-15/9.1 through 3-2-15/9.17 and 3-2-15/9.21.

The required gross thicknesses are obtained by adding corrosion additions, t_S, given in 3-2-15/9.25.1 TABLE 8.

Strength calculations using beam theory, grillage analysis or FEM are to be performed with net scantlings.

9.3 Local Net Plate Thickness

The minimum local net plate thickness t of the hatch cover top plating is:

$$t = 15.8 F_p s \sqrt{\frac{p}{0.95Y}} \quad \text{mm}$$

$$t = 23.64 F_p s \sqrt{\frac{p}{0.95Y}} \quad \text{in.}$$

but not less than 1% of the spacing of the stiffener or 6 mm (0.24 in.) if that be greater.

where

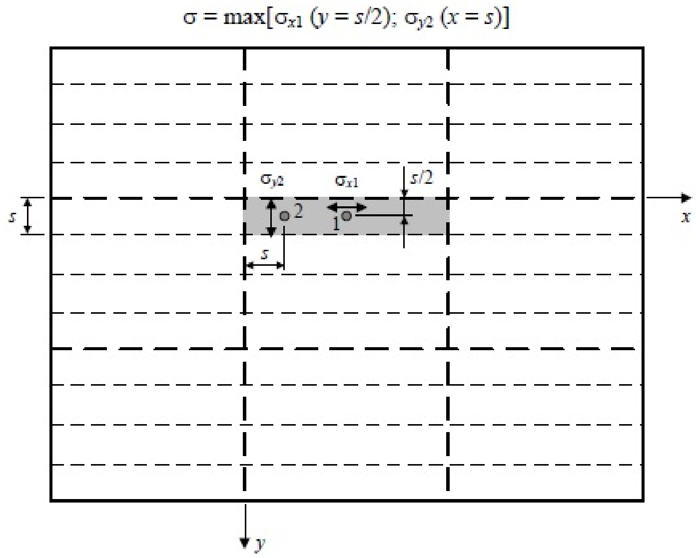
F_p	=	factor for combined membrane and bending response	
	=	1.5	in general
	=	$2.375\frac{\sigma}{y}$ for $\frac{\sigma}{0.8Y} \geq 0.8$	for the attached plate flange of primary supporting members
s	=	stiffener spacing, in m (ft)	
p	=	pressure p_V and p_L, as defined in 3-2-15/3.3 and 3-2-15/9.9.1, in kN/m² (tf/m², Ltf/ft²)	
σ	=	maximum normal stress of hatch cover top plating, determined according to 3-2-15/9.3 FIGURE 3, N/mm² (kgf/mm², psi)	

Y is as defined in 3-2-15/9.1

For flange plates under compression sufficient buckling strength according to 3-2-15/9.17 is to be demonstrated.

The normal stress σ of the hatch cover plating may be determined in a distance s from webs of adjacent primary supporting members perpendicular to secondary stiffeners and in a distance s/2 from the web of an adjacent primary supporting member parallel to secondary stiffeners, refer to 3-2-15/9.3 FIGURE 3. The greater of both stresses is to be taken. For the distribution of normal stress σ between two parallel girders, refer to 3-2-15/9.17.3(b).

FIGURE 3
Determination of Normal Stress of the Hatch Cover Plating



9.3.1 Local Gross Plate Thickness of Hatch Covers for Wheel Loading

The local gross plate thickness of hatch covers subject to wheel loading is to be as given in, refer to 3-2-3/5.17.

Where the hatch cover is subject to other load as well, the hatch cover is to comply with the applicable requirement in 3-2-15/9.

9.3.2 Lower Plating of Double Skin Hatch Covers and Box Girders

The thickness to fulfill the strength requirements is to be obtained from the calculation according to 3-2-15/9.15 under consideration of permissible stresses according to 3-2-15/9.1.1. When the lower plating is taken into account as a strength member of the hatch cover, the net thickness, in mm (in.), of lower plating is to be taken not less than 5 mm (0.20 in.).

When project cargo is intended to be carried on a hatch cover, the net thickness must not be less than:

$t = 6.5s$ mm

$= 0.078s$ in.

but not less than 5 mm (0.20 in.)

where s is as defined in 3-2-15/9.3

Project cargo means especially large or bulky cargo lashed to the hatch cover. Examples are parts of cranes or wind power stations, turbines, etc. Cargoes that can be considered as uniformly distributed over the hatch cover (e.g., timber, pipes or steel coils) need not to be considered as project cargo.

When the lower plating is not considered as a strength member of the hatch cover, the thickness of the lower plating will be specially considered.

9.5 Net Scantlings of Secondary Stiffeners

The net section modulus Z and net shear area A_s of uniformly loaded hatch cover stiffeners constrained at both ends must not be less than:

$Z = \frac{104}{Y} s_s \ell_s^2 p$ cm³, for design load according to 3-2-15/3.3

$= \frac{2793}{Y} s_s \ell_s^2 p$ in³

$Z = \frac{93}{Y} s_s \ell_s^2 p$ cm³, for design load according to 3-2-15/9.9.1

$= \frac{2498}{Y} s_s \ell_s^2 p$ in³

$A_s = \frac{10.8 s_s \ell_s p}{Y}$ cm², for design load according to 3-2-15/3.3

$= \frac{2418 s_s \ell_s p}{Y}$ in²

$A_s = \frac{9.6 s_s \ell_s p}{Y}$ cm², for design load according to 3-2-15/9.9.1

$= \frac{2149 s_s \ell_s p}{Y}$ in²

where

ℓ_s = secondary stiffener span, to be taken as the spacing of primary supporting members or the distance between a primary supporting member and the edge support, in m (ft)

s_s = secondary stiffener spacing in m (ft)

Y is as defined in 3-2-15/9.1

p is as defined in 3-2-15/9.3

For secondary stiffeners of lower plating of double skin hatch covers, requirements mentioned above are not applied due to the absence of lateral loads.

The net thickness, in mm (in.), of the stiffener (except u-beams/trapeze stiffeners) web is to be taken not less than 4 mm (0.16 in.).

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

For flat bar secondary stiffeners and buckling stiffeners, the ratio h/t_w is to be not greater than following equation:

$\frac{h}{t_w} \leq 15k^{0.5}$

where

h = height of the stiffener, in m (ft)

t_w = net thickness of the stiffener, in m (ft)

k = 235/Y (23.963/Y, 34084/Y)

Y is as defined in 3-2-15/9.1

Stiffeners parallel to primary supporting members and arranged within the effective breadth according to 3-2-15/9.15.1 must be continuous at crossing primary supporting member and may be regarded for calculating the cross sectional properties of primary supporting members. It is to be verified that the combined stress of those stiffeners induced by the bending of primary supporting members and lateral pressures does not exceed the permissible stresses according to 3-2-15/9.1.1. The requirements of this paragraph are not applied to stiffeners of lower plating of double skin hatch covers if the lower plating is not considered as strength member.

For hatch cover stiffeners under compression sufficient safety against lateral and torsional buckling according to 3-2-15/9.17.3 is to be verified.

For hatch covers subject to wheel loading stiffener scantlings are to be determined by direct calculations under consideration of the permissible stresses according to 3-2-15/9.1.1.

9.7 Net Scantlings of Primary Supporting Members

9.7.1 Primary Supporting Members

Scantlings of primary supporting members are obtained from calculations according to 3-2-15/9.15 under consideration of permissible stresses according to 3-2-15/9.1.1.

For all components of primary supporting members sufficient safety against buckling must be verified according to 3-2-15/9.17. For biaxial compressed flange plates this is to be verified within the effective widths according to 3-2-15/9.17.3(b).

The net thickness of webs of primary supporting members shall not be less than:

$t = 6.5s$ mm

$= 0.078s$ in.

but not less than 5 mm (0.20 in.)

where s is as defined in 3-2-15/9.3

9.7.2 Edge Girders (Skirt Plates)

Scantlings of edge girders are obtained from the calculations according to 3-2-15/9.15 under consideration of permissible stresses according to 3-2-15/9.1.1.

The net thickness of the outer edge girders exposed to wash of sea shall not be less than the largest of the following values:

$$t = 15.8s\sqrt{\frac{p_H}{0.95Y}} \quad \text{mm}$$

$$= 8.5s \quad \text{mm}$$

$$t = 23.652s\sqrt{\frac{p_H}{0.95Y}} \quad \text{in.}$$

$$= 0.102s \quad \text{in.}$$

but not less than 5 mm (0.20 in.)

where

p_H is as defined in 3-2-15/3.5.

Y is as defined in 3-2-15/9.1.

s is as defined in 3-2-15/9.3.

The stiffness of edge girders is to be sufficient to maintain adequate sealing pressure between securing devices. The moment of inertia of edge girders is not to be less than:

$I = uqs_{SD}^4$ cm^4 (in^4)

where

u	=	6 (58.842, 7.693 · 10^{-3})
q	=	packing line pressure, in N/mm (kgf/mm, lbf/in). Minimum 5 N/mm (0.51 kgf/mm, 28.55 lbf/in)
s_{SD}	=	spacing of securing devices, in m (ft)

9.9 Cargo Loads

9.9.1 Distributed Loads

The load on hatch covers due to cargo loads p_L resulting from heave and pitch (i.e., ship in the upright condition) is to be determined according to the following formula:

$p_L = p_C(1 + a_a)$ kN/m^2 (tf/m^2, Ltf/ft^2)

where

p_C	=	uniform cargo load, in kN/m^2 (tf/m^2, Ltf/ft^2)	
a_a	=	vertical acceleration addition	
	=	$F_D m_D$	
F_D	=	$0.11\frac{v_0}{\sqrt{e_H L}}$	
m_D	=	$m_0 - 5(m_0 - 1)\frac{x'}{L}$	for $0 \le \frac{x'}{L} \le 0.2$
	=	1.0	for $0.2 < \frac{x'}{L} \le 0.7$
	=	$1 + \frac{m_0 + 1}{0.3}\left[\frac{x'}{L} - 0.7\right]$	for $0.7 < \frac{x'}{L} \le 1.0$
m_0	=	$1.5 + F_D$	
v_0	=	maximum speed at summer load line draft, in knots. v_0 is not to be taken less than $\sqrt{e_H L}$	
e_H	=	1 (1,0.3048)	
x'	=	distance between the transverse coaming or hatch cover skirt plate considered and aft end of the length L, in m (ft)	

L is as defined in 3-1-1/3.1.

9.9.2 Point Loads

The loads due to a concentrated force P_S, except for container load, resulting from heave and pitch (i.e., ship in the upright condition) is to be determined as follows:

$P_P = P_S(1 + a_a)$ kN (tf, Ltf)

where

P_S = single force, in kN (tf, Ltf)

a_a is as defined in 3-2-15/9.9.1.

9.11 Container Loads

9.11.1 General

Where containers are stowed on hatch covers the load applied at each corner of a container stack and resulting from heave and pitch (i.e., ship in the upright condition) is to be determined as follows:

$P = \frac{M}{4} \cdot (1 + a_a) \quad \mathrm{kN(tf, Ltf)}$

where

M = maximum designed mass of container stack, in kN (tf, Ltf)

a_a is as defined in 3-2-15/9.9.1.

The loads applied at each corner of a container stack resulting from heave, pitch, and the vessel's rolling motion are to be considered are to be determined as follows, see also 3-2-15/9.11 FIGURE 4:

$A_z = \frac{M}{2} \cdot (1 + a_a) \cdot \left(0.45 - 0.42\frac{h_m}{fP}\right) \quad \mathrm{kN(tf, Ltf)}$

$B_z = \frac{M}{2} \cdot (1 + a_a) \cdot \left(0.45 + 0.42\frac{h_m}{fP}\right) \quad \mathrm{kN(tf, Ltf)}$

$B_y = 0.24465M$ kN (tf, Ltf)

where

A_z, B_z = support forces in z-direction at the forward and aft stack corners

B_y = support force in y-direction at the forward and aft stack corners

M = maximum designed weight of container stack, in kN (tf, Ltf)

h_m = designed height of center of gravity of stack above hatch cover top, in m (ft), may be calculated as weighted mean value of the stack, where the center of gravity of each tier is taken to be located at the center of each container

f_p = distance between foot points, in m (ft)

a_a is as defined in 3-2-15/9.9.1.

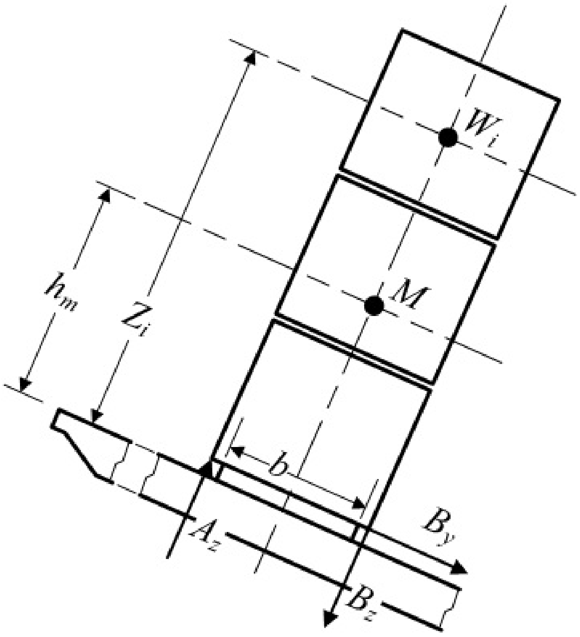
When strength of the hatch cover structure is assessed by grillage analysis according to 3-2-15/9.15, h_m and z_i need to be taken above the hatch cover supports. Force B_y does not need to be considered in this case.

Values of A_z and B_z applied for the assessment of hatch cover strength are to be shown in the drawings of the hatch covers.

It is recommended that container loads as calculated above are considered as limit for foot point loads of container stacks in the calculations of cargo securing (container lashing).

In the case of mixed stowage (20-foot and 40-foot container combined stack), the foot point forces at the fore and aft end of the hatch cover are not to be higher than resulting from the design stack weight for 40-foot containers, and the foot point forces at the middle of the cover are not to be higher than resulting from the design stack weight for 20-foot containers.

FIGURE 4
Forces due to Container Loads



9.11.2 Load Cases with Partial Loading

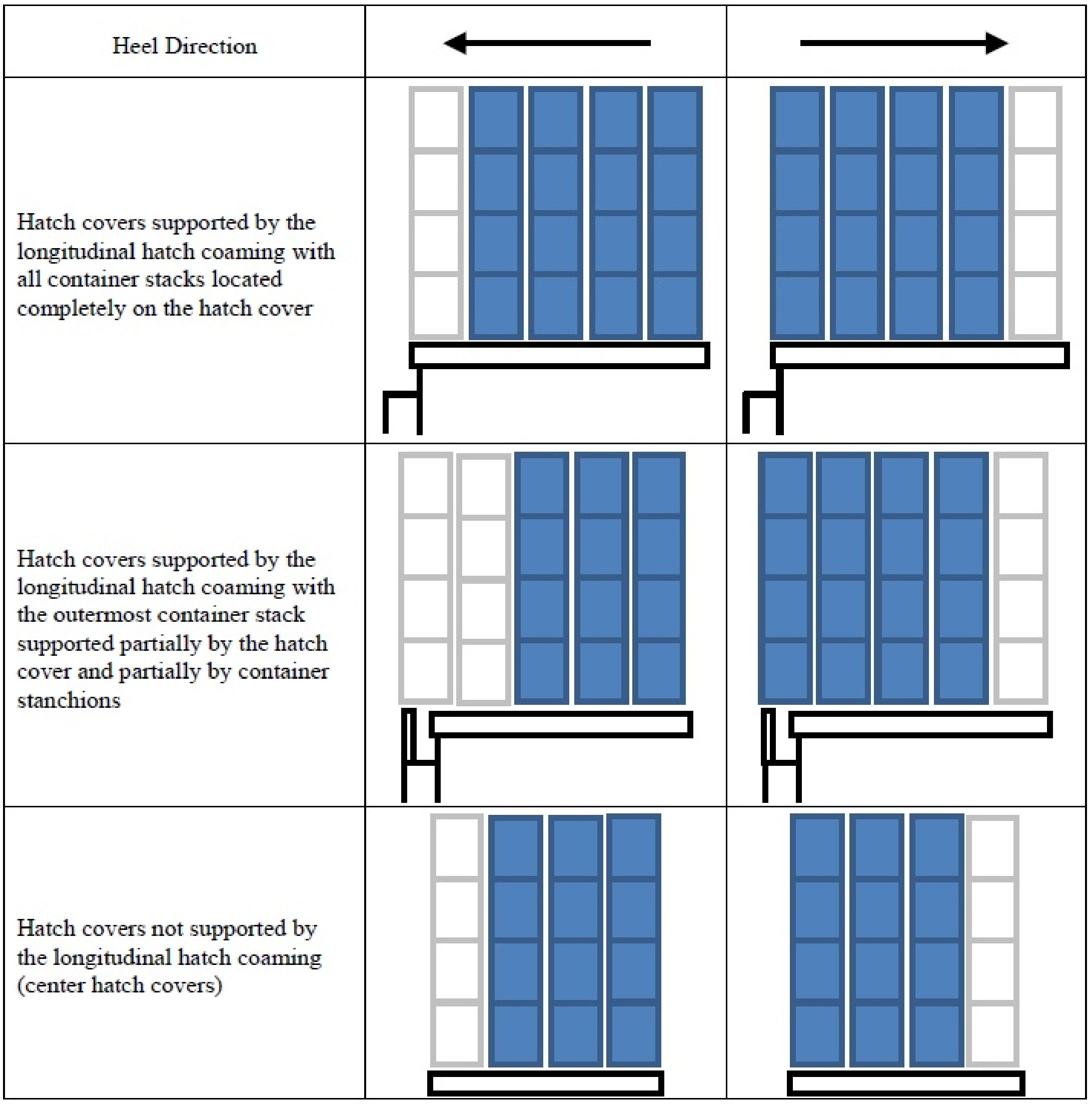
The load cases contained in 3-2-15/9.11.1 are also to be considered for partial non homogeneous loading which may occur in practice (e.g., where specified container stack places are empty). For each hatch cover, the heel directions, as shown in 3-2-15/9.11.2 FIGURE 5, are to be considered.

The load case "partial loading of container hatch covers" can be evaluated using a simplified approach, where the hatch cover is loaded without the outermost stacks that are located completely on the hatch cover. If there are additional stacks that are supported partially by the hatch cover and partially by container stanchions then the loads from these stacks are also to be neglected, see 3-2-15/9.11.2 FIGURE 5.

In addition, the case where only the stack places supported partially by the hatch cover and partially by container stanchions are left empty is to be assessed in order to consider the maximum loads in the vertical hatch cover supports.

Depending on the specific loading arrangements it may be necessary to consider additional partial load cases where more or different container stacks are left empty.

FIGURE 5
Partial Loading of a Container Hatch Cover



9.13 Loads due to Elastic Deformations of the Vessel's Hull

Hatch covers, which in addition to the loads according to 3-2-15/3.3 to 3-2-15/3.5 and 3-2-15/9.9 to 3-2-15/9.11 are loaded in the vessel's transverse direction by forces due to elastic deformations of the vessel's hull, are to be designed such that the sum of stresses does not exceed the permissible values given in 3-2-15/9.1.1.

9.15 Strength Calculations

Strength calculation for hatch covers may be carried out by either, grillage analysis or FEM. Double skin hatch covers or hatch covers with box girders are to be assessed using FEM, see 3-2-15/9.15.2.

9.15.1 Effective Cross-sectional Properties for Calculation by Beam Theory or Grillage Analysis

Cross-sectional properties are to be determined considering the effective breadth. Cross sectional areas of secondary stiffeners parallel to the primary supporting member under consideration within the effective breadth can be included, see 3-2-15/9.17.3(b) FIGURE 7.

The effective breadth of plating e_m of primary supporting members is to be determined according to 3-2-15/9.15 TABLE 2, considering the type of loading. Special calculations may be required for determining the effective breadth of one-sided or non-symmetrical flanges.

The effective cross sectional area of plates is not to be less than the cross sectional area of the face plate.

For flange plates under compression with secondary stiffeners perpendicular to the web of the primary supporting member, the effective width is to be determined according to 3-2-15/9.17.3(b).

TABLE 2
Effective Breadth e_m of Plating of Primary Supporting Members

ℓ/e	0	1	2	3	4	5	6	7	≥ 8
e_{m1}/e	0	0.36	0.64	0.82	0.91	0.96	0.98	1.00	1.00
e_{m2}/e	0	0.20	0.37	0.52	0.65	0.75	0.84	0.89	0.90
e_{m1}	is to be applied where primary supporting members are loaded by uniformly distributed loads or else by not less than 6 equally spaced single loads								
e_{m2}	is to be applied where primary supporting members are loaded by 3 or less single loads Intermediate values may be obtained by direct interpolation.								
ℓ	length of zero-points of bending moment curve: $\ell = \ell_o$ for simply supported primary supporting members $\ell = 0.6\ell_o$ for primary supporting members with both ends constraint, where ℓ_o is the unsupported length of the primary supporting member								
e	width of plating supported, measured from center to center of the adjacent unsupported fields								

9.15.2 General Requirements for FEM Calculations

For strength calculations of hatch covers by means of finite elements, the cover geometry shall be idealized as realistically as possible. Element size must be appropriate to account for effective breadth. In no case element width shall be larger than stiffener spacing. In way of force transfer points and cutouts the mesh has to be refined where applicable. The ratio of element length to width shall not exceed 4.

The element height of webs of primary supporting member must not exceed one-third of the web height. Stiffeners, supporting plates against pressure loads, have to be included in the idealization. Stiffeners may be modeled by using shell elements, plane stress elements or beam elements. Buckling stiffeners may be disregarded for the stress calculation.

9.17 Buckling Strength of Hatch Cover Structures

For hatch cover structures sufficient buckling strength is to be demonstrated.

Definitions

a = length of the longer side of a single plate field (x-direction), in mm (in.)

b = breadth of the shorter side of a single plate field (y-direction), in mm (in.)

a_r = aspect ratio of single plate field

= a/b

n = number of single plate field breadths within the partial or total plate field

t = net plate thickness in mm (in.)

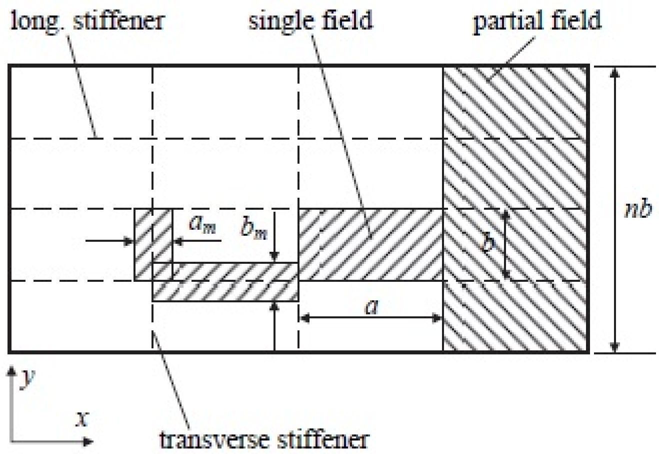
σ_{mx} = membrane stress in x-direction, in N/mm² (kgf/mm², psi)

σ_{my} = membrane stress in y-direction, in N/mm² (kgf/mm², psi)

τ = shear stress in the $x - y$ plane, in N/mm² (kgf/mm², psi)

Compressive and shear stresses are to be taken positive; tension stresses are to be taken negative.

FIGURE 6
General Arrangement of Panel



longitudinal: stiffener in the direction of the length a
transverse: stiffener in the direction of the breadth b

If stresses in the x- and y-direction already contain the Poisson-effect (calculated using FEM), the following modified stress values may be used. Both stresses σ_x^* and σ_y^* are to be compressive stresses, in order to apply the stress reduction according to the following formulae:

$$\sigma_{mx} = \left(\sigma_x^* - 0.3\sigma_y^*\right)/0.91$$

$$\sigma_{my} = \left(\sigma_y^* - 0.3\sigma_x^*\right)/0.91$$

where

σ_x^*, σ_y^* = stresses containing the Poisson-effect

Where compressive stress fulfills the condition $\sigma_y^* < 0.3\sigma_x^*$, then $\sigma_{my} = 0$ and $\sigma_{mx} = \sigma_x^*$

Where compressive stress fulfills the condition $\sigma_x^* < 0.3\sigma_y^*$, then $\sigma_{mx} = 0$ and $\sigma_{my} = \sigma_y^*$

The correction factor (F_1) for boundary condition at the longitudinal stiffeners is defined in 3-2-15/9.17 TABLE 3.

TABLE 3
Correction Factor F_1

Stiffeners sniped at both ends	1.00
Guidance values(1) where both ends are effectively connected to adjacent structures	1.05 for flat bars 1.10 for bulb sections 1.20 for angle and tee-sections 1.30 for u-type sections(2) and girders of high rigidity
An average value of F_1 is to be used for plate panels having different edge stiffeners.	

Notes:

1 Exact values may be determined by direct calculations.

2 Higher value may be taken if it is verified by a buckling strength check of the partial plate field using non-linear FEA but not greater than 2.0.

σ_r = reference stress

= $0.9E\left(\frac{t}{b}\right)^2$, in N/mm^2 (kgf/mm^2, psi)

ψ = edge stress ratio taken equal to:

= σ_2/σ_1

σ_1 = maximum compressive stress, in N/mm^2 (kgf/mm^2, psi)

σ_2 = minimum compressive stress or tension stress, in N/mm^2 (kgf/mm^2, psi)

SF = safety factor (based on net scantling approach), taken equal to:

= 1.25 for hatch covers when subjected to the vertical design load according to 3-2-15/3.3

= 1.10 for hatch covers when subjected to loads according to 3-2-15/3.5 and 3-2-15/9.9 to 3-2-15/9.13

λ = reference degree of slenderness, taken equal to:

= $\sqrt{\frac{Y}{K\sigma_r}}$

K = buckling factor according to 3-2-15/9.17.1 TABLE 5

Y is as defined in 3-2-15/9.1.1.

E is as defined in 3-2-A4/3.1.1

9.17.1 Strength of Hatch Cover Plating

Each single plate field of the top and bottom plating of the hatch cover are to satisfy the following condition:

$$\left(\frac{|\sigma_{mx}|SF}{k_xY}\right)^{e1} + \left(\frac{|\sigma_{my}|SF}{k_yY}\right)^{e2} - B\left(\frac{\sigma_{mx}\sigma_{my}SF^2}{Y^2}\right) + \left(\frac{|\tau|SF\sqrt{3}}{k_\tau Y}\right)^{e3} \le 1.0$$

The first two terms and the last term of the above condition shall not exceed 1.0.

The reduction factors k_x, k_y and k_τ are given in 3-2-15/9.17.1 TABLE 4.

Where $\sigma_{mx} \leq 0$ (tension stress), $k_x = 1.0$.

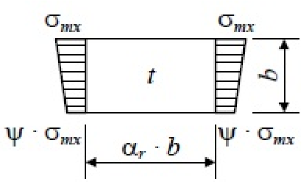
Where $\sigma_{my} \leq 0$ (tension stress), $k_y = 1.0$.

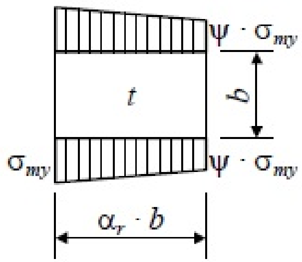
The exponents e_1, e_2, and e_3 as well as the factor B are to be taken as given in 3-2-15/9.17.1 TABLE 4.

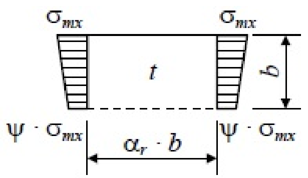
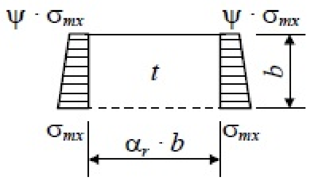
TABLE 4
Coefficients e_1, e_2, e_3 and Factor B

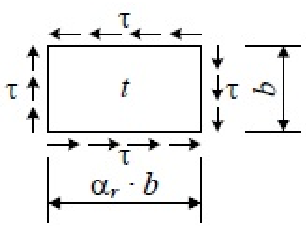
Exponents $e_1 - e_3$ and Factor B	*Plate Panel*
e_1	$1 + K_x^4$
e_2	$1 + K_y^4$
e_3	$1 + K_x K_y \quad K_\tau^2$
B σ_{mx} and σ_{my} positive (compression stress)	$(K_x K_y)^5$
B σ_{mx} and σ_{my} negative (tension stress)	1

TABLE 5
Buckling and Reduction Factors for Plane Elementary Plate Panels

Buckling Load Case	*Edge Stress Ratio* ψ	*Aspect Ratio* $a_r = a/b$	*Buckling Factor* K	*Reduction Factor* κ
1 	$1 \geq \psi \geq 0$	$a_r \geq 1$	$K = \frac{8.4}{\psi + 1.1}$	$\kappa_x = 1$ for $\lambda \leq \lambda_c$
	$0 \geq \psi \geq -1$		$K = 7.63 - \psi(6.26 - 10\psi)$	$\kappa_x = c\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > \lambda_c$
	$\psi \leq -1$		$K = 5.975(1 - \psi)^2$	$c = (1.25 - 0.12\psi) \leq 1.25$
				$\lambda_c = \frac{c}{2}\left(1 + \sqrt{1 - \frac{0.88}{c}}\right)$

Buckling Load Case	*Edge Stress Ratio* ψ	*Aspect Ratio* $a_r = a/b$	*Buckling Factor* K	*Reduction Factor* κ
2 	$1 \geq \psi \geq 0$	$a_r \geq 1$	$K = F_1\left(1 + \frac{1}{a_r^2}\right)^2 \cdot \frac{2.1}{(\psi + 1.1)}$	$\kappa_y = c\left(\frac{1}{\lambda} - \frac{R + F^2(H - R)}{\lambda^2}\right)$
	$0 \geq \psi \geq -1$	$1 \leq a_r \leq 1.5$	$K = F_1\left[\left(1 + \frac{1}{a_r^2}\right)^2 \cdot \frac{2.1(1 + \psi)}{1.1} - \frac{\psi}{a_r^2}\left(5.87 - 1.87a_r^2 + \frac{8.6}{a_r^2} - 10\psi\right)\right]$	$c = (1.25 - 0.12\psi) \leq 1.25$
				$R = \lambda\left(1 - \frac{\lambda}{c}\right)$ for $\lambda < \lambda_c$
				$R = 0.22$ for $\lambda \geq \lambda_c$
				$\lambda_c = \frac{c}{2}\left(1 + \sqrt{1 - \frac{0.88}{c}}\right)$
		$a_r > 1.5$	$K = F_1\left[\left(1 + \frac{1}{a_r^2}\right)^2 \cdot \frac{2.1(1 + \psi)}{1.1} - \frac{\psi}{a_r^2}\left(5.87 - 1.87a_r^2 + \frac{8.6}{a_r^2} - 10\psi\right)\right]$	$F = \left(1 - \frac{\frac{K}{0.91} - 1}{\lambda_p{}^2}\right) \cdot c_1 \geq 0$
				$\lambda_p^2 = \lambda^2 - 0.5$ for $1 \leq \lambda_p^2 \leq 3$
				$c_1 = \left(1 - \frac{F_1}{a_r}\right) \geq 0$
	$\psi \leq -1$	$1 \leq a_r \leq \frac{3(1 - \psi)}{4}$	$K = 5.975F_1\left(\frac{1 - \psi}{a_r}\right)^2$	$H = \lambda - \frac{2\lambda}{c\left(T + \sqrt{T^2 - 4}\right)} \geq R$
		$a_r > \frac{3(1 - \psi)}{4}$	$K = F_1\left[3.9675\left(\frac{1 - \psi}{a_r}\right)^2 + 0.5375\left(\frac{1 - \psi}{a_r}\right)^4 + 1.87\right]$	$T = \lambda\frac{14}{15\lambda} + \frac{1}{3}$

Buckling Load Case	*Edge Stress Ratio* ψ	*Aspect Ratio* $a_r = a/b$	*Buckling Factor* K	*Reduction Factor* κ
3 	$1 \geq \psi \geq 0$	$a_r > 0$	$K = \dfrac{4\left(0.425 + \dfrac{1}{a_r^2}\right)}{3\psi + 1}$	
	$0 \geq \psi \geq -1$		$K = 4\left(0.425 + \dfrac{1}{a_r^2}\right)(1 + \psi) - 5\psi(1 - 3.42\psi)$	$\kappa_x = 1$ for $\lambda \leq 0.7$ $\kappa_x = \dfrac{1}{\lambda^2 + 0.51}$ for $\lambda > 0.7$
4 	$1 \geq \psi \geq -1$	$a_r > 0$	$K = \left(0.425 + \dfrac{1}{a_r^2}\right)\dfrac{3 - \psi}{2}$	

Buckling Load Case	***Edge Stress Ratio*** ψ	***Aspect Ratio*** $\alpha_r = a/b$	***Buckling Factor*** K	***Reduction Factor*** κ
5 	-----	-----	$K = K_\tau \cdot \sqrt{3}$	
		$\alpha_r \geq 1$	$K_\tau = \left[5.34 + \frac{4}{\alpha_r^2}\right]$	$\kappa_\tau = 1$ for $\lambda \leq 0.84$ $\kappa_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$
		$0 < \alpha_r < 1$	$K_\tau = \left[4 + \frac{5.34}{\alpha_r^2}\right]$	
Explanations for boundary conditions	- - - - - plate edge free ——— plate edge simply supported			

9.17.2 Webs and Flanges of Primary Supporting Members

For non-stiffened webs and flanges of primary supporting members sufficient buckling strength as for the hatch cover top and bottom plating is to be demonstrated according to 3-2-15/9.17.1.

9.17.3 Strength of Partial and Total Fields of Hatch Covers

9.17.3(a) Longitudinal and Transverse Secondary Stiffeners. IIt is to be demonstrated that the continuous longitudinal and transverse stiffeners of partial and total plate fields comply with the conditions set out in 3-2-15/9.17.3(c) through 3-2-15/9.17.3(d).

For u-type stiffeners, the proof of torsional buckling strength according to 3-2-15/9.17.3(d) can be omitted.

Single-side welding is not permitted to use for secondary stiffeners except for u-stiffeners.

9.17.3(b) Effective Width of Hatch Cover Top and Bottom Plating. For demonstration of buckling strength according to 3-2-15/9.17.3(c) through 3-2-15/9.17.3(d) the effective width of plating may be determined by the following formulae:

$b_m = \kappa_x \cdot b$ for longitudinal stiffeners, in mm (in.)

$a_m = \kappa_y \cdot a$ for transverse stiffeners, in mm (in.)

where

a and b are as defined in 3-2-15/9.17.

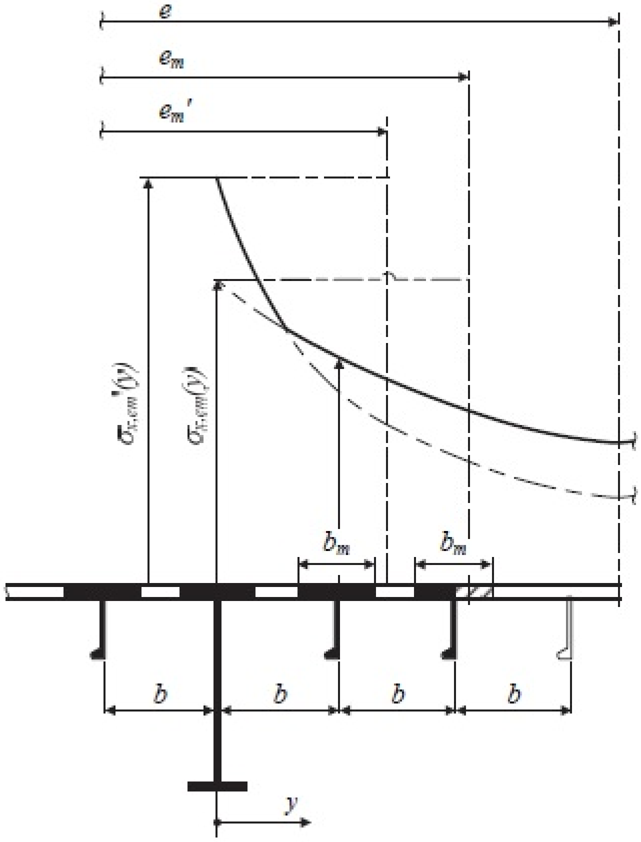
κ_x , κ_y are as defined in 3-2-15/9.17.1.

See also 3-2-15/9.17 FIGURE 6.

The effective width of plating is not to be taken greater than the value obtained from 3-2-15/9.15.1.

The effective width e'_m of stiffened flange plates of primary supporting members may be determined as follows:

FIGURE 7
Stiffening Parallel to Web of Primary Supporting Member



i) *Stiffening Parallel to Web of Primary Supporting Member*

$b < e_m$

$e'_m = nb_m$

$n = \left(\frac{e_m}{b}\right)$

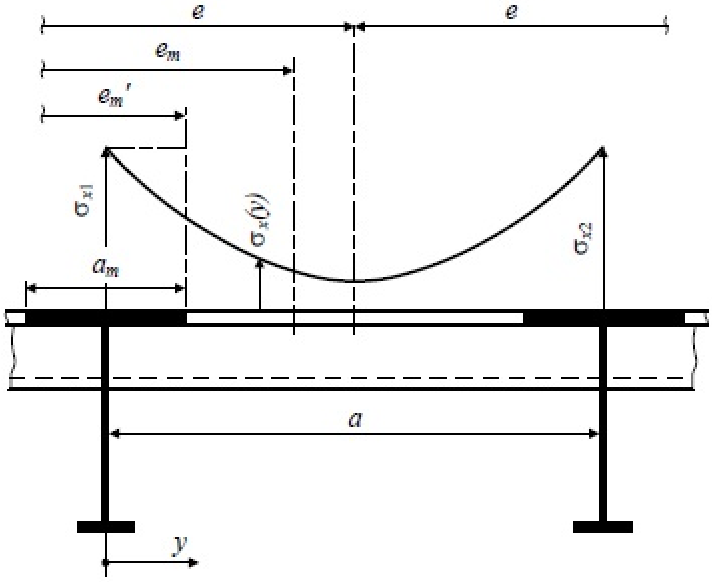
where

b_m = effective width of plating for transverse stiffeners, in mm (in.)

e and e_m are as defined in 3-2-15/9.15.

b and n are as defined in 3-2-15/9.17.

FIGURE 8
Stiffening Perpendicular to Web of Primary Supporting Member



ii) *Stiffening Perpendicular to Web of Primary Supporting Member*

$a \geq e_m$

$e_m' = na_m < e_m$

$n = 2.7\frac{e_m}{a} \leq 1$

where

a_m = effective width of plating for longitudinal stiffeners, in mm (in.)

e and e_m are as defined in 3-2-15/9.15.

α and n are as defined in 3-2-15/9.17.

For $b \geq e_m$ or $a < e_m$, respectively, b and a have to be exchanged.a_m and b_m for flange plates are in general to be determined for $\psi = 1$.

Scantlings of plates and stiffeners are in general to be determined according to the maximum stresses $\sigma_{mx}(y)$ at webs of primary supporting member and stiffeners, respectively. For stiffeners with spacing b under compression arranged parallel to primary supporting members no value less than $0.25Y$ shall be inserted for $\sigma_{mx}(y = b)$.

The stress distribution between two primary supporting members can be obtained by the following formula:

$$\sigma_{mx}(y) = \sigma_{x1}\{1 - \frac{y}{e}[3 + c_1 - 4c_2 - 2\frac{y}{e}(1 + c_1 - 2c_2)]\}$$

where

c_1 = $\frac{\sigma_{x2}}{\sigma_{x1}}$ $0 \le c_1 \le 1$

c_2 = $\frac{1.5}{e} \cdot (e''_{m1} + e''_{m2}) - 0.5$

e''_{m1} = proportionate effective breadth e_{m1} or proportionate effective width e'_{m1} of primary supporting member 1 within the distance e, as appropriate, in mm (in.)

e''_{m2} = proportionate effective breadth e_{m2} or proportionate effective width e'_{m2} of primary supporting member 2 within the distance e, as appropriate, in mm (in.)

σ_{x1}, σ_{x2} = normal stresses in flange plates of adjacent primary supporting member 1 and 2 with spacing e, based on cross-sectional properties considering the effective breadth or effective width, as appropriate, in N/mm^2 (kgf/mm^2, psi)

y = distance of considered location from primary supporting member 1, in mm (in.)

e is as defined in 3-2-15/9.15.

Shear stress distribution in the flange plates may be assumed linearly.

9.17.3(c) Lateral Buckling of Secondary Stiffeners

$$\frac{\sigma_a + \sigma_b}{Y} SF \le 1$$

where

σ_a = uniformly distributed compressive stress in the direction of the stiffener axis

= σ_{mx} for longitudinal stiffeners, in N/mm^2 (kgf/mm^2, psi)

= σ_{my} for longitudinal stiffeners, in N/mm^2 (kgf/mm^2, psi)

σ_b = bending stress in the stiffener

= $\frac{M_0 + M_1}{Z_{st} \cdot 10^3}$, in N/mm^2 (kgf/mm^2)

= $998\left(\frac{M_0 + M_1}{Z_{st} \cdot 10^3}\right)$, in psi

M_0 = bending moment due to the deformation w of stiffener, taken equal to:

= $F_{ki}\frac{p_z w}{c_f - p_z}$ with $(c_f - p_z) > 0$, in N-mm (kgf-mm, lbf-in)

M_1 = bending moment due to the lateral load p_l equal to:

= $\frac{p_\ell b a^2}{24.10^3}$ for longitudinal stiffeners, in N-mm (kgf/mm)

= $\frac{15593 p_\ell b a^2}{24.10^3}$ for longitudinal stiffeners, in lbf-in

= $\frac{p_\ell a (nb)^2}{c_s 8 \cdot 10^3}$ for transverse stiffeners, in N-mm (kgf/mm)

= $\frac{15593 p_\ell a (nb)^2}{c_s 8 \cdot 10^3}$ for transverse stiffeners, in lbf-in

n is as defined in 3-2-15/9.17, to be taken equal to 1 for ordinary transverse stiffeners.

p_ℓ	=	lateral load, in kN/m^2 (tf/m^2, Ltf/ft^2)	
F_{Ki}	=	ideal buckling force of the stiffener	
F_{Kix}	=	$\frac{\pi^2}{a^2} E I_x \cdot 10^4$	for longitudinal stiffeners, in N (kgf)
	=	$\frac{\pi^2}{a^2} E I_x$	for longitudinal stiffeners, in lbf
F_{Kiy}	=	$\frac{\pi^2}{(nb)^2} E I_y \cdot 10^4$	for transverse stiffeners, in N (kgf)
F_{Kiy}	=	$\frac{\pi^2}{(nb)^2} E I_y$	for transverse stiffeners, in lbf
I_x, I_y	=	net moments of inertia of the longitudinal or transverse stiffener including effective width of attached plating according to 3-2-15/9.17.3(b). I_x and I_y are to comply with the following criteria:	
	=	$I_x \geq \frac{bt^3}{12 \cdot 10^4}$ cm^4	
	=	$I_x \geq \frac{bt^3}{12}$ in^4	
	=	$I_y \geq \frac{at^3}{12 \cdot 10}$ cm^4	
	=	$I_y \geq \frac{at^3}{12}$ in^4	
p_z	=	nominal lateral load of the stiffener due to σ_x, σ_y and τ	
p_{zx}	=	$\frac{t}{b}\left(\sigma_{xl}\left(\frac{\pi b}{a}\right)^2 + 2c_y\sigma_{my} + \sqrt{2}\tau_1\right)$	for longitudinal stiffeners, in N/mm^2 (kgf/mm^2, psi)
p_{zy}	=	$\frac{t}{a}\left(2c_x\sigma_{xl} + \sigma_{my}\left(\frac{\pi a}{nb}\right)^2\left(1 + \frac{A_y}{at}\right) + \sqrt{2}\tau_1\right)$	for transverse stiffeners, in N/mm^2 (kgf/mm^2, psi)
σ_{xl}	=	$\sigma_{mx}\left(1 + \frac{A_x}{bt}\right)$, in N/mm^2 (kgf/mm^2,psi)	
c_x, c_y	=	factor taking into account the stresses perpendicular to the stiffener's axis and distributed variable along the stiffener's length	
	=	$0.5(1 + \psi)$	for $0 \leq \psi \leq 1$
	=	$\frac{0.5}{1 - \psi}$	for $\psi \leq 0$
A_x, A_y	=	net sectional area of the longitudinal or transverse stiffener, respectively, without attached plating, in mm^2 (in^2)	
τ_1	=	$\left[\tau - t\sqrt{YE\left(\frac{m_1}{a^2} + \frac{m_2}{b^2}\right)}\right] \geq 0$, in N/mm^2 (kgf/mm^2, psi)	

for longitudinal stiffeners:

$\frac{a}{b} > 2.0$: $m_1 = 1.47$ $m_2 = 0.49$

$\frac{a}{b} > 2.0$: $m_1 = 1.96$ $m_2 = 0.37$

for transverse stiffeners:

$\frac{a}{nb} > 0.5$: $m_1 = 0.37$ $m_2 = \frac{1.96}{n^2}$

$\frac{a}{nb} > 0.5$: $m_1 = 0.49$ $m_2 = \frac{1.47}{n^2}$

w = $w_0 + w_1$, in mm (in.)

w_0 = assumed imperfection. For stiffeners sniped at both ends, w_0 must not be taken less than the distance from the midpoint of plating to the neutral axis of the profile including effective width of plating.

$w_{0x} \leq min\left(\frac{a}{250}, \frac{b}{250}, 10\right)$ for longitudinal stiffeners, in mm

$w_{0x} \leq min\left(\frac{a}{9.843}, \frac{b}{9.843}, 0.394\right)$ for longitudinal stiffeners, in inches

$w_{0y} \leq min\left(\frac{a}{250}, \frac{nb}{250}, 10\right)$ for transverse stiffeners, in mm

$w_{0y} \leq min\left(\frac{a}{9.843}, \frac{nb}{9.843}, 0.394\right)$ for transverse stiffeners, in inches

w_1 = deformation of stiffener at midpoint of stiffener span due to lateral load p_ℓ. In case of uniformly distributed load the following values for w_1 may be used:

= $\dfrac{p_\ell b a^4}{384 \cdot 10^7 \cdot EI_x}$ for longitudinal stiffeners, in mm

= $\dfrac{1550 p_\ell b a^4}{384 \cdot 10^2 \cdot EI_x}$ for longitudinal stiffeners, in inches

= $\dfrac{5 a p_\ell (nb)^4}{384 \cdot 10^7 \cdot EI_y c_S^2}$ for transverse stiffeners, in mm

= $\dfrac{775 a p_\ell (nb)^4}{3840 \cdot EI_y c_S^2}$ for transverse stiffeners, in inches

c_f = elastic support provided by the stiffener

i) *For longitudinal stiffeners:*

$$c_{fx} = F_{Kix}\frac{\pi^2}{a^2}(1 + c_{px}), \text{ in N/mm}^2 (\text{kgf/mm}^2, \text{psi})$$

$$c_{px} = \frac{1}{1 + \dfrac{0.91\left(\dfrac{12 \cdot 10^4 I x}{t^3 b}\right)}{c_{xa}}}, \text{ in N/mm}^2 (\text{kgf/mm}^2)$$

$$c_{px} = \frac{1}{1 + \dfrac{0.91\left(\dfrac{12 \cdot 1_x}{t^3 b} - 1\right)}{c_{xa}}}, \text{ in psi}$$

$$c_{xa} = \left[\frac{a}{2b} + \frac{2b}{a}\right]^2 \quad \text{for } a \geq 2b$$

$$= \left[1 + \left(\frac{a}{2b}\right)^2\right]^2 \quad \text{for } a < 2b$$

ii) *For transverse stiffeners:*

c_{fy} = $c_S F_{Kiy} \frac{\pi^2}{(nb)^2}\left(1 + c_{py}\right)$, in $\mathrm{N/mm^2}$($\mathrm{kgf/mm^2}$,psi)

c_{py} = $\dfrac{1}{\dfrac{0.91\left(\dfrac{12 \cdot 10^4 I_y}{t^3 a} - 1\right)}{c_{ya}}}$, in $\mathrm{N/mm^2}$($\mathrm{kgf/mm^2}$)

c_{py} = $\dfrac{1}{\dfrac{0.91\left(\dfrac{12 I_y}{t^3 a} - 1\right)}{c_{ya}}}$, in psi

c_{ya} = $\left[\frac{nb}{2a} + \frac{2a}{nb}\right]^2$ for $nb \geq 2a$

= $\left[1 + \left(\frac{nb}{2a}\right)^2\right]^2$ for $nb < 2a$

c_s = factor accounting for the boundary conditions of the transverse stiffener

= 1.0 for simply supported stiffeners

= for partially constraint stiffeners

Z_{st} = net section modulus of stiffener (long. or transverse) including effective width of plating according to 3-2-15/9.17.3(b), in $\mathrm{cm^3}$ ($\mathrm{in^3}$)

ψ , σ_{mx}, σ_{my}, τ, SF, t, a, and b are as defined in 3-2-15/9.17,

Y is as defined in 3-2-15/9.1.1,

E is as defined in 3-2-A4/3.1.1.

If no lateral load p is acting, the bending stress σ_b is to be calculated at the midpoint of the stiffener span for the flange which results in the largest stress value. If a lateral load p is acting, the stress calculation is to be carried out for both flanges of the stiffener's cross sectional area (if necessary for the biaxial stress field at the plating side).

9.17.3(d) Torsional Buckling of Secondary Stiffeners.

i) *Longitudinal Secondary Stiffeners*. The longitudinal ordinary stiffeners are to comply with the following criteria:

$$\frac{\sigma_{mx} SF}{K_T Y} \leq 1.0$$

where

κ_T = coefficient taken equal to:

= 1.0 for $\lambda T \leq 0.2$

= $\dfrac{1}{\Phi + \sqrt{\Phi^2 - \lambda_T^2}}$ for $\lambda T \leq 0.2$

Φ = $0.5[1 + 0.21(\lambda_T - 0.2) + \lambda_T^2]$

λ_T = reference degree of slenderness taken equal to:

= $\sqrt{\dfrac{Y}{\sigma_{KIT}}}$

$$\sigma_{KiT} = \frac{E}{I_P}\left(\frac{\pi^2 I_\omega 10^2}{a^2}\varepsilon + 0.385 I_T\right), \text{ in N/mm}^2\text{ (kgf/mm}^2\text{)}$$

$$= \frac{E}{100 I_P}\left(\frac{\pi^2 I_\omega 10^2}{a^2}\varepsilon + 0.385 I_T\right), \text{ in psi}$$

For I_p, I_T, I_ω see 3-2-15/9.17.3(d) FIGURE 9 and 3-2-15/9.17.3(d) TABLE 6.

I_p = net polar moment of inertia of the stiffener related to the point C, in cm^4 (in^4)

I_T = net St. Venant's moment of inertia of the stiffener, in cm^4 (in^4)

I_ω = net sectional moment of inertia of the stiffener related to the point C, in cm^6 (in^6)

ε = degree of fixation taken equal to:

$$= 1 + 10^{-3}\sqrt{\frac{a^4}{\frac{3}{4}\pi^4 I_\omega\left(\frac{b}{t^3} + \frac{4h_w}{3t_w^3}\right)}}$$

where I_ω in cm^6 and b, t, h_w, and t_w in mm

$$= 1 + \sqrt{\frac{a^4}{\frac{3}{4}\pi^4 I_\omega\left(\frac{b}{t^3} + \frac{4h_w}{3t_w^3}\right)}}$$

where I_ω in in^6 and b, t, h_w, and t_w in inches

h_w = web height, in mm (in.)

t_w = net web thickness, in mm (in.)

b_f = flange breadth, in mm (in.)

t_f = net flange thickness, in mm (in.)

A_w = net web area

= $h_w t_w$, in mm^2 (in^2)

A_f = net flange area

= $b_f t_f$, in mm^2 (in^2)

e_f = $h_w + \frac{t_f}{2}$, in mm (in.)

SF , σ_{mx}, a, and b are as defined in 3-2-15/9.17.

Y is as defined in 3-2-15/9.1.1.

E is as defined in 3-2-A4/3.1.1.

ii) *Transverse Secondary Stiffeners*. For transverse secondary stiffeners loaded by compressive stresses and which are not supported by longitudinal stiffeners, sufficient torsional buckling strength is to be demonstrated in accordance with 3-2-15/9.17.3(d).i.

FIGURE 9
Dimensions of Stiffeners

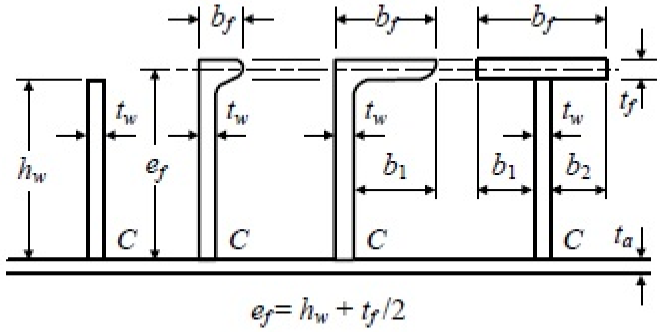


TABLE 6
Moments of Inertia

Section	I_P	I_T	I_ω
Flat bar	$\frac{h_w^3 \cdot t_w}{3 \cdot i_m}$	$\frac{h_w \cdot t_w^3}{3 \cdot i_m}\left(1 - 0.63\frac{t_w}{h_w}\right)$	$\frac{h_w^3 \cdot t_w^3}{36 \cdot j_m}$
Sections with bulb or flange	$\frac{1}{i_m}\left(\frac{A_W \cdot h_W^2}{3} + A_f \cdot e_f^2\right)$	$\frac{h_w \cdot t_w^3}{3 \cdot i_m}\left(1 - 0.63\frac{t_w}{h_w}\right)$ + $\frac{b_f}{3 \cdot i_m}\left(1 - 0.63\frac{t_f}{b_f}\right)$	for bulb and angle sections: $\frac{a_f \cdot e_f^2 \cdot b_f^2}{12 \cdot j_m}\left(\frac{A_f + 2.6A_W}{A_f + A_W}\right)$ for tee-sections: $\frac{b_f^3 \cdot t_f \cdot e_f^2}{12 \cdot j_m}$
i_m is 10^4 for cm^4 and 1 for in^4 j_m is 10^6 for cm^6 and 1 for in^6			

9.19 Details of Hatch Covers

9.19.1 Container Foundations on Hatch Covers

The substructures of container foundations are to be designed for cargo and container loads according to 3-2-15/3.3 through 3-2-15/3.5 and 3-2-15/9.9 through 3-2-15/9.11 applying the permissible stresses according to 3-2-15/9.1.1.

9.19.2 Weathertightness

*9.19.2(a) Packing Material (General).*The packing material is to be suitable for all expected service conditions of the ship and is to be compatible with the cargoes to be transported. The packing material is to be selected with regard to dimensions and elasticity in such a way that expected deformations can be carried. Forces are to be carried by the steel structure only.

The packing is to be compressed so as to give the necessary tightness effect for all expected operating conditions. Special consideration shall be given to the packing arrangement in ships with large relative movements between hatch covers and coamings or between hatch cover sections.

*9.19.2(b) Dispensation of Weathertight Gaskets.*For hatch covers of cargo holds solely for the transport of containers, upon request by the owners and subject to compliance with the following conditions the fitting of weathertight gaskets according to 3-2-15/9.19.2(a) may be dispensed with:

- The hatchway coamings shall be not less than 600 mm (23.622 in.) in height.

- The exposed deck on which the hatch covers are located is situated above a depth $H(x)$. $H(x)$ is to be shown to comply with the following criteria:

  $H(x) \geq d + f_b + h$ m (ft)

  where

  f_b = minimum required freeboard for the vessel, in m (ft)

  h = 4.6 m (15.09 ft) for $\frac{x}{L_f} \leq 0.75$

  = 6.9 m (22.64 ft) for $\frac{x}{L_f} > 0.75$

  L is as defined in 3-1-1/3.1.
  L_f is as defined in 3-1-1/3.3.
  d is as defined in 3-1-1/9.

- Labyrinths, gutter bars or equivalents are to be fitted proximate to the edges of each panel in way of the coamings. The clear profile of these openings is to be kept as small as possible.
- Where a hatch is covered by several hatch cover panels the clear opening of the gap in between the panels shall be not wider than 50 mm. (2.0 in.)
- The labyrinths and gaps between hatch cover panels shall be considered as unprotected openings with respect to the requirements of intact and damage stability calculations.
- Cargo holds and fire-fighting systems are to be provided with an efficient bilge pumping system (see 4-6-4/5.5 and 4-7-2/7.3.5).
- Bilge alarms are to be provided in each hold fitted with non-weathertight covers (see 4-6-4/5.5.13).
- Furthermore, Section 3, Stowage and Segregation of Cargo Transport Units Containers Containing Dangerous Goods, of IMO MSC/Circ.1087 Guidelines for Partially Weathertight Hatchway Covers On Board Containerships is recommended concerning the stowage and segregation of containers containing dangerous goods.

9.19.2(c) Drainage Arrangements. Cross-joints of multi-panel covers are to be provided with efficient drainage arrangements.

9.21 Hatch Coaming Strength Criteria

9.21.1 Local Net Plate Thickness of Coamings

The net thickness of weather deck hatch coamings shall not be less than the larger of the following values:

$$t = 14.2s\sqrt{\frac{P_H}{0.95Y}} \text{ mm}$$

$$= 21.26s\sqrt{\frac{P_H}{0.95Y}} \text{ in.}$$

but not less than $6 + \frac{L_1}{100}$ mm $\left(0.236 + \frac{1.2L_1}{10000} \text{ in.}\right)$

where

L_1 = L , need not be taken greater than 300 m (958 ft)

s is as defined in 3-2-15/9.3.

p_H is as defined in 3-2-15/3.5.

Y is as defined in 3-2-15/9.1.1.

Longitudinal strength aspects are to be observed.

9.21.2 Net Scantlings of Secondary Stiffeners of Coamings

The stiffeners must be continuous at the coaming stays. For stiffeners with both ends constraint the elastic net section modulus Z and net shear area A_S calculated on the basis of net thickness, must not be less than:

$$Z = \frac{83}{Y} s \ell_x^2 P_H \quad \text{cm}^3$$

$$= \frac{2230}{Y} s \ell_s^2 P_H \quad \text{in}^3$$

$$A_S = \frac{10 s \ell_S P_H}{Y} \quad \text{cm}^2$$

$$= \frac{2240 s \ell_S P_H}{Y} \quad \text{in}^2$$

where

ℓ_s = secondary stiffener span to be taken as the spacing of coaming stays, in m (ft)

s is as defined in 3-2-15/9.3.

p_H is as defined in 3-2-15/3.5.

Y is as defined in 3-2-15/9.1.1.

For sniped stiffeners of coaming at hatch corners section modulus and shear area at the fixed support have to be increased by 35%. The gross thickness of the coaming plate at the sniped stiffener end shall not be less than:

$$t = 19.6\sqrt{\frac{P_H s(\ell * 0.5s)}{Y}} \quad \text{mm}$$

$$= 29.32\sqrt{\frac{P_H s(\ell - 0.5s)}{Y}} \quad \text{in.}$$

where

s is as defined in 3-2-15/9.3.

p_H is as defined in 3-2-15/3.5.

Y is as defined in 3-2-15/9.1.1.

9.21.3 Coaming Stays

Coaming stays are to be designed for the loads transmitted through them and permissible stresses according to 3-2-15/9.1.

9.21.3(a) Coaming Stay Section Modulus.At the connection with deck, the net section modulus Z, in cm^3 (in^3) of the coaming stays designed as beams with flange (as shown in 3-2-15/9.21.3 FIGURE 10 a and b) shall not be less than:

$$Z = \frac{526}{Y} e_s h_s^2 p_H \quad \text{cm}^3$$

$= \frac{14138}{Y} e_s h_s^2 p_H$ in^3

where

e_s	=	spacing of coaming stays, in m (ft)
h_s	=	height of coaming stays of coamings where h_s < 1.6 m (5.25 ft), in m (ft)

p_H is as defined in 3-2-15/3.5.

Y is as defined in 3-2-15/9.1.1.

Coaming stays of coamings having a height of 1.6 m (5.25 ft) or more are to be designed using direct calculations under consideration of the permissible stresses according to 3-2-15/9.1.1. The effective breadth of the coaming plate shall not be larger than the effective plate breadth according to 3-2-15/9.15.1.

Coaming stays are to be supported by appropriate substructures. Face plates may only be included in the calculation if an appropriate substructure is provided and welding ensures an adequate joint.

9.21.3(b) Web Thickness of Coaming Stays. At the connection with deck, the gross thickness t_w, in mm (in.), of the coaming stays designed as beams with flange (as shown in 3-2-15/9.21.3 FIGURE 10 a and b) shall not be less than:

$$t_w = \frac{2}{y} \cdot \frac{e_s h_s P_H}{h_w} + t_s \quad \text{mm}$$

$$= \frac{373.34}{Y} \cdot \frac{e_s h_s P_H}{h_w} + t_s \quad \text{in.}$$

where

h_w	=	web height of coaming stay at its lower end, in m (ft)
t_s	=	corrosion addition according to 3-2-15/9.25, in mm (in.)

e_s and h_s are as defined in 3-2-15/9.21.3(a).

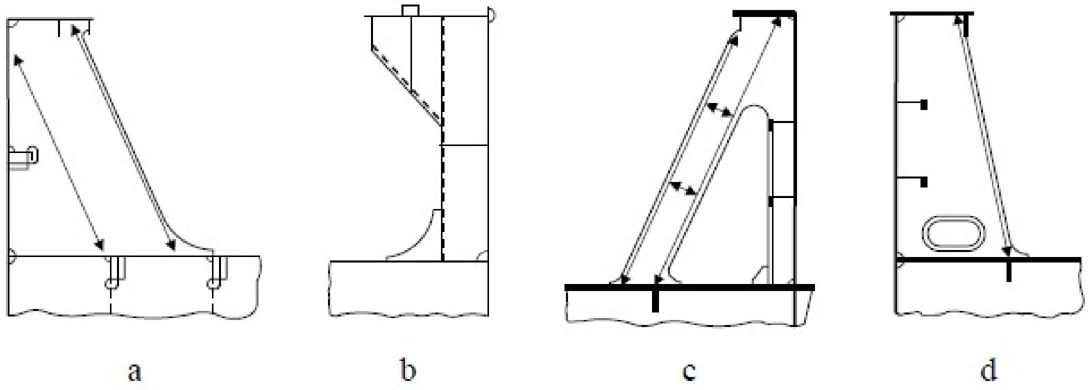
p_H is as defined in 3-2-15/3.5.

Y is as defined in 3-2-15/9.1.1.

For other designs of coaming stays, such as those shown in 3-2-15/9.21.3 FIGURE 10 c and d, the stresses are to be determined through a grillage analysis or FEM. The calculated stresses are to comply with the permissible stresses according to 3-2-15/9.1.1.

Webs are to be connected to the deck by fillet welds on both sides with a fillet weld throat thickness of at least $0.44t_w$.

FIGURE 10
Examples for Typical Coaming Stay Configurations



9.21.3(c) Coaming Stays Under Friction Load. For coaming stays, which transfer friction forces at hatch cover supports, fatigue strength is to be considered in the design.

9.21.4 Further Requirements for Hatch Coamings

9.21.4(a) Longitudinal Strength. Hatch coamings which are part of the longitudinal hull structure are to be designed according to the requirements for longitudinal strength (see also 3-2-15/5.9).

For structural members welded to coamings and for cutouts in the top of coamings sufficient fatigue strength is to be verified.

Longitudinal hatch coamings with a length exceeding 0.1*L* m (ft) are to be provided with tapered brackets or equivalent transitions and a corresponding substructure at both ends. At the end of the brackets they are to be connected to the deck by full penetration welds of minimum 300 mm (11.81 in.) in length.

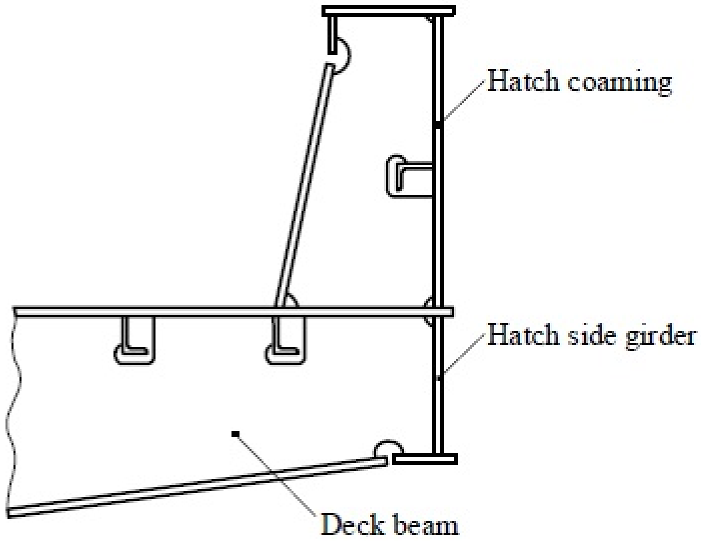
9.21.4(b) Local Details. Local details are to be adequate for the purpose of transferring the loads on the hatch covers to the hatch coamings and, through them, to the deck structures below. Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.

Structures under deck are to be checked against the load transmitted by the stays.

9.21.4(c) Stays. On ships carrying cargo on deck, such as timber, coal or coke, the stays are to be spaced not more than 1.5 m (5 ft) apart.

9.21.4(d) Extend of Coaming Plates. Coaming plates are to extend to the lower edge of the deck beams or hatch side girders are to be fitted that extend to the lower edge of the deck beams. Extended coaming plates and hatch side girders are to be flanged or fitted with face bars or half-round bars. 3-2-15/9.21.4(d) FIGURE 11 gives an example.

FIGURE 11
Example for Arrangement of Coaming Plates



9.21.4(e) Drainage Arrangement at the Coaming. If drain channels are provided inside the line of gasket by means of a gutter bar or vertical extension of the hatch side and end coaming, drain openings are to be provided at appropriate positions of the drain channels.

Drain openings in hatch coamings are to be arranged with sufficient distance to areas of stress concentration (e.g., hatch corners, transitions to crane posts).

Drain openings are to be arranged at the ends of drain channels and are to be provided with non-return valves to prevent ingress of water from outside. It is unacceptable to connect fire hoses to the drain openings for this purpose.

If a continuous outer steel contact between cover and ship structure is arranged, drainage from the space between the steel contact and the gasket is also to be provided for.

9.23 Closing Arrangements

9.23.1 Securing Devices

*9.23.1(a) General.*Securing devices between cover and coaming and at cross-joints are to be provided to ensure weathertightness. Sufficient packing line pressure is to be maintained.

Securing devices must be appropriate to bridge displacements between cover and coaming due to hull deformations.

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

Sufficient number of securing devices is to be provided at each side of the hatch cover considering the requirements of 3-2-15/9.7.2. This applies also to hatch covers consisting of several parts.

Specifications of the materials are to be shown in the drawings of the hatch covers.

9.23.1(b) Rod Cleats. Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

9.23.1(c) Hydraulic Cleats. Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

9.23.1(d) Cross-sectional Area of the Securing Devices.The gross cross-sectional area of the securing devices is not to be less than:

$$A = q s_{SD} k \ell \quad \text{cm}^2(\text{in}^2)$$

where

s_{SD}	=	spacing between securing devices as defined in 3-2-15/9.7.2, in m (ft), not to be taken less than 2 m (6.5 ft)	
k_ℓ	=	$0.28\left(\frac{235}{Y}\right)^{e\ell}$	where Y in N/mm^2
	=	$2.75\left(\frac{23.963}{Y}\right)^{e\ell}$	where Y in kgf/mm^2
	=	$2.317 \cdot 10^3\left(\frac{34084}{Y}\right)^{e\ell}$	where Y in psi
Y	=	minimum yield strength of the material as defined in 3-2-15/9.1.1, in N/mm^2 (kgf/mm^2, psi), but is not to be taken greater than $0.7\sigma_m$	
σ_m	=	tensile strength of the material, in N/mm^2 (kgf/mm^2, psi)	
e_ℓ	=	0.75 for Y >235 N/mm^2 (23.963 kgf/mm^2, 34084 psi) 235/Y (23.963/Y, 34084/Y)	
	=	1.00 for Y ≤235 N/mm^2 (23.963 kgf/mm^2, 34084 psi)	

q is as defined in 3-2-15/9.7.2.

Rods or bolts are to have a gross diameter not less than 19 mm (0.75 in.) for hatchways exceeding 5 m^2 (54 ft^2) in area.

Securing devices of special design in which significant bending or shear stresses occur may be designed as anti-lifting devices according to 3-2-15/9.23.1(e). As load the packing line pressure q multiplied by the spacing between securing devices s_{SD} is to be applied.

9.23.1(e) Anti Lifting Devices. The securing devices of hatch covers, on which cargo is to be lashed, are to be designed for the lifting forces resulting from loads according to 3-2-15/9.11, see 3-2-15/9.23.1(e) FIGURE 12. Unsymmetrical loadings, which may occur in practice, are to be considered. Under these loadings the equivalent stress in the securing devices is not to exceed:

$$\sigma_V = \frac{42}{k_\ell} \quad \text{N/mm}^2$$

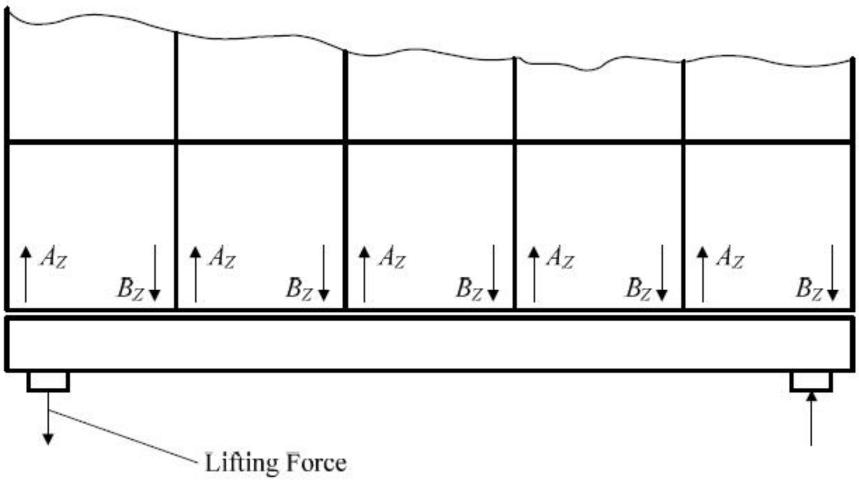
$$= \frac{42.08}{k_\ell} \quad \text{kgf/mm}^2$$

$$= \frac{50.41}{k_\ell} \quad \text{psi}$$

where k_ℓ is as defined in 3-2-15/9.23.1(d).

The partial load cases given in 3-2-15/9.11.2 FIGURE 5 may not cover all unsymmetrical loadings, critical for hatch cover lifting.

FIGURE 12
Lifting Forces at a Hatch Cover



9.23.2 Hatch Cover Supports, Stoppers and Supporting Structures

9.23.2(a) Horizontal Mass Forces. For the design of hatch cover supports the horizontal mass force is to be calculated:

$F_h = m_h a_h$ N

$= 0.102 m_h a_h$ kgf

$= 0.031 m_h a_h$ lbf

where

a_{hX} = 0.2g in longitudinal direction, in m/s^2 (ft/s^2)

a_{hY} = 0.5g in transverse direction, in m/s^2 (ft/s^2)

m_h = sum of mass of cargo lashed on the hatch cover and mass of hatch cover, in kg (lb)

g as defined in 3-5-1/11.1.2.

The accelerations in longitudinal direction and in transverse direction do not need to be considered as acting simultaneously.

9.23.2(b) Hatch Cover Supports. For the transmission of the support forces resulting from the load cases specified in 3-2-15/3.3 through 3-2-15/3.5 and 3-2-15/9.9, and of the horizontal mass forces specified in 3-2-15/9.23.2(a), supports are to be provided which are to be designed such that the nominal surface pressures in general do not exceed the following values:

$P_{nmax} = d_h p_n$ N/mm^2(kgf/mm^2, psi)

where

d_h = 3.75 – 0.015L where L in m

= 3.75 – 0.004572L where L in ft

$d_{h\max}$ = 3.0

$d_{h\min}$ = 1.0 in general

= 2.0 for partial loading conditions, see 3-2-15/9.11.1

p_n = see 3-2-15/9.23.2(b) TABLE 7

For metallic supporting surfaces not subjected to relative displacements the nominal surface pressure applies:

$$P_{n\max} = 3p_n \quad \mathrm{N/mm^2 (kgf/mm^2, psi)}$$

Drawings of the supports must be submitted. In the drawings of supports the permitted maximum pressure given by the material manufacturer related to long time stress must be specified.

TABLE 7
Permissible Nominal Surface Pressure p_n

Support Material	*p_n N/mm^2 (kgf/mm^2, psi) when loaded by:*	
	Vertical Force	*Horizontal Force (on Stoppers)*
Hull structural steel	25 (2.55, 3626)	40 (4.08, 5802)
Hardened steel	35 (3.57, 5076)	50 (5.10, 7252)
Lower friction materials	50 (5.10, 7252)	—

When the maker of vertical hatch cover support material can provide proof that the material is sufficient for the increased surface pressure, not only statically but under dynamic conditions including relative motion for adequate number of cycles, permissible nominal surface pressure may be relaxed at the discretion. However, realistic long term distribution of spectra for vertical loads and relative horizontal motion are subject to approval.

Where large relative displacements of the supporting surfaces are to be expected, the use of material having low wear and frictional properties is recommended.

If necessary, sufficient abrasive strength may be shown by tests demonstrating an abrasion of support surfaces of not more than 0.3 mm/year (0.012 in/year) in service under a total distance of shifting of 15000 m/year (49213 ft/year).

The substructures of the supports must be of such a design that a uniform pressure distribution is achieved.

Irrespective of the arrangement of stoppers, the supports must be able to transmit the following force P_{sh} in the longitudinal and transverse direction:

$$P_{sh} = a \cdot \frac{P_{sV}}{\sqrt{d_h}}$$

where

P_{sV} = vertical supporting force

a is as defined in 3-5-1/11.1.2.

For non-metallic, low-friction support materials on steel, the friction coefficient may be reduced but not to be less than 0.35.

Supports as well as the adjacent structures and substructures are to be designed such that the permissible stresses according to 3-2-15/9.1.1 are not exceeded.

For substructures and adjacent structures of supports subjected to horizontal forces P_{sh}, a fatigue strength analysis is to be carried out.

9.23.2(c) Hatch Cover Stoppers. Hatch covers shall be sufficiently secured against horizontal shifting. Stoppers are to be provided for hatch covers on which cargo is carried.

The greater of the loads resulting from 3-2-15/3.5 and 3-2-15/9.23.2(a) is to be applied for the dimensioning of the stoppers and their substructures.

The permissible stress in stoppers and their substructures, in the cover, and of the coamings is to be determined according to 3-2-15/9.1.1. In addition, the provisions in 3-2-15/9.23.2(b) are to be observed.

9.25 Corrosion Addition and Steel Renewal

9.25.1 Corrosion Addition for Hatch Covers and Hatch Coamings

The scantling requirements of the above sections imply the following general corrosion additions t_S:

TABLE 8
Corrosion Additions t_s for Hatch Covers and Hatch Coamings

Application	*Structure*	t_S *mm (in.)*
Weather deck hatches of container ships, car carriers, paper carriers, passenger vessels	Hatch covers	1.0 (0.04)
	Hatch coamings	1.0 (0.04)
Weather deck hatches of all other ship types covered by this UR Section	Hatch covers in general	2.0 (0.08)
	Weather exposed plating and bottom plating of double skin hatch covers	1.5 (0.06)
	Internal structure of double skin hatch covers and closed box girders	1.0 (0.04)
	Hatch coamings not part of the longitudinal hull structure	1.5 (0.06)
	Hatch coamings part of the longitudinal hull structure	1.0 (0.04)
	Coaming stays and stiffeners	1.5 (0.06)

9.25.2 Steel Renewal

Steel renewal is required where the gauged thickness is less than $t_{net} + 0.5$ mm ($t_{net} + 0.02$ in.) for

- Single skin hatch covers,
- The plating of double skin hatch covers, and
- Coaming structures the corrosion additions t_S of which are provided in 3-2-15/9.25.1 TABLE 8.

Where the gauged thickness is within the range $t_{net} + 0.5$ mm ($t_{net} + 0.02$ in.) and $t_{net} + 1.0$ mm ($t_{net} + 0.04$ in.), coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. Coating is to be maintained in condition with only minor spot rusting.

For the internal structure of double skin hatch covers, thickness gauging is required when hatch cover top or bottom plating renewal is to be carried out, or when this is deemed necessary , on the basis of the plating corrosion or deformation condition. In these cases, steel renewal for the internal structures is required where the gauged thickness is less than t_{net} mm (in.).

For corrosion addition $t_S = 1.0$ mm(0.04 in.) the thickness for steel renewal is t_{net} mm (in.) and the thickness for coating or annual gauging is when gauged thickness is between t_{net} mm (in.) and $t_{net} + 0.5$ mm ($t_{net} + 0.02$ in.).

For single skin hatch covers and for the plating of double skin hatch covers, steel renewal is required where the gauged thickness is less than $t_{net} + 0.5$ mm ($t_{net} + 0.02$ in.). Where the gauged thickness is within the range $t_{net} + 0.5$ mm ($t_{net} + 0.02$ in.) and $t_{net} + 1.0$ mm ($t_{net} + 0.04$ in.), coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. Coating is to be maintained in condition with only minor spot rusting.

For the internal structure of double skin hatch covers, thickness gauging is required when hatch cover top or bottom plating renewal is to be carried out, or when this is deemed necessary , on the basis of the plating corrosion or deformation condition. In these cases, steel renewal for the internal structures is required where the gauged thickness is less than tnet mm (in.).

For corrosion addition $t_S = 1.0$ mm (0.04 in.) the thickness for steel renewal is t_{net} mm (in.) and the thickness for coating or annual gauging is when gauged thickness is between tnet mm (in.) and $t_{net} + 0.5$ mm ($t_{net} + 0.02$ in.).

11 Hatchways in Decks at Higher Levels

11.1 Hatchways in Decks at Higher Levels

Special consideration will be given to the omission of gaskets on covers of hatchways in decks located above Position 2, where it can be demonstrated that the closing arrangements are weathertight. The procedure for testing such covers will also be subject to special consideration. For tests during subsequent surveys, refer to 7-3-2/1.1.1(f) and 7-3-2/5.1.11 of the ABS *Rules for Survey After Construction (Part 7).*

11.3 Hatchways in Lower Decks or within Fully Enclosed Superstructures

The following scantlings are intended for vessels of unrestricted service having conventional type covers. Scantlings for different types of covers or for vessels of restricted service will be separately considered.

11.3.1 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 3-2-3/5.1. 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:

$$SM = 7.8hs\ell^2 \quad \text{cm}^3$$

$$SM = 0.0041hs\ell^2 \quad \text{in}^3$$

where

h = h_{cs}, in m (ft), the tween deck height for decks not intended to carry cargoes or when uniform loading p does not exceed 25.66 kN/m^2 (2617 kgf/m^2, 536 lbf/ft^2) and/or load density does not exceed 7.01 kN/m^3 (715 kgf/m^3, 44.7 lbf/ft^3)

= h_{cs}, in m (ft), or p/7.01 m (p/715 m, p/44.7 ft), whichever is greater, for decks intended to carry cargoes when uniform loading p exceeds 25.66 kN/m^2 (2617 kgf/m^2, 536 lbf/ft^2) and/or load density exceeds 7.01 kN/m^3 (715 kgf/m^3, 44.7 lbf/ft^3)

s = spacing of the stiffeners, in m (ft)

ℓ = length of the stiffener, in m (ft)

11.3.2 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 3-2-3/5.17, for platform deck plating, except that the thickness of plate panels adjacent to the edges of the cover is to be at least 15% greater than that obtained from 3-2-3/5.17.

11.3.3 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:

$$SM = 7.8hs\ell^2 \quad \text{cm}^3$$

$$SM = 0.0041hs\ell^2 \quad \text{in}^3$$

where

c = 1.18

h = tween-deck height, in m (ft). 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 (kgf/m^2, lbf/ft^2), and n is defined as 7.04 (715, 45).

s = spacing of hatch beams, in m (ft)

ℓ = length of hatch beams, in m (ft)

The wood covers are not to be less than 63.5 mm (2.50 in.) thick where the spacing of the beams does not exceed 1.52 m (5 ft). Where the height to which the cargo may be loaded on top of a hatch exceeds about 2.6 m (8.5 ft), or where the spacing of the beams exceeds 1.52 m (5 ft), the thickness of the wood covers is to be suitably increased.

13 Small Hatches on the Exposed Fore Deck

The requirements of this Subsection apply to vessels with length, L, of 80 m (263 feet) or more as defined in 3-1-1/3.1 and to all small hatches [opening normally 2.5 m^2 (27 ft^2) or less] and located on the exposed fore deck within the forward 0.25L, where the deck in way of the hatch is less than 0.1L or 22 m (72.2 ft) above the summer load line, whichever is less.

Hatches designed for emergency escape need not comply with 3-2-15/13.3.i, 3-2-15/13.3.ii, 3-2-15/13.5.iii and 3-2-15/13.7.

13.1 Strength

For small rectangular steel hatch covers, the plate thickness, stiffener arrangement and scantlings are to be in accordance with 3-2-15/13 TABLE 9 and 3-2-15/13 FIGURE 13. Stiffeners, where fitted, are to be aligned with the metal-to-metal contact points required in 3-2-15/13.5 (see also 3-2-15/13 FIGURE 13). Primary stiffeners are to be continuous. All stiffeners are to be welded to the inner edge stiffener (see 3-2-15/13 FIGURE 14).

The upper edge of the hatchway coaming is to be suitably reinforced by a horizontal section, normally not more than 170 to 190 mm (6.9 to 7.5 in) 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 (24 kgf/mm^2, 34,000 psi) yield strength steel. Strength of small hatch covers constructed of aluminum alloy may be in accordance with 3-2-15/7.1.

13.3 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.

Emergency escape hatches need not comply with *i)* and *ii)* above.

13.5 Requirements for Primary Securing

i) 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 3-2-15/13 FIGURE 13, and of sufficient capacity to withstand the bearing force.

ii) 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. A short bar for on/off tilting of quick acting cleats is acceptable.

iii) 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 knuckling the forks' tips upward, and raising the top surface on the free end, or by any similar method. The plate thickness of un-stiffened steel forks is not to be less than 16 mm ($5/8$ in.). An example arrangement is shown in 3-2-15/13 FIGURE 14. Emergency escape hatches need not comply with the forgoing requirements in this paragraph.

iv) For small hatch covers located in Position 1 on the exposed deck forward of the superstructure or deckhouse, the hinges are to be fitted on the fore edge such that the predominant direction of green water will cause the cover to close.

v) 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.

vi) 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.

vii) On small hatches located elsewhere the hinges are to be placed either on the fore edge or outboard edge, whichever is more practical for protection against green water coming from beam sea and/or bow quartering sea at their location.

13.7 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. Emergency escape hatches need not comply with the forgoing requirements in this paragraph.

TABLE 9
Scantlings for Small Steel Hatch Covers on the Fore Deck

Nominal Size	*Cover Plate Thickness*	*Primary Stiffeners*	*Secondary Stiffeners*
(mm x mm)	*(mm)*	*Flat Bar (mm x mm); number*	
630 x 630	8	---	---
630 x 830	8	100 x 8; 1	---
830 x 630	8	100 x 8; 1	---
830 x 830	8	100 x 10; 1	---
1030 x 1030	8	120 x 12; 1	80 x 8; 2
1330 x 1330	8	150 x 12; 2	100 x 10; 2

FIGURE 13
Arrangement of Stiffeners

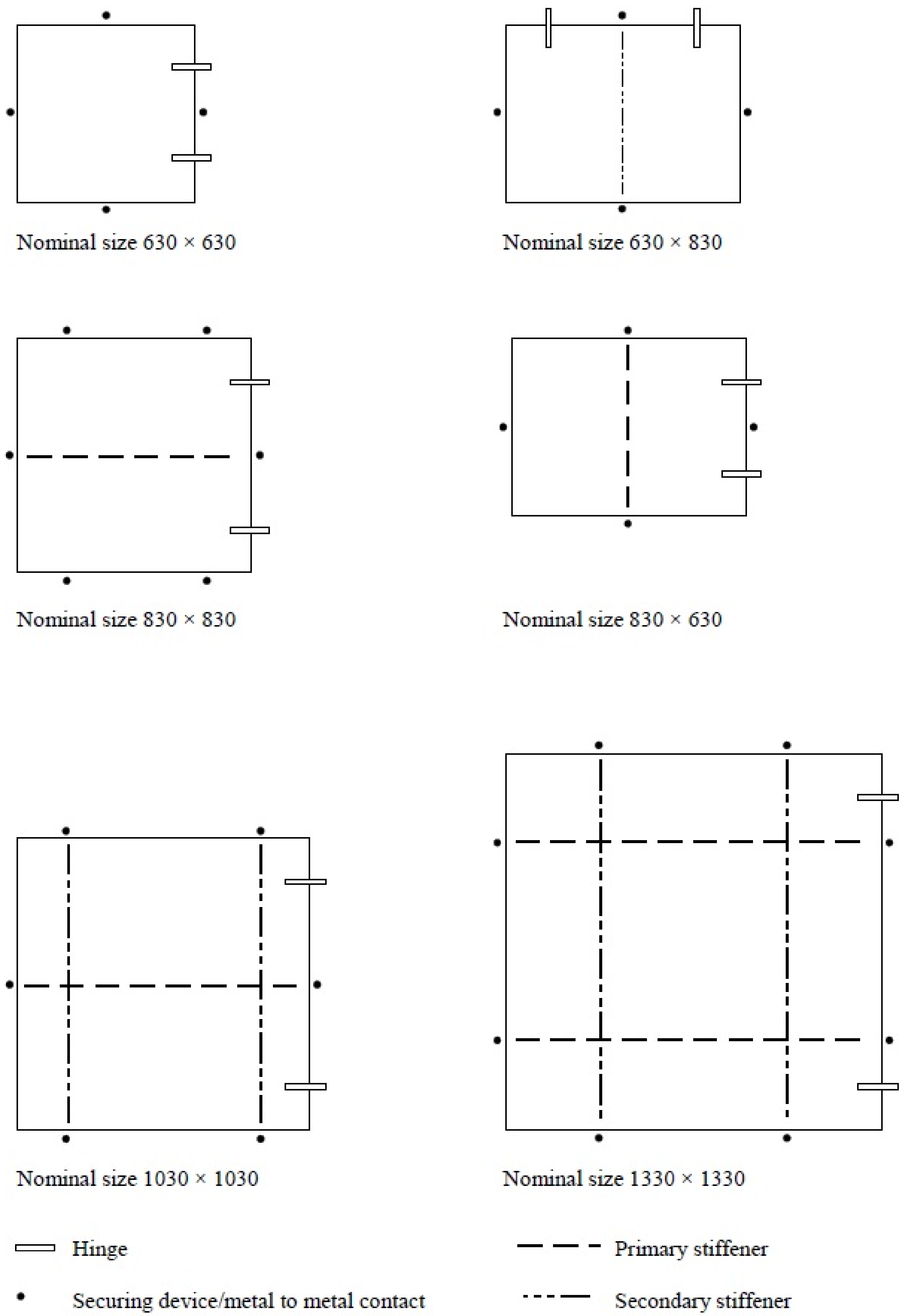
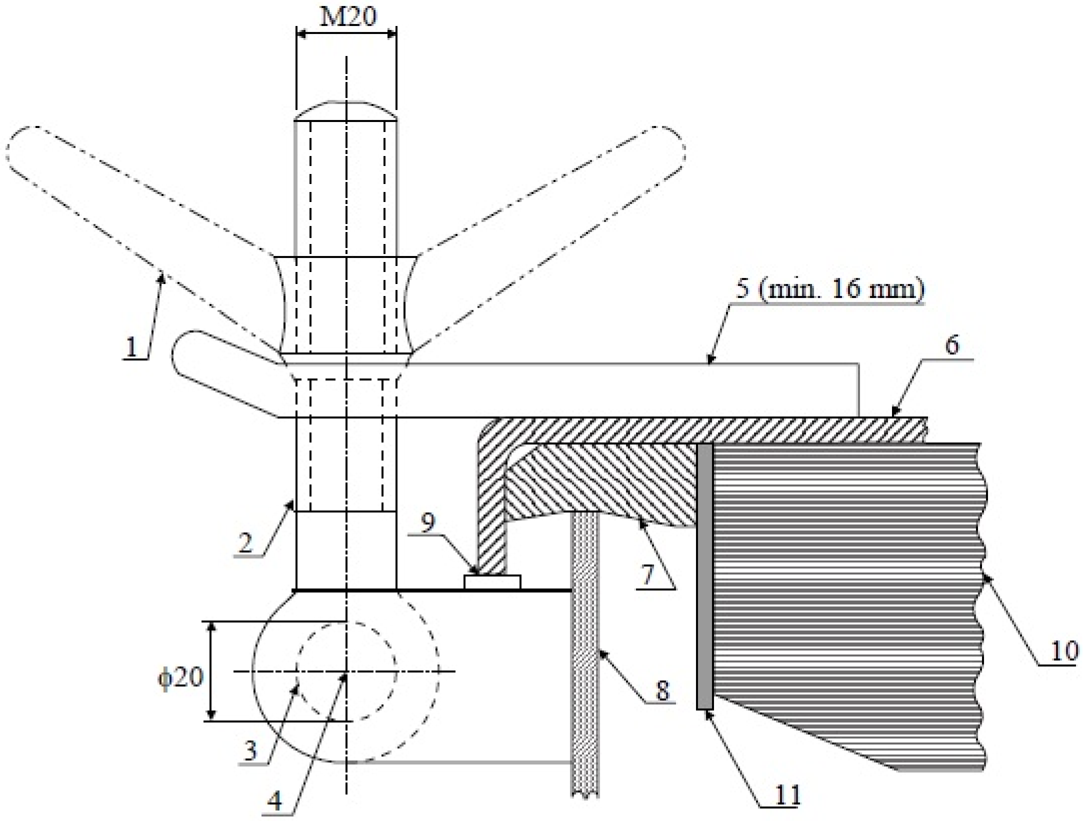


FIGURE 14
Example of Primary Securing Method



1: butterfly nut (Note: Dimensions in millimeters)
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

15 Other Hatchways

15.1 Hatchways within Open Superstructures

Hatchways within open superstructures are to be considered as exposed.

15.3 Hatchways within Deckhouses

Hatchways within deckhouses may be flush or are to have coamings and closing arrangements related to the degree of protection offered by the deckhouse itself, in terms of construction and the means provided for the closing of all external deckhouse openings.

17 Additional Requirements for Subdivision

17.1 External Opening below Damage Waterline

All external openings leading to compartments assumed intact in the damage analysis, which are permitted by 3-3-1/5.3 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.

17.3 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 3-2-9/1.3 and 3-2-9/9.

19 Machinery Casings

19.1 Arrangement

Machinery-space openings in Position 1 or 2 are to be framed and efficiently enclosed by steel casings of ample strength, and, wherever practical, those openings in freeboard decks are to be located within superstructures or deckhouses. Where the machinery casings are exposed, plating and stiffeners are to be in accordance with the requirements in 3-2-11/3. Access openings in exposed casings are to be fitted with steel doors complying with the requirements of 3-2-11/5.3, the sills of which are to be at least 600 mm (23.5 in.) above the deck if in Position 1, and at least 380 mm (15 in.) 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 3-2-11/5.3, 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 3-2-11/5.3. The sill of the exterior door is not to be less than 600 mm (23.5 in.), and the sill of the second/interior door is to be not less than 230 mm (9 in.). Other openings in such casings are to be fitted with equivalent steel covers, permanently attached in their proper positions. See also 4-7-2/1.9.5 and 4-7-2/1.9.6.

19.3 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 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.

19.5 Casings within Open Superstructures

Scantlings of casings within open superstructures are to be in compliance with 3-2-11/3 for exposed casings on superstructure decks. Where end bulkheads to the superstructures are not provided, the arrangements and scantlings of casings are to be in compliance with 3-2-11/3 for an exposed casing on the freeboard deck.

19.7 Casings within Enclosed Superstructures

The thickness of casings within enclosed superstructures is to be not less than obtained from the following equation:

$$t = 4.6 + L/64 + (s - 760)/150 \quad \text{mm} \qquad \text{but not less than 6.0 mm}$$

$$t = 0.181 + L/5333 + (s - 30)/150 \quad \text{in.} \qquad \text{but not less than 0.23 in.}$$

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

$t = 0.18 + (s - 30)/150$ in.

where

L = length of vessel, as defined in 3-1-1/3.1, in m (ft) but need not be taken greater than 122 m (400 ft)

s = the stiffener spacing, in mm (in.), but is not to be taken less than 760 mm (30 in.)

Where accelerated corrosion is expected, maybe such as in way of wet spaces, the thickness of coaming plates ought to be increased. Where casings are used in lieu of girders or deep beams, the plating in way of them 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

$SM = 0.0041chsl^2$ in^3

where

c = 0.14

s = spacing of stiffeners, in m (ft)

h = tween-deck height, in m (ft)

ℓ = length, between support, of the stiffeners, in m (ft)

Casings which support girders or pillars are to be stiffened in such a manner as to provide supports not less effective than required for stanchions or pillars.

19.9 Casings within Deckhouses

Casings within deckhouses are to have scantlings, sill heights and closing arrangements to entrances related to the degree of protection offered by the deckhouse itself, in terms of construction and the means provided for closing of all external deckhouse openings.

19.11 Exposed Casings on Superstructure Decks for Vessels Under 90 m (295 ft) in Length *(2022)*

Exposed casings on superstructure decks are to have plating not less in thickness than that obtained from the following equation:

$t = 0.033L + 3.5$ mm
$t = 0.0004L + 0.14$ in.

where

t = spacing of coaming stays, in m (ft)

L = height of coaming stays of coamings where h_s < 1.6 m (5.25 ft), in m (ft)

Stiffeners in association with the plating to which they are attached are to have section modulus, SM, as obtained from the following equation:

$$SM = 7.8chs\ell^2 \quad \text{cm}^3$$
$$SM = 0.0041chs\ell^2 \quad \text{in}^3$$

where

c = 0.25

s = spacing of stiffeners, in m (ft)

h = height of casing, in m (ft)

ℓ = length, between supports, of the stiffeners, in m (ft)

21 Miscellaneous Openings in Freeboard and Superstructure Decks

21.1 Manholes and Scuttles

Manholes and flush scuttles in Position 1 or 2 or within superstructures other than enclosed superstructures are to be closed by covers capable of being made watertight. Unless secured by bolts spaced not more than 5 times the bolts' diameter, the covers are to be permanently attached.

21.3 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 a deckhouse or companionway as well. Doorways in such deckhouses or companionways are to be fitted with doors complying with the requirements of 3-2-11/5.3.

21.5 Escape Openings

i) The closing appliances of escape openings are to be of a type that is operable from each side.

ii) The maximum force needed to open the hatch cover is not to exceed 150 N (15.3 kgf, 33.7 lbf).

iii) The use of a spring equalizing, counterbalance or other suitable device on the hinge side to reduce the force needed for opening is acceptable.

21.7 Companionway Sills *(2022)*

The height above the deck of sills to the doorways in companionways is to be as follows:

Position 1	*Position 2*
For vessels 24 meters (79 feet) in length and greater	
600 mm (23.5 in.)	380 mm (15 in.)
For vessels under 24 meters (79 feet) in length [1,2]	
450 mm (17.5 in.)	300 mm (12 in.)

Notes:

1 Sill heights may be reduced on vessels which have freeboard in excess of the minimum geometric freeboard and/or a superstructure deck with height of deck in excess of the standard height of a superstructure.

2 For vessels with L < 24 m (79 ft), the sill height should be as indicated above, unless otherwise specifically requested by flag Administration.

21.9 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.

21.11 Chain Pipe Opening

Chain pipes through which anchor chains or wires are led are to be provided with permanently attached closing appliances minimizing the ingress of water. Steel, aluminum plate or 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.

Note: * Examples of acceptable arrangements are such as:

i) Steel plates with cutouts to accommodate chain links or

ii) Canvas hoods with a lashing arrangement that maintains the cover in the secured position.

PART 3

CHAPTER 2

Hull Structures and Arrangements

SECTION 16

Protection of Shell Openings

1 Cargo, Gangway, or Fueling Ports

1.1 Construction *(2019)*

Cargo, gangway, or fueling ports in the sides of vessels are to be 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 arrangements are to be provided for the support of the beams over the opening. Thick insert plates are to be fitted in the side shell to compensate for the openings. Doubler plates are not allowed. Shell doublings are to be fitted, as required, to compensate for the openings, and the corners of the openings are to be well rounded.

Unless otherwise specifically required, openings in the side shell are to have a minimum corner radius of 0.1 times the width of the opening but need not exceed 450 mm (18 in.). Additionally, the minimum radius in way of narrow vertical ligaments between adjacent openings having the same depth is not to be less than 150 mm (6 in.).

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 cargo space 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.

In general, all outer doors are to open outwards.

1.3 Location *(2019)*

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 at least 230 mm (9 in.) above the upper edge of the uppermost load line, including all assigned seasonal marks.

Cargo ports or similar openings having their lower edge below the line defined above are to be fitted with a second internal door of equivalent strength and water-tightness to the shell door, with a leakage detection device for the enclosed compartment between both doors. The drain from this compartment is to be led to the bilge with a screw-down valve, remotely controlled from an accessible location (see 4-6-4/3.3).

1.5 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.

3 Bow Doors, Inner Doors, Side Shell Doors and Stern Doors

3.1 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.

3.3 Arrangement

3.3.1 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 n the case of damage to or detachment of the bow door.

3.3.2 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.

3.3.3 Inner Doors

An inner door is to be fitted in the extension of the collision bulkhead required by 3-2-9/3.1.1. A vehicle ramp made watertight and conforming to 3-2-9/3.3 FIGURE 1B in the closed position may be accepted for this purpose.

3.3.4 Side Shell and Stern Doors

Side shell doors fitted abaft of the collision bulkhead and stern doors leading into enclosed spaces are to meet the requirements of this Section.

Stern doors and side shell doors may be situated either above or below the freeboard deck (see 3-2-16/1.1).

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.

5 Securing, Locking and Supporting of Doors

5.1 Definitions

5.1.1 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.

5.1.2 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.

5.1.3 Locking Device

A device, which locks a securing device in the closed position.

7 Securing and Supporting Devices

7.1 General

Securing and supporting devices are to be arranged in accordance with this subsection, and are to have scantlings as required by 3-2-16/13.9, 3-2-16/15.5 or 3-2-16/17.9 as appropriate.

7.3 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 3-2-16/7.5.1.

7.5 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.

7.5.1 Clearance and Packing

The maximum design clearance between the door and securing/supporting devices is not to exceed 3 mm (0.12 in.). 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.

7.5.2 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 3-2-16/19.5.1 is not to be less than M_{yo} as given by the following equation:

$$M_{yo} = W_c + 0.1\sqrt{a^2 + b^2} \quad \sqrt{F_x^2 \quad + F_z^2}$$

where W, a, b, c, F_x and F_z are as defined in 3-2-16/17.

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 3-2-16/19.5.4.

9 Securing and Locking Arrangement

9.1 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.

9.3 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.

9.3.1 Hydraulic Securing Devices *(2022)*

Where hydraulic securing devices are applied, the system is to be mechanically lockable in the closed position. In the event of a loss of hydraulic fluid, the securing devices are to remain locked.

The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in the closed position.

9.3.2 Remote Control *(2022)*

Where bow doors and inner doors give access to a vehicle deck, or where side shell doors or stern doors are located partially or totally below the freeboard deck with a clear opening area greater than 6 m^2 (65 ft^2), an arrangement for remote control from a position above the freeboard deck is to be provided, allowing closing and opening of the doors and associated securing and locking of every door. The operating panels for doors are to be accessible to authorized persons only. A notice plate giving instructions to the effect that all securing devices are to be closed and locked before leaving harbor is to be placed at each operating panel and is to be supplemented by warning indicator lights, as required by 3-2-16/9.4.1.

9.4 Indicator/Monitoring *(2022)*

The following requirements for indicators, water leakage protection and door surveillance are required for vessels fitted with bow doors and inner doors. The requirements also apply to vessels fitted with side shell doors or stern doors in the boundary of special category spaces or ro-ro spaces through which such spaces may be flooded.

The requirements are not applicable to ro-ro cargo vessels where no part of the side shell doors or stern doors is located below the uppermost waterline and the area of the door opening is not greater than 6 m^2 (65 ft^2).

9.4.1 Indicators

The indicator system is to be designed on the fail safe principle and in accordance with the following. See 3-2-16/9.4.1(e).

9.4.1(a) Location and Type.

Separate indicator lights are to be provided on the navigation bridge and on each operating panel to show that the doors are closed and that their locking devices are properly positioned.

The indication panel on the navigation bridge is to be equipped with a mode selection function "harbor/sea voyage", arranged so that an audible and visible alarm is given on the navigation bridge if, in the sea voyage condition, the doors are not closed, or any of the securing devices are not in the correct position.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the operating panels.

9.4.1(b) Indicator Lights.

Indicator lights are to be designed so that they cannot be manually turned off. The indication panel is to be provided with a lamp test function.

9.4.1(c) Power Supply.

The power supply for the indicator system is to be independent of the power supply for operating and closing the doors and is to be provided with a backup power supply from the emergency source of power or other secure power supply (e.g., UPS).

9.4.1(d) Protection of Sensors.

Sensors are to be protected from water, ice formation and mechanical damage.

9.4.1(e) Fail Safe Principle.

The alarm/indicator system is considered designed on a fail-safe principle when the following are provided, as applicable.

i) The indicator panel is provided with:

- A power failure alarm
- An earth failure alarm
- A lamp test
- Separate indication for door closed, door locked, door not closed and door not locked.

ii) Limit switches electrically closed when the door is closed (when more limit switches are provided, they may be connected in series)

iii) Limit switches electrically closed when securing arrangements are in place (when more limit switches are provided, they may be connected in series)

iv) Two electrical circuits (also in one multicore cable), one for the indication of door closed/not closed and the other for door locked/not locked.

v) In the case of dislocation of limit switches, indication to show: not closed/not locked/securing arrangements not in place, as appropriate.

9.4.2 Water Leakage Protection

A drainage system is to be arranged in the areas between the bow door and ramp or, where no ramp is fitted, between the bow door and inner door. The system is to be equipped with an audible alarm function to the navigation bridge being set off when the water levels in these areas exceed 0.5 m (1.6 ft) or the high water level alarm, whichever is the lesser. See 3-2-16/9.4.1(e).

For vessels fitted with bow and inner doors, a water leakage detection system with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door. See 3-2-16/9.4.1(e).

For passenger vessels fitted with side shell or stern doors, a water leakage detection system with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through any of the doors.

For cargo vessels fitted with side shell or stern doors, a water leakage detection system with audible alarm is to be arranged to provide an indication to the navigation bridge of leakage through any of the doors. See 3-2-16/9.4.1(e).

9.4.3 Door Surveillance

Between the bow door and the inner door, a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room. The system is to monitor the position of doors and a sufficient number of their securing devices. Special consideration is to be given for the lighting and contrasting color of objects under surveillance.

11 Tightness

11.1 Bow Doors

Bow doors are to be so fitted as to provide tightness consistent with operational conditions and to give effective protection to the inner doors.

11.3 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.

11.5 Side Shell and Stern Doors

Side shell doors and stern doors are to be so fitted as to ensure water tightness.

11.7 Testing at Watertight Door Manufacturer

To comply with relevant subdivision and damage stability regulations, doors which become immersed by an equilibrium or intermediate waterplane at any stage of assumed flooding are to be hydrostatically tested at the manufacturer's plant. The head of water used for the test shall correspond at least to the head measured from the lower edge of the door opening, at the location in which the door is to be fitted in the vessel, to the most unfavorable damage waterplane.

13 Bow Door Scantlings

13.1 General

Bow doors are to be framed and stiffened so that the whole structure is equivalent to the intact bow structure when closed.

13.3 Primary Structure

Scantlings of primary members are to be designed so that the allowable stresses indicated in 3-2-16/25.1 are not exceeded when the structure is subjected to the design loads indicated in 3-2-16/19.1. Normally, simple beam theory may be applied to determine the bending stresses. Members are to be considered to have simply supported end connections.

13.5 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 3-2-5/1.1 and 3-2-5/5. Consideration is to be given, where necessary, to differences in fixity between the requirements in 3-2-5/1.1, 3-2-5/5, and bow door stiffeners.

In addition, stiffener webs are to have a net sectional area not less than that obtained from the following equation:

$A = VQ/10\ \text{cm}^2 (A = VQ\ \text{cm}^2, A = VQ/6.5\ \text{in}^2)$

where

V	=	shear force, in kN (tf, Ltf), in the stiffener calculated using the uniformly distributed external pressure, P_{eb}, given in 3-2-16/19.1
Q	=	as defined in 3-2-1/5.3.

13.7 Plating

The thickness of bow door plating is to be not less than that required for side shell plating at the same location.

13.9 Securing and Supporting Devices

Scantlings of securing and supporting devices are to be designed so that the allowable stresses indicated in 3-2-16/25.1 are not exceeded when the structure is subjected to the design loads indicated in 3-2-16/19.3. 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 3-2-16/25.5.

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.

13.9.1 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 3-2-16/25.3.

13.9.2 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 3-2-16/25.1 by more than 20% under the above loads.

13.9.3 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 3-2-16/19.5.3 without exceeding the allowable stresses in 3-2-16/25.1.

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 3-2-16/25.1. The opening moment, M_o, to be balanced by this force is as given in 3-2-16/19.5.2.

13.9.4 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.

13.11 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 (0.15 tf/m^2, 0.014 Ltf/ft.^{2}).

15 Inner Door Scantlings

15.1 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 3-2-3, 3-2-7, and 3-2-8.

15.3 Primary Structure

Scantlings of primary members are to be designed so that the allowable stresses indicated in 3-2-16/25.1 are not exceeded when the structure is subjected to the design loads indicated in 3-2-16/21.1.

15.5 Securing and Supporting Devices

Scantlings of securing and supporting devices are to be designed so that the allowable stresses indicated in 3-2-16/25.1 are not exceeded when the structure is subjected to the design loads indicated in 3-2-16/21. 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 3-2-16/25.5.

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 3-2-16/25.3.

17 Side Shell Door and Stern Door Scantlings

17.1 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 3-2-3, 3-2-7, and 3-2-8.

17.3 Primary Structure

Scantlings of primary members are to be designed so that the allowable stresses indicated in 3-2-16/25.1 are not exceeded when the structure is subjected to the design loads indicated in 3-2-16/23. Normally, simple beam theory may be applied to determine the bending stresses. Members are considered to have simply supported end connections.

17.5 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 3-2-5 for frames in the same location. In addition, the net sectional area of stiffener webs is to be in accordance with 3-2-16/13.5, using the external pressure, p_e, given in 3-2-16/23.

17.7 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.

17.9 Securing and Supporting Devices

Scantlings of securing and supporting devices are to be designed so that the allowable stresses indicated in 3-2-16/25.1 are not exceeded when the structure is subjected to the design loads indicated in 3-2-16/23. 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 3-2-16/25.5.

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.

17.9.1 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 3-2-16/25.3.

17.9.2 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 3-2-16/25.1 by more than 20% under the above loads.

19 Bow Door Design Loads

19.1 External Pressure

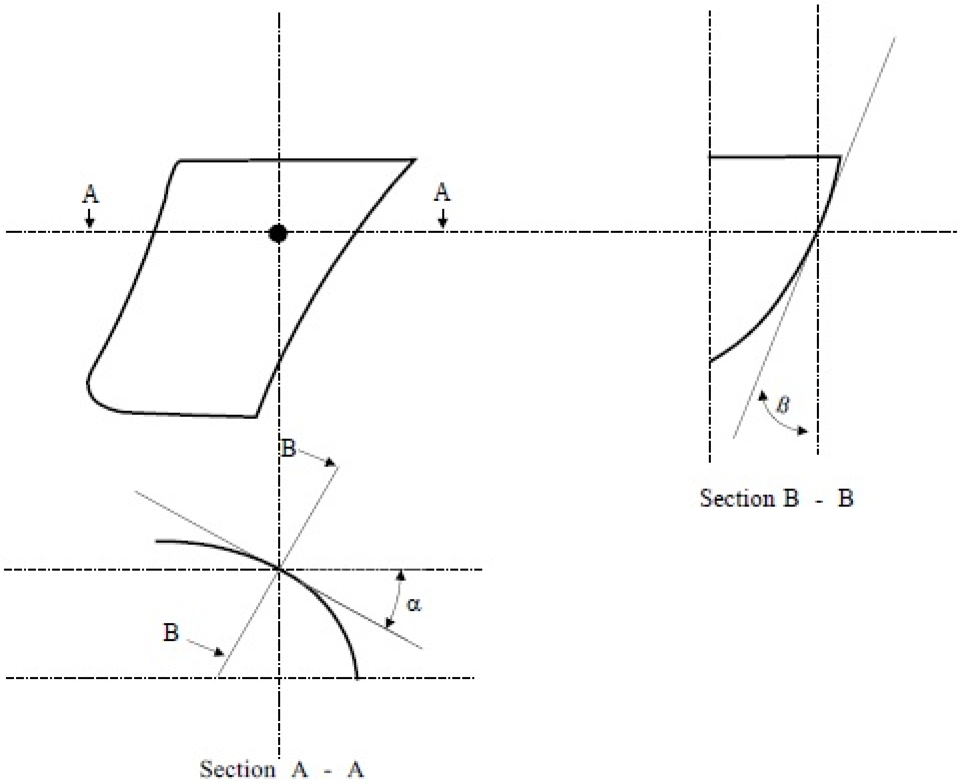
The design external pressure, P_{eb}, is to be taken as indicated by the following equation:

$$P_{eb} = nc(0.22 + 0.15\tan\beta)(0.4V_d\sin\alpha + 0.6\sqrt{kL_1})^2 \quad \mathrm{kN/m^2 (tf/m^2, Ltf/ft^2)}$$

where

n	=	2.75 (0.280, 0.0256)
c	=	1.0
L	=	length of vessel, as defined in 3-1-1/3.1, in m (ft.)
L_1	=	length of vessel, in m (ft.), as defined in 3-1-1/3.1, but need not be taken as greater than 200 m (656 ft.)
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 3-2-16/19.1 FIGURE 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 3-2-16/19.1 FIGURE 1.
k	=	1.0 (1.0, 0.305)
V_d	=	vessel design speed, as defined in 3-2-14/3.1.

FIGURE 1
Entry and Flare Angles



19.3 External Forces

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 (tf, Ltf)

F_y = the design external force in the horizontal direction, in kN (tf, Ltf)

F_z = the design external force in the vertical direction, in kN (tf, Ltf)

A_x = area, in m^2 (ft^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 (ft^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 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_z = area, in m^2 (ft^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 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.

P_{em} = bow door pressure, P_{eb}, determined using α_m and β_m in place of α and β.

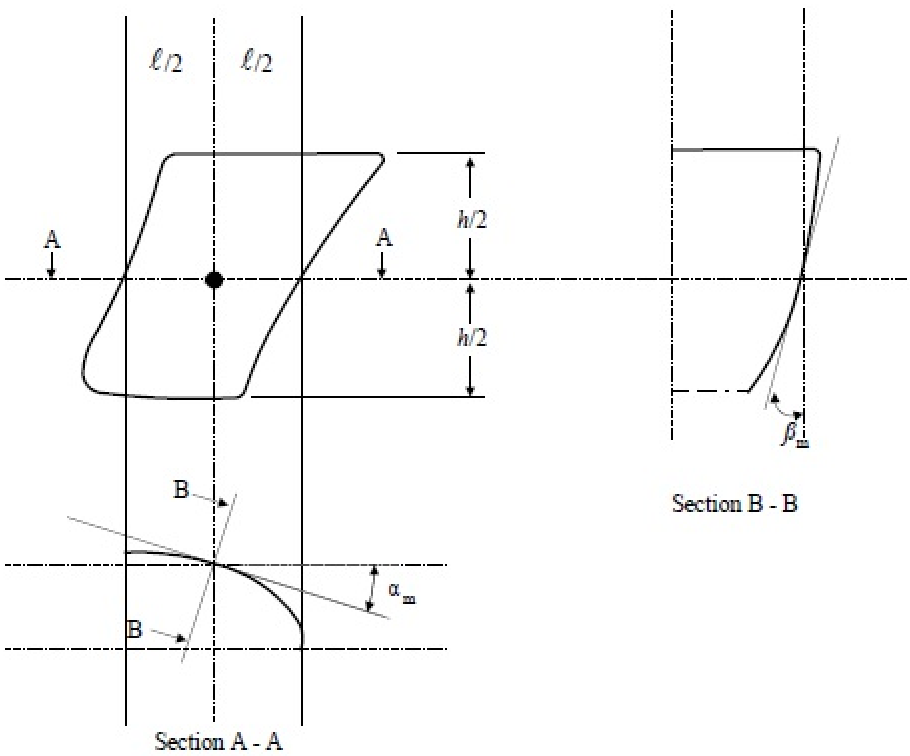
β_m = lare angle measured at a point on the bow door $\ell/2$ aft of the stem line on a plane $h/2$ above the bottom of the door, as shown in 3-2-16/19.3 FIGURE 2.

α_m = entry angle measured at the same point as β_m. See 3-2-16/19.3 FIGURE 2.

h = height, in m (ft.), 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 (ft.), of the door at a height $h/2$ above the bottom of the door

FIGURE 2
Definition of α_m and β_m



19.5 Visor Door Forces, Moments and Load Cases

19.5.1 Closing Moment

For visor doors, the closing moment, M_y is to be taken as indicated by the following equation:

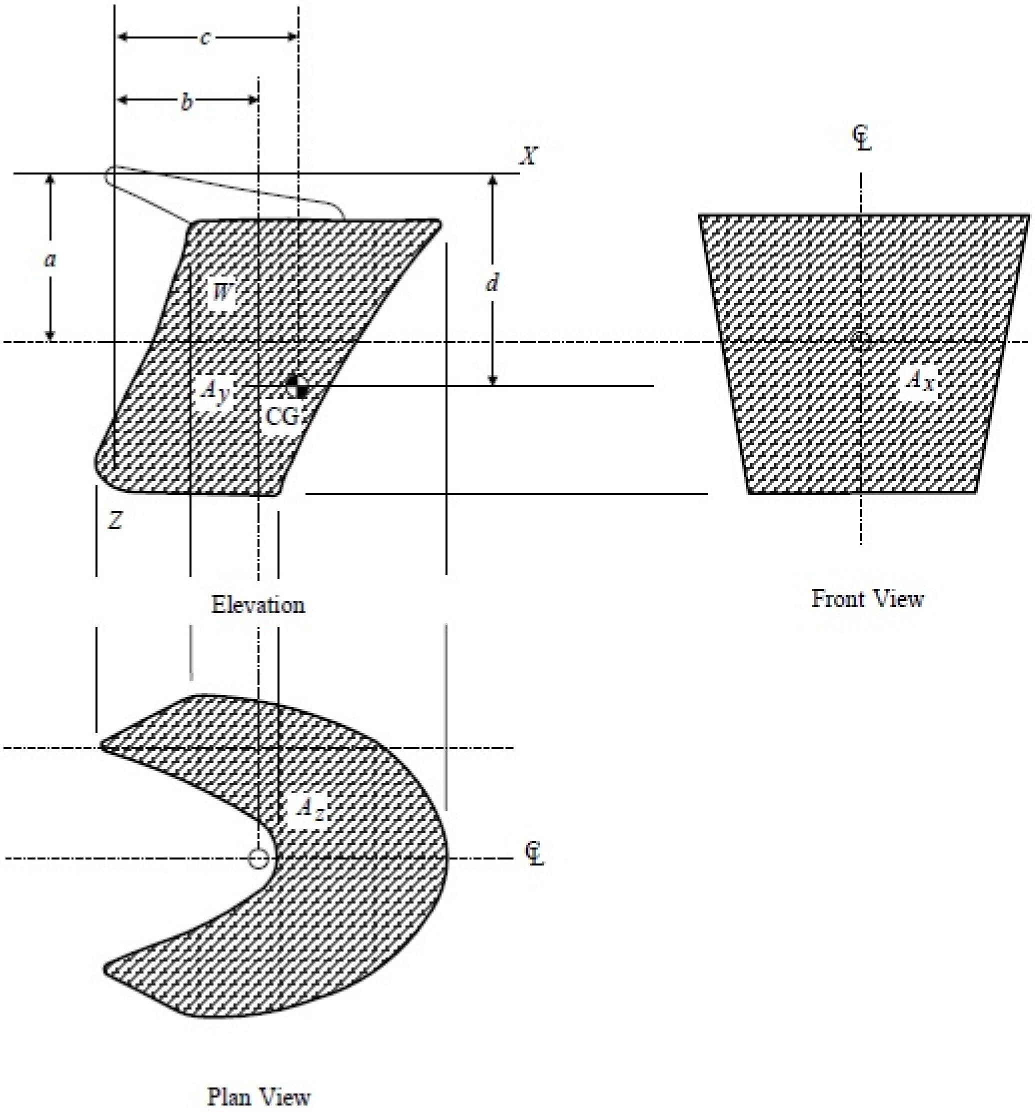
$M_y = F_x a + Wc - F_z b$ kN-m(tf-m,Ltf-ft.)

where

W	=	weight of the visor door, in kN (tf, Ltf)
α	=	vertical distance, in m (ft), from the visor pivot to the centroid of the transverse vertical projected area of the visor door. See 3-2-16/19.5.1 FIGURE 3.
b	=	horizontal distance, in m (ft), from visor pivot to the centroid of the horizontal projected area of the visor door. See 3-2-16/19.5.1 FIGURE 3.
c	=	horizontal distance, in m (ft), from the visor pivot to the center of gravity of the visor. See 3-2-16/19.5.1 FIGURE 3.

F_x and F_z are as defined in 3-2-16/19.3

FIGURE 3
Visor Type Bow Door



19.5.2 Opening Moment

The opening moment, M_o, is to be taken as indicated by the following equation:

$M_o = Wd + 5A_x a$ kN-m ($Wd + 0.5A_x a$ tf-m, $Wd + 0.047A_x a$ Ltf-ft)

where

d = vertical distance, in m (ft), from the hinge axis to the center of gravity of the door

W, A_x and a are as indicated above.

19.5.3 Vertical design Force

The vertical design force is to be taken as $F_z - W$ where F_z is as defined in 3-2-16/19.3 and W is as defined in 3-2-16/19.5.1.

19.5.4 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.

19.5.5 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.

19.7 Side-Opening Door Load Cases

19.7.1 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.

19.7.2 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.

21 Inner Door Design Loads

21.1 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} = 0.45L1 kN/m^2 (0.046L_1 tf/m^2, 0.00128L_1 Ltf/ft^2)

P_h = 10h kN/m^2 (1.0h tf/m^2, 0.029h Ltf/ft^2)

where

L_1 is as defined in 3-2-16/19.1.

h = the distance, in m (ft), from the load point to the top of the cargo space.

21.3 Internal Pressure

The design internal pressure, P_i is to be taken as not less than 25 kN/m^2 (2.5 tf/m^2, 0.23 Ltf/ft^2).

23 Side Shell and Stern Doors

23.1 Design Forces for Primary Members

The design force, in kN (tf, Ltf), for primary members is to be the greater of the following:

External force: $F_e = A\,p_e$

Internal force: $F_i = F_o + W$

23.3 Design Forces for Securing or Supporting Devices of Doors Opening Inwards

The design force, in kN (tf, Ltf), 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: $F_i = F_o + W$

23.5 Design Forces for Securing or Supporting Devices of Doors Opening Outwards

The design force, in kN (tf, Ltf), 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 (ft^2), of the door opening

W = weight of the door, in kN (tf, Ltf)

F_p = total packing force, in kN (tf, Ltf). Packing line pressure is normally not to be taken less than 5.0 N/mm (0.51 kg/mm, 28.6 lbf/in.).

F_o = the greater of F_c and kA, in kN (tf, Ltf)

k = 5 (0.51, 0.047)

F_c = accidental force, in kN (tf, Ltf), due to loose cargo, etc., to be uniformly distributed over the area A and not to be taken less than 300 kN (30.6 tf, 30.1 Ltf). 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 (tf/m^2, Ltf/ft^2), determined at the center of gravity of the door opening and not taken less than:

$p_e = k_1$ for $Z_G \geq d$

$p_e = k_2(d - Z_G) + k_1$ for $Z_G < d$

Moreover, for vessels fitted with bow doors, p_e for stern doors is not to be taken less than:

$p_e = nc(0.8 + 0.6(k_3 L)^{0.5})^2$

For vessels fitted with bow doors, and operating in restricted service, the value of p_e for stern doors will be specially considered.

k_1 = 25.0 (2.55, 0.233)

k_2 = 10.0 (1.02, 0.0284)

d = draft, in m (ft), as defined in 3-1-1/9

Z_G = height of the center of area of the door, in m (ft), above the baseline.

n = 0.605 (0.0616, 0.00563)

c = 1

k_3 = 1.0 (1.0, 0.305)

L = length of vessel, in m (ft), as defined in 3-1-1/3.1, but need not be taken as greater than 200 m (656 ft).

25 Allowable Stresses

25.1 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	(8.2/Q kgf/mm^2, 11600/Q psi)
Bending Stress:	$\sigma = 120/Q$ N/mm^2	(12.2/Q kgf/mm^2, 17400/Q psi)
Equivalent Stress: $\left(\sqrt{\sigma^2 + 3\tau^2}\right)$:	$\sigma_e = 150/Q$ N/mm^2	(15.3/Q kgf/mm^2, 21770/Q psi)

where Q is as defined in 3-2-1/5.3.

25.3 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 $0.8\sigma_f$, where σ_f is the yield stress of the bearing material.

25.5 Tensile Stress on Threaded Bolts

The tensile stress in threaded bolts is not to exceed $125/Q$ N/mm^2 ($12.7/Q$ kgf/mm^2, $18000/Q$ psi).

27 Operating and Maintenance Manual

The following information is to be submitted for review.

27.1 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

27.3 Operating Procedures

Documented operating procedures for closing and securing the doors are to be kept onboard and posted at an appropriate location.

PART 3

CHAPTER 2

Hull Structures and Arrangements

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, and if applicable, at the boundary of first tier deckhouses and at the ends of superstructures is to be at least 1.0 m (39.5 in.) from the deck surface. Where this height would interfere with the 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.

1.3 Strength of Bulwarks

1.3.1 Vessels under 90 m (295 ft) in Length

i) Bulwarks are to be of ample strength in proportion to their height and efficiently stiffened at the upper edge. The bulwark plating is to be kept clear of the sheerstrake and the lower edge effectively stiffened.

ii) For vessels under 61 m (200 ft) in length, the bulwark plating on freeboard decks is to be of a thickness adequate for the intended service of the vessel. For vessels 61 m (200 ft) in length and over, the bulwark plating on freeboard decks is not to be less than 6.5 mm (0.25 in.) in thickness. Bulwarks are to be supported by efficient stays. Stays on freeboard decks are to be spaced not more than 1.83 m (6 ft) apart and are to be efficiently attached to the bulwarks and deck plating. Where it is intended to carry timber deck cargoes, the bulwark stays are to be not over 1.52 m (5 ft) 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.

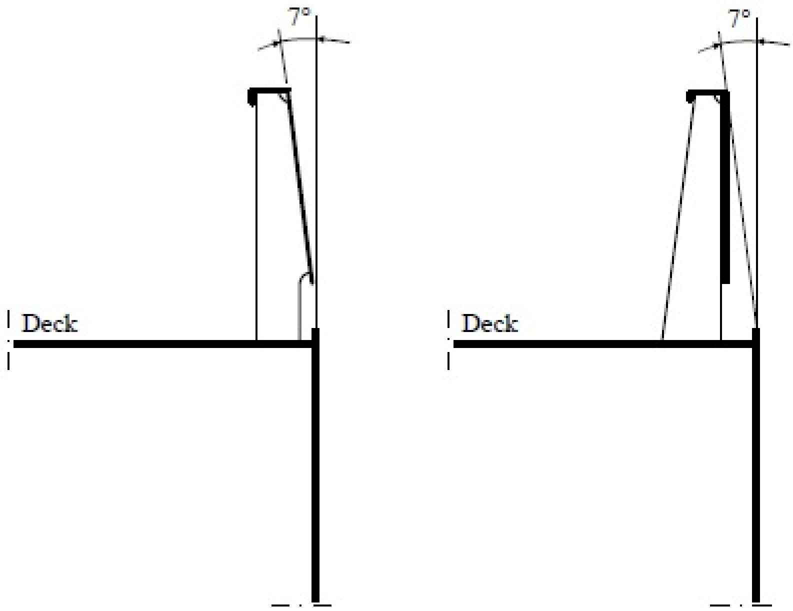
1.3.2 Other Steel Vessels *(2019)*

i) The strength of bulwark structures is to be in proportion to their height. The bulwark plating is to be kept clear of the sheer strake, it is to have the upper edge effectively stiffened and it is to be supported by efficient stays.

ii) Bulwarks on freeboard decks are to have stays spaced not more than 1.83 m (6 ft) apart. The stays are to be formed either of a flanged plate or built-up tee sections and are to be efficiently attached to the bulwark and deck plating.

iii) Where it is intended to carry timber deck cargoes, the bulwark stays are not to be spaced over 1.52 m (5 ft) apart and shall have increased scantlings and strength of attachments to the deck and bulwark.

FIGURE 1
Bulwark Stanchion Offset for OSV *(2019)*



1.5 Guard Rails

1.5.1

Fixed, removable or hinged stanchions are to be fitted at approximately 1.5 m (5 ft) apart. Removable or hinged stanchions are to be capable of being locked in the upright position.

1.5.2 *(1 July 2021)*

At least every third stanchion is to be supported by a bracket or stay. Dimensions and arrangement of stanchion and stays are to be as shown in 3-2-17/1.5 FIGURE 2. Where this arrangement 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 not to be taken as less than 60 mm (2.36 in.) (see 3-2-17/1.5 FIGURE 3). The thickness of the flat bar stanchions is not to be less than 15 mm (0.59 in.).

For any of the above arrangements *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 supporting member below the deck unless the deck plating thickness exceeds 20 mm (0.79 in.) and welded to deck with double continuous fillet weld with minimum leg size of 7.0 mm (0.28 in.) or as specified by the design standard.

v) The underdeck supporting member of the stanchion is to be a minimum of 100 × 12 mm (4.0 × 0.5 in.) flat bar welded to deck by double continuous fillet weld (see 3-2-17/1.5 FIGURE 3).

Alternative arrangements could be acceptable provided that it can be shown equivalent in strength and stiffness to the above requirements or based on recognized international standards.

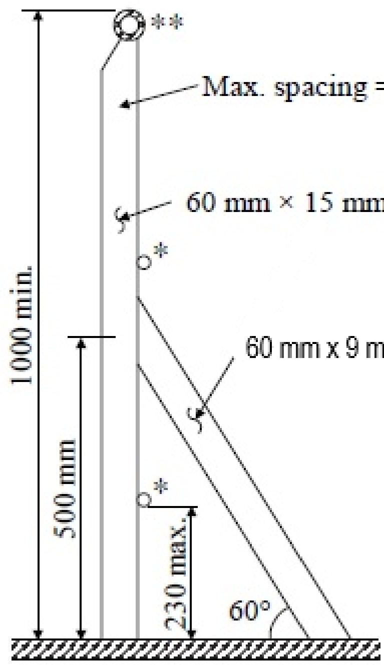
Lengths of chain may only be accepted in lieu of guard rails if they are fitted between two fixed stanchions and/or bulwarks.

Where necessary for the normal operation of the vessel, steel wire ropes may be accepted in lieu of guard rails. They may be used with either fixed or portable stanchions and shall be made taut by means of turnbuckles.

FIGURE 2
Guardrail Stanchion *(1 July 2021)*

** Top Rail = 34 mm outside diameter pipe with 2.6 mm minimum wall thickness (or pipes having an equivalent section modulus)

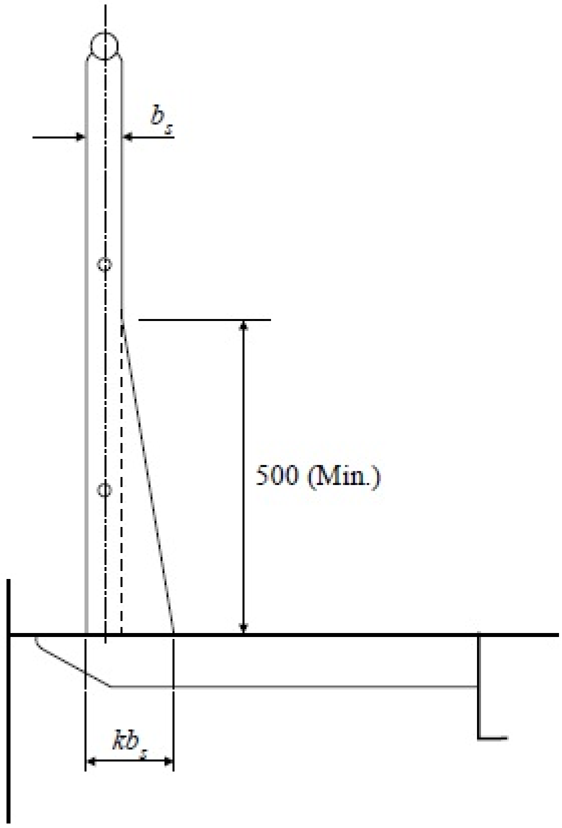
* = 19 mm solid round bar or 26.9 mm outside diameter pipe with 2.3 mm minimum wall thickness (or pipes having an equivalent section modulus)



Standard stanchion, rail, and stay sizes.

(Stay to be provided at every third stanchion)

FIGURE 3
Guardrail Stanchion



1.5.3 *(2019)*

The clear opening below the lowest course is not to exceed 230 mm (9 in.). Where a foot-stop is installed at the deck level the clear opening below the lowest course may be measured from the top of the foot-stop. The clear distances between the lowest and the middle courses, as well as the middle and the upper courses are not to exceed 380 mm (15 in.).

1.5.4 *(2019)*

For vessels with rounded gunwales, stanchions are to be placed on the flat of the deck.

1.5.5 Additional Requirements for Offshore Support Vessels *(2019)*

The distance between the lower rail and the top of the sheerstrake is not to exceed 230 mm (9 in.).

Stanchion, rails and stays are to be provided with a protective coating.

3 Access and Crew Protection

3.1 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 under-deck passages, etc., are to be provided for the protection of the crew in getting to and from their quarters, the machinery space, and all other parts (see 3-2-17/3.3 TABLE 1).

3.3 Access to Bow

Satisfactory means are to be provided enabling crew the safe access to the bow even in severe weather conditions.

3.3.1 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 1
Acceptable Arrangement for Access

<table>
<tr><th rowspan="2">Type of Vessel</th><th rowspan="2">Locations of access in Vessel</th><th rowspan="2">Assigned Summer Freeboard</th><th colspan="3">Acceptable arrangements according to type of freeboard assigned</th></tr>
<tr><th>Type B–100</th><th>Type B–60</th><th>Type B & B+</th></tr>
<tr><td rowspan="4">Offshore Support Vessel</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 navigating equipment, or both</td><td>≤ 3000 mm
(≤ 118 in.)</td><td>a
b
e</td><td>a
b
c(1)
e
f(1)</td><td rowspan="3">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
(> 118 in.)</td><td>a
b
e</td><td>a
b
c(1)
c(2)
e
f(1)
f(2)</td></tr>
<tr><td rowspan="2">1.2: Access to Ends
1.2.1 Between poop and bow (if there is no bridge), or
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
(≤118 in.)</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
(> 118 in.)</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><td></td></tr>
</table>

Note: Deviations from some or all of these requirements or alternative arrangements for such cases as vessels with very high gangways may be allowed, subject to agreement on a case-by-case basis with the relevant flag Administration.

<table>
<tr><th rowspan="2">Type of Vessel</th><th rowspan="2">Locations of access in Vessel</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>
</table>

All Vessels other than Oil Tankers*, Chemical Tankers* and Gas Carriers*	**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 navigating equipment, or both	≤ 3000 mm (≤ 118 in.)	a b e	a b e	a b c(1) e f(1)	a b c(1) c(2) c(4) d(1) d(2) d(3) e f(1) f(2) f(4)
		> 3000 mm (> 118 in.)	a b e	a b e	a b c(1) c(2) e f(1) f(2)	
	1.2: Access to Ends **1.2.1** Between poop and bow (if there is no bridge), or **1.2.2.** Between bridge and bow, or **1.2.3.** Between a deckhouse containing living accommodation or navigating 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 ship.	≤ 3000 mm (≤ 118 in.)	a b c(1) e f(1)	a b c(1) c(2) e f(1) f(2)	a b c(1) c(2) e f(1) f(2)	
		> 3000 mm (> 118 in.)	a b c(1) d(1) e f(1)	a b c(1) c(2) d(1) d(2) e f(1) f(2)	a b c(1) c(2) c(4) d(1) d(2) d(3) e f(1) f(2) f(4)	
Oil Tankers*, Chemical Tankers* and Gas Carriers*	**2.1: Access to Bow** **2.1.1.**Between poop and bow, or **2.1.2.** Between a deckhouse containing living accommodation or navigating 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 ship.	$\le (A_f + H_s)$**	a e f(1) f(5)			
		$> (A_f + H_s)$**	a e f(1) f(2)			
	2.2:Access to After End In the case of a flush deck vessel, between crew accomodation and the after end of ship.	As required in 1.2.4 for other types of ships				

*Oil Tanker, Chemical Tanker and Gas Carrier as defined in SOLAS: II-1/2.22, 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 under-deck passageway with clear opening at least 0.8 m (2.6 ft) in width and 2.0 m (6.6 ft) in height, providing access to the locations in question and located as close as practicable to the freeboard deck. For tankers, see also 5C-1-7/17.5, 5C-1-7/31.5, 5C-1-7/31.9, 5C-1-7/31.11 and 5C-1-7/31.17.

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 (2 ft) in width, with a foot-stop and guard rails extending on each side throughout its length. Guard rails are to be as required in 3-2-17/3.1 and 3-2-17/1.5 except that stanchions are to be fitted at intervals not more than 1.5 m (5 ft).

c) A permanent walkway at least 0.6 m (2 ft) in width fitted at freeboard deck level consisting of two rows of guard rails with stanchions spaced not more than 3 m (10 ft). The number of courses of rails and their spacing are to be as required in 3-2-17/1.5. Hatchway coamings not less than 0.6 m (2 ft) 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 (0.4 in.) minimum diameter wire rope lifeline supported by stanchions about 10 m (33 ft) 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 (3.3 ft) 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 3-2-17/3.1 and 3-2-17/1.5.1 & 3-2-17/1.5.3 except that stanchions are to be fitted at intervals not more than 1.5 m (5 ft);
- 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 (131 ft) apart;
- having shelters of substantial construction, set in way of the gangway at intervals not exceeding 45 m (148 ft) if the length of the exposed deck to be traversed exceeds 70 m (230 ft). 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 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 (3.3 ft) and two rows of guard rails are fitted between the hatchways.
(*) For tankers less than [100 m (328 ft)] 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 (2 ft).

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 are to be provided.

3) Generally, the width of the gangway or walkway should not exceed 1.5 m (5 ft).

3.5 Embarkation, Disembarkation and Pilot Transfer Arrangement *(2023)*

For vessels that are to comply with the SOLAS Convention, the following are to be met:

The means of embarkation and disembarkation for in port and port-related operations are to be provided, such as gangways and accommodation ladders. They are to be designed and constructed in accordance with recognized international standards such as ISO 7061 and ISO 5488. The details are to be submitted for review.

The pilot transfer arrangements are to be provided in accordance with the applicable requirements in SOLAS Regulation V/23. The details of pilot ladder are to be submitted for our review by the manufacturer as complying with the recommendations by the International Organization for Standardization, in particular publication ISO 799.

Commentary:

Exceptions may be allowed as per II-1 Regulation 3-9 of SOLAS as given below:

Circumstances where compliance may be deemed unreasonable or impractical may include where the ship:

1 Has small freeboards and is provided with boarding ramps; or

2 Is engaged in voyages between designated ports where appropriate shore accommodation/embarkation ladders (platforms) are provided.

End of Commentary

5 Freeing Ports

Where bulwarks on the weather portions of freeboard or superstructure decks form wells, such as passage between the bulwark and the cargo rail or the cargo deck between port and starboard cargo rails, or the passage between the bulwark and the deckhouse bulkhead etc., provision is to be made for rapidly freeing the decks of water and for draining them.

5.1 Basic Area *(2019)*

Except as provided in 3-2-17/5.3 and 3-2-17/5.5, the minimum freeing-port area A_{fp} on each side of the vessel for each well on the freeboard deck is to be obtained from the following equations:

1) Where the length of bulwark, ℓ, in the well is 20 m (66ft) or less:

$A = 0.7 + 0.035\ell$ m^2 $\quad\quad$ $A = 7.6 + 0.115\ell$ ft^2

2) Where ℓ exceeds 20 m (66 ft)

$A = 0.07\ell$ m^2 $\quad\quad$ $A = 0.23\ell$ ft^2

In no case need ℓ be taken as greater than $0.7L_f$ where L_f is as defined in 3-1-1/3.3.

5.1.1 Offshore Support Vessels *(2019)*

5.1.1(a) On Superstructure Decks (2019)

The minimum area for each well on superstructure decks is to be one-half of the area obtained from the above equations.

5.1.1(b) Basic Area Adjustments

If the bulwark or part of bulwark is more than 1.2 m (3.9 ft) in average height, the required area is to be increased by according to the following equations:

$A_{s>1.2} = 0.02\ell_s(h_b - 1.2)$ m²	$A_{s>1.2} = 0.02\ell_s(h_b - 3.9)$ ft²	for sloped or curved parts
$A_{q>1.2} = 0.04\ell_q(hb - 1.2)$ m²	$A_{q>1.2} = 0.04\ell_q(h_b - 3.9)$ ft²	for quadrilateral parts

where

$A_{s>1.2}, A_{q>1.2}$	=	additions to the basic area A, in m² (ft²)
ℓ_s	=	length of height increase, in m (ft), measured horizontally from the point of intersection of the slope (or curve) at height of 1.2 m (3.9 ft) to the vertical at the highest point of slope (or curve)
ℓ_q	=	length of lifted quadrilateral part of bulwark, in m (ft), measured horizontally from the vertical at the highest point of slope (or curve)
h_b	=	full height of the lifted part of bulwark, in m (ft)

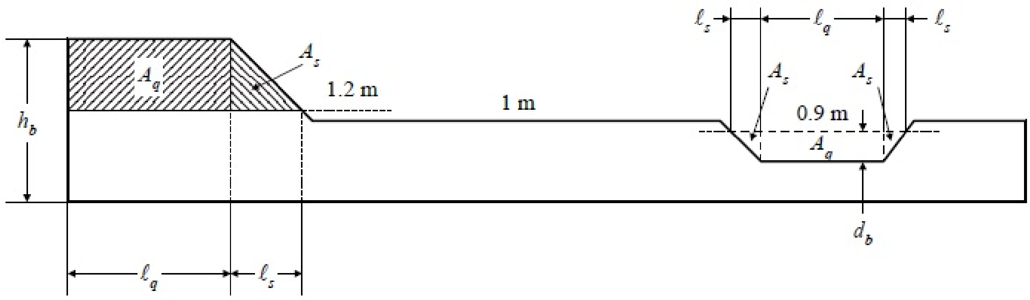
If the bulwark or part of bulwark is less than 0.9 m (3 ft) in average height, the required area may be decreased the effects of the following equations:

$A_{s<0.9} = 0.02\ell_s(0.9 - d_b)$ m²	$A_{s<0.9} = 0.02\ell_s(3.0 - d_b)$ ft²	for sloped or curved parts
$A_{q<0.9} = 0.04\ell_q(0.9 - d_b)$ m²	$A_{q<0.9} = 0.02\ell_q(3.0 - d_b)$ ft²	for quadrilateral parts

where

$A_{s<0.9}, A_{q<0.9}$	=	deductions from the basic area A, in m² (ft²)
ℓ_s	=	length of height decrease, in m (ft), measured horizontally from the point of intersection of the slope (or curve) at height of 0.9 m (3 ft) to the vertical from the lowest point of slope (or curve)
ℓ_q	=	length of lowered quadrilateral part of bulwark, in m (ft), measured horizontally from the vertical at the lowest point of slope (or curve)
d_b	=	depth of the concaved part of bulwark below 0.9 m (3 ft) line, in m (ft)

FIGURE 4
Freeing Ports Area Adjustment



5.1.2 Other Steel Vessels *(2019)*

5.1.2(a) Basic Area Adjustments

If the bulwark is more than 1.2 m (3.9 ft) in average height, the required area is to be increased by 0.004 m^2 per m (0.04 ft^2 per ft) of length of well for each 0.1 m (1 ft) difference in height. If the bulwark is less than 0.9 m (3 ft) in average height, the required area may be decreased by 0.004 m^2 per m (0.04 ft^2 per ft) of length of well for each 0.1 m (1 ft) difference in height.

5.3 Vessels with Less than Standard Sheer

In vessels without sheer the freeing port area calculated as described above is to be increased by 50%. Where the sheer is less than the standard, the percentage is to be obtained by interpolation.

5.5 Trunks *(2019)*

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 applicable table.

TABLE 2A
Offshore Support Vessels *(2019)*

Breadth of hatchway or trunk b, in relation to the breadth B of the vessel	*Area of freeing ports A_{fp} in relation to the total area of the bulwarks A_{bk}*
$b_t/B \le 0.4$	$A_{fp}/A_{bk} = 0.2$
$0.4 < b_t/B < 0.75$	$A_{fp}/A_{bk} = 0.1 + 0.114(2.5bt/B - 1)$
$b_t/B \ge 0.75$	$A_{fp}/A_{bk} = 0.1$

TABLE 2B
Other Steel Vessels *(2019)*

Breadth of hatchway or trunk in relation to the breadth of vessel	*Area of freeing ports in relation to the total area of the bulwarks*
40% or less	20%
75% or more	10%

The area of freeing ports at intermediate breadths is to be obtained by linear interpolation.

5.7 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.

5.9 Details of Freeing Ports *(2019)*

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. When the height of the freeing port opening is greater than 230 mm (9 in.), such openings in the bulwarks are to be protected by horizontal rails or bars spaced not more than 230 mm (9 in.) apart. If shutters are fitted to freeing ports, an ample clearance is to be provided to prevent jamming and such shutters are only allowed on flat, not curved portions of the bulwarks. Hinges on shutters are to have pins or bearings of noncorrosive material and are to be located at or as near as possible to the top of the shutters. If shutters are fitted with securing appliances, these are to be of approved construction.

7 Portlights

Portlights are defined as rectangular, round, or oval openings with an area not exceeding 0.16 m^2 (1.7 ft^2). This Subsection applies to passenger vessels and cargo vessels (See 5C-7-2/7.13) and OSVs unless otherwise specified. 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.

7.1 Location

7.1.1 General

i) 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 0.025*B* or 500 mm (19.5 in.) above the maximum summer load waterline (or summer timber load waterline, if assigned), whichever is the greater distance.

ii) Portlights are not to be fitted in spaces which are used for the carriage of cargo.

7.1.2 Offshore Support Vessels

In addition, a portlight fitted in an external door is to be treated the same as a portlight in the adjacent bulkhead.

7.3 Deadlights and Storm Covers – Offshore Support Vessels

Portlights to spaces below the bulkhead/freeboard deck or to spaces within enclosed superstructures or enclosed deckhouses on the first and second tiers above the freeboard deck are to be fitted with efficient hinged inside deadlights arranged such that they can be effectively closed and secured watertight, except as noted below:

i) Portlights fitted on second tier deckhouse with cabin bulkheads and doors in the second tier that separate the portlights from direct access leading below may be fitted without deadlights.

ii) Portlights in side bulkheads set inboard from the side shell in the second tier protecting direct access leading below may be fitted with external storm covers in lieu of deadlights provided the storm covers are accessible, permanently attached and capable of being effectively closed and secured weathertight.

iii) Portlights located in first tier deckhouse bulkheads where the deckhouse is not protecting openings leading below or is not considered buoyant in stability calculation may be fitted without deadlights.

Portlights located higher than the second tier above the freeboard deck may be fitted without deadlights. However, portlights fitted in the front bulkheads of deckhouses located in the first tier above the weather deck on the forecastle are to be fitted with inside deadlights or storm covers that are permanently attached and capable of being effectively closed and secured weathertight.

7.5 Construction

The following requirements are to be complied as applicable.

7.5.1 General

7.5.1(a) Offshore Support Vessels

Portlights, together with their glasses and deadlights, are to comply with ISO 1751 or an equivalent national standard. However, portlight frames of cast iron or non-metallic materials are not permitted.

Where portlights are fitted in the side shell, in the sides of superstructures and in the front bulkheads of superstructures and deckhouses on weather decks, they are to be of Type A portlights (designated as per ISO 1751).

Where portlights are fitted in the ends of superstructures or the sides and ends of deckhouses, they are to be of Type B portlights (designated as per ISO 1751).

Deadlights and storm covers are to be of a strength equivalent to the adjacent bulkhead. Non-metallic deadlights and storm covers are not acceptable.

7.5.1(b) Other Steel Vessels (1 July 2022)

Portlights to spaces below the bulkhead/freeboard deck, to spaces within enclosed superstructures, or to first tier deckhouses on the freeboard deck protecting openings leading below or considered buoyant in stability calculations are to be fitted with efficient hinged, inside deadlights. The deadlights are to be capable of being closed and secured watertight if fitted below the freeboard deck, and weathertight if fitted above. 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.

7.5.2 Non-opening Type

Where vessels are subject to damage stability requirements of 3-3-1/5.3, portlights found to be situated below a final damage equilibrium waterline are to be of non-opening type.

7.5.3 Locked Type

Portlights where permitted in 3-2-17/7.5.2 to be of opening type are to be of such construction as will prevent unauthorized opening where:

7.5.3(a)

the sills of which are below the bulkhead/freeboard deck as permitted in 3-2-17/7.3, or

7.5.3(b)

fitted in spaces used alternatively for the carriage of cargo or passengers.

7.5.4 Automatic Ventilating Type

Automatic ventilating portlights are not to be fitted in the shell plating below the bulkhead/ freeboard deck without special approval.

9 Windows

Windows are defined as being rectangular, round, or oval openings with an area exceeding 0.16 m^2 (1.7 ft^2).

9.1 Location *(2019)*

Windows may only be fitted in the following locations:

i) In front, after end bulkheads and side bulkheads of deckhouse and superstructures, in the second tier and higher above the freeboard deck

ii) In first tier deckhouses that are not considered buoyant in the stability calculations or that do not protect openings leading below

A window fitted in an external door is to be treated the same as a window in the adjacent bulkhead.

9.3 Deadlight Arrangement

9.3.1 Offshore Support Vessels and Steel Vessels under 90 m (295 ft) in Length *(2019)*

i) Windows to spaces within enclosed superstructures or enclosed deckhouses on the second tier above the freeboard deck are to be fitted with efficient hinged inside deadlights arranged such that they can be effectively closed and secured watertight, except as noted below:

- Windows fitted on second tier deckhouse with cabin bulkheads and doors in the second tier that separate the window from direct access leading below may be fitted without deadlights.
- Windows in side bulkheads set inboard from the side shell in the second tier protecting direct access leading below may be fitted with external storm covers in lieu of deadlights provided the storm covers are accessible, permanently attached and capable of being effectively closed and secured weathertight.
- Windows located in first tier deckhouse bulkheads where the deckhouse is not protecting openings leading below or is not considered buoyant in stability calculation may be fitted without deadlights.

ii) Windows located higher than the second tier above the freeboard deck may be fitted without deadlights. However, windows fitted in the front bulkheads of deckhouses located in the first tier above the weather deck on the forecastle are to be fitted with inside deadlights or storm covers that are permanently attached and capable of being effectively closed and secured weathertight.

iii) Where windows in the wheelhouse front are required to have deadlights or storm covers, at least two of the deadlights or storm covers are to have means of providing a clear view.

9.3.2 Other Steel Vessels

Windows in side bulkheads set inboard from the side shell in the second tier that protect direct access below to spaces listed in 3-2-17/7.5.1, are to be provided with either hinged inside deadlights or, where they are accessible, permanently attached external storm covers of approved design and substantial construction capable of being closed and secured weathertight.

Cabin bulkheads and doors may be accepted in place of deadlights or storm covers in the second tier and above provided they separate side scuttles and windows from a direct access leading below or to the second tier considered buoyant in the stability calculations.

9.5 Construction

9.5.1 Offshore Support Vessels and Steel Vessels under 90 m (295 ft) in Length *(2019)*

i) Window frames are to be metal or other approved material and secured to the adjacent structure.

ii) Window cutouts are to have a minimum of 6.5 mm (0.25 in.) radius at all corners and the glazing is to be set into the frames in an approved, flexible seawater and sunlight resistant packing or compound.

iii) Special attention is to be paid to the windows installed in angled deckhouse fronts.

iv) Deadlights and storm covers are to be of a strength equivalent to the adjacent bulkhead. Non-metallic deadlights and storm covers are not acceptable.

In general, windows are to be fitted from the outside. Windows in the third tier and higher above the freeboard deck may be fitted from the inside. The window frames may be fitted from inside, provided all window frame load-carrying elements, mechanical fastenings and welded connections in the load path between the window glazing and the bulkheads are to have strength equivalent to the approved glazing ultimate load. The yield strength of the bolts, including the screw connection to the window frame, and the window frame flange is not to be exceeded when the window is subject to 4 times the glazing design pressure.

Windows are also to comply with a recognized international standard or an equivalent national standard (such as ISO 3903 and ISO 5779).

9.5.2 Other Steel Vessels

Window frames are to be metal or other approved material and secured to the adjacent structure. Window cutouts are to have a suitable radius at all corners and the glazing is to be set into the frames in an appropriate, flexible seawater and sunlight resistant packaging or compound. Special attention is to be paid to the windows installed in angled deckhouse fronts.

9.7 Window Glazing

9.7.1 Offshore Support Vessels

The thickness of the thermally toughened monolithic safety glass is to be not less than the greater of the following:

t = 9.5 mm (0.37 in.)

$$t = s\left(\sqrt{\frac{f_w \beta h_w}{4000}}\right) \text{ mm}$$

$$t = s\left(\sqrt{\frac{f_w \beta h_w}{13123}}\right) \text{ in.}$$

where

t	=	required window thickness, in mm (in.)
ℓ	=	greater dimension of window panel, in mm (in.)
s	=	lesser dimension of window panel, in mm (in.)
h_w	=	pressure head for windows, in m (ft), given in the 3-2-11/3.5
β	=	$0.985 - 0.00357\,(\ell/s)^2 - 0.729/(\ell/s)$ $\quad \ell/s < 5$
	=	0.75 $\quad \ell/s \geq 5$
f_w	=	as given below

i) f_w for superstructure sides or bulkheads of deckhouse located completely or partially on the superstructure or exposed forecastle deck:

	2nd Tier	*3rd Tier*	*4th Tier and above*
Front bulkhead	1.41	1.41	0.62
Side bulkhead	1.22	1.22	0.48
Aft bulkhead	1.04	0.70	0.32

Notes:

1 Bulkheads of deckhouses are considered to be completely or partially on the superstructure or exposed forecastle deck when any portion of the bulkhead is within one (1) ICLL standard superstructure height above the deck. When the bulkhead is entirely one standard superstructure or higher above the superstructure or exposed forecastle deck fw is to be taken per 3-2-17/9.7.ii).

2 The tiers indicated above represent the Tier location of the superstructure or exposed forecastle deck in relation to the freeboard deck.

ii) For deckhouses located other than i) above:

$$f_w = 1.0$$

The above requirements are for thermally toughened monolithic glass which is to comply with ISO 21005 or an equivalent national standard. Alternatively, glazing with a flexural strength of not less than 160 N/mm^2 (23206 psi) approved by recognized standard is also acceptable.

Windows of glazing other than thermally toughened monolithic glass will be specially considered with regards to design, manufacture and testing.

9.7.2 Steel Vessels under 90 m (295 ft) in Length *(2019)*

The thickness of the window glazing is not to be less than the greater of the following:

$$t = s\left(\sqrt{\frac{pk_1}{C_1\sigma_a}}\right) \quad \text{mm(in.)}$$

$$t = s\left(\sqrt[3]{\frac{pk_2}{C_2E}}\right) \quad \text{mm(in.)}$$

where

C_1	=	1000 (1.0)
C_2	=	20 (0.02)
t	=	required window thickness, in mm (in.)
s	=	lesser dimension of window, in mm (in.)
h	=	pressure head, in m (ft), given in 3-2-11/3.5
p	=	9.8h kN/m^2 (0.44h psi)
k_1	=	factor given in 3-2-17/9.7.2 TABLE 2
k_2	=	factor given in 3-2-17/9.7.2 TABLE 2
σ_a	=	$0.30\sigma_f$
σ_f	=	material flexural strength; see 3-2-17/9.7.2 TABLE 3
E	=	material flexural modulus; see 3-2-17/9.7.2 TABLE 3

For tempered monolithic glass, t is not to be less than 9.5 mm (0.37 in.) for front windows and nor 6.5 mm (0.25 in.) for side and end windows.

TABLE 2

ℓ/s	k_1	k_2
>5	0.750	0.142
5	0.748	0.142
4	0.741	0.140
3	0.713	0.134
2	0.610	0.111
1.8	0.569	0.102
1.6	0.517	0.091
1.4	0.435	0.077
1.2	0.376	0.062
1	0.287	0.044

ℓ = greater dimension of window panel, in mm (in.)

s = lesser dimension of window panel, in mm (in.)

TABLE 3

Glazing	*Flexural Strength*	*Flexural Modulus*
Tempered Monolithic	119 MPa (17,200 psi)	73,000 MPa (10,600,000 psi)
Laminated Glass	69 MPa (10,000 psi)	2,620 MPa (380,000 psi)
Polycarbonate*	93 MPa (13,500 psi)	2,345 MPa (340,000 psi)
Acrylic (poly methyl methacrylate)*	110 MPa (16,000 psi)	3,000 MPa (435,000 psi)

* Indicated values are for reference. Aging effects are to be considered for design.

9.7.3 Other Steel Vessels

The thickness of the thermally toughened monolithic safety glass is to be not less than the greater of the following:

$t = 8$ mm (0.37 in.) for front windows

$t = 6.5$ mm (0.26 in.) for side and end windows

$t = s\sqrt{\frac{\beta h}{4000}}$ mm $\qquad t = s\sqrt{\frac{\beta h}{13123}}$ in.

where

t = required window thickness, in mm (in.)

ℓ = greater dimension of window panel, in mm (in.)

s = lesser dimension of window panel, in mm (in.)

h = pressure head for windows, in m (ft), given in 3-2-11/3.5

β = $0.985 - 0.00357(\ell/s)^2 - 0.729/(\ell/s)$ $\qquad \ell/s < 5$

= 0.75 $\qquad \ell/s \geq 5$

The above requirements are for thermally toughened monolithic glass, which is to comply with ISO 21005 or an equivalent national standard. Alternatively, glazing with a flexural strength of not less than 160 N/mm^2 (23206 psi) approved by recognized standard is also acceptable.

Windows of glazing other than thermally toughened monolithic glass will be specially considered with regards to design, manufacture, and testing.

9.9 Testing

9.9.1 Offshore Support Vessels and Other Steel Vessels

i) All windows and portlights are to be hose-tested in position under a water pressure of at least 2 bar (2 kgf/cm^2, 30 lbs/in^2) at the time of construction and, if considered necessary, at subsequent surveys.

ii) The flexural strength of the thermally toughened glass is to be verified by compliance with the proof loads in ISO 614.

9.9.2 Vessels under 90 m (295 ft) in Length

All windows and portlights are to be hose-tested after installation.

11 Ventilators, Tank Vents and Overflows

11.1 General

Ventilators are to comply with the requirements of 3-2-17/11.3. Tank vents and overflows are to comply with the requirements in 3-2-17/11.5. In addition, for those located on the fore deck, the requirements given in 3-2-17/11.7 are to be complied with.

11.3 Ventilators

11.3.1 Construction of Coamings

11.3.1(a) For Vessels Under 90m (295 ft) In Length

Ventilators on exposed freeboard decks, superstructure deck or deckhouses are to have coamings of steel or equivalent material. Coaming plate thicknesses are to be obtained from the following equation.

$t = 0.01d + 5.5$ mm

$t = 0.01d + 0.22$ in.

where

t = thickness of coaming in mm (in.)

d = diameter of ventilator in mm (in.), but not less than 200 mm (7.5 in.)

The maximum coaming plate thickness required is 10 mm (0.40 in.). The coamings are to be effectively secured to the deck. Coamings which are more than 900 mm (35.5 in.) 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 (6 in.) 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.

11.3.1(b) For All Other Vessels

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. The minimum coaming-plate thickness is to be calculated from the following table.

Outer Diameter of a Ventilator d_v, in mm (in.)	*Coaming Plate Thickness t_c, in mm (in.)*
$d_v \leq 200$ (8)	7.5 (0.3)
$200\ \text{mm} < d_v < 457\ \text{mm}$ $8\ \text{in.} < d_v < 18\ \text{in.}$	$t_c = 7.5 + [2.5(d_v - 200)]/257\ \text{mm}$ $t_c = 0.3 + 0.01(d_v - 8)\ \text{in.}$
$d_v \geq 457(18)$	10 (0.4)

Coamings are to be secured to the stiffened deck plating. Coamings which are more than 900 mm (35.5 in.) high and which are not supported by or clamped to adjacent structures are to be bracketed at the deck attachment. Ventilators passing through superstructures, other than enclosed superstructures, are to have 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 (6 in.) in diameter is to be provided, to facilitate survey of the damper. The closure provided for the inspection port or opening is to maintain the watertight integrity and, if appropriate, the fire integrity of the coaming in question.

11.3.2 Height of Coamings

Ventilators in Position 1 are to have coamings at least 900 mm (35.5 in.) above the deck. Ventilators in Position 2 are to have coamings at least 760 mm (30 in.) above the deck (see 3-2-15/3 for definition of Positions). In exposed positions, the height of coamings may be required to be increased.

11.3.3 Means for Closing Openings *(1 July 2021)*

Except as provided below, ventilator openings are to be provided with permanently attached closing appliances. Ventilators in Position 1, the coamings of which extend to more than 4.5 m (14.8 ft) above the deck, and in Position 2, the coamings of which extend to more than 2.3 m (7.5 ft) above the deck, need not be fitted with closing arrangements, unless unusual features or the design makes this necessary. See also 4-7-2/1.9.5 and 4-7-2/1.9.6.

These coaming height requirements may be modified in vessels measuring less than 24 m (79 ft) in length on a case-by-case basis.

11.5 Tank Vents and Overflows

Tank vents and overflows are to be in accordance with the requirements of 4-6-4/9.3 and 4-6-4/9.5 of these Rules. In addition, where applicable, the requirements given below in 3-2-17/11.7 are to be complied with.

11.7 Ventilators, Tank Vents and Overflows on the Fore Deck

11.7.1 Application

The requirements of this paragraph apply to all ventilators, tank vents and overflows of vessel with length, L of 80 meters (263 feet) or more, located on the exposed fore deck within the forward $0.25L$ and where the height of the exposed fore deck in way of the item is less than $0.1L$ or 22 meters (72 ft) above the scantling waterline, whichever is lesser.

11.7.2 Applied Loading to the Air Pipes and Ventilators

11.7.2(a) Pressure. The pressures p, in kN/m^2 (tf/m^2, Ltf/ft^2), acting on air pipes, ventilator pipes and their closing devices, may be calculated from:

$$p = f\rho V^2 C_d C_s C_p \quad \text{N/m}^2\ (\text{tf/m}^2, \text{Ltf/ft}^2)$$

where:

f = 0.5 (0.05, 0.0156)

ρ = density of sea water, 1.025 t/m³ (1.025 t/m³, 0.0286 Lt/ft³)

V = velocity of water over the fore deck,

= 13.5 m/sec (44.3 ft/sec) for $d \leqslant 0.5d_1$

= $13.5\sqrt{2\left(1-\frac{d}{d_1}\right)}$ m/sec ($44.3\sqrt{2\left(1-\frac{d}{d_1}\right)}$ ft/sec) for $0.5d_1 < d < d_1$

d = distance from summer load waterline to exposed deck

d_1 = 0.1L or 22 m (72 ft), whichever is the lesser

C_d = shape coefficient

= 0.5 for pipes

= 1.3 for pipes or ventilator heads in general

= 0.8 for 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

11.7.2(b) Force. Forces acting in the horizontal direction on the pipe and its head (closing device) may be calculated from the above pressures using the largest projected area of each component.

11.7.3 Strength Requirements for Ventilators, Tank Vents and Overflows and their Closing Devices

11.7.3(a) Bending Moment and Stress. Bending moments and stresses in air pipes and ventilator pipes are to be calculated at penetration pieces, at weld or flange connections and at toes of supporting brackets. Bending stresses in the net section are not to exceed 0.8Y, where Y is the specified minimum yield stress or 0.2% proof stress of the steel at room temperature. Then, irrespective of corrosion protection, a corrosion addition of 2.0 mm (0.08 in.) is to be applied to the minimum pipe wall thickness needed to meet above limits.

11.7.3(b) Tank Vents and Overflows

i) For standard tank vents and overflows of 760 mm (30 in.) height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in 3-2-17/11.7.3 TABLE 5. Where brackets are required, minimum three radial brackets are to be fitted.

ii) Brackets are to be of gross thickness of 8 mm (0.32 in.) or more, of minimum length of 100 mm (4.0 in.) and height according to 3-2-17/11.7.3 TABLE 4, but need not extend over the head attachment flange. Bracket toes at the deck are to be supported.

iii) For other configurations; loads according to 3-2-17/11.7.2 are to be applied and supports determined to comply with the strength requirements above. Brackets, where fitted, are to be of thickness and length in proportion to their depth.

iv) Final (gross) pipe thickness is not to be taken less than as indicated in 4-6-4/9.3.2 and 4-6-4/9.5.6.

v) The minimum internal diameter of the air pipe or overflow is not to be less than 65 mm (2.5 in.).

11.7.3(c) Ventilators

i) For standard ventilators of 900 mm (35.4 in.) height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in 3-2-17/11.7.3 TABLE 5. Brackets, where required, are to be as specified in 3-2-17/11.7.3(b).iii).

ii) For ventilators of height greater than 900 mm (35.4 in.), brackets or alternative means of support are to be provided. Coamings are not to be taken less than as indicated in 3-2-17/11.3 nor in 3-2-17/11.7.3 TABLE 5.

11.7.3(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 3-2-17/11.7.2.

11.7.3(e) Rotary Heads. Rotating type mushroom ventilator heads are not to be used for applications in this location.

TABLE 4
760 mm (30 in.)[3] High Tank Vents and Overflows Thickness and Bracket Standards

Nominal Pipe Size		*Minimum Fitted Gross Thickness*		*Maximum Projected Area of Head*		*Height [1] of Brackets*	
A	*B*						
mm	*in.*	*mm*	*in.*	*cm²*	*in²*	*mm*	*in.*
65	2½	6.0	---	---	---	480	18.9
80	3	6.3	0.25	---	---	460	18.1
100	4	7.0	0.28	---	---	380	15.0
125	5	7.8	0.31	---	---	300	11.8
150	6	8.5	0.33	---	---	300	11.8
175	7	8.5	0.33	---	---	300	11.8
200	8	8.5[2]	0.33[2]	1900	295	300	11.8
250	10	8.5[2]	0.33[2]	2500	388	300[2]	11.8[2]
300	12	8.5[2]	0.33[2]	3200	496	300[2]	11.8[2]
350	14	8.5[2]	0.33[2]	3800	589	300[2]	11.8[2]
400	16	8.5[2]	0.33[2]	4500	698	300[2]	11.8[2]

Notes:

1) Brackets [see 3-2-17/11.7.3(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 (0.41 in.) or where the tabulated projected head area is exceeded

3) For other air pipe heights, the relevant requirements of 3-2-17/11.7.3 are to be applied.

TABLE 5
900 mm (35.4 in.)[2] High Ventilator Thickness and Bracket Standards

Nominal Pipe Size		*Minimum Fitted Gross Thickness*		*Maximum Projected Area of Head*		*Height [1] of Brackets*	
A	*B*						
mm	*in.*	*mm*	*in.*	*cm²*	*in²*	*mm*	*in.*
80	3	6.3	0.25	---	---	460	18.1
100	4	7.0	0.28	---	---	380	15.0
150	6	8.5	0.33	---	---	300	11.8
200	8	8.5	0.33	550	85	---	---
250	10	8.5	0.33	880	136	---	---
300	12	8.5	0.33	1200	186	---	---
350	14	8.5	0.33	2000	310	---	---
400	16	8.5	0.33	2700	419	---	---
450	18	8.5	0.33	3300	511	---	---
500	20	8.5	0.33	4000	620	---	---

Notes:

1 Brackets [see 3-2-17/11.7.3(b)] need not extend over the head attachment flange.

2 For other ventilator heights, the relevant requirements of 3-2-17/11.7.3 are to be applied.

PART 3

CHAPTER 2

Hull Structures and Arrangements

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 (0.08 in.).

3 Sparring

Sparring is to be fitted to the sides above the 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 (1.625 in.) thick, finished, nor is it to provide less protection to the framing than is obtained from battens at least 140 mm (5.5 in.) wide, finished, and spaced 380 mm (15 in.) 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 containers and similar containerized or batched cargoes, if applicable. In such cases, the notation **NS** will be entered in the *Record,* indicating no sparring.

5 Corrosion Protection of Steel

5.1 All Spaces *(2023)*

Unless otherwise approved, all steel surfaces are to be suitably protected by an efficient corrosion prevention system, such as protective coatings and/or cathodic protection as applicable. For guidance, the ABS *Guidance Notes on Cathodic Protection of Ships* and the ABS *Guidance Notes on the Application and Inspection of Marine Coatings Systems* may be referred to.

5.3 Dedicated Salt Water Ballast Tanks and Double-side Skin Spaces

All dedicated seawater ballast tanks in all ships greater than or equal to 500 gross tonnage shall have an efficient corrosion prevention system, such as hard protective coatings or equivalent in accordance with SOLAS Regulation II-1/3-2. The scheme for the selection, application and maintenance of the system shall be approved by ABS, based on IMO Resolution A.798(19) and IACS UI SC 122. The scheme for the selection, application and maintenance of the system shall be approved by ABS, based on IMO Resolution A.798(19) and IACS UI SC 122.

The ABS *Guide for Performance Standards for Corrosion Protection* is provided as an aid in satisfying the protective coating requirements contained in the IMO PSPC and related Unified Interpretations from IACS and IMO.

Where a long retention period of salt water ballast is expected the use of inhibitors or sacrificial anodes should be considered. When such tanks are designed as dual purpose (for example brine/sea water ballast, brine/drill water or brine tank/chain locker) they are to have a hard, corrosion resistant coating applied as well.

5.5 Void Spaces

Void spaces are recommended to be coated.

5.7 Fuel Oil Tanks

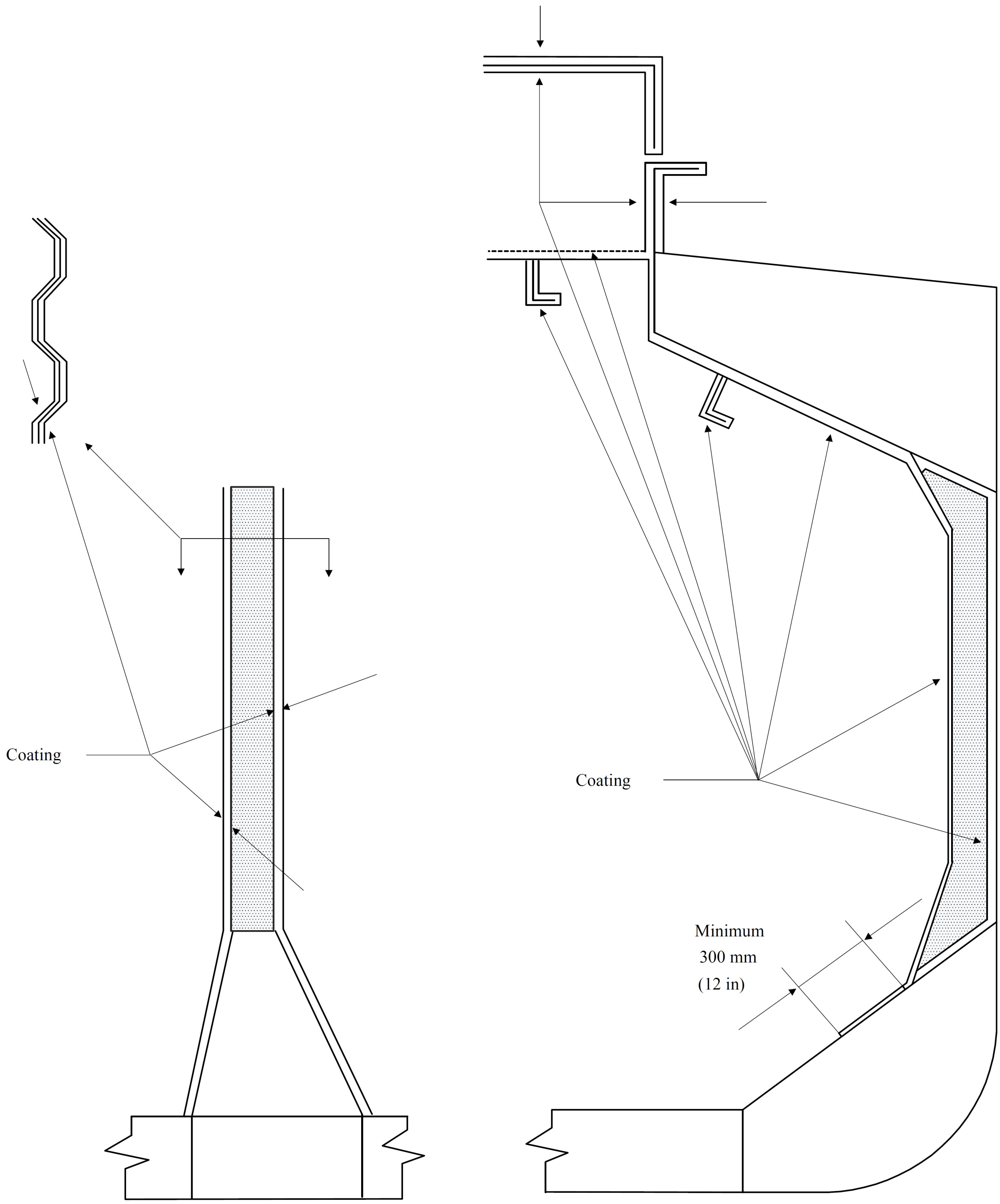
Corrosion protective coating is not required for internal surfaces of spaces intended for the carriage of fuel oil, including cargo fuel oil and base oil (diesel oil).

5.9 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 (12 in.) 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 3-2-18/5.9 FIGURE 1.

In the selection of coatings, due consideration is to be given by the Owner to the intended cargoes and conditions expected in service.

FIGURE 1
Extent of Coatings



a) TRANSVERSE BULKHEAD

b) HOLD, HATCH COAMINGS AND HATCH COVER

5.11 Integral Tanks for Urea Based Ammonia Solution as SCR Reductants *(2020)*

Where urea based ammonia solution (e.g., 40%/60% urea/water solution) used for reducing NOx as SCR Reductants is stored in integral tanks, these tanks are to be coated with appropriate anti-corrosion coating recommended by a coating manufacturer as compatible with the solution. In no case is a reduction in scantlings in association with protective coatings is to be considered. See also Part 6, Chapter 3.

PART 3

CHAPTER 2
Hull Structures and Arrangements

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 0.5 mm ($^1/_{32}$ in.) 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 (0.08 in.) and is not greater than 5 mm ($^3/_{16}$ in.), the weld leg size is to be increased by the amount of the opening in excess of 2.0 mm (0.08 in.). Where the opening between members is greater than 5 mm ($^3/_{16}$ in.), 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.

1.1.4

For all welds in ballast tanks required to be in compliance with the IMO PSPC and/or IMO PSPC-COT Regulations, continuous welding is to be adopted.

3 Tee Connections

3.1 Size of Fillet Welds

Tee connections are generally to be formed by continuous or intermittent fillet welds on each side, as required by 3-2-19/3 TABLE 1. The leg size, w, of fillet welds (see figure in 3-2-19/3 TABLE 1) is obtained from the following equations:

$w = t_{p\ell} \times C \times \frac{s}{\ell} + 2.0$ mm

$w = t_{p\ell} \times C \times \frac{s}{\ell} + 0.08$ in.

$w_{\min} = 0.3t_{p\ell}$ or 4.5 mm (0.18 in.) [4.0 mm (0.16 in.) where 3-2-19/9 is applicable], whichever is greater.

where

ℓ	=	the actual length of weld fillet, clear of crater, in mm (in.).
s	=	the distance between successive weld fillets, from center to center, in mm (in.).
s/ℓ	=	1.0 for continuous fillet welding
$t_{p\ell}$	=	thickness of the thinner of the two members being joined, in mm (in.).
C	=	weld factors given in 3-2-19/3 TABLE 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 $0.7t_{p\ell} + 2.00$ mm$\left(0.7t_{p\ell} + 0.08 \text{ in.}\right)$, whichever is less.

The throat size, *t*, is to be not less than 0.70 *w*.

For the weld size for $t_{p\ell}$ less than 6.5 mm (0.25 in.) or less, see 3-2-19/3.11.

Alternatively, on vessels with length, *L*, below 90 meters (295 feet) weld sizes and spacing may be assessed based on 3-2-19/3 TABLE 2.

3.3 Length and Arrangement of Fillet

Where an intermittent weld is permitted by 3-2-19/3 TABLE 1, the length of each fillet weld is to be not less than 75 mm (3 in.) for $t_{p\ell}$ of 7 mm (0.28 in.) or more nor less than 65 mm (2.5 in.) for lesser $t_{p\ell}$. The unwelded length on one side is to be not more than $32t_{p\ell}$.

3.5 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.

3.7 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.

3.9 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.

3.11 Thin Plating

For plating of 6.5 mm (0.25 in) or less, the requirements of 3-2-19/3.1 may be modified as follows:

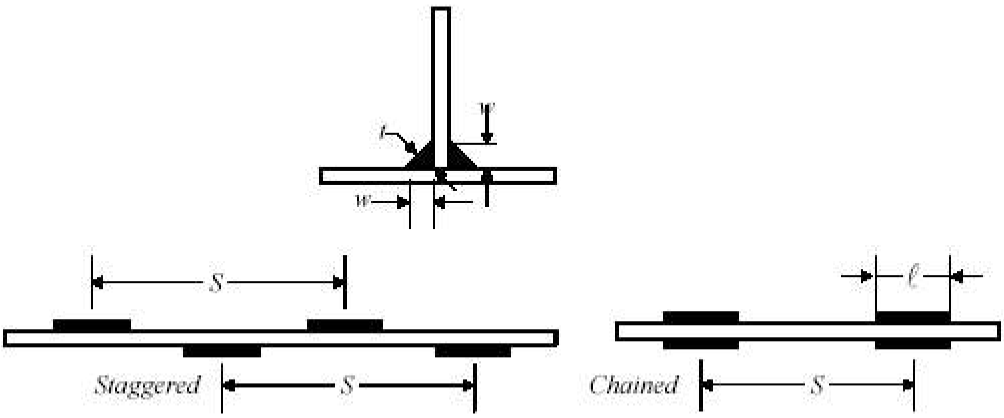
$$w = t_{p\ell}C\frac{s}{\ell} + 2.0\left(1.25 - \frac{\ell}{s}\right) \text{ mm}$$

$$w = t_{p\ell}C\frac{s}{\ell} + 0.08\left(1.25 - \frac{\ell}{s}\right) \text{ in.}$$

$w_{min} = 3.5 \text{ mm}(0.14 \text{ in.})$

The use of the above equations for plating in excess of 6.5 mm (0.25 in.) may be also considered depending upon the location and the quality control procedures.

TABLE 1
Weld Factors for Vessels 90 m (295 ft) in Length and Greater



w = leg size in mm (in.) t = throat size in mm (in.)

I.	**Periphery Connections**	**Factor C**
		C = Continuous DC = Double Continuous
A.	Tight Joints	
	1. Strength deck to sheer strake (See 3-2-19/15)	0.42 DC
	2. Main longitudinal bulkhead to deck, bottom or inner bottom (See 3-2-19/15)	0.42 DC
	3. All other tight joints except X.B. (See 3-2-9/7.5)	
	a. watertight bulkhead, $t_{p\ell} \leq 12.5$ mm (0.50 in.) where one side intermittent and the other side continuous	0.12 & 0.58 C
	b. watertight bulkhead, $t_{p\ell} \leq 12.5$ mm (0.50 in.) where double continuous	0.35 DC
	c. 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 3)	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 3)	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 (10 in^2)	0.12
	b. face area > 64.5 cm^2 (10 in^2)	0.15
	3. End Attachment	
	a. unbracketed (see note 1)	0.55 DC
	b. bracketed	0.40 DC
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. 0.125*L* forward	0.15
	d. in aft peak above waterline and in forward peak	0.15
	2. Slab longitudinals	(see note 5)
	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 2)	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 3-2-19/15)**	
	1. Main Engine and Major Auxiliaries	0.40 DC
	2. Boilers and other Auxiliaries	0.35 DC
	3. Windlass and Major Deck Machinery	0.40 DC
	4. Heavy Duty Specialist Offshore Equipment	0.45 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 4)	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.	**Superstructures/Deckhouses**	
	1. To Side Shell Plating	Full penetration welds
	2. To Decks and/or bulkheads to which they are attached	0.35 DC
	3. External bulkheads and exposed decks connections	0.35 DC
	4. Internal decks to external bulkheads	0.35 DC
	5. Elsewhere	0.20
XI.	**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 6)	0.40 DC
	2. To Deck	
	a. end quarter span	0.40 DC
	b. mid half span (See note 6)	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 3-2-19/15 and 3-2-9/7)	0.42 DC
XII.	**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	
	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
	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
XIII.	**Additional Weld Factors for Single Side Skin Bulk Carriers**	Factor C
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)	
	a. bracketed	$(0.63 - C_{pl} / t_{pl})$DC
	C_{pl} = 2.00 (0.08) mm (in.)	

Notes:

1 The weld size is to be determined from the thickness of the member being attached.

2 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.

3 With longitudinal framing, the weld size is to be increased to give an equivalent weld area to that obtained without cut-outs for longitudinals.

4 The weld size is to be determined from the thickness of the side plating.

5 Slab longitudinals within D_s / 4 from strength deck. For these slab longitudinals the leg size w and w_{min} in 3-2-19/3.1 may both be taken as $0.23t_{pl}$ + 1.0 mm ($0.23t_{pl}$ + 0.04 in.) with a minimum of 4.5 mm (0.18 in.), but need not be greater than 8 mm. Where the slab longitudinal is located more than $D_s/4$ from the strength deck, special consideration will be given to the weld size.

6 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.

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.

8 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 (0.25 in.), except where indicated in Note 9 below or an approval has been given in accordance with 3-2-19/9

9 For double hull tankers of length less than 150 m (492 ft), the minimum fillet welding leg size of 6 mm (0.25 in.) does not apply to longitudinals or other structures within inside of the double hull spaces.

10 The weld size is to be increased for high stress areas which are to be confirmed by “Calculation of Structural Responses” as specified in 5C-1-5/9.

TABLE 2
Weld Sizes and Spacing for Vessels Under 90 m (295 ft) in Length – Millimeters

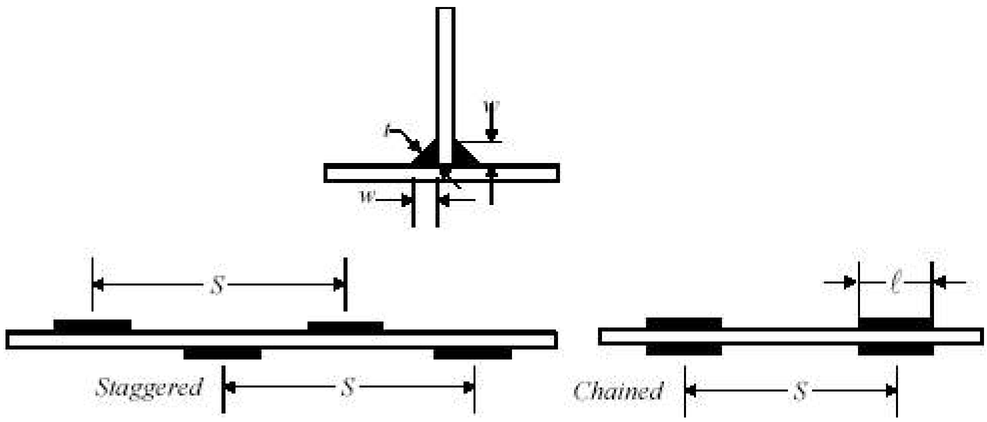
For weld requirements for thicknesses intermediate to those shown in the table, use the nearest thickness shown in the table.

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.

For slab longitudinals, the attachment is to be made by double continuous fillet welds of a size w which is 0.3 times the thickness of the thinner plate, but need not be greater than 8.0 mm.

Where automatic double continuous fillet welding is provided, a reduction in fillet size of 1.5 mm will be permitted, provided that the specified size of fillet in 3-2-19/3 TABLE 2 is 6.5 mm or greater, the gap between the members does not exceed 1.0 mm and the penetration at the root is at least 1.5 mm into the member being attached. This reduction does not apply for slab longitudinals.

Where it is desirable to substitute continuous welding for intermittent welding, as given in 3-2-19/3 TABLE 2, a reduction from the required size of fillet may be allowed if equivalent strength is provided.



	Weld size for lesser thickness of members joined, mm							
	5	*6.5*	*8*	*9.5*	*11*	*12.5*	*14.5*	*16*
Nominal leg size of fillet *w*	3	5	6.5	6.5	8	8	8	8
Nominal throat size of fillet *t*	2	3.5	4.5	4.5	5.5	5.5	5.5	5.5
Length of fillet weld	40	65	75	75	75	75	75	75

Structural Items	*Spacing of Welds S, mm*							
Single-Bottom Floors To center keelson *Note:* Connections elsewhere to take same weld as floors in double bottom	In accordance with 3-2-19/6							
Double-Bottom Floors								
To shell in aft peaks of vessels having high power and fine form	—	—	150	125	150	150	150	125
To shell flat of bottom forward (fore-end strengthening) and in peaks	—	—	250	225	250	250	225	200
To shell elsewhere	*300	*300	300	275	300	275	250	250

Structural Items	*Spacing of Welds S, mm*							
Solid floors to center vertical keel plate in engine room, under boiler bearers, wide-spaced floors with longitudinal frames	In accordance with 3-2-19/6							
Solid floors to center vertical keel plate elsewhere, and open-floor brackets to center vertical keel	*250	*250	250	225	250	225	200	175
Solid floors and open-floor brackets to margin plate	In accordance with 3-2-19/6							
To inner bottom in engine room	In accordance with 3-2-19/6							
To inner bottom at forward end (fore-end strengthening)	*275	*275	275	250	275	250	225	200
To inner bottom elsewhere	*300	*300	300	275	300	275	250	250
Wide spaced with longitudinal framing to shell and inner bottom	In accordance with 3-2-19/6							
Solid floor stiffeners at watertight or oiltight boundaries	300	300	300	275	300	275	250	250
Watertight and oiltight periphery connections of floors throughout double bottom	In accordance with 3-2-19/6							
Center Girder								
Nontight to inner-bottom or center strake in way of engine and to shell or bar keel	In accordance with 3-2-19/6							
Nontight to inner-bottom or center strake clear of engine	150	150	150	125	150	125	125	125
Watertight or oiltight to inner bottom, rider plate, shell or bar keel	In accordance with 3-2-19/6							
Intercostals								
Intercostals and continuous longitudinal girders to shell on flat bottom forward (fore-end strengthening) and to inner bottom in way of engines.	—	150	150	125	150	125	125	‡Dbl. Cont.
Intercostals and continuous longitudinal girders to shell and inner bottom elsewhere and to floors	*275	*275	275	250	275	250	225	225
Watertight and oiltight periphery connections of longitudinal girders in double bottom	In accordance with 3-2-19/6							
Frames								
To shell in aft peaks of vessels having high power and fine form	—	—	150	125	150	150	150	125
To shell for $0.125L$ forward and in peaks	—	—	250	225	250	250	225	225
To shell elsewhere—See *Note* 1	*300	*300	300	275	300	275	250	250
Unbracketed to inner bottom	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	†Dbl. Cont.	†Dbl. Cont.
Frame brackets to frames, decks and inner bottom	Dbl. Cont.	Dbl. Cont.	‡Dbl. Cont.	Dbl. Cont.	‡Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	†Dbl. Cont.
Longitudinals to shell and inner bottom	*300	*300	300	275	300	275	250	250

Structural Items	*Spacing of Welds S, mm*							
Longitudinals to shell on flat of bottom forward (fore-end strengthening)	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	‡Dbl. Cont	‡Dbl. Cont.	Dbl. Cont.	Dbl. Cont.
Girders and Webs								
To shell and to bulkheads or decks in tanks	—	200	225	200	225	200	175	150
To bulkheads or decks elsewhere	—	—	250	225	250	225	200	175
Webs to face plate where area of face plate is 64.5 sq. cm. or less	*250	*250	300	275	300	275	250	250
Webs to face plate area of face plate exceeds 64.5 sq. cm	—	—	250	225	250	225	200	175
Bulkheads								
Peripheries of swash bulkheads	—	200	225	200	225	200	175	150
Peripheries of nontight structural bulkheads	—	225	250	225	250	225	200	175
Peripheries of deep tank or watertight bulkheads	In accordance with 3-2-19/6							
Stiffeners to deeptank bulkheads—See *Note* 1	—	*300	300	275	300	275	250	250
Stiffeners to ordinary watertight bulkheads and deckhouse fronts—See *Note* 1	—	*300	300	275	300	275	250	250
Stiffeners to nontight structural bulkheads; stiffeners on deckhouse sides and after ends—See *Note* 2	*300	*300	*‡300	300	‡300	300	300	250
Stiffener brackets to beams, decks, etc.	Dbl. Cont.	Dbl. Cont.	‡Dbl. Cont.	Dbl. Cont.	‡Dbl Cont.	Dbl. Cont.	Dbl. Cont.	†Dbl. Cont.
Decks								
Peripheries of platform decks and nontight flats								
Upper Weld	Cont.	Cont.	‡Cont.	Cont.	‡Cont.	Cont.	Cont.	†Cont.
Lower Weld	300	300	‡300	300	‡300	300	300	250
Peripheries of strength decks,exposed decks, and all watertight or oiltight decks, tunnels and flats	In accordance with 3-2-19/6							
Beams (transverse or longitudinal) to decks	*300	*300	300	275	300	275	250	250
Beams knees to beams and frames	Dbl. Cont.	Dbl. Cont.	‡Dbl. Cont.	Dbl. Cont.	‡Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	†Dbl. Cont.
Hatch coamings to exposed decks	—	—	—	In accordance with 3-2-19/6				
Transverses or deep beams to decks in tanks	—	200	225	200	225	200	175	150
Transverse or deep beams to deck elsewhere	—	—	250	225	250	225	200	175
Foundations								
To top plates, shell or inner bottom for main engines and major auxiliaries	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	†Dbl. Cont.	†Dbl. Cont.
To top plates, shell or inner bottom for boilers and other auxiliaries	In accordance with 3-2-19/6							
Additional Welding for Vessels Classed “Oil Carrier”(See Note 4)								
Girders and Webs								

Structural Items	*Spacing of Welds S, mm*							
Centerline girder to shell	—	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	†Dbl. Cont.	†Dbl. Cont.	†Dbl. Cont.
Centerline girder to deck	—	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	†Dbl. Cont.	Dbl. Cont.
Bulkhead webs to plating	—	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.
To face plates	—	150	150	150	150	125	125	‡Dbl. Cont.
Transverses								
Bottom transverses to shell	—	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	†Dbl. Cont.	†Dbl. Cont.	†Dbl. Cont.
Side, deck and bulkhead transverses to plating	—	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.
To face plates	—	150	150	150	150	125	125	‡Dbl. Cont.

See general notes at beginning of table

Notes:

1 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.

2 Unbracketed stiffeners of nontight structural bulkheads, deckhouse sides and after ends are to have a pair of matched intermittent welds at each end.

3 Where the symbol, "—" (dash), is shown in place of the spacing of intermittent fillet welds, it is to indicate that the corresponding thickness is not anticipated for that particular structural member.

4 The welding of longitudinals may be as required under frames or decks above. In addition, they are to have double continuous welds at the ends and in way of transverses equal in length to the depth of the longitudinal. For deck longitudinals, only a matched pair of welds is required at the transverses. For slab longitudinals, the attachment is to be made by double continuous fillet welds of a size w which is 0.3 times the thickness of the thinner plate, but need not be greater than 8.0 mm.

‡ Nominal size of fillet w may be reduced 1.5 mm.

† Nominal size of fillet w is increased 1.5 mm.

* Fillet welds are to be staggered.

TABLE 2
Weld Sizes and Spacing for Vessels Under 90 m (295 ft) in Length – Inches

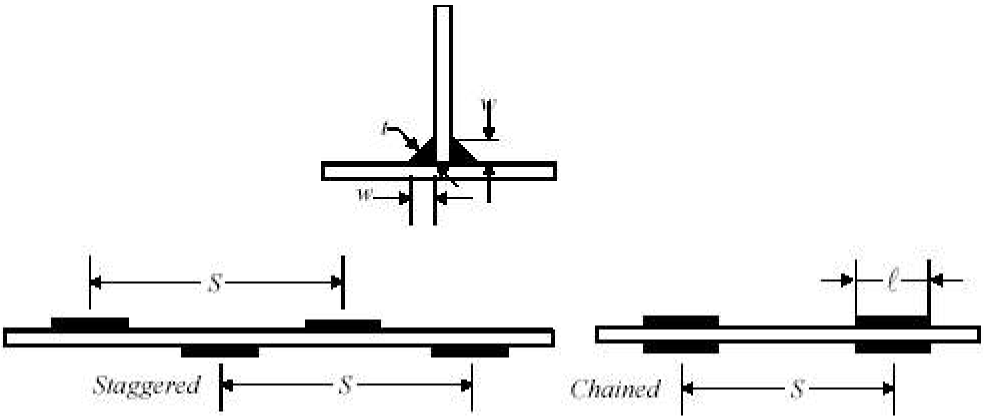
For weld requirements for thicknesses intermediate to those shown in the table, use the nearest thickness shown in the table.

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.

For slab longitudinals, the attachment is to be made by double continuous fillet welds of a size w which is 0.3 times the thickness of the thinner plate, but need not be greater than $^{5}/_{16}$ in.

Where automatic double continuous fillet welding is provided, a reduction in fillet size of 1/16 in. will be permitted, provided that the specified size of fillet in 3-2-19/3 TABLE 2 is 1/4 in. or greater, the gap between the members does not exceed 0.04 in. and the penetration at the root is at least 1/16 in. into the member being attached. This reduction does not apply for slab longitudinals.

Where it is desirable to substitute continuous welding for intermittent welding, as given in 3-2-19/3 TABLE 2, a reduction from the required size of fillet may be allowed if equivalent strength is provided.



	Weld size for lesser thickness of members joined, in.							
	0.19	*0.25*	*0.32*	*0.38*	*0.44*	*0.50*	*0.57*	*0.63*
Nominal leg size of fillet *w*	$^{1}/_{8}$	$^{3}/_{16}$	$^{1}/_{4}$	$^{1}/_{4}$	$^{5}/_{16}$	$^{5}/_{16}$	$^{5}/_{16}$	$^{5}/_{16}$
Length of fillet weld	$1^{1}/_{2}$	$2^{1}/_{2}$	3	3	3	3	3	3

Structural Items	*Spacing of Welds S, in.*							
Single-Bottom Floors To center keelson *Note:* Connections elsewhere to take same weld as floors in double bottom	In accordance with 3-2-19/6							
Double-Bottom Floors								
To shell in aft peaks of vessels having high power and fine form	—	—	6	5	6	6	6	5
To shell flat of bottom forward (fore-end strengthening) and in peaks	—	—	10	9	10	10	9	8
To shell elsewhere	*12	*12	12	11	12	11	10	10
Solid floors to center vertical keel plate in engine room, under boiler bearers, wide-spaced floors with longitudinal frames	In accordance with 3-2-19/6							

Structural Items	*Spacing of Welds S, in.*							
Solid floors to center vertical keel plate elsewhere, and open-floor brackets to center vertical keel	*10	*10	10	9	10	9	8	7
Solid floors and open-floor brackets to margin plate	In accordance with 3-2-19/6							
To inner bottom in engine room	In accordance with 3-2-19/6							
To inner bottom at forward end (fore-end strengthening)	*11	*11	11	10	11	10	9	8
To inner bottom elsewhere	*12	*12	12	11	12	11	10	10
Wide spaced with longitudinal framing to shell and inner bottom	In accordance with 3-2-19/6							
Solid floor stiffeners at watertight or oiltight boundaries	—	12	12	11	12	11	10	10
Watertight and oiltight periphery connections of floors throughout double bottom	In accordance with 3-2-19/6							
Center Girder								
Nontight to inner-bottom or center strake in way of engine and to shell or bar keel	In accordance with 3-2-19/6							
Nontight to inner-bottom or center strake clear of engine	6	6	6	5	6	5	5	5
Watertight or oiltight to inner bottom, rider plate, shell or bar keel	In accordance with 3-2-19/6							
Intercostals								
Intercostals and continuous longitudinal girders to shell on flat bottom forward (fore-end strengthening) and to inner bottom in way of engines.	—	6	6	5	6	5	5	‡Dbl. Cont.
Intercostals and continuous longitudinal girders to shell and inner bottom elsewhere and to floors	*11	*11	11	10	11	10	9	9
Watertight and oiltight periphery connections of longitudinal girders in double bottom	In accordance with 3-2-19/6							
Frames								
To shell in aft peaks of vessels having high power and fine form	—	—	6	5	6	6	6	5
To shell for $0.125L$ forward and in peaks	—	—	10	9	10	10	9	9
To shell elsewhere—See *Note* 1	*12	*12	12	11	12	11	10	10
Unbracketed to inner bottom	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	†Dbl. Cont.	†Dbl. Cont.
Frame brackets to frames, decks and inner bottom	Dbl. Cont.	Dbl. Cont.	‡Dbl. Cont.	Dbl. Cont.	‡Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	†Dbl. Cont.
Longitudinals to shell and inner bottom	*12	*12	12	11	12	11	10	10
Longitudinals to shell on flat of bottom forward (fore-end strengthening)	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	‡Dbl. Cont	‡Dbl. Cont.	Dbl. Cont.	Dbl. Cont.
Girders and Webs								

Structural Items	*Spacing of Welds S, in.*							
To shell and to bulkheads or decks in tanks	—	8	9	8	9	8	7	6
To bulkheads or decks elsewhere	—	—	10	9	10	9	8	7
Webs to face plate where area of face plate is 64.5 sq. cm. or less	*10	*10	12	11	12	11	10	10
Webs to face plate area of face plate exceeds 64.5 sq. cm	—	—	10	9	10	9	8	7
Bulkheads								
Peripheries of swash bulkheads	—	8	9	8	9	8	7	6
Peripheries of nontight structural bulkheads	—	9	10	9	10	9	8	7
Peripheries of deep tank or watertight bulkheads	In accordance with 3-2-19/6							
Stiffeners to deeptank bulkheads—See *Note* 1	—	*12	12	11	12	11	10	10
Stiffeners to ordinary watertight bulkheads and deckhouse fronts—See *Note* 1	—	*12	12	11	12	11	10	10
Stiffeners to nontight structural bulkheads; stiffeners on deckhouse sides and after ends—See *Note* 2	*12	*12	*‡12	12	‡12	12	12	10
Stiffener brackets to beams, decks, etc.	Dbl. Cont.	Dbl. Cont.	‡Dbl. Cont.	Dbl. Cont.	‡Dbl Cont.	Dbl. Cont.	Dbl. Cont.	†Dbl. Cont.
Decks								
Peripheries of platform decks and nontight flats								
Upper Weld	Cont.	Cont.	‡Cont.	Cont.	‡Cont.	Cont.	Cont.	†Cont.
Lower Weld	12	12	‡12	12	‡12	12	12	10
Peripheries of strength decks,exposed decks, and all watertight or oiltight decks, tunnels and flats	In accordance with 3-2-19/6							
Beams (transverse or longitudinal) to decks	*12	*12	12	11	12	11	10	10
Beams knees to beams and frames	Dbl. Cont.	Dbl. Cont.	‡Dbl. Cont.	Dbl. Cont.	‡Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	†Dbl. Cont.
Hatch coamings to exposed decks	—	—	—	In accordance with 3-2-19/6				
Transverses or deep beams to decks in tanks	—	8	9	8	9	8	7	6
Transverse or deep beams to deck elsewhere	—	—	10	9	10	9	8	7
Foundations								
To top plates, shell or inner bottom for main engines and major auxiliaries	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	†Dbl. Cont.	†Dbl. Cont.
To top plates, shell or inner bottom for boilers and other auxiliaries	In accordance with 3-2-19/6							
Additional Welding for Vessels Classed "Oil Carrier"(See Note 4)								
Girders and Webs								
Centerline girder to shell	—	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	†Dbl. Cont.	†Dbl. Cont.	†Dbl. Cont.

Structural Items	*Spacing of Welds S, in.*							
Centerline girder to deck	—	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	†Dbl. Cont.	Dbl. Cont.
Bulkhead webs to plating	—	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.
To face plates	—	6	6	6	6	5	5	‡Dbl. Cont.
Transverses								
Bottom transverses to shell	—	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	†Dbl. Cont.	†Dbl. Cont.	†Dbl. Cont.
Side, deck and bulkhead transverses to plating	—	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.	Dbl. Cont.
To face plates	—	6	6	6	6	6	6	‡Dbl. Cont.

See general notes at beginning of table

Notes:

1 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.

2 Unbracketed stiffeners of nontight structural bulkheads, deckhouse sides and after ends are to have a pair of matched intermittent welds at each end.

3 Where the symbol, "—" (dash), is shown in place of the spacing of intermittent fillet welds, it is to indicate that the corresponding thickness is not anticipated for that particular structural member.

4 The welding of longitudinals may be as required under frames or decks above. In addition, they are to have double continuous welds at the ends and in way of transverses equal in length to the depth of the longitudinal. For deck longitudinals only, a matched pair of welds is required at the transverses. For slab longitudinals, the attachment is to be made by double continuous fillet welds of a size *w* which is 0.3 times the thickness of the thinner plate, but need not be greater than $^{1}/_{16}$ in.

‡ Nominal size of fillet w may be reduced $^{1}/_{16}$ in.

† Nominal size of fillet w is increased $^{1}/_{16}$ in.

* Fillet welds are to be staggered.

5 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 3-2-19/3 TABLE 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.

6 Tee Joints at Boundary Connections

For vessels under 90 meters (295 feet) in length, tee joints at boundary connections of bulkheads, decks, inner bottoms, etc. are to have continuous welding on both sides where the thinner of the plates is 12.5 mm ($^{1}/_{2}$ in.) thick or greater. In general, the size of the welds, *w*, is to be such that the two together are not less than the thickness of the thinner plate plus 1.5 mm ($^{1}/_{16}$ in.). Where the thickness of the thinner plate is less than 12.5 mm ($^{1}/_{2}$ in.), the attachment may be made by a continuous weld on one side 1.5 mm ($^{1}/_{16}$ in.) less than the thickness of the thinner plate with intermittent welding on the opposite side of the size required by 3-2-19/3 TABLE 2 for stiffeners to deep tank bulkheads, except in way of tanks where equivalent continuous welds are to be used.

7 Ends of Unbracketed Stiffeners

Unbracketed stiffeners of shell, watertight and oil-tight 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.

9 Reduced Weld Size

9.1 General

Reduction in fillet weld sizes, except for slab longitudinals of thickness greater than 25 mm (1.0 in.), may be specially approved by the Surveyor in accordance with either 3-2-19/9.3 or 3-2-19/9.5 provided that the requirements of 3-2-19/3 are satisfied.

9.3 Controlled Gaps

Where quality control facilitates working to a gap between members being attached of 1 mm (0.04 in.) or less, a reduction in fillet weld leg size w of 0.5 mm (0.02 in.) may be permitted.

9.5 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 (0.04 in.) or less, a reduction in fillet weld leg size of 1.5 mm (0.06 in.) may be permitted, provided that the penetration at the root is at least 1.5 mm (0.06 in.) into the members being attached.

11 Lapped Joints

11.1 General

Lapped joints are generally to have overlaps of not less width than twice the thinner plate thickness plus 25 mm (1.0 in.).

11.3 Overlapped End Connections

Overlapped end connections of longitudinal strength members within the midship 0.4*L* 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.

11.5 Overlapped Seams

11.5.1 Steel Vessels Under 90 m (295 ft) in Length

Overlapped seams are to have welds on both edges of the sizes required by 3-2-19/6 for tee-connections at boundaries.

Overlapped seams are not to be fitted in way of bottom shell, side shell, bilge, freeboard deck, or tanks carrying flammable liquids. Where used elsewhere, overlapped seams are not to be in connections subject to compressive stresses and are not to be in connections with in-plane shear exceeding 10.35 kN/cm^2 (1.055 tf/cm^2 , 6.7 Ltf/in^2).

11.5.2 Other Marine Vessels

Overlapped seams are to have continuous welds on both edges of the sizes required by 3-2-19/3 TABLE 1 for the boundaries of deep tank or watertight bulkheads, except that for seams of plates 12.5 mm ($^1/_2$ in.) or less clear of tanks, one edge may have intermittent welds in accordance with 3-2-19/3 TABLE 1 for watertight bulkhead boundaries.

11.7 Overlaps for Lugs *(2019)*

The overlaps for lugs and collars in way of cut-outs for the passage of stiffeners through webs and bulkhead plating are not to be less than three times the thickness of the lug, but need not be greater than 50 mm (2.0 in.).

11.9 Overlaps of Pipe Penetration Collars *(2021)*

In general, overlaps of collar plates in way of pipe penetrations through watertight boundaries are not to be less than 30 mm (1.2 in.) in width for pipes with Nominal Diameter (ND) up to 100 mm (4.0 in.), and need not exceed 50 mm (2.0 in.) in width for pipes with ND over 550 mm (21.7 in.). Intermediate widths may be obtained by interpolation for pipes with ND between 100 (4.0 in.) and 550 mm (21.7 in.), but an average value of 40 mm (1.6 in.) is considered acceptable.

The collar plate is to be equal to, or greater than, the thickness of the watertight boundary plate penetrated, of equivalent material, and continuously welded in accordance with 3-2-19/Table 1 for the boundaries of deep tank or watertight bulkheads.

On a case-by-case basis, strength verification is to be carried out for pipe penetrations in areas of high stress concentration such as an area close to a large bracket toe, a cluster of pipe penetrations or a hatch corner.

13 Plug Welds or Slot Welds *(2021)*

Plug welds or slot welds may be approved only for particular applications where access for welding from inside the hull or shell is impracticable such as: very narrow recesses at ends, one side of rudder plating, fairleads or one side of box keel.

Where used in the body of doublers and similar locations, such welds may be spaced about 305 mm (12 in.) between centers in both directions. Doubler plates are not acceptable in tanks carrying flammable liquids. Where doubler plates are proposed in way of equipment foundations when large tensile forces normal to the doubler plates could exist, the doubler plate and welds are to be assessed for yielding and buckling, as applicable.

Where plug or slot welds are used, weld details are to comply with a recognized standard (IACS CSR, AWS D1.1, AISC, etc.).

Suitable torch angles are to be applied to minimize lack of fusion in the root corner during slot welding. Welders are to be suitably trained and qualified to perform slot welds.

15 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.

17 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. See 2-4-3/5 of the ABS *Rules for Materials and Welding (Part 2)*. Fillet weld sizes may be determined from structural analyses based on sound engineering principles, provided that they meet the overall strength standards of these Rules.

PART 3

CHAPTER 2

Hull Structures and Arrangements

SECTION 20

Guidance on Finite Element Analysis

1 General

The intent of this Section is to provide guidance on the use on finite element methods (FEM) for evaluating linear response of hull structural components, equipment foundations and reinforcement structure to the applied loads, where such analysis is necessary.

Finite element methods can be applied with varying level of detail and complexity to determine stress levels, deflection magnitudes and other parameters of structural components. The choice of the type of finite element and evaluation criteria should match the desired level of detail, loading scenario, boundary conditions and complexity of the structural component

1.1 Submittal Items *(1 July 2021)*

Submit a report documenting the analysis along with all structural drawings pertaining to the area of the structure that is being analyzed. The Finite Element (FE) model may be submitted for review along with the report.

The report is to include the following background information of the analysis:

i) The list of drawings/plans used in the analysis, including their versions and dates.

ii) Detailed descriptions of structural modeling principles and any deviations in the model from the structural drawings

iii) Description and plots of the structural models showing:

  a) Geometry

  b) Plate thickness

iv) Material properties and beam properties, if applicable

v) Details of boundary conditions applied

vi) All loading conditions analyzed

vii) Data for load application*

viii) Summaries and plots of calculated deflections and reactions and validation of the load direction and global balance in the model

ix) Summaries and plots of calculated stresses *x)* Details of buckling assessments, if necessary

xi) Comparison table for design/drawing scantlings and FEA model scantlings

xii) Reference of software used in analysis, including its version and date

xiii) Element type used

Note:

* Details on how loads (static, dynamic, impact, etc.) are determined for structural evaluation.

3 Structural Modeling

3.1 Finite Element Types *(1 July 2021)*

The choice of the type of finite element is guided by the complexity of the structural system or component being analyzed, the level of detail desired and the outcomes measured. Two node line element and three or four node membrane/plate element are considered sufficient for representation of a structure, and requirements in this Section assume the use of such element types in the models. Higher order elements may also be applied. Details of basic element types are given in 3-2-20/3.1 TABLE 1.

TABLE 1
Finite Element Type *(1 July 2021)*

Rod (or truss) element	Line element with axial stiffness only and constant cross-sectional area along the length of the element
Beam element	Line element with axial, torsional and bi-directional shear and bending stiffness and with constant properties along the length of the element
Membrane (or plane-stress) element	Plate element with in-plane stiffness and with constant thickness
Shell (or bending plate) element	Plate element with in-plane and out-of-plane bending stiffness and with constant thickness
Solid element	Tetrahedron or brick element with axial, torsional and bi-directional shear. Bending response be can included using several through-thickness elements (linear) or one through-thickness element (quadratic)

3.3 Model Types

3.3.1 Beam/Grillage Model

Beam/grillage models consist entirely of beam and rod elements, and are suitable for the solution of simple to more elaborate beam problems of one, two or three-dimensional configuration. Examples where such models could be applied are for deck beams, girders, floors, and bulkhead stiffening. Such models provide bending moment and shear force distributions, axial, bending and shear stresses, and deflection magnitudes.

3.3.2 Plate Element Model *(1 July 2021)*

Plate element models are applied in cases where a precise representation of the geometry of the structural component or system is necessary, the complexity of the structure warrants it, or when the desired structural response cannot be determined from beam or grillage models. Plate/shell element models are commonly used for thin walled marine applications.

3.3.3 Solid Element Model *(1 July 2021)*

Solid element models are generally used for parts/components where the dimensions of the part/component are comparable to the thickness, such as castings and forgings. The required number of elements and nodes to accurately predict bending response for thin walled structures is much greater than for shell elements, increasing the computational time.

3.5 Modeling Guidance *(1 July 2021)*

i) The model should include, as applicable, all primary load-carrying members of the structure being analyzed. Secondary structural members that may significantly affect load distributions and local response of the primary members may also be appropriately included in the model.

ii) For beam elements, cross sectional properties are to be based on an effective width of the attached plating. The effective width of plating of beam elements is not to exceed the sum of one-half of the spacing on either side of the structural member or $1/3$ of the unsupported span of the member, whichever is less. The offset of stiffener cross-section may be considered for beam elements where appropriate.

iii) Plate element meshing is to follow the stiffening system as far as practicable. The mesh size used should be adequate to represent the overall stiffness of the considered structure. For meshing of large systems such as deck, shell or bulkhead plate/framing systems, the mesh size is to not exceed the spacing between the frames. The mesh should be progressively and smoothly refined to capture structural details where important or found necessary. A mesh convergence study should be done to confirm the response of the model is not mesh dependant while also optimizing computational time.

iv) At least three elements are to be used, where practical, to model webs of primary supporting members such as girders, transverses, stringers and floors. Rod elements may be used to model flanges of primary supporting members and brackets. The cross sectional area of rods/beams representing sniped or tapered flanges is to be considered proportionally using an average area over the length of the element.

v) The aspect ratio of plate elements, in general, is not to exceed three. The use of triangular plate elements is to be kept to a minimum.

vi) Shell elements are to be used for plate elements subjected to lateral loading.

vii) Gross scantlings are to be used in modeling the structure.

viii) Discontinuities that cause stress concentrations or change the response of a member, such as lightening holes or penetrations, should be included when possible.

5 Boundary Conditions *(1 July 2021)*

Boundary conditions applied are to reflect, as closely as possible, the actual support conditions of the structure.

The model extent should be sufficient to establish proper boundary conditions. Where the model has been extended to points well away from the areas of interest within the model, boundary conditions may be reasonably simplified, for example assuming fully fixed conditions for plate elements models.

A separate local FE model with fine mesh zones in conjunction with the boundary conditions obtained from global (parent) model may be used to check the localized stresses against yielding strength and fatigue strength as applicable.

7 Loads *(1 July 2021)*

Loads applied on a model are to be as required by the relevant rule or the design loads of the structural member, whichever is greater.

In addition to static loads, other loads such as hull girder and dynamic loads arising out of acceleration, ship motion, etc. are to be considered where applicable and relevant. If accelerations from model tests, recognized standards or direct calculations are not available, the acceleration parameters in accordance with Part 5 of the *Marine Vessel Rules*, as applicable for specific vessel type are to be considered.

In typical cases, it is not necessary to consider the self weight of the structure, unless it is expected to be a significant component of the loads acting on the structure.

Loads are to be applied in a manner so as to match, as closely as possible, the expected distribution and manifestation of the load within the structure in the actual situation.

9 Acceptance Criteria

9.1 Allowable Stresses *(2022)*

Unless otherwise specified in these Rules or relevant regulations, individual stress components and, as applicable, direct combinations of such stresses in beam or grillage models are not to exceed the allowable stress F.

$$F = F_y/FS$$

where

F_y = specified minimum yield strength of the material

FS = Factor of Safety

For static loadings:

= 1.67 for axial or bending stress

= 2.50 for shear stress

For loads combining static and dynamic:

= 1.25 for axial or bending stress

= 1.88 for shear stress

For plate element models, and unless otherwise specified in these Rules or relevant regulations, the Von-Mises equivalent stress is not to exceed the limits specified in 3-2-20/9.1 TABLE 2 for the specific mesh size.

TABLE 2
Stress Limits for Plate Element Models *(2022)*

Mesh Size	*Stress Limit*	
	Static + Dynamic	*Static*
1 x stiffener spacing (SS)	0.90 $S_m F_y$	0.63 $S_m F_y$
$1/2$ x SS	0.95 $S_m F_y$	0.67 $S_m F_y$
$1/3$ x SS	1.00 $S_m F_y$	0.70 $S_m F_y$
$1/4$ x SS (1)	1.06 $S_m F_y$	0.74 $S_m F_y$
$1/5$ x SS ~ $1/10$ x SS (1)	1.12 $S_m F_y$	0.78 $S_m F_y$
$1/10$ x SS ~ Plate Thickness (1)	1.18 $S_m F_y$	0.82 $S_m F_y$

Notes:

1 Stress limits greater than 1.00 $S_m F_y$ are to be restricted to small areas in way of structural discontinuities. A small area is defined at one particular high stress location in a structural detail with a potential crack location. The high stress includes stress risers due to structural discontinuities and presence of attachments, but excludes the effects of welds. To determine high stress, the mesh size needs to be finer than 1/10 longitudinal spacing, but not finer than plate thickness.

2 $S_m = 1.0$ for mild steel

=	0.95	for HT 32
=	0.908	for HT 36
=	0.875	for HT 40

3 For intermediate mesh size, the stress limit may be obtained by linear interpretation

4 For longitudinally effective structure that is modeled without the hull girder loads, the allowable stresses are to be decreased by 10%

5 The above limits have been developed for models which are based on gross scantlings. Adjustments may be made to the allowable stress if net scantlings are used.

6 The above limits are combined stresses including tertiary stresses resulting from the local bending of plate panels between stiffeners. Where the tertiary stress is not represented in the model, the effect of tertiary stress estimated by formulae is to be appropriately added in the calculated element stress.

7 For SafeHull Structural Assessment, the allowable values as given in ABS *Guide for 'SafeHull-Dynamic Loading Approach' for Vessels* are to be applied.

9.3 Buckling Strength *(1 July 2021)*

Buckling strength is to be adequate for the critical locations and high stress areas subject to compressive and/or shear stresses.

Plate panels and primary supporting members are to be checked against buckling (serviceability state limit) and ultimate state limit using stresses obtained from the structural FE analyses. For this purpose, established analytical or empirical formulas suitable to the hull structure are to be used.

Buckling and ultimate strength criteria for plate panels and primary supporting members of the vessels are to be in accordance with Part 5 of the *Marine Vessel Rules*, as applicable for specific vessel type. For vessels that do not have specific requirements in Part 5 of the *Marine Vessel Rules*, reference is made to Appendix A2 of the *Guide for 'SafeHull-Dynamic Loading Approach' for Vessels*.

PART 3

CHAPTER 2

Hull Structures and Arrangements

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/cm² (tf/cm², Ltf/in²)

N = shear flow, kN/cm (tf/cm, Ltf/in.)

t = thickness of the plating, cm (in.)

3 Calculation of the Shear Flow Around Closed Sections

The shear flow of a closed and prismatic structure is expressed by the following equation.

N = $(Fm/I)+N_i$, kN/cm (tf/cm, Ltf/in.)

F = total shear force at the section under consideration, in kN(tf, Ltf)

m = first moment about the neutral axis of the section, in cm³(in³), 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 = $\int_0^p Zt \; ds + \sum_{i=0}^{n} a_i z_i$ cm³(in³)

I = moment of inertia of the section, in cm⁴(in⁴)

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 (tf/cm, Ltf/in)

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

a = equivalent sectional area of the stiffener or girder attached to the deck, shell and bulkhead plating, in cm²(in²)

s = length along girth and longitudinal bulkhead, in cm (in.)

5 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.

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

$$\oint N\frac{ds}{t} = \frac{F}{I}\oint_i m_i\frac{ds}{t} + N_{i-1}\int_{Div}\frac{ds}{t} + N_i\oint\frac{ds}{t} + N_{i+1}\int_{Div}\frac{ds}{t} = 0$$

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.

PART 3

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 and are applicable for vessels with freeboard length, L_f, of 65 meters (213 feet) and above.

1 General

1.1 Application

The requirements in this Appendix apply to all classed cargo vessels 65 m (213 ft) and above in length that are contracted for construction on or after 1 July 1998.

Additional requirements in Appendix 3-2-A3 are applied to bulk carriers, ore carriers and combination carriers having a freeboard length (L_f) of 150 m (492 ft) and above. L_f is as defined in 3-1-1/3.3.

3 Definitions

3.1 Loading Guidance

Loading guidance is a generic term covering both loading manual and loading instrument, as defined below.

3.1.1 Loading Manual

A loading manual is a document containing sufficient information to assist 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.

3.1.2 Loading Instrument

A loading instrument is an instrument designed to assess vessel's still water bending moments, shear forces and, where applicable, the still water torsional moments and lateral loads at the specified points along the length for the purpose not to exceed the specified values in any loaded or ballast condition.

3.3 Category I Vessels

Category I vessels are any of the following:

i) Vessels with large deck openings where combined stresses due to vertical and horizontal hull girder bending, torsional and lateral loads need be considered, such as container carriers.

ii) Vessels designed for non-homogeneous loading where the cargo and/or ballast may be unevenly distributed, except those belonging to 3-2-A2/3.5.iii. Examples of such vessel are bulk carriers, ore carriers and combination carriers.

iii) Vessels, such as oil carriers and fuel carriers, except those belonging to 3-2-A2/3.5.iii.

iv) Chemical carriers and gas carriers

3.5 Category II Vessels

Category II vessels are any of the following:

i) Vessels with such arrangements that only allow a small possibility for variation in cargo and ballast distribution, such as passenger ships.

ii) Vessels on regular and fixed trading pattern where the loading manual gives sufficient guidance, such as ro-ro ferries.

iii) Vessels less than 120 m (394 ft) in length, L, when their design takes into account the uneven distribution of cargo or ballast.

5 Loading Documents

5.1 Loading Manual

All vessels are to be provided with a loading manual reviewed and stamped by ABS in accordance with 3-2-A2/7, except for Category II vessels with deadweight not exceeding 30% of the displacement at the summer load line.

5.3 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 3-2-A2/9.3 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.

7 Loading Manual

7.1 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 lower decks and double bottom loading.

v) If cargoes other than bulk cargoes are contemplated, such as different deck cargoes, they 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.

vii) Information on the heavy ballast draft forward used for the fore-end strengthening required in 3-2-4/13.

7.3 Loading Conditions

The above information is to be based on the intended service conditions. See 3-2-A2/11 TABLE 1 for the selection of loading conditions.

7.5 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.

9 Loading Instrument

In addition to the loading manual indicated in 3-2-A2/5.1, Category I vessels of 100 m (328 ft) or more in length are to be provided with a loading instrument verified in accordance with 3-2-A2/9.

9.1 Type

A loading instrument is to be digital. A single point loading instrument is not acceptable.

9.3 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

9.5 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.

11 Annual Surveys

The requirements in 7-3-2/1.1.5 are to be complied with as follows:

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 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	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	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	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	Chemical Carriers:	
	2.4.1	conditions for oil carriers
	2.4.2	all approved high density cargoes
2.5	Combination Carriers	
	2.5.1	conditions as specified in 2.1 and 2.2 above.
2.6	Offshore Support Vessels	
	2.6.1	anchor handling operations
	2.6.2	pipe laying and/or seabed trenching
	2.6.3	outboard weights lifting either with use of heavy cranes or A-frames
	2.6.4	homogeneous cargo if consistent with the service of the vessel
	2.6.5	heavy deck cargo with empty holds and/or tanks or non-homogeneous conditions
	2.6.6	cargo deck and/or lower decks or inner bottom cargoes

2.6.7	cargoes of typical densities within the expected range
2.6.8	high densities cargoes
2.6.9	part loaded conditions
2.6.10	short voyages (e.g. half bunker)
2.6.11	tank cleaning conditions
2.6.12	docking conditions afloat

PART 3

CHAPTER 2

Hull Structures and Arrangements

APPENDIX 3

Loading Manuals and Loading Instruments: Additional Requirements for Bulk Carriers, Ore Carriers and Combination Carriers 150 Meters (492 Feet) and above in Length (L_f)

1 Application

The requirements in this Appendix apply to bulk carriers, ore carriers and combination carriers having a freeboard length (L_f), as defined in 3-1-1/3.3, of 150 m (492 ft) and above. Unless otherwise stated, these requirements are additional to those in Appendix 3-2-A2.

3 Required Loading Guidance

3.1 Loading Manual

All vessels are to be provided with a Loading Manual, reviewed and stamped by ABS in accordance with 3-2-A3/5.

3.3 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 3-2-A3/7.

3.5 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.

5 Loading Manual

5.1 Required Information

5.1.1 Permissible Limits

In addition to 3-2-A2/7.1, the loading manual is to include the following information:

5.1.1(a) For single side skin bulk carriers,

i) The permissible limits of still water bending moments and shear forces in the hold flooded condition in accordance with 5C-3-3/3.1 and 5C-3-A5a/1.

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.

5.1.1(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.

5.1.1(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.

5.1.1(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.

5.1.2 Loading Rate and Sequence

5.1.2(a) The maximum rate of ballast change

5.1.2(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.

5.1.2(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 3-2-A3/7.1.4 TABLE 2 contain, as guidance only, an example of a Loading Sequence Summary Form and aspects that may be considered in developing the sequence.

5.1.2(d) Typical sequences for change of ballast at sea, where applicable.

5.3 Loading Conditions

The above information is to be based on the intended service conditions. See 3-2-A3/7.1.4 TABLE 1 for the selection of loading conditions, which replaces 3-2-A2/11 TABLE 1 for the vessels covered by this Appendix.

7 Loading Instrument

7.1 Required Verifications

In addition to 3-2-A2/9.3, at least the following aspects are to be demonstrated to the Surveyor for his/her verification:

7.1.1

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;

7.1.2

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;

7.1.3

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;

7.1.4

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 in accordance with 5C-3-3/3.1 and 5C-3-A5a/1 are satisfactory.

TABLE 1
Loading Conditions in the Loading Manual For Bulk Carriers, Ore Carriers and Combination Carriers 150 Meters (492 Feet) 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 5.1.2(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.

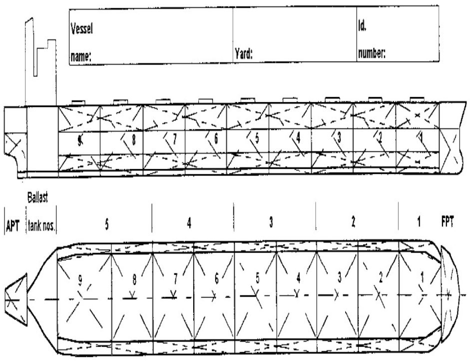
5 Conditions during loading/unloading are also to be included.

TABLE 2
Guidance on Loading/Unloading Sequences

1.	In addition to 3-2-A3/5.1.2(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 vice 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 3-2-A3/5.1.2(c)]

Vessel name:	Yard:	Id. number:



Port (specific or typical):	Condition at commencement of loading/discharging	
Total mass of cargo to be loaded/discharged:	Condition at end of loading/discharging	
Dock water density (t/m3):	Maximum Loading/discharging rate:	Average Loading/discharging rate:
Number of loaders/dischargers:	Maximum Ballasting/Deballasting rate:	Average Ballasting/Deballasting rate:

Volume of Hold, Vh (m3)									
Height of hold,h (m)									

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.

	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	Trim	d fwd	Maximum	
(m)	(m)	(m)	S.F. (%)	B.M. (%)

CARGO OPERATIONS											BALLAST OPERATIONS									Values at end of pour (from harbour to sea)				
Pour no. /grade	Hold 9	Hold 8	Hold 7	Hold 6	Hold 5	Hold 4	Hold 3	Hold 2	Hold 1	Upper / Lower/Peak	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	d fwd (m)	Trim (m)	d fwd (m)	Maximum S.F. (%)	Maximum B.M. (%)
1										Upper														
										Lower/Peak														
2										Upper														
										Lower/Peak														
3										Upper														
										Lower/Peak														
4										Upper														
										Lower/Peak														
5										Upper														
										Lower/Peak														
6										Upper														
										Lower/Peak														
7										Upper														
										Lower/Peak														
8										Upper														
										Lower/Peak														
..										Upper														
										Lower/Peak														
Draft Survey (for loading):	Total cargo onboard (t):				Remaining cargo to be loaded (t):					Total amount of bunkers onboard (t):														
n-1										Upper														
										Lower/Peak														
n										Upper														
										Lower/Peak														

	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	Trim	d fwd	Maximum	
(m)	(m)	(m)	S.F. (%)	B.M. (%)

Approved by:

PART 3

CHAPTER 2

Hull Structures and Arrangements

APPENDIX 4

Buckling Strength of Longitudinal Strength Members for Vessels Over 61 m (200 ft) in Length

1 Application

These requirements apply to plate panels and longitudinals subject to hull girder bending and shear stresses.

3 Elastic Buckling Stresses

3.1 Elastic Buckling of Plates

3.1.1 Compression

The ideal elastic buckling stress is given by:

$$\sigma_E = 0.9mE\left(\frac{t_b}{s}\right)^2 \qquad \mathrm{N/mm^2 (kgf/mm^2, psi)}$$

For plating with longitudinal stiffeners (parallel to compressive stress):

$$m = \frac{8.4}{\Psi + 1.1} \quad \text{for} \quad (0 \le \Psi \le 1)$$

For plating with transverse stiffeners (perpendicular to compressive stress):

$$m = c\left[1 + \left(\frac{s}{\ell}\right)^2\right]^2 \frac{2.1}{\Psi + 1.1} \quad \text{for} \quad (0 \le \Psi \le 1)$$

where

E	=	2.06×10^5 N/mm² (21,000 kgf/mm², 30×10^6 psi)	
t_b	=	net thickness of plating, in mm (in.), after making standard deductions as given in 3-2-A4/3.3.3 TABLE 1A or 3-2-A4/3.3.3 TABLE 1B, as applicable	
s	=	shorter side of plate panel, in mm (in.)	
ℓ	=	longer side of plate panel, in mm (in.)	
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 3-2-A4/7.1), varying linearly across panel.	

3.1.2 Shear

The ideal elastic buckling stress is given by:

$$\tau_E = 0.9 k_t E \left(\frac{t_b}{s}\right)^2 \quad \mathrm{N/mm^2 (kgf/mm^2, psi)}$$

where

$$k_t = 5.34 + 4\left(\frac{s}{\ell}\right)^2$$

E, t_b, s and ℓ are as defined in 3-2-A4/3.1.1

3.3 Elastic Buckling of Longitudinals

3.3.1 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:

$$\sigma_E = \frac{E I_a}{c_1 A \ell^2} \quad \mathrm{N/mm^2 (kgf/mm^2, psi)}$$

where

I_a	=	moment of inertia, in cm^4 (in^4), of longitudinal, including plate flange and calculated with thickness as specified in 3-2-A4/3.1.1
A	=	cross-sectional area, in cm^2 (in^2), of longitudinal, including plate flange and calculated with thickness as specified in 3-2-A4/3.1.1
ℓ	=	span, in m (ft), of longitudinal
c_1	=	1000 (1000, 14.4)
E	=	as defined in 3-2-A4/3.1.1

3.3.2 Torsional Buckling Mode

The ideal elastic buckling stress for the torsional mode is given by:

$$\sigma_E = \frac{\pi^2 E I_w}{10 c_1 I_p \ell^2}\left(m^2 + \frac{K}{m^2}\right) + 0.385 E \frac{I_t}{I_p} \quad \mathrm{N/mm^2 \left(kgf/mm^2, psi\right)}$$

where

K	=	$c_2 \dfrac{C \ell^4}{\pi^4 E I_w}$
m	=	number of half waves given by 3-2-A4/3.3.3 TABLE 2
E	=	as defined in 3-2-A4/3.1.1
c_2	=	10^6 (10^6, 20736)
I_t	=	St. Venant's moment of inertia, in cm^4 (in^4), of profile (without plate flange)

= $c_3\frac{h_w t_w^3}{3}$ for flat bars (slabs)

= $c_3\frac{1}{3}\left[h_w t_w^3 + b_f t_f^3\left(1 - 0.63\frac{t_f}{b_f}\right)\right]$ for flanged profiles

c_3 = $10^{-4}(10^{-4}, 1.0)$

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

= $c_3\frac{h_w^3 t_w}{3}$ for flat bars (slabs)

= $c_3\left(\frac{h_w^3 t_w}{3} + h_w^2 b_f t_f\right)$ for flanged profiles

I_w = warping constant, in cm^6 (in^6), of profile about connection of stiffener to plate

= $c_4\frac{h_w^3 t_w^3}{36}$ for flat bars (slabs)

= $c_4\left(\frac{t_f b_f^3 h_w^2}{12}\right)$ for "Tee" profiles

= $c_4\frac{b_f^3 h_w^2}{12\left(b_f + h_w\right)^2}\left[t_f\left(b_f^2 + 2b_f h_w + 4h_w^2\right) + 3t_w b_f h_w\right]$ for angles and bulb profiles

c_4 = $10^{-6}(10^{-6}, 1.0)$

h_w = web height, in mm (in.)

t_w = web thickness, in mm (in.), after making standard deductions as specified in 3-2-A4/3.1.1

b_f = flange width, in mm (in.)

t_f = flange thickness, in mm (in.), after making standard deductions as specified in 3-2-A4/3.1.1 For bulb profiles the mean thickness of the bulb may be used.

ℓ = span of profile, in m (ft)

s = spacing of profiles, in mm (in.)

C = spring stiffness exerted by supporting plate panel

= $\frac{k_p E t_p^3}{3s\left(1 + \frac{1.33 k_p h_w t_p^3}{s t_w^3}\right)}$ N (kgf, lbf)

k_p = $1 - \eta_p$, not to be taken less than zero

t_p = plate thickness, in mm (in.), after making standard deductions as specified in 3-2-A4/3.1.1

η_p = $\frac{\sigma_a}{\sigma_{Ep}}$

σ_α = calculated compressive stress. For longitudinals, see 3-2-A4/7.1

σ_{Ep} = elastic buckling stress of supporting plate as calculated in 3-2-A4/3.1

For flanged profiles, k_p need not be taken less than 0.1.

3.3.3 Web and Flange Buckling

For web plate of longitudinals the ideal buckling stress is given by:

$$\sigma_E = 3.8E\left(\frac{t_w}{h_w}\right)^2 \quad \mathrm{N/mm^2(kgf/mm^2, psi)}$$

For flanges on angles and T-sections of longitudinals, the following requirements will apply:

$$\frac{b_f}{t_f} \le 15$$

b_f = flange width, in mm (in.), for angles, half the flange width for T-sections.

t_f = as built flange thickness, in mm (in.)

TABLE 1A
Standard Deduction t_k for Vessels Under 90 m (295 ft) in Length *(2019)*

	Structure	*Standard Deduction*	*Limit Values min.-max. in mm (in.)*
— —	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 (0.02-0.04)
— —	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	1.0-3.0 (0.04-0.12)
—	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	1.5-4.0 (0.06-0.16)

Notes:

1. Provided the structural members are protected against corrosion by coating or equivalent, zero corrosion deduction for structural members may be considered for bulkheads separating passenger spaces at both sides.

2. For the side shell below the waterline, the side structure below loading line with void spaces inside is to consider 0.05t (0.5 mm (0.02 in.) – 1.0 mm (0.04 in.)) corrosion deduction.

3. For the side shell below the waterline, the side structure below loading line with ballast or liquid cargo inside the tanks is to consider 0.10t (1.0 mm (0.04 in.) – 3.0 mm (0.12 in.)) corrosion deduction.

TABLE 1B
Standard Deduction t_k for Vessels 90 m (295 ft) in Length and Above
(2019)

	Structure	*Standard Deduction*	*Limit Values min.-max. in mm (in.)*
— —	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 (0.02-0.04)
— —	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 (0.08-0.12)
—	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 (0.08-0.16)

Notes:

1 Provided the structural members are protected against corrosion by coating or equivalent, zero corrosion deduction for structural members may be considered for bulkheads separating passenger spaces at both sides.

2 For the side shell below the waterline, the side structure below loading line with void spaces inside is to consider $0.05t$ (0.5 mm (0.02 in.) – 1.0 mm (0.04 in.)) corrosion deduction.

3 For the side shell below the waterline, the side structure below loading line with ballast or liquid cargo inside the tanks is to consider $0.10t$ (2.0 mm (0.08 in.) – 3.0 mm (0.12 in.)) corrosion deduction.

TABLE 2
Number of Half Waves

	$0 < K \le 4$	$4 < K \le 36$	$36 < K \le 144$	$144 < K \le 400$	$(m-1)^2 \quad m^2 < K \le m^2(m+1)^2$
m	1	2	3	4	m

5 Critical Buckling Stresses

5.1 Compression

The critical buckling stress in compression, σ_c, is determined as follows:

$$\sigma_c = \sigma_E \qquad \text{when} \quad \sigma_E \le \frac{\sigma_F}{2}$$

$$= \sigma_F\left(1 - \frac{\sigma_F}{4\sigma_E}\right) \qquad \text{when} \quad \sigma_E > \frac{\sigma_F}{2}$$

where

σ_F = yield stress of material, in N/mm² (kgf/mm², lbf/in²). σ_F may be taken as 235 N/mm² (24 kgf/mm², 34,000 psi) for mild steel.

σ_E = ideal elastic buckling stress calculated according to 3-2-A4/3

5.3 Shear

The critical buckling stress in shear, τ_c, is determined as follows:

$$\tau_c = \tau_E \quad \text{when} \quad \tau_E \leq \frac{\tau_F}{2}$$

$$= \tau_F\left(1 - \frac{\tau_F}{4\tau_E}\right) \quad \text{when} \quad \tau_E > \frac{\tau_F}{2}$$

where

τ_F = $\frac{\sigma_F}{\sqrt{3}}$

σ_F = as given in 3-2-A4/5.1

τ_E = ideal elastic buckling stress in shear calculated according to 3-2-A4/3.1.2

7 Working Stress

7.1 Longitudinal Compressive Stress

The compressive stresses are given in the following formula:

$$\sigma_a = c_5\frac{M_w + M_{sw}}{I_n}y \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, lbf/in}^2\text{)}$$

$$= \text{minimum } 30/Q \text{ N/mm}^2 \ (3.1/Q \text{ kgf/mm}^2,\ 4400/Q \text{ lbf/in}^2)$$

where

M_{sw} = still water bending moment, as given in 3-2-1/3.7.1(a), in kN-m (tf-m, Ltf-ft)

M_w = wave bending moment, as given in 3-2-1/3.7.1(a), in kN-m (tf-m, Ltf-ft)

I_n = moment of inertia, in cm⁴ (in⁴), of the hull girder

y = vertical distance, in m (ft), from the neutral axis to the considered point

Q = as defined in 3-2-1/5.3 (1.0 for ordinary strength steel)

c_5 = 10^5 (10^5, 322,560)

M_w and M_{sw} are to be taken as sagging or hogging bending moments, respectively, for members above or below the neutral axis.

7.3 Shear Stresses

7.3.1 Ships without Effective Longitudinal Bulkheads

The working shear stress, τ_a, in the side shell of ships without effective longitudinal bulkheads is given by the following formula:

$$\tau_a = c_6 \frac{(F_{sw} + F_w) m_s}{2 t_s I} \quad \mathrm{N/mm^2 (kgf/mm^2, lbf/in^2)}$$

where

I	=	moment of inertia of the hull girder section, in cm^4 (in^4), at the section under consideration.
m_s	=	first moment, in cm^3 (in^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 position under consideration.
t_s	=	thickness of the side shell plating, in cm (in.), at the position under consideration.
F_{sw}	=	hull girder shearing force in still water, in kN (tf, Ltf). See 3-2-1/3.3.
F_w	=	F_{wp} or F_{wn}, in kN (tf, Ltf), as specified by 3-2-1/3.5.3, depending upon loading
c_6	=	10 (10, 2240)

7.3.2 Ships with Two or More Effective Longitudinal Bulkheads

The working shear stress, τ_a, in the side shell or longitudinal bulkhead plating is to be calculated by an acceptable method and in accordance with 3-2-1/3.9.4.

9 Scantling Criteria

9.1 Buckling Stress

The design buckling stress, σ_c, of plate panels and longitudinals (as calculated in 3-2-A4/5.1) is to be such that:

$$\sigma_c \geq \beta \sigma_a$$

where

β	=	1	for plating and for web plating of stiffeners (local buckling)
β	=	1.1	for stiffeners

The critical buckling stress, τ_c, of plate panels (as calculated in 3-2-A4/5.3) is to be such that:

$$\tau_c \geq \tau_a$$

where

τ_a	=	the working shear stress in the plate panel under consideration, in N/mm^2 (kgf/mm^2, lbf/in^2), as determined by 3-2-A4/7.3.

Alternatively for transverse framing vessels between 61 meters (200 feet) and 90 meters (295 feet) in length, the deck and bottom plate may be taken not less than:

$$t = \frac{s}{45} \sqrt{\frac{SM_R}{SM_A}} \cdot \frac{1}{\sqrt{Q}} + t_k \quad \mathrm{mm(in.)}$$

where

t = thickness of bottom shell or deck plating, in mm (in.)

t_k = Standard deduction as given in 3-2-A4/Table 1A or 1B as the case may be, in mm(in.)

s = frame spacing, in mm (in.)

SM_R = hull girder section modulus required by 3-2-1/3, in cm^2-m (in^2-ft)

SM_A = bottom or deck hull girder section modulus, in cm^2-m (in^2-ft)

Q = as defined in 3-2-1/5.3

PART 3

CHAPTER 2
Hull Structures and Arrangements

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 considered based on submitted documents and calculations supporting the review.

3 Spade Rudders

3.1 Rudder Blade

3.1.1 Shear Force *(2020)*

For regular spade rudders as shown in 3-2-A5/3 FIGURE 1(a), the shear force, $V(z)$, at a horizontal section of the rudder above baseline is given by the following equation:

$$V(z) \quad = \frac{zC_R}{A}\left[c_\ell + \frac{z}{2\ell_R}(c_u - c_\ell)\right] \quad \text{kN(tf, Ltf)}$$

where

z	=	distance from the rudder baseline to the horizontal section under consideration, in m (ft)
C_R	=	rudder force, as defined in 3-2-14/3, in kN (tf, Ltf)
A	=	total projected area of rudder blade in m^2 (ft^2), as defined in 3-2-14/3

c_ℓ, c_u and ℓ_R are dimensions as indicated in 3-2-A5/3 FIGURE 1(a), in m (ft).

For spade rudders with embedded rudder trunks let deep in the rudder blade, as shown in 3-2-A5/3 FIGURE 1(b), the shear forces at rudder horizontal sections above rudder baseline in areas A_1, and A_2, are given by the following equations:

$$V(z')_1 = \frac{z'C_{R1}}{A_1}\left[c_u - \frac{z'}{2\ell_\ell}(c_u - c_b)\right] \quad \text{kN(tf, Ltf)}, \quad \text{over} \quad \text{area} \quad A_1$$

$$V(z)_2 = \frac{zC_{R2}}{A_2}\left[c_\ell + \frac{z}{2\ell_b}(c_b - c_\ell)\right] \quad \text{kN(tf, Ltf)}, \quad \text{over} \quad \text{area} \quad A_2$$

where

z' = $\ell_R - z$

C_{R1} = rudder force over rudder area A_1, in kN (tf, Ltf)

= $\frac{A_1}{A} C_R$

C_{R2} = rudder force over rudder area A_2, in kN (tf, Ltf)

= $\frac{A_2}{A} C_R$

A_1 = partial rudder blade area above neck bearing and below rudder top, in mm^2 (ft^2)

A_2 = partial rudder blade area above rudder baseline and below neck bearing, in mm^2 (ft^2)

z, A, and C_R are as indicated in 3-2-A5/3.1.1.

c_ℓ, c_b, c_u, ℓ_u and ℓ_b are dimensions as illustrated in 3-2-A5/3 FIGURE 1(b).

3.1.2 Bending Moment *(2020)*

For regular spade rudders, bending moment, $M(z)$, at a horizontal section z meters (feet) above the baseline of the rudder is given by the following equation:

$$M(z) = \frac{z^2 C_R}{2A}\left[c_\ell + \frac{z}{3\ell_R}(c_u - c_\ell)\right] \quad \text{kN} - \text{m}, (\text{tf} - \text{m}, \text{Ltf} - \text{ft})$$

For spade rudders with embedded rudder trunk, the bending moment at a horizontal section within area A_1 is obtained from the following:

$$M(z')_1 = \frac{(z')^2 C_{R1}}{2A_1}\left[c_u - \frac{z'}{3\ell_\ell}(c_u - c_b)\right] \quad \text{kN} - \text{m}, (\text{tf} - \text{m}, \text{Ltf} - \text{ft})$$

With the maximum bending moment M_1 over area A_1 equals to:

$$M_1 = C_{R1}\ell_\ell\left[1 - \frac{2c_b + c_u}{3(c_b + c_u)}\right] \quad \text{kN} - \text{m}, (\text{tf} - \text{m}, \text{Ltf} - \text{ft})$$

For spade rudders with embedded rudder trunk, the bending moment at a horizontal section within area A_2 is obtained from the following:

$$M(z)_2 = \frac{z^2 C_{R2}}{2A_2}\left[c_\ell + \frac{z}{3\ell_b}(c_b - c_\ell)\right] \quad \text{kN} - \text{m}, (\text{tf} - \text{m}, \text{Ltf} - \text{ft})$$

With the maximum bending moment M_2 over area A_2 equals to:

$$M_2 = C_{R2}\ell_b\frac{2c_\ell + c_b}{3(c_\ell + c_b)} \quad \text{kN} - \text{m}, (\text{tf} - \text{m}, \text{Ltf} - \text{ft})$$

where $z, z', C_{R1}, C_{R2}, A_1, A_2, c_\ell, c_u$ and ℓ_R are as defined in 3-2-A5/3.1.1.

3.3 Lower Stock

3.3.1 Shear Force

For regular spade rudder, the shear force,V_ℓ , at any section of the lower stock between the top of the rudder and the neck bearing is given by the following equation:

$$V_\ell = C_R \quad \text{kN(tf, Ltf)}$$

For spade rudder with embedded rudder trunk, the shear force at any section of the stock between the top of the rudder and the neck bearing is given by the following equation:

$$V_\ell = \frac{M_2 - M_1}{\ell_u + \ell_\ell} \quad \text{kN(tf, Ltf)}$$

where C_R, ℓ_ℓ, and ℓ_u are as defined in 3-2-A5/3.1.1.

3.3.2 Bending Moment at Neck Bearing

For regular spade rudder, the bending moment in the rudder stock at the neck bearing, M_n, is given by the following equation:

$$M_n = C_R\left[\ell_\ell + \frac{\ell_R(2c_\ell + c_u)}{3(c_\ell + c_u)}\right] \quad \text{kN} - \text{m}(\text{tf} - \text{m}, \text{Ltf} - \text{ft})$$

where

C_R	=	rudder force as defined in 3-2-14/3

c_ℓ, c_u, ℓ_ℓ and ℓ_R are dimensions as indicated in 3-2-A5/3 FIGURE 1, in m (ft.).

For spade rudder with embedded rudder trunk, the bending moment in the rudder stock at the neck bearing is given by the following equation:

$$M_n = M_2 - M_1 \quad \text{kN} - \text{m}(\text{tf} - \text{m}, \text{Ltf} - \text{ft})$$

where M_1 and M_2 as defined in 3-2-A5/3.1.2.

Where partial submergence of the rudder leads to a higher bending moment in the rudder stock at the neck bearing (compared with the fully submerged condition), M_n is to be calculated based on the most severe partially submerged condition.

3.5 Moment at Top of Upper Stock Taper

For regular spade rudder, the bending moment in the upper rudder stock at the top of the taper, M_t, is given by the following equation:

$$M_t = C_R\left[\ell_\ell + \frac{\ell_R(2c_\ell + c_u)}{3(c_\ell + c_u)}\right] \times \left[\frac{(\ell_u + \ell_R + \ell_\ell - z_t)}{\ell_u}\right] \quad \text{kN} - \text{m}, (\text{tf} - \text{m}, \text{Ltf} - \text{ft})$$

For spade rudder with embedded rudder trunk, the bending moment in the upper rudder stock at the top of the taper is given by the following equation:

$$M_t = M_R \quad \left[\frac{(\ell_R + \quad \ell_u - \quad z_t)}{\ell_u}\right] \quad \text{kN} - \text{m}(\text{tf} - \text{m}, \text{Ltf} - \text{ft})$$

where

z_t	=	distance from the rudder baseline to the top of the upper rudder stock taper in m (ft.)
C_R	=	rudder force, as defined in 3-2-A5/3.1.1
M_R	=	is the greater of M_1 and M_2, as defined in 3-2-A5/3.1.2

c_ℓ, c_u, ℓ_ℓ, ℓ_u and ℓ_R are dimensions as indicated in 3-2-A5/3 FIGURE 1, in m (ft).

3.7 Bearing Reaction Forces

For regular spade rudder, the reaction forces at the bearings are given by the following equations:

P_u = reaction force at the upper bearing

= $-\frac{M_n}{\ell_u}$ kN(tf, Ltf)

P_n = reaction force at the neck bearing

= $C_R + \frac{M_n}{\ell_u}$ kN(tf, Ltf)

For spade rudder with embedded rudder trunk, the reaction forces at the bearings are given by the following equations:

P_u = $-\frac{M_n}{\ell_u + \ell_\ell}$ kN(tf, Ltf)

P_n = $C_R + P_u$ kN(tf, Ltf)

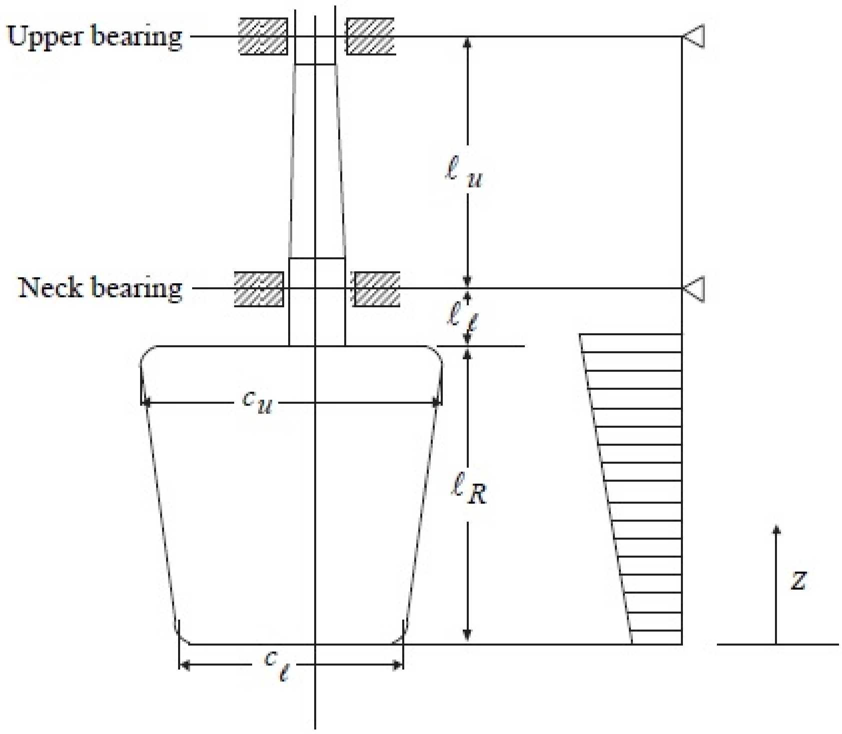
where

M_n = bending moment at the neck bearing, as defined in 3-2-A5/3.3.2

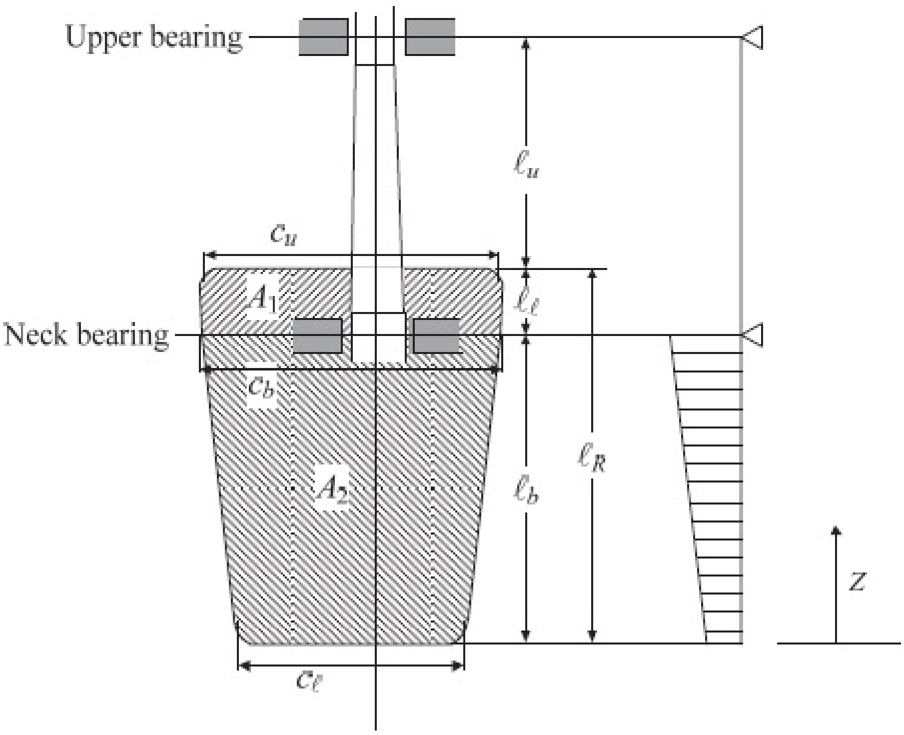
C_R = rudder force, as defined in 3-2-14/3.

ℓ_u is as indicated in 3-2-A5/3 FIGURE 1, in m (ft).

FIGURE 1
Spade Rudder



(a) Regular Spade Rudder



(b) Spade Rudder With Embedded Rudder Trunk

5 Rudders Supported by Shoe Piece

5.1 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 3-2-A5/5.1 FIGURE 2.

w_R = rudder load per unit length

= $\frac{C_R}{\ell_R}$ kN/m (tf/m, Ltf/ft)

where

C_R = rudder force, as defined in 3-2-14/3

k_s = spring constant reflecting support of the shoe piece

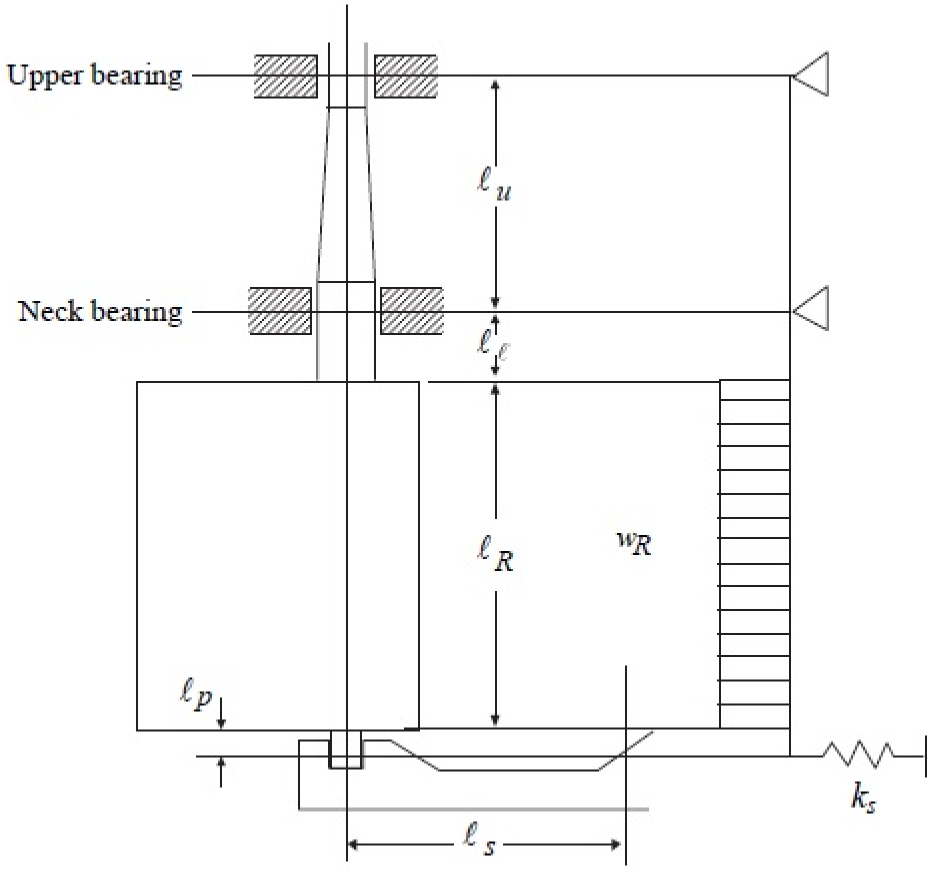
= $\frac{n_s I_s}{\ell_s^3}$ kN/m (tf/m, Ltf/ft)

n_s = 6.18 (0.630, 279)

I_s = moment of inertia of shoe piece about the vertical axis, in cm^4 (in^4)

ℓ_s, ℓ_R and ℓ_p are dimensions as indicated in 3-2-A5/5.1 FIGURE 2, in m (ft).

FIGURE 2
Rudder Supported by Shoe Piece



7 Rudders Supported by a Horn with One Pintle

7.1 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 3-2-A5/7.1 FIGURE 3.

w_{R1} = rudder load per unit length above pintle

= $-\frac{C_{R1}}{\ell_{R1}}$ kN/m (tf/m, Ltf/ft)

w_{R2} = rudder load per unit length below pintle

= $\frac{C_{R2}}{\ell_{R2}}$ kN/m (tf/m, Ltf/ft)

where

C_{R1} = rudder force, as defined in 3-2-14/3.3

C_{R2} = rudder force, as defined in 3-2-14/3.3

k_h = spring constant reflecting support of the horn

$$= \frac{1}{\dfrac{\ell_h^3}{n_b I_h} + \dfrac{\sum\left(\frac{s_i}{t_i}\right) e^2 \ \ell_h}{n_t \ a^2}} \quad \mathrm{kN/m(tf/m, Ltf/ft)}$$

n_b = 4.75 (0.485, 215)

n_t = 3.17 (0.323, 143)

a = mean area enclosed by the outside lines of the rudder horn, in cm^2 (in^2)

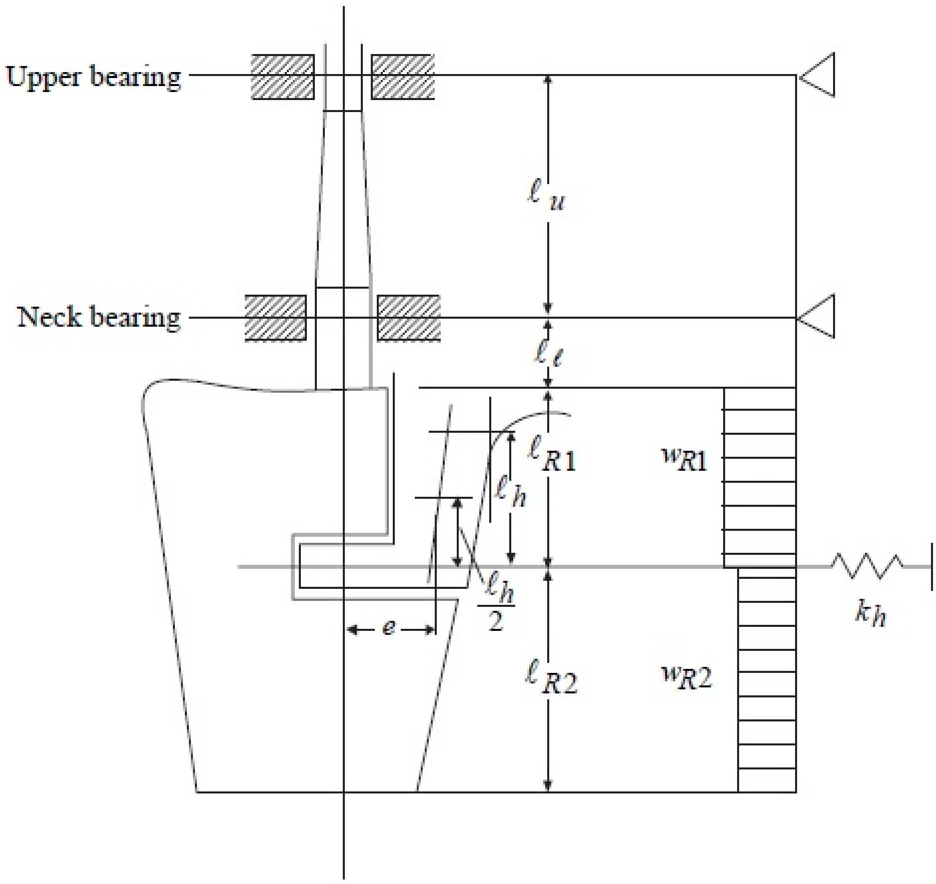
s_i = the girth length of each segment of the horn of thickness t_i, in cm (in.)

t_i = the thickness of each segment of horn outer shell of length s_i, in cm (in.)

I_h = moment of inertia of horn section at ℓ_h about the longitudinal axis, in cm^4 (in^4)

e, ℓ_h, ℓ_{R2} and ℓ_{R2} are dimensions as indicated in 3-2-A5/7.1 FIGURE 3, in m (ft)

FIGURE 3
Rudder Supported by a Horn with One Pintle



9 Rudders Supported by a Horn Arranged with Two Pintles (Supports)

9.1 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 3-2-A5/9 FIGURE 4.

w_{R1} = rudder load per unit length above lower rudder support/pintle

= $-\frac{C_{R1}}{\ell_{R1}}$ kN/m (tf/m, Ltf/ft)

w_{R2} = rudder load per unit length below lower rudder support/pintle

= $\frac{C_{R2}}{\ell_{R2}}$ kN/m (tf/m, Ltf/ft)

where

C_{R1} = rudder force, as defined in 3-2-14/3.3

C_{R2} = rudder force, as defined in 3-2-14/3.3

ℓ_{R1} and ℓ_{R2} are dimensions as indicated in 3-2-A5/9 FIGURE 4, in m (ft).

In 3-2-A5/9 FIGURE 4 the variables K_{11}, K_{22}, K_{12} are rudder horn compliance constants calculated for rudder horn with 2-conjugate elastic supports. The 2-conjugate elastic supports are defined in terms of horizontal displacements, y_i, by the following equations:

- At the lower rudder horn bearing:

  $y_1 = -K_{12} \quad B_2 - K_{22} \quad B_1$ m (ft)

- At the upper rudder horn bearing:

  $y_2 = -K_{11} \quad B_2 - K_{12} \quad B_1$ m (ft)

where

y_1, y_2 = horizontal displacement at lower and upper rudder horn bearings, respectively

B_1, B_2 = horizontal support force, in kN (tf, Ltf), at lower and upper rudder horn bearings, respectively

K_{11}, K_{22}, K_{12} = spring constant of the rudder support obtained from the following:

K_{11} = $m\left[1.3\frac{\lambda^3}{3EJ_{1h}} + \frac{e^2\lambda}{GJ_{th}}\right]$ m/kN (m/tf, ft/Ltf)

K_{22} = $m\left[1.3\left[\frac{\lambda^3}{3EJ_{1h}} + \frac{\lambda^2(d-\lambda)}{2EJ_{1h}}\right] + \frac{e^2\lambda}{GJ_{th}}\right]$ m/kN (m/tf, ft/Ltf)

K_{12} = $m\left[1.3\left[\frac{\lambda^3}{3EJ_{1h}} + \frac{\lambda^2(d-\lambda)}{EJ_{1h}} + \frac{\lambda(d-\lambda)^2}{EJ_{1h}} + \frac{(d-\lambda)^3}{3EJ_{2h}}\right] + \frac{e^2d}{GJ_{th}}\right]$ m/kN (m/tf, ft/Ltf)

m = 1.00 (9.8067, 32.691)

d = height of the rudder horn, in m (ft), defined in 3-2-A5/9 FIGURE 4. This value is measured downwards from the upper rudder horn end, at the point of curvature transition, to the mid-line of the lower rudder horn pintle.

λ = length, in m (ft), as defined in 3-2-A5/9 FIGURE 4. This length is measured downwards from the upper rudder horn end, at the point of curvature transition, to the mid-line of the upper rudder horn bearing. For $\lambda = 0$, the above formulae converge to those of spring constant k_h for a rudder horn with 1-pintle (elastic support), and assuming a hollow cross section for this part.

e = rudder-horn torsion lever, in m (ft), as defined in 3-2-A5/9 FIGURE 4 (value taken at vertical location $\ell_h/2$).

E = Young's modulus of the material of the rudder horn in kN/m^2 (tf/m^2, Ltf/in^2)

G = modulus of rigidity of the material of the rudder horn in kN/m^2 (tf/m^2, Ltf/in^2)

J_{1h} = moment of inertia of rudder horn about the x axis, in m^4 (ft^4), for the region above the upper rudder horn bearing. Note that J_{1h} is an average value over the length λ (see 3-2-A5/9 FIGURE 4).

J_{2h} = moment of inertia of rudder horn about the x axis, in m^4 (ft^4), for the region between the upper and lower rudder horn bearings. Note that J_{2h} is an average value over the length $d - \lambda$ (see 3-2-A5/9 FIGURE 4).

J_{th} = torsional stiffness factor of the rudder horn, in m^4 (ft^4)

= $\dfrac{4F_T^2}{\sum_i \frac{u_i}{t_i}}$ for any thin wall closed section, in m^4 (ft^4)

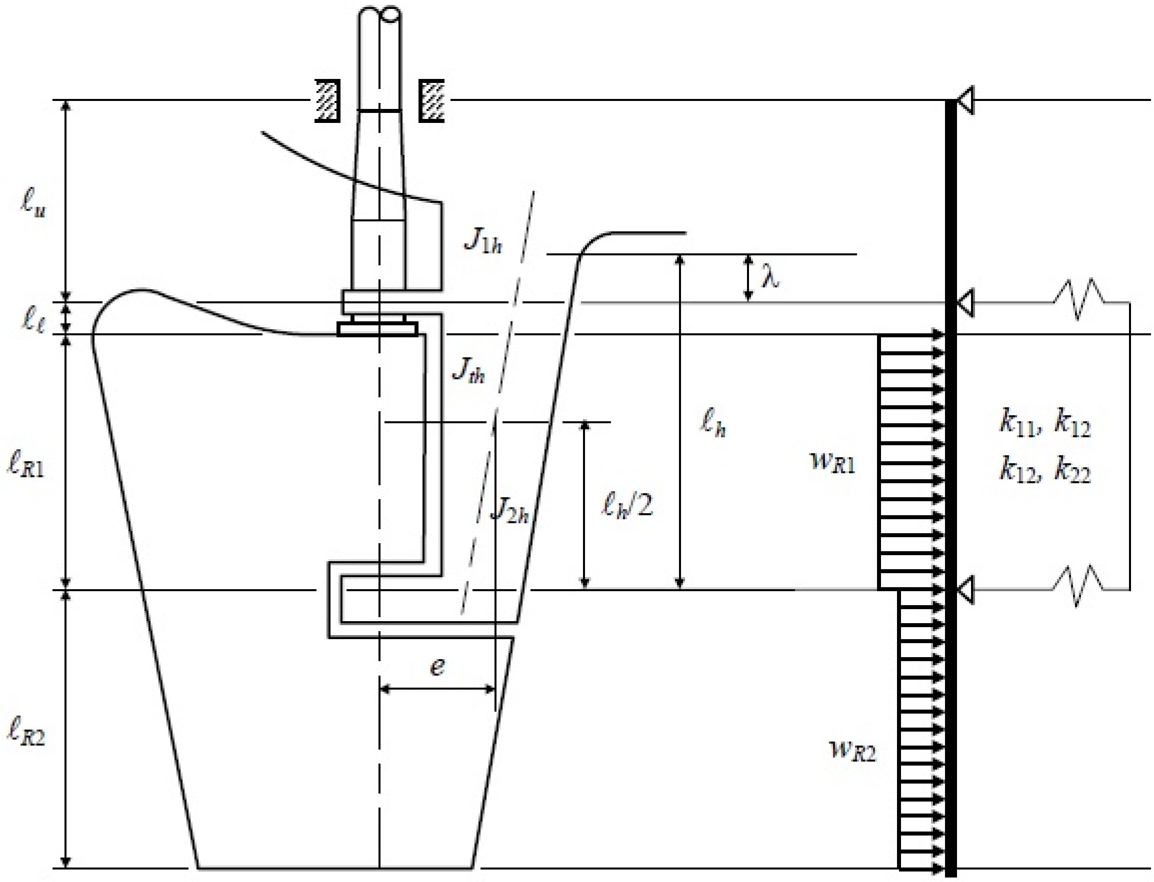
Note that the J_{th} value is taken as an average value, valid over the rudder horn height.

F_T = mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn, in m^2 (ft^2)

u_i = length, in mm (in.), of the individual plates forming the mean horn sectional area

t_i = thickness, in mm (in.), of the individual plates mentioned above

FIGURE 4
Rudder Supported by a Horn Arranged with Two Pintles (Supports)



PART 3

CHAPTER 2

Hull Structures and Arrangements

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 spans, the section modulus *SM* and inertia *I* at the midspan required by 3-2-15/8.1.1, 3-2-15/8.3.2, 3-2-15/8.5.1 and 3-2-15/9.1 may be obtained from the following equations.

$$SM = \frac{C_1 K_1 p s l^2}{\sigma_a} \quad \text{cm}^3(\text{in}^3)$$

$$I = C_2 K_2 p s \ell^3 \quad \text{cm}^4(\text{in}^4)$$

where

C_1	=	125 (125, 1.5)
C_2	=	2.87 (28.2, 2.85×10^{-5}) for 3-2-15/8.1.1 and 3-2-15/8.3.2
	=	2.26 (22.1, 2.24×10^{-5}) for 3-2-15/8.5.1 and 3-2-15/9.1
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

$\ell_1/\ell, SM_1$ and SM are as indicated in 3-2-A6/1 FIGURE 1

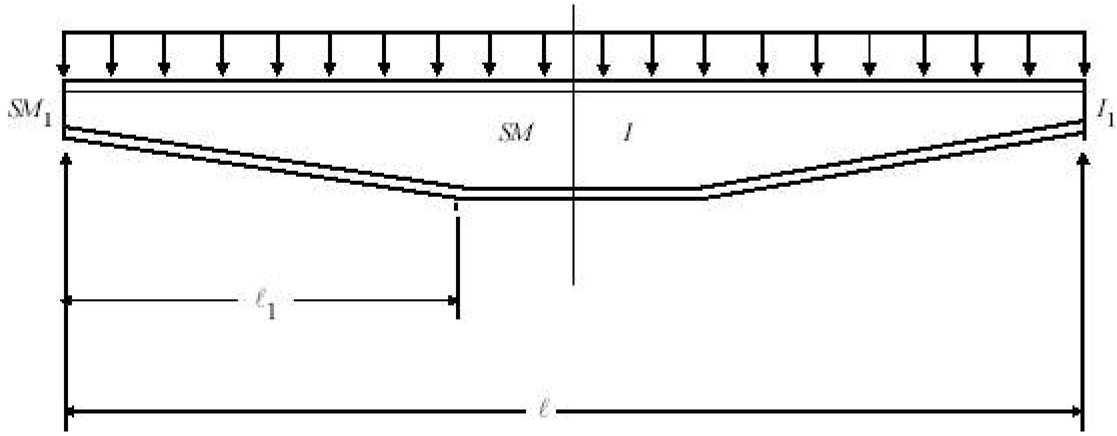
σ_a	=	allowable stress given in 3-2-15/8.1.1, 3-2-15/8.3.2, 3-2-15/8.5.1 and 3-2-15/9.1, in kN/mm^2 (kgf/mm^2, psi)
K_2	=	$1+8\alpha^3\frac{(1-\beta)}{(0.2+3\sqrt{\beta})}$, but not less than 1.0
β	=	ratio of the moments of inertia, I_1 and I, at the locations indicated in 3-2-A6/1 FIGURE 1
	=	I_1/I

p = design load given in 3-2-15/3.3, in kN/m^2 (tf/m^2, psi)

s = spacing of beams or stiffeners, in m (ft).

ℓ = span of free ended constructional elements, in m (ft).

FIGURE 1
SM and I of Construction Elements



PART 3

CHAPTER 2
Hull Structures and Arrangements

APPENDIX 7
Ice Operations

1 Application

This Appendix provides guidance for Marine Vessels intended for operation in ice infested waters. A general characterization of the vessel's ice operations is provided along with an overview of ice management roles. References are made to the various ABS ice class criteria and guidance.

3 General

In addition to conventional open water functions, Marine Vessels may play unique roles in Arctic and other ice-infested waters, specifically through icebreaking operations and ice management. These roles are critical elements of Arctic offshore oil and gas operations as they can potentially extend the drilling season and reduce the frequency of disconnection events. A Marine Vessel may be expected to maneuver more rigorously in ice than a traditional ice-strengthened transit ship due to ice management responsibilities and advanced propulsion systems; (e.g., podded propulsors and azimuthing thrusters). For this reason, special attention should be given to the strength of the stern region and appendages beyond the basic ice strengthening requirements.

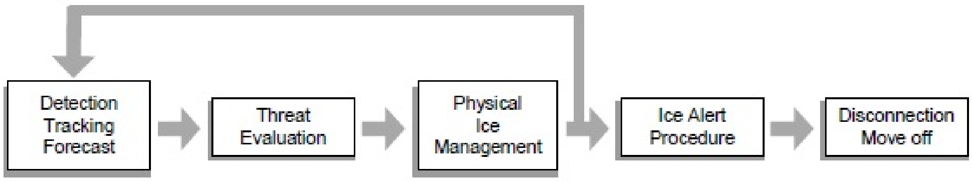
5 Ice Management

Ice management involves operational procedures that are used to reduce global and local design ice loads. Ice management is most commonly used to support floating systems in both sea ice and glacial ice environments and can significantly influence their design. It can also be used to mitigate the risk of deep draft ice features interacting with sea floor facilities. In certain cases, ice management can be used as a means of modifying ice loads on fixed structures, although this approach is not common. It is also a relevant consideration in terms of supporting other in-ice activities, such as EER systems and tanker offloading operations.

Floating structures that are deployed in ice-covered waters are often supported by highly capable ice management vessels, with the intended role of modifying the local ice environment, reducing ice loads on the structure and enhancing ice clearance around it. The requirement to identify potentially adverse ice features or situations requiring ice management, and then to deal with them in a timely manner, increases the range of environmental considerations that are normally associated with fixed structures. Fixed structures may also rely on ice management to ensure access to re-supply and offloading facilities and to clear potential escape routes for EER craft.

Ice management systems typically consist of a series of processes and procedures as shown schematically in 3-2-7/5 FIGURE 1, below. In actual ice management operations, a sequence of events takes place in time at or near the site of the offshore facility. A similar sequence of events is considered, or assumed, during the design cycle of the ice management system.

FIGURE 1
Ice Management System and Its Elements



Physical ice management refers to the actual vessel operations that are intended to break up and clear sea ice and/or specific features within an ice cover, and deflect icebergs and small glacial ice masses. Specific approaches and techniques have been developed for both sea ice and glacial ice management that recognize the capabilities and limitations of the vessels and equipment involved and the ice conditions at hand.

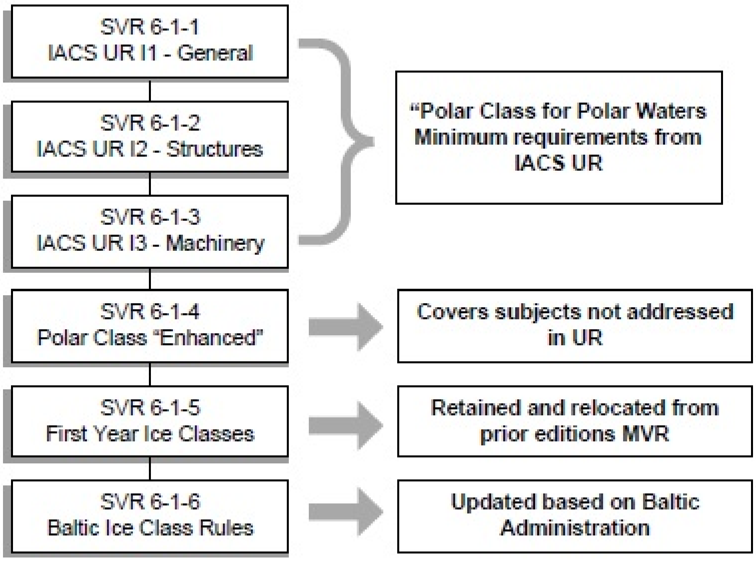
The criteria presented in this chapter can be applied to the design of offshore support vessels intended for physical ice management operations.

The rules for icebreakers (and ice going transit-vessels) outlined in Part 6, Chapter 1 of ABS *Rules for Building and Classing Marine Vessels (Marine Vessel Rules) and ABS Guide for Vessels Operating in Low Temperature Environments (LTE Guide)* can be applied in general for all Ice Management Vessel (IMV) designs. These publications give basic design criteria for the vessel's hull, machinery, deck outfitting, winterization, etc.

7 Overview of ABS Ice Class Rules

Part 6, Chapter 1 contains several systems of ice class notations. If operation in ice is anticipated, it is the vessel Owner's option to select which ice class notation system to be applied, and it is the Owner's responsibility to operate the vessel in a manner consistent with the basis underlying the technical criteria for the selected ice class. 3-2-7/7 FIGURE 2 outlines the various ice class notation systems offered in Part 6, Chapter 1.

FIGURE 2
Organization of ABS Ice Class Rules



The ice class notations are intended to indicate a vessel's ability to operate in specified conditions (i.e., geographic region, and ice and vessel parameters); considering a particular vessel operating profile (i.e., ice breaking or escorted); and possibly, particular ice-vessel interaction scenarios (e.g., an impact of the vessel bow with the ice). To accommodate the variations in the conditions affecting design, several ice class systems have been developed and included in the Rules. 3-2-7/7 TABLE 1, reproduced from Section 6-1-1, *'Strengthening for Navigation in Ice'*, summarizes the offered Ice Class Notations of the Rules. The position of an entry in the table is only intended to provide a general impression of approximate correspondence between the systems of the offered ice class notations. The absolute strength of a particular hull structure can only be determined by appropriate analysis.

TABLE 1
Ice Class Notations

Polar Class (6-1-1, 6-1-2, 6-1-3)	*Polar Class, Enhanced (6-1-4)*	*First-year Ice Class (6-1-5)*	*Baltic Class (6-1-6)*
PC1	**PC1, Enhanced**		
PC2	**PC2, Enhanced**		
PC3	**PC3, Enhanced**		
PC4	**PC4, Enhanced**		
PC5	**PC5, Enhanced**		
PC6	**PC6, Enhanced**		**1AA**
PC7	**PC7, Enhanced**	**A0**	**1A**
		B0	**1B**
		C0	**1C**
		D0	

Note: The shaded columns shaded are eligible for **Ice Breaker** class notation.

9 IACS Polar Classes

9.1 Background Information

The International Maritime Organization (IMO) issued guidelines for ships operating in Arctic Ice-covered Waters (IMO Arctic Guidelines, 2002). In 2009, updated Guidelines were approved to take account of technical, technological, and regulatory developments since their initial publication. In addition, application was extended to address ships operating in Polar waters, which includes both Arctic and Antarctic waters (IMO Guidelines for Ships Operating in Polar Waters 2009). 3-2-A7/Figures 3 and 4 show the Arctic and Antarctic waters as defined in the Guidelines.

The IMO is currently working on an initiative to prepare a comprehensive Polar Code for ships operating in polar waters to enhance the existing voluntary measures related to maritime safety and environmental protection in polar waters. Although it is at an early stage of development, there has been strong support to develop a risk-based code with functional requirements supported by prescriptive provisions, and the developed code is likely to be made mandatory under SOLAS and/or MARPOL.

Ships operating in Polar waters are exposed to a number of unique risks. Poor weather conditions and the relative lack of good charts, communication systems and other navigational aids pose challenges for mariners. The remoteness of the area makes rescue or clean-up operations difficult and costly. Cold temperatures may reduce the effectiveness of numerous components of the ship, ranging from deck machinery and emergency equipment to sea suctions. When ice is present, it can impose additional loads on the hull, propulsion system and appendages. The IMO Polar Guidelines address the criteria for (a) construction provisions (b) equipment (c) operations and (d) environmental protection and damage control. One of the most important aspects of the IMO 2009 Guidelines for ship designers, builders and operators is that the construction provisions refer to the IACS Unified Requirements (URs) Concerning Polar Class (IACS Requirements for Polar Class, 2007) developed by the International Association of Classification Societies (IACS).

FIGURE 3
Maximum Extent of Arctic Waters(1)

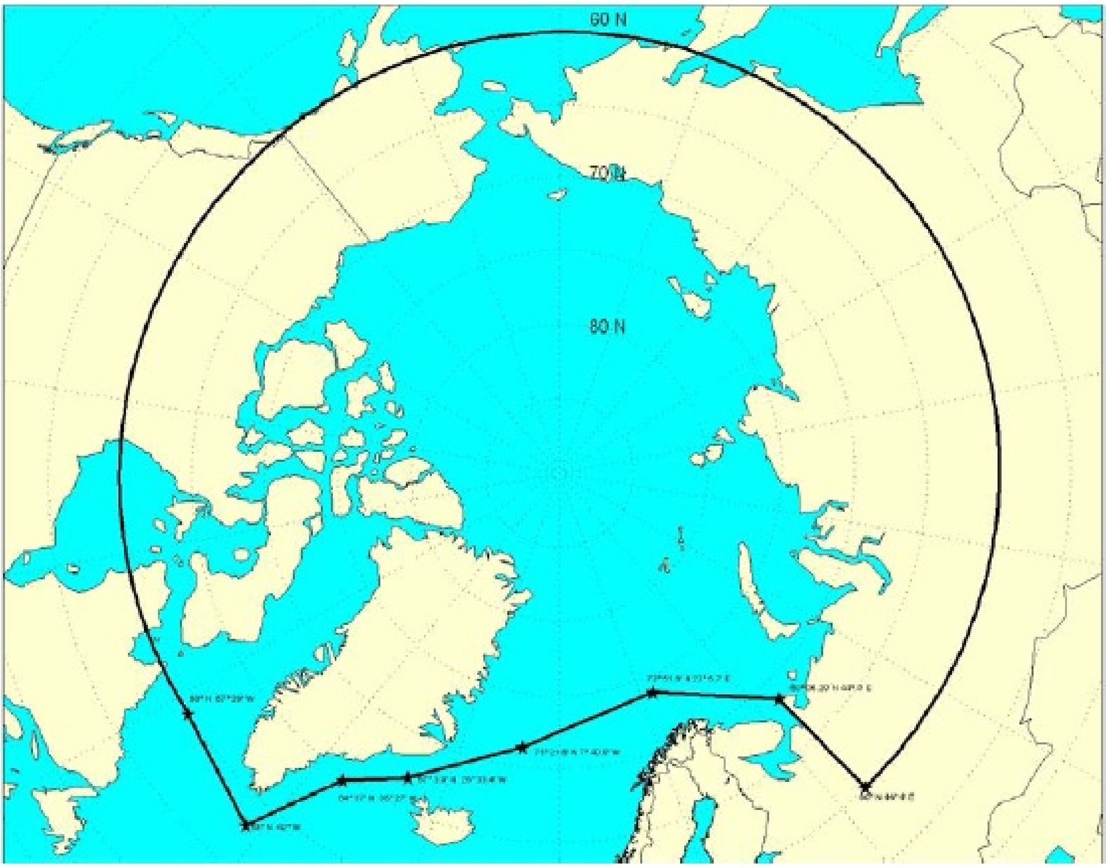
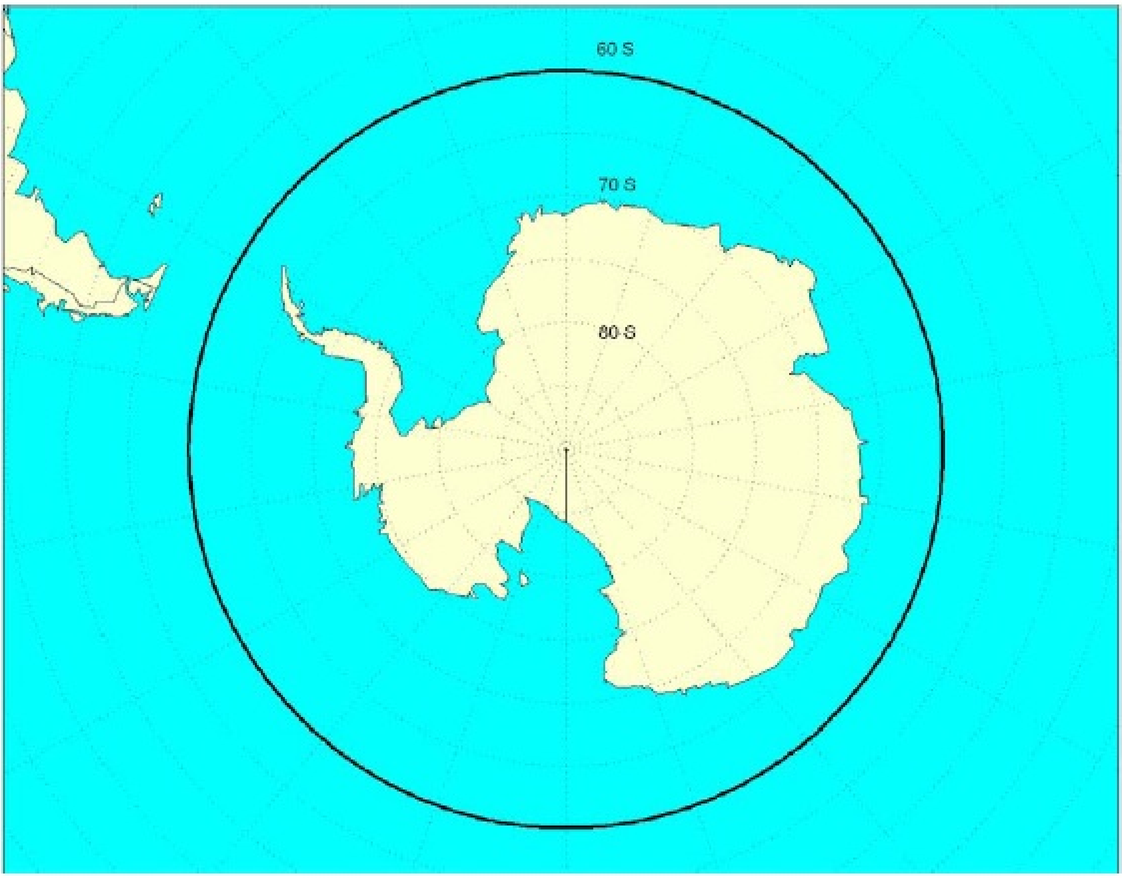


FIGURE 4
Maximum Extent of Antarctic Waters(1)



Source:	1	IMO Resolution A.1024(26) Guidelines for Ships Operating in Polar Waters
Note:		Maps are for illustrative purposes only

9.3 Description of IACS Polar Classes

The International Association of Classification Societies (IACS) Unified Requirements for Polar Ships (UR I), adopted by ABS in Sections 6-1-1, 6-1-2, and 6-1-3 of the *Marine Vessel Rules,* are based on both Arctic and Antarctic navigation. The IACS Polar Class rules were implemented into the *Marine Vessel Rules* in January 2012, effectively replacing the previous general Arctic ice class notations (**A5** to **A1**).

There are seven ice classes in the Polar Class requirements (**PC1** to **PC7**). The IACS rules assume limited icebreaker assistance. The rules are based on an interaction scenario of a glancing impact with an ice floe on the bow shoulder. From this scenario, the ice loading is derived and then the local hull structure and scantling requirements are derived. The division of the IACS Polar Classes and the associated descriptions are reproduced in 3-2-7/9.3 TABLE 2 below. The descriptions are intended to guide owners, designers and administrations in selecting an appropriate Polar Class to match the requirements for a vessel with its intended mission.

The classes are intended to cover the full range of ships in operation, providing flexibility to designers using uncomplicated descriptions of ice conditions. The lowest classes **PC6** and **PC7** have been approximately aligned with the highest Finnish Swedish Ice Class Rules (FSICR), 1AS and 1A respectively. The highest polar class (**PC1**) is intended to offer a level of capability analogous to that provided by an unrestricted open water class notation. It defines a ship which can operate year-round in all polar waters, subject to due caution on the part of the Master. This caution implies, for example, limiting speed in certain conditions, avoiding aggressive maneuvers, avoiding impacts with obvious glacial ice features, etc.

TABLE 2
Polar Class Descriptions

Polar Class	*Ice description based on WMO sea ice nomenclature*
PC1	Year-round operation in polar waters
PC2	Year-round operation in moderate multi-year ice condition
PC3	Year round operation in second year ice which may include multi-year ice inclusions
PC4	Year round operations in thick first-year ice which may include old ice inclusions
PC5	Year round operations in medium first-year ice which may include old ice inclusions
PC6	Summer-Autumn operations in medium first-year ice which may include old ice inclusions
PC7	Summer/Autumn operation in thin first year ice which may include old ice inclusions

9.5 Theoretical Background of Structural Requirements

Section 6-1-2 contains hull structural design criteria from the IACS Unified Requirements (UR I2) which provides definitions and requirements for hull area, design loads, shell plate requirements, framing requirements, corrosion/abrasion addition and steel renewal, material grades and longitudinal strength requirements. The design load for Polar Class ships takes a physics-based approach that ice loads can be rationally linked to the design scenario. The design scenario is a glancing collision with an ice edge, such as the edge of a channel or of a floe. The formulation of the load equation is derived from the solution of an energy based collision model in which the kinetic energy is equated to ice crushing energy. Ice thickness, ice crushing strength, hull form, ship size and ship speed are all taken into account. The flexural failure of the ice sheet is also considered as a limiting state due to the collision. The results are in close agreement with a variety of past studies and operational experience. The forces generated during a glancing impact are represented in ways that allow them to be used in developing scantlings for individual structural elements, grillages, and supporting structure.

Although most traditional ship structural rule formulations are based on elastic criteria, the IACS Requirements for Polar Class incorporate plastic design criteria. Using plastic design can help provide a better balance of material distribution to resist design and extreme loads. This is particularly important because extreme ice loads can be considerably in excess of design values. This is more likely for ice loads than for wave loading. The use of plastic methods should provide a considerable strength reserve, which may or may not be the case with elastic design. The selection of structural design criteria for plastic design is more difficult than in elastic design of which the first onset of yield is relatively easy to predict, and thus offers a simple criterion for design. In plastic design, there are many possible limit states ranging from yield through final rupture. The selected design limit state represents a condition of substantial plastic stress, prior to the development of large plastic strains and deformations.

The shell plate thickness requirements are derived using ultimate strength criterion where the ultimate strength is determined when plastic folding occurs due to a perfectly plastic hinge formation. The local framing members in the side and bottom structures are to be dimensioned such that the effects of shear, bending, and both combined do not cause the development of plastic collapse mechanisms. The required section property requirements are derived from an analytical energy method considering three limit-states, two of which involve the combination of shear and bending while the third one is purely shear. Bending and shear interaction is treated rigorously by taking into account the actual section shape in the calculation procedure. The application of an iterative procedure should be advantageous to optimize the framing members considering shear and section modulus requirements. The scantling requirements are provided for both transversely and longitudinally framed structures.

In the original IACS UR, each classification society is left to establish the structural requirements for large web frames and load-carrying stringers. ABS has developed specific criteria for these structural members considering plastic behavior. Requirements for the web area (resistance to plastic shear force) and plastic section modulus (resistance to plastic moment) are provided in Section 6-1-2.

9.7 Theoretical Background of Machinery Requirements

Section 6-1-3 contains machinery requirements adopted from the Unified Requirements (UR I3) related to the strength of main propulsion, steering gear, emergency and other essential auxiliary support systems. Propeller ice interaction load formulas form the basis of the propulsion line component strength calculations. The load formulas were developed through extensive international research and development efforts which included numerical simulations of propeller-ice interaction validated with full scale measurements and analyses of propeller damage service histories. The calculated loads are the expected, single occurrence, maximum values for a ship's entire service life in normal operating conditions. Design load formulas are provided for both open and ducted propellers and include the maximum backward and forward blade bending forces, blade spindle torque, propeller ice torque, and propeller ice thrust applied to the shaft. Response torque criteria in the propulsion line are determined on the basis of torsional vibration analysis considering specific torque excitation cases.

The propeller blades should be designed with respect to two overall limit states, namely *extreme static* and *fatigue*. The extreme criterion is based on the calculated maximum expected loads applied via finite element analysis with acceptance criteria for permissible stress levels. Propeller blade fatigue criterion is based on a load distribution for the ship service life and the S-N curve of the blade material. The propulsion line components should be designed according to the "selective strength principle" so that first damage does not cause significant risk to the ship's safety and other shaft line components. In most cases the propeller is considered the sacrificial component. Additional subjects in Section 6-1-3 include vertical and longitudinal acceleration criteria for equipment and machinery supports, provisions to protect systems from freezing and ingestion of ice, and specific requirements for sea inlets, ballast tanks, cooling water systems and ventilations systems.

11 Polar Classes "Enhanced" Requirements

While the IACS Polar UR presents the best available basis for the design of the next generation of ice-capable ships, it stipulates that the individual classification society should supply its own procedures and criteria for several design issues. Relative to existing ice strengthening standards the IACS UR is either silent or lacks explicit requirements for several items. Section 6-1-4 contains additional criteria to address such items, and to expand the criteria themselves by addressing numerous detailed considerations. Many of the enhanced criteria in Section 6-1-4 are retained requirements of the general ice class criteria that existed in the *Marine Vessel Rules* prior to the formal adoption of the Polar Class rules. When a vessel complies with the requirements of Section 6-1-4, it can receive the Polar Class notation followed by **Enhanced**. A list of subjects addressed in the Enhanced requirements is provided in 3-2-7/11 TABLE 3.

TABLE 3
List of Subjects Addressed in Enhanced Requirements

Ice breaker class*
Vessels intended to operate astern*
Local framing details
Peak frames
Double bottoms
Ice decks
Stem and stern frames

Towing arrangements
Addition machinery arrangement considerations
Power of propulsion machinery**
Flexible couplings
Bossings
Rudder, steering arrangements, and propeller nozzles

Note:
* Indicates optional criteria
** Indicates recommendatory criteria

Section 6-1-1 and 6-1-2 provide optional criteria for an **Ice Breaker** notation which can be applied to Polar Classes (**PC1** to **PC6**). The intended application of the criteria given in structural requirements of the IACS Polar UR (Section 6-1-2) is for ships navigating in ice-infested polar waters, except for ice breakers. Ice Breaking vessels are considered ships that have an operational profile to provide ice management functions and to be the lead vessel escorting another vessel navigating in ice. An **Ice Breaker** notation requires additional design considerations which will allow the ship to undertake aggressive operations in ice-covered waters. This includes increased stern ice belt and stern lower hull area factors to provide adequate structural redundancy. Due to aggressive maneuvering demands of offshore support vessels, it is recommended to seek the optional ice breaker notation.

Additionally, comparable optional criteria are given for a ship intended to navigate in ice while travelling astern. If a vessel is intended to operate astern in ice regions, the aft section of the vessel is to be designed using the Bow and Bow Intermediate hull area requirements. Design guidance is provided to define the appropriate stern icebelt and stern intermediate regions and their associated hull area factors.

Powering requirements were excluded from the IACS Polar UR due to conflicting operational philosophies which exist for ice strengthened ships. However, recommended powering criteria are provided for Polar Class ships in Section 6-1-4. The total ahead power delivered to the propellers is to be sufficient for the vessel to maintain its design service speed under the ice conditions associated with the selected Polar Class notation. Empirical formulations are provided to satisfy two different criteria. Suitable self-propelled ice model tests also provide acceptable means of demonstrating satisfactory power of propulsion machinery.

13 First Year Ice Classes

Ice classes applicable to vessels intending to navigate in first year ice are given in Section 6-1-5. The structural design criteria for these classes reflect ice thicknesses, other ice properties, and the extent of ice cover expected to be experienced by the ship. Four first year ice classes are available (**A0**, **B0**, **C0**, **D0**, and **E0**). General guidance is provided for the selection of the most suitable first year ice class. 3-2-7/13 TABLE 4, reproduced from Section 6-1-5, identifies recommended ice classes with respect to anticipated operational philosophy (independent or escorted) and ice conditions.

TABLE 4
First Year Ice Class Selection Guidance

Ice Class	*Navigating independently or when escorted by an ice-capable vessel of the following ice classes*	*Year around navigation in water with first-year ice with the ice conditions given in Table 5, below*
A0	Escorted by **PC4** or Higher Ice Class Vessel	Extreme
B0	Escorted by **PC3** or Higher Ice Class Vessel	Extreme
A0, **B0**, **C0**	Escorted by **PC5** or Higher Ice Class Vessel	Very Severe
A0	Independently	Severe

Ice Class	*Navigating independently or when escorted by an ice-capable vessel of the following ice classes*	*Year around navigation in water with first-year ice with the ice conditions given in Table 5, below*
B0	Independently	Medium
C0	Independently	Light
D0	Independently	Very Light
E0	Independently	Very Light drift ice [in coastal areas]

TABLE 5
First Year Ice Conditions Severity Definitions

Thickness of First-Year Ice Cover in m (ft)	*Concentration of Ice(1)*			
	Very Close and Consolidated Ice, Fast Ice (from 10/10 to 9/10 or from 8/8 to 7/8)	*Close Ice (from 9/10 to 6/10 or from 7/8 to 5/8)*	*Open Ice (from 6/10 to 3/10 or from 5/8 to 2/8) and Fresh Channel(2) in Fast Ice (more than 6/10 or 5/8)*	*Very Open Ice (less than 3/10 or 2/8), Fresh Channel(2) in Fast Ice (6/10 or 5/8 and less) and Brash Ice*
1.0 (3.3) and above	Extreme	Extreme	Very severe	Severe
from 0.6 (2) to 1.0 (3.3)	Extreme	Very severe	Severe	Medium
from 0.3 (1) to 0.6 (2)	Very severe	Severe	Medium	Light
less than 0.3 (1)	Severe	Medium	Light	Very light

Notes:

1 These ratios of mean area density of Ice in a given area are from the — “World Meteorological Organization Sea Ice Nomenclature”, Appendix B.7, and give the ratio of area of Ice concentration to the total area of sea surface within some large geographic locales.

2 Provided the channel is wider than the ship

15 Baltic Ice Classes

The ice class notations and ice strengthening requirements in Section 6-1-6 of the *Marine Vessel Rules*, Baltic Ice Class are in accordance with the *Finnish-Swedish Ice Class Rules (FSICR) 2010* developed for vessels navigating in the Baltic Sea area in winter, or in other sea areas in similar ice conditions. The administrations of Sweden (Swedish Transport Agency, STA) and Finland (Finnish Transport Safety Agency, TraFi) provide icebreaker assistance to vessels bound for their ports in winter. Depending on the ice conditions, restrictions by the administrations may apply to the size and ice class of the vessel.

Four Baltic Ice Class notations are available as follows:

- **Ice Class I AA**; vessels with such structure, engine output and other properties that they are normally capable of navigating in difficult ice conditions without the assistance of icebreakers (equivalent to FSICR Ice Class 1A Super)
- **Ice Class I A**; vessels with such structure, engine output and other properties that they are capable of navigating in difficult ice conditions, with the assistance of icebreakers when necessary (equivalent to FSICR Ice Class 1A)
- **Ice Class I B**; vessels with such structure, engine output and other properties that they are capable of navigating in moderate ice conditions, with the assistance of icebreakers when necessary (equivalent to FSICR Ice Class 1B)

- **Ice Class I C**; vessels with such structure, engine output and other properties that they are capable of navigating in light ice conditions, with the assistance of icebreakers when necessary (equivalent to FSICR Ice Class 1C)

TraFi and the STA maintain the *Guidelines for the Application of the Finnish-Swedish Ice Class Rules* which provide background information concerning the implementation of the Baltic rules and the history of their development. The application of the rules and design philosophies of the engine power regulations, hull structural design, and machinery requirements are described. For additional guidance on the Baltic rules, reference can be made to these guidelines.

17 Winterization

Vessels operating in the low temperature environments are faced with additional challenges related to outfitting and equipment as well as issues pertaining to the ability of the crew to function in a difficult environment. The ABS *Guide for Vessels Operating in Low Temperature Environments* provides guidance for winterization related issues beyond the basic hull strengthening and machinery requirements in the ice class rules.

The *LTE Guide* specifies ABS requirements and criteria for obtaining the optional notations Cold Climate Operation (**CCO(TDST, TMAT)**), Cold Climate Operation-Polar (**CCO-POLAR(TDST, TMAT)**), Cold Climate Operation Plus (**CCO(TDST, TMAT)+**), Cold Climate Operation-Polar Plus (**CCO-POLAR(TDST, TMAT)+**), and **DE-ICE**. The **CCO** notation identifies the basic level of the prescriptive criteria contained in the Guide related to the design, construction, operation and survey of the vessel. For the **CCO-POLAR** notation, the Guide provides criteria for vessels that intend to operate in Polar Regions on a continuous basis. **DE-ICE** is a notation available for vessels occasionally operating in low temperatures subject to ice accretion. The appended Plus (**+**) notation indicates the placement of additional equipment onboard for the crew and recognizes specific low temperature training for the crew.

The *LTE Guide* also contains a series of Appendices that provide supporting information relative to the requirements. Additional Appendices cover climatic conditions, notes on specific vessel requirements, other reference sources, a list of administration contacts associated with navigation in Baltic, Arctic, and Antarctic areas, and a list of meteorological organization contacts.

19 Direct Calculation

While direct calculations are not permitted in the IACS Polar UR as an alternative to the prescribed procedures, prudent shipbuilders and operators may seek alternative methods to check the strength of structural systems subject to specialized operational scenarios or service missions. Direct design is an attractive option to complement the ice class rules and can address the added structural risks from adverse environmental and operational conditions. A revision of the ABS *Guidance Notes on Ice Class* is anticipated for publication in 2012 and includes guidance on developing supplementary loading conditions and structural analysis procedures which may be used to assess the adequacy of the structural design for additional ice/ship interactions. In addition the Guidance Notes describe plastic grillage analysis methods to determine the limit load of hull structure grillages subject to ice pressure.

21 Ice Load Monitoring System

The ABS *Guide for Ice Load Monitoring Systems* provides requirements for the installation of, and the information to be provided by ice load monitoring systems fitted on ice-classed ABS vessels. These systems are intended as an aid to the Master and navigating officers when a vessel is operating in ice infested waters so that appropriate action can be taken to minimize the likelihood of the vessel sustaining structural damage from interaction with the ice. The Guide specifies ice load monitoring systems extending from basic monitoring systems to sophisticated, integrated systems, the selection of which is left to the Owner. The information provided in the Guide is intended to assist the Owner in selecting the most appropriate system for a vessel based on the vessel's probable operating parameters.

It can be beneficial for the Owner of an ABS ice-classed vessel having recorded in-service data from an ice loads monitoring system to make that data available to ABS. This will permit correlation with survey results which will validate design requirements and help to refine the monitoring criteria, themselves.

PART 3

CHAPTER 2
Hull Structures and Arrangements

APPENDIX 8
Review of Temporary Industrial Equipment and Modules

1 General

Where a portable industrial module is installed, it is to be subjected to review by ABS as applicable in 3-2-A8/1.1 and subjected to survey in presence of and to the satisfaction of the attending Surveyor in accordance with Appendix 7-A1-17 of the ABS *Rules for Survey After Construction (Part 7)*.

Modular units may be used for various purposes, such as Workshops, Instrument Control/MCC/Battery/Switchgear Rooms, Laboratories, Wireline Units, R.O.V. Control Room, etc. They may not be used for accommodations or living spaces.

1.1 Applicability and Types of Industrial Modules

Requirements of this Appendix apply to portable industrial equipment modules where the forces on the cargo deck exceed the rated deck capacity, to any portable industrial equipment module which is not a standard container box or to a securing arrangement which is not covered in the vessel's approved Cargo Securing Manual. Nothing in this Appendix is intended to permit installations of industrial equipment which would require a temporary notation. These rules do not apply to accommodation modules.

Where a container box is considered acceptable as a portable modular unit in accordance with the applicable Rules for the intended purpose, the container is to be confirmed as being certified to a recognized standard.

1.3 Background

The installation of temporary industrial equipment, industrial spaces, and workshops has become increasingly prevalent in recent years. Irrespective of the amount of time that portable modules are installed onboard, the potential risks to personnel within and around these modules is of concern and therefore it is imperative that details are reviewed as required.

1.5 Analysis of Vessel Structure *(2019)*

Where isolated deck cargo exceeds the rated deck capacity, the vessel scantlings are to comply with Section 5D-1-4. The vessels structure will be analyzed using standard accelerations applied from the IMO *Code of Safe Practice for Cargo Stowage and Securing (CSS Code)*. The accelerated loads will be decoupled and applied into the deck supporting members via the contact points of the cargo. The resulting stresses in deck members are not to exceed those values found in 5D-2-2/1.3.

If a vendor provides drawings or documents of design loads or forces, then these design loads are to include accelerations in the transverse, longitudinal, and vertical direction due to vessel motions of roll, pitch and heave.

A load which exceeds the rated deck capacity is one who's static weight divided by its contact area to the deck is in excess of what ABS has approved as the rated deck capacity.

3 Submission of Data *(2019)*

In general, for the installation of industrial equipment and modules, the list of plans in 5D-2-1/7 applies. When a vessel is carrying independent tanks on deck which contain Hazardous and Noxious Liquid Substances, as defined in Section 5D-2-3 of the Rules, *International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code)*, *IMO Resolution A.673 (16)* and *IEC 60092-502,* then the list of plans in 5D-2-3/7 applies.

Some flag Administrations may have specific requirements on certification dates and construction standards of industrial modules that are manned. When these requirements are applicable, all required documentation should be submitted to ABS.

5 Structural Review

5.1 Arrangements

A revised General Arrangement drawing is to be submitted for the vessel whenever industrial equipment is installed on deck. This submittal will be kept available for reference by ABS for the duration of the installation. The General Arrangement is to show the exact location of each piece of industrial equipment and is to be furnished to ABS at the start of the project. If the location of equipment changes, then a new arrangement is to be submitted to ABS. At the completion of a project or when all industrial equipment has been removed, a notice shall be furnished to ABS. At this time a clean General Arrangement is not required, provided that it has not changed from the revision which previously reviewed by ABS prior to the installation of the equipment.

Stacked arrangements of container boxes as modular units require design review by ABS, and are to be surveyed accordingly.

5.3 Securing Arrangement and Securing Details

Where securing devices used are outside the scope of the vessel's Cargo Securing Manual, the equipment exceeds rated deck capacity, or a Cargo Securing Manual has not been approved for the vessel, details of securing devices are to be reviewed by ABS. These details may be provided either on a separate drawing or on the General Arrangement. All securing details are to be shown. If the equipment does not exceed the deck capacity and the securing devices are included in the approved Cargo Securing Manual, then the securing is at the discretion of the vessel's crew in accordance with the vessel's Cargo Securing Manual.

5.3.1 Plate Clips

A clip is a piece of vertical plate where the horizontal edge is welded to the deck and likewise the vertical edge is welded to the piece of equipment or skid, see 3-2-A8/5.3.1 FIGURE 1.

In some cases, a vendor may request securing devices, including plate clips, not be welded to their equipment, as shown in 3-2-A8/5.3.1 FIGURE 2. In this case, the clip may be slotted into a corner casting or fit tightly around an accessible edge. In this case effectiveness of the clips is to be reduced and the weld at the deck sized to take appropriate loads.

If plate clips are the only means of securing, then clips should ideally be provided in both the transverse and longitudinal directions. These clips, in their quantity, size, and welds, are to be able to resist the forces of sliding, tipping, and vertical accelerations in their effective direction, and calculations should be performed to confirm this for both shear and weld strength.

A plate clip is generally only effective along the plane to which it is parallel.

Additional calculations may be necessary to check the bending strength adequacy of the clip based on the clip design and the proposed arrangement.

Required details for plate clips are:

- Plate thickness
- Weld size and details
- Dimensions of the clip

FIGURE 1
Clip Welded to Equipment *(1 July 2016)*

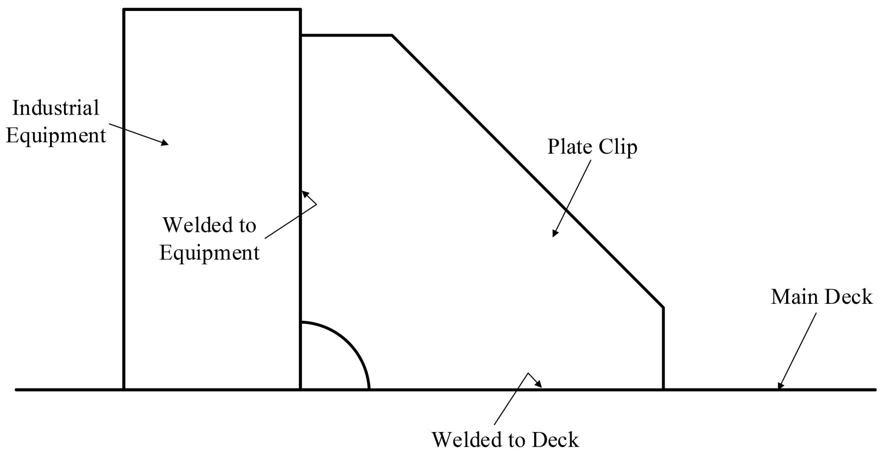
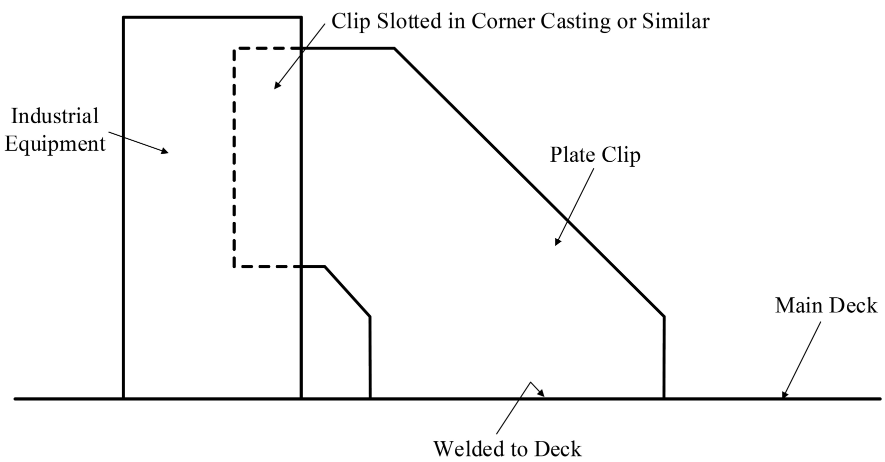


FIGURE 2
Clip Not Welded to Equipment *(1 July 2016)*



5.3.2 Lashings including Chain and Wire Rope

All chains, wire ropes, turnbuckles and all other pieces of lashing equipment being used are to comply with those approved in the vessel's Cargo Securing Manual, if one is provided. Securing devices not in the cargo securing manual may be used if details of them are provided.

When lashings are used, they are to be able to resist the forces of sliding, tipping, and vertical accelerations in their effective direction.

The effective direction of a lashing is defined in the IMO *Code of Safe Practice for Cargo Stowage and Securing (CSS Code) ANNEX 13* which provides reductions in working loads of devices based on the angles formed between the deck and cargo.

Required details for lashings are:

- Securing point on deck
- Securing point on the equipment
- Angle of the lash with respect to the deck and respect to the centerline of the vessel
- Material and type of lashing (i.e., Chain, wire rope, turnbuckle, shackles, etc.)
- Safe Working Load of lashings

5.3.3 ISO Fittings

ISO fitting means, any deck socket, twist lock, deck casting, or securing device which is ISO or type approved.

Where ISO fittings are used, cut sheets or manufacturer specifications of all parts are to be provided to ABS; or at a minimum the manufacturer and model are to be noted on the arrangement, securing drawing or furnished to ABS.

5.5 Weights

A static weight is to be provided to ABS for every piece of industrial equipment which exceeds the rated deck capacity. This weight should be noted on the drawing or provided in a separate document.

All weights are subject to motion based accelerations per the IMO *Code of Safe Practice for Cargo Stowage and Securing (CSS Code)*. The *CSS Code* provides not only vertical accelerations but also transverse and longitudinal sliding and tipping forces.

If the vendor or manufacturer of the equipment provides design loads, these loads are to incorporate accelerations consistent with the *CSS Code*.

5.7 Deck Contact Area, Skids and Mounting Frames

For all industrial equipment and cargo, the contact area to the deck is to be specified.

For equipment which sits on a skid or frame, details of the skid are to be provided, including identification of members and how the skid is secured to the deck as well as how the piece of equipment is secured to the skid or frame.

If the piece of equipment has integral contact points which are part of the design, then these contact areas are to be noted on the arrangement drawing. Additionally, vendor drawings, documents and details pertaining to the installation of industrial equipment are to be furnished to ABS if release is authorized by the vendor. Additional details and information may be requested to verify contact area.

Structural credit will not be given to a skid or frame on which industrial equipment is mounted. However, loads will be reasonably distributed along the contact area and appropriately applied to the deck and/or vessel structure.

5.9 Dynamic Loads

Dynamic loads are to be provided for any piece of equipment such as a cable reel, ROV frame, or any other piece of equipment which will deploy anything over the vessel side.

If the manufacture of such equipment provided design loads then this information is to be furnished to ABS. These design loads are to include dynamic forces for the equipment when it is in use. Generally, dynamic loads will exceed the accelerations applied to the static weight from the IMO *Code of Safe Practice for Cargo Stowage and Securing (CSS Code)*. Therefore these loads are to be applied to supporting members appropriately. If dynamic forces are included in the design loads it is at the discretion of ABS to determine whether the dynamic forces are sufficient per applicable rules and regulations.

7 Statutory

7.1 Ventilation

When any piece of equipment or independent tank is installed on deck, ventilation openings and their proximity to hazards and cargoes are to comply with the Section 5D-2-3 of the Rules as well as the applicable regulations, including the *International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code)* and IMO *Resolution A.673 (16)* and *IEC 60092-502.* When a piece of equipment or independent tank is installed on deck and modification is necessary to meet the applicable requirements, then a revised ventilation arrangement is to be submitted to ABS for review.

7.3 Doors, Windows and Hatches

When any piece of equipment or independent tank is installed on deck, doors, windows, hatches and other tonnage openings are to comply with the Section 5D-2-3 of the Rules as well and applicable regulations, to include their proximity to hazards or cargoes as defined in the rules and the *International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code)*, IMO *Resolution A.673 (16)* and *IEC 60092-502.* When a piece of equipment or independent tank is installed on deck and modification is necessary to meet the applicable requirements, then the appropriate revised plans arrangement is to be submitted to ABS for review.

Hatches which are not escape hatched and not normally used for access in normal operations which are in a hazardous zone, cargo area or any other area as defined in an applicable requirement or regulation, may be welded shut as a suitable means of securing them from access which industrial equipment or independent tanks are installed.

7.5 Fire Control Plans and Lifesaving

When industrial equipment is installed onboard and the equipment or module is fitted with a fire detection system or additional fire-fighting equipment, details of the system are to be included on the Fire Control Plan and submitted to ABS for review. Additionally, any modification to the vessel's Fire Control Plan as a result of the installation of industrial equipment is to be submitted to ABS for review.

If industrial equipment installed on deck contains products or hazards which either obstruct or interfere with embarkation stations, escape routes or other means of life saving are to be in accordance with *SOLAS* and the applicable regulations.

The vessel’s life-saving plan is to be amended to indicate installation and location of additional portable modular units. Surveyor is to endorse the onboard life-saving plan to indicate ABS verification.

9 Electrical

9.1 General

If industrial equipment or cargo is going to be tied into the vessel's electrical systems, then drawings showing the proposed modifications is to provided (i.e., Vessel One Line Diagram, etc.)

11 Mechanical and Piping

11.1 General

11.1.1 Hazardous Zone Plan

When equipment or tanks are installed on deck and they contain products as defined in the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code), IMO Resolution A.673 (16) and IEC 60092-502, then a hazardous zone plan is to submitted. The plan should include these areas as defined in the applicable regulations along with an electrical equipment register.

13 Equipment Designed for Specialized Work

Where equipment is installed for specialized work such as Oil Spill Recovery, Well Intervention or Stimulation, Fire Fighting, Safety Standby, Pipe Laying, Cable Laying, etc. and scope of work being done requires a Notation for the equipment to be utilized, then the appropriate Notation should be requested.

13.1 Reels and ROV Frames

ROVs and reels are to be in accordance with the appropriate sections as follows: ROVs and their frames are specified in Part 5D, Chapter 5, reels and their frames are specified in Part 5D, Chapter 8 for pipe laying and Part 5D, Chapter 15 for Cable Laying. Also, reference may be made to the ABS *Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities (Underwater Vehicles Rules).* This does not alleviate the necessity for a Class Notation for a permanent or long term installation.

This equipment is not only subject to accelerated loads but also dynamics loads during operation.

Typically, this type of equipment is designed to a maximum operating condition and therefore dynamic loads are likely incorporated in the vendor design. ABS understands that for confidentiality reasons, vendors may not provide design specifications including dynamic loads. In this case, if a vendor only provides uncoupled loads or reactions at contact areas, then ABS may request confirmation that dynamic loads were applied to the vendor supplied loads.

If a vendor does not provide dynamic loads and the uncoupled loads and reactions do not include dynamic loading, then it is the shipyard's responsibility to specify maximum operating sea state and dynamics loads which will affect the equipment.

15 Stability and Tonnage

Whenever industrial equipment is installed the ABS Tonnage and Load Line, and Stability Departments should be contacted for any implications which may be a result of the installation of the equipment.

17 Use and Occupancy of Industrial Equipment

Industrial Equipment and modules are to not be occupied in heavy weather conditions. For information about modules in which living accommodations are provided, please see the ABS *Guide for Portable Accommodation Modules*.

ABS may place other restrictions and conditions on the use and occupancy of the industrial equipment on a case-by-case basis and will take into account the purpose of the equipment and operating conditions.

PART 3

CHAPTER 3
Subdivision and Stability

CONTENTS

PART 3

CHAPTER 3
Subdivision and Stability

SECTION 1
General Requirements

1 Application Scope

i) Vessels of characters within the scope of 3-3-1/5.1 TABLE 1 are to meet the stability and subdivision criteria specified in the following sections, as applicable.

ii) In case the criteria listed in this Section are not applicable to a particular vessel, the intact and damage stability are to be reviewed by ABS in accordance with other recognized criteria appropriate to the vessel's type, size and intended service.

iii) Vessels that are configured as mobile offshore units are to comply with the subdivision and stability requirements of the ABS *Rules for Building and Classing Mobile Offshore Units (MOU Rules)*.

iv) In the situation where the stability review is conducted and found satisfactory by the flag State Administration, the stability information and calculations specified in the following sections need not be submitted.

v) Attained subdivision index "A" calculated by ABS in accordance with Regulation II-1/7 of SOLAS 1974 as amended is to be indicated in the *Record*.

3 Review Procedures *(1 July 2020)*

3.1 Submission of Plans

The following subdivision and stability drawings and documents, as applicable, are to be submitted for ABS review:

i) Trim and Stability Booklet or simplified guidance for Master

ii) General arrangement plan, with outboard profile

iii) Capacity plan or table with centers of gravity and free surface values for tanks and holds

iv) Lines plan

v) Tank Sounding Tables, if not included in the Trim and Stability Booklet.

vi) Cross curves of stability, if not included in the Trim and Stability Booklet.

vii) List of down-flooding points, including their transverse, longitudinal and vertical locations, used in the calculation of the intact and damage stability criteria.

viii) Draft Marks. Drawing showing the draft mark details, longitudinal locations of marks fore and aft referenced to the forward and after perpendiculars or to the nearest frames and vertical reference points. Navigational draft marks should be based on the vessel's lowest vertical projection.

ix) Intact and damage (if required) stability calculations supporting the max. KG or min. GM curve

x) Stability Test Procedure

xi) Stability Test Results

xii) Hydrostatic table, if not included in the Trim and Stability Booklet

3.3 Administration Review

3.3.1

Where the vessel is issued a certificate by the flag Administration or its agent other than ABS, such Certificate may be accepted as evidence that the vessel has subdivision and stability in accordance with the criteria in the respective Convention. Examples of these certificates are listed below:

- SOLAS Cargo Ship Safety Construction Certificate
- International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk
- International Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk
- International Load Line Certificate
- International Oil Pollution Prevention Certificate
- Passenger Ship Safety Certificate
- Cargo Ship Safety Construction Certificate

3.3.2

Where the Administration undertakes the review of subdivision and stability and ABS is issuing one or more of the above Certificates, the acceptance of subdivision and stability by the Administration is required before the certificate is issued.

3.5 ABS Review

In all other cases, the information and calculations for subdivision and stability are to be submitted to ABS for review.

5 Criteria

5.1 Intact Stability *(1 July 2020)*

Vessels of applicable size, type and service are to comply with the intact stability criteria as indicated in 3-3-1/5.1 TABLE 1.

TABLE 1
Vessel Intact Stability Criteria – Application Scope

Vessel Type, Size, & Characters	*Applicable Intact Stability Requirement*
All Vessels of applicable size, type and service	Regulation 10 of the International Convention on Load Lines (ICLL), intact stability guidance IMO Code on Intact Stability 2008, Part A, as applicable
Cargo Vessels [1,2]	IMO Code on Intact Stability 2008, Part A, as applicable

Vessel Type, Size, & Characters	*Applicable Intact Stability Requirement*
Tankers [1,3]	Regulation 27 in Annex I of the International Convention for Prevention of Pollution from Ships, 1973/1978, as amended.
Tankers[1,4]	ABS Rules, Appendix 3-3-A1
Offshore Support Vessels [1] • General requirements • Anchor handling vessels • Towing Vessels • Heavy lifting vessels	ABS Rules, Appendix 3-3-A2 • 3-3-A2/11 • Additional requirements in 3-3-A2/13 • Additional requirements in 3-3-A2/15 • Additional requirements in 3-3-A2/17
Fishing Vessels under 90 Meters (295 Feet)	IMO Code on Intact Stability 2008, Part B, Section 2.1.3.1 (see Appendix 3-3-A3)

Notes:

1 Vessels for which load line is not required; however intact stability is performed for classification purpose.

2 Cargo vessels of 24 m (79 ft.) in length and over with or without deck cargo

3 Tankers of 5,000 deadweight tonnes (4921 Ltons) and above delivered on or after 1 February 2002 or for which the building contract is placed on or after 1 February 1999 or, in the absence of a building contract, the keels of which are laid or which are in a similar stage of construction on or after 1 August 1999.

4 Tankers for which Regulation 27 in Annex I of the International Convention for Prevention of Pollution from Ships, 1973/1978 is not applicable.

5.3 Subdivision and Damage Stability

Vessels of applicable size, type and service are to comply with the subdivision and damage stability criteria as indicated in 3-3-1/5.1 TABLE 1:

TABLE 2
Vessel Subdivision and Damage Stability Criteria – Application Scope

Vessel Type, Size, & Characters	*Applicable Damage Stability Requirement*
Passenger Vessels[1,2]	SOLAS Regulation II-1 Parts B, B-1, and B-2, as amended (ABS Rules Section 5C-7-3)
Cargo Vessels[1]	SOLAS Regulation II-1 Parts B, B-1, and B-2, as amended
Oil Tankers[1]	Regulation 28 in Annex I to MARPOL 73/78, as amended
Gas Carriers[1]	IGC Code (ABS Rules Section 5C-8-2)
Chemical Carriers[1]	IBC Code (ABS Rules Section 5C-9-2)
Bulk Carriers [3]	ABS Rules, Appendix 5C-8-2
Offshore Support Vessels [1,4]	***i)*** Less than 100M in length - IMO Guidelines for the Design and Construction of Offshore Supply Vessels 2008, as amended ***ii)*** Greater than 100M in length - SOLAS Chapter II-1, Parts B, B-1, and B-2, as amended

Vessel Type, Size, & Characters	*Applicable Damage Stability Requirement*
All other Offshore Supply Vessels – General • Special purpose ships (5)	ABS Rules, Appendix 3-3-A5 • 3-3-A5/5.3
Fishing Vessels	ABS Rules, Appendix 3-3-A6 "Damage Stability Requirements for Fishing Vessels"

Notes:

1 Vessels of applicable size, type and service are to have subdivision and damage stability as required by the International Convention for the Safety of Life at Sea (SOLAS), 1974, as amended.

2 Definition of Passenger vessels, refer to Section 5C-1-1,

3 Bulk carriers for which the request for class for new construction is received on or after 1 July 1998

4 Offshore Support Vessel of 80 m (262 ft) or more in subdivision length

5 Special purpose offshore supply vessels in carrying more than twelve special personnel or for special purpose

5.5 Carriage of Hazardous and Noxious Liquid Substances

Where it is intended to carry limited amounts (the lesser of 800 m^3 or a volume in cubic meters equal to 40% of the vessel's deadweight calculated at a cargo density of 1.0) of hazardous and noxious liquid substances in bulk on offshore support vessels, the arrangement is to comply with IMO Resolution A.673 (16), "Guidelines for the Transport and Handling of Limited Amounts of Hazardous and Noxious Liquid Substances in Bulk in Offshore Support Vessels" as amended by IMO Resolutions MSC.236(82) and MEPC.158(55).

Where the amount of hazardous and noxious liquid substances carried is greater than the lesser of 800 m^3 or a volume in cubic meters equal to 40% of the vessel's deadweight calculated at a cargo density of 1.0, the vessel shall comply with the survival capability requirements of Chapter 2 of the International Bulk Chemical Code or the International Gas Carrier Code.

Consideration will be given to the arrangement which complies with the published requirements of the flag Administration.

5.7 Intact Stability for Anchor Handling/Towing Vessels

Each vessel receiving a towing notation is to comply with the additional intact stability criteria in 3-3-A2/13 and 3-3-A2/17.

5.9 Intact Stability for Vessels Equipped with Lifting Appliances

Each vessel equipped to lift loads is to comply with the additional intact stability criteria in 3-3-A2/17.

7 Lightship Determination *(1 July 2020)*

7.1

Upon completion, each vessel is to undergo an inclining experiment to determine the actual displacement and position of the center of gravity for the lightship condition. The inclining experiment is to be conducted in accordance with Part B Chapter 8 and Annex 1 of the 2008 Intact Stability Code and ASTM Standard F-1321-14, "*Standard Guide for Conducting a Stability Test (Lightweight Survey and Inclining Experiment) to Determine the Light Ship Displacement and Centers of Gravity of a Vessel*"

7.3

If the inclining experiment results on the initial vessel in a series have been approved, the inclining experiment required by 3-3-1/7.1 may be waived provided that, for each sister vessel (built to the same plans), the weights and centers of any known differences are documented and a lightweight survey is conducted to confirm the effects of the differences on the lightship characteristics.

7.5

If it can be demonstrated that the performance of an inclining experiment is not practicable or safe or yields inaccurate results due to the specific proportions, arrangements, strength or hull of a ship, the vessel's lightship characteristics may be determined by a detailed weight estimate confirmed by a lightweight survey. A formal request for an inclining experiment waiver shall be made to ABS technical office and shall include the technical justification for the request.

7.7

Prior to the performance of each inclining experiment or lightweight survey, a test procedure shall be submitted for approval. The procedure shall include the following data, as applicable:

- Identification of the vessel to be inclined.
- Date and location of the experiment.
- Inclining weight data.
- Pendulum locations and lengths. Alternate measuring devices may be proposed for use.
- Approximate draft and trim of the vessel, including location of draft and freeboard readings.
- Condition of each tank.
- Estimated items to be installed, removed, or relocated after the experiment, including the weight and location of each item.
- Schedule of the test.
- Details of weight movements
- Person or persons responsible for conducting the experiment.

7.9

Each inclining experiment and lightweight survey must be performed in the presence of an ABS Surveyor and in accordance with the approved experiment procedure.

7.11 Vessels Undergoing Modifications

For vessels undergoing modifications, the lightship values may be approved without conducting a lightweight survey or inclining experiment if the submitted detailed weight calculation shows a change in both lightship weight and LCG of less than shown below.

i) Lightship LCG, relative to the approved lightship data determined by an inclining test or lightweight survey, is not to exceed 0.5% of L***, Lightship VCG, when compared to the approved value is not to exceed 1%, and Lightship displacement, corrected for any known differences relative to the inclined vessel, is not to exceed:

2% of the lightship displacement from the approved lightship data determined by the inclining test or lightweight survey

ii) Where a ship is within these limits, the calculated values of lightweight, lightship LCG and lightship VCG should be used in all subsequent stability information supplied to the Master.

iii) When a ship does not exceed the deviation limits specified in ii above, amended stability information should be provided to the master using the new calculated lightship properties if any of the following deviations from the approved values are exceeded:

a) 1% of the Lightship displacement; or *b)* 0.5% of L for the LCG; or

c) 0.5% of the VCG

iv) Where a ship is outside of either of the limits in ii above, an inclining experiment is to be performed to determine the new lightship values that will be used in all subsequent stability information supplied to the Master.

*** Length (L) is the length as defined in the International Convention on Load Lines in force.

9 Free Surface *(1 July 2020)*

For all loading conditions, the initial metacentric height and the righting arm curve should be corrected for the effect of free surfaces of liquids in tanks.

9.1

In determining the correction to initial metacentric height, the transverse moments of inertia of the tanks should be calculated at 0° angle of heel according to the categories indicated in 3-3-1/9.5 i) and ii) below.

9.3

The righting arm 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; or
- Correction based on the moment of inertia, calculated at 0° angle of heel, modified at each angle of heel calculated.

9.5

Free surface shall be included as follows:

i) For slack, non-consumable tanks (e.g., liquid cargo, water ballast) with filling levels that do not change during the voyage, the free surface correction should be defined for the actual filling level of each tank.

ii) For tanks with variable filling levels (e.g., consumable liquids such as fuel oil, diesel oil and fresh water, and also liquid cargo and water ballast during liquid transfer operations), the free surface correction, except as permitted in iv) and v), should be the maximum value attainable between the filing limits envisaged for each tank, consistent with any operating instructions.

iii) For each type of consumable liquid, the maximum free surface of at least one transverse pair of tanks or a single centerline tank shall be included. The tank or tanks to be taken into account should be those where the effect of free surface is the greatest.

iv) Where water ballast tanks, including roll reduction and anti-heeling tanks, are to be filled and discharged during the course of the voyage, the free surface effects should be calculated to take account of the most onerous transitory stage relating to such operations.

v) During liquid transfer operations, the free surface effects should be calculated to take account of the most onerous transitory stage relating to such operations.

11 Standard Loading Conditions *(1 July 2020)*

The following conditions of loading are to be examined in the Trim and Stability Booklet:

i) Vessel at the maximum Load Line draft, with full stores and fuel and fully loaded with cargo corresponding to the worst service departure condition in which all the relevant stability criteria are met.

ii) Vessel with 10% stores and fuel and fully loaded cargoes of i) above, arrival condition.

iii) Vessel with full stores and fuel in ballast departure condition.

iv) Vessel with 10% stores and fuel in ballast arrival condition.

v) Vessel in the worst anticipated operating condition (i.e., arrival condition with deck cargo only – 100% deck cargo with 10% stores and fuel).

vi) Other loading conditions applicable to a vessel in a particular service (i.e., offshore support vessels, fishing vessels)

On a case-by-case basis, specific loading conditions may be excluded if it can be shown that the conditions are not applicable to a specific vessel type and/or operation.

13 Trim and Stability Booklet *(1 July 2020)*

13.1 *(1 July 2020)*

Operating guidance for the Master is to be provided in a Trim and Stability Booklet.

13.3 *(1 July 2020)*

Each trim and stability book is to contain sufficient information to enable the Master to operate the vessel in compliance with the applicable intact and damage stability requirements in Section 3-3-1. Information on loading restrictions used to determine compliance with applicable intact and damage stability criteria is to encompass the entire range of operating drafts and the entire range of the operating trims.

13.5 *(1 July 2020)*

The format of the trim and stability booklet and the information included will vary dependent on the vessel type and operation. Units of measure used in the trim and stability booklet are to agree with the units of measure of the draft markings.

13.7 *(1 July 2020)*

In developing the trim and stability booklet, consideration is to be given to including the following information:

i) A table of contents and index for the booklet. All pages are to be numbered.

ii) A general description of the vessel, including identification, lightship data, amount and location of fixed ballast, vessel principal dimensions, Load Line draft, freeboard and allowances, maximum displacement and deadweight, etc.

iii) A brief description of the stability criteria satisfied including assumptions made in the calculations.

iv) Instructions on the use of the booklet.

v) General arrangement plans showing watertight compartments, closures, vents, down-flooding angles, and allowable deck loadings.

vi) Hydrostatic curves or tables.

vii) Cross Curves of stability

viii) Capacity plan showing capacities and vertical, longitudinal, and transverse centers of gravity of stowage spaces and tanks.

ix) Draft Marks Drawing showing the draft mark details, longitudinal locations of marks fore and aft referenced to the forward and after perpendiculars or to the nearest frames and vertical reference points. Navigational draft marks should be based on the vessel's lowest vertical projection.

x) Tank sounding/ullage tables showing capacities, vertical centers of gravity, longitudinal centers of gravity and free surface data in graduated intervals for each tank. This may be submitted as a separate document.

xi) Information on loading restrictions, such as a maximum KG or minimum GM curve that can be used to determine compliance with applicable intact and damage stability criteria.

xii) In addition to the standard loading conditions in 3-3-1/11, loading conditions showing vessel specific operations (lifting, towing, etc.) also are to be included.

xiii) A rapid and simple means for evaluating the trim and stability of other loading conditions. This should include clear, step by step instructions for the calculation and evaluation of the loading condition, blank loading forms, and a worked example.

xiv) General precautions for preventing unintentional flooding.

xv) References to the Damage Control Booklet and/or Cargo Securing Manual, as applicable.

xvi) Any other necessary guidance for the safe operation of the vessel under normal and emergency conditions (i.e., required liquid ballast, fuel burn-off sequence, maximum cargo height, crane loads, etc.).

xvii) The inclining experiment report may be included as an appendix.

15 Damage Control Information

15.1 General

A plan showing clearly for each deck and hold and boundaries of the watertight compartments, the openings therein with the means of closure and position of any controls thereof, and the arrangements for the correction of any list due to flooding, is to be permanently exhibited or readily available on the navigation bridge for the guidance of the officer in charge of the vessel. Furthermore, the damage control plan is to be permanently exhibited or readily available on the bridge, in the cargo control room, machinery control room, and engineering office.

In addition, booklets containing the aforementioned information are to be made available to the officers of the vessel.

The damage control plan and damage control booklet are to be clear and easy to understand. Information which is not directly relevant to damage control is not to be included.

General precautions to be included are consisting of a listing of equipment, conditions, and operational procedures considered being necessary to maintain watertight integrity under normal ship operations.

Specific precautions to be included are consisting of a listing of elements (i.e., closures, security of cargo, sounding of alarms, etc.) considered to be vital to the survival of the ship and crew.

For ships to which the damage stability requirements of SOLAS 1974 as amended apply, damage stability information is to be provided in a simple and easily understandable way of assessing the ship's survivability in the anticipated damage cases involving a compartment or group of compartments.

15.3 Damage Control Plan

The damage control plan is to be of a scale adequate to show clearly the required content of the plan.

The plan is to include inboard profile, plan views of each deck and transverse sections to the extent necessary to show the following:

i) The watertight boundaries of the ship;

ii) The locations and arrangement of cross-flooding systems, blow-out plugs and any mechanical means to correct list due to flooding, together with the locations of all valves and remote controls, if any;

iii) The locations of all internal watertight closing appliances including, on ro-ro ships, internal ramps or doors acting as extension of the collision bulkhead and their controls and the locations of their local and remote controls, position indicators and alarms . The locations of those watertight closing appliances which are not allowed to be opened during the navigation and of those watertight closing appliances which are allowed to be opened during navigation, according to the regulation II-1/22.4 of SOLAS 1974 as amended , are to be clearly indicated;

iv) The locations of all doors in the shell of the ship, including position indicators, leakage detection and surveillance devices;

v) The locations of all external watertight closing appliances in cargo ships, position indicators and alarms;

vi) The locations of all weather-tight closing appliances in local subdivision boundaries above the bulkhead deck and on the lowest exposed weather decks, together with locations of controls and position indicators, if applicable; and

vii) The locations of all bilge and ballast pumps, their control positions and associated valves.

15.5 Damage Control Booklet

The information listed in the damage control plan is to be repeated in the damage control booklet.

The damage control booklet is to include general instructions for controlling the effects of damage, such as:

i) Immediately closing all watertight and weather-tight closing appliances;

ii) Establishing the locations and safety of persons on board, sounding tanks and compartments to ascertain the extent of damage and repeated soundings to determine rates of flooding; and

iii) Cautionary advice regarding the cause of any list and of liquid transfer operations to lessen list or trim, and the resulting effects of creating additional free surfaces and of initiating pumping operations to control the ingress of water.

The booklet is to contain additional details to the information shown on the damage control plan, such as the locations of flooding detection systems, sounding devices, tank vents and overflows which do not extend above the weather deck, pump capacities, piping diagrams, instructions for operating cross-flooding systems, means of accessing and escaping from watertight compartments below the bulkhead deck for use by damage control parties, and alerting ship management and other organizations to stand by and co-ordinate assistance, if required.

If applicable to the ship, locations of non-watertight openings with non-automatic closing devices through which progressive flooding might occur are to be indicated as well as guidance on the possibility of non-structural bulkheads and doors or other obstructions retarding the flow of entering seawater to cause at least temporary conditions of unsymmetrical flooding.

Where the results of the subdivision and damage stability analyses are included, additional guidance is to be provided for the crew to be aware that the analysis results are only for assisting them in estimating the ship's relative survivability.

The guidance is to indicate the criteria on which the analyses were based and clearly indicate that the initial conditions of the ship's loading extents and locations of damage, permeability, assumed for the analyses may have no correlation with the actual damaged condition of the ship.

17 Onboard Computers for Stability Calculations

Except for the vessels indicated below, the use of onboard computers for stability calculations is not a requirement of class. However, if stability software is installed onboard vessels contracted on or after 1 July 2005, it is required to cover all stability requirements applicable to the vessel and is to be approved by

ABS for compliance with the requirements of Appendix 3-3-A7, “Computer Software for Onboard Stability Calculations”.

Tanker, including oil carriers, fuel oil carriers, gas carriers, and chemical carriers are to be fitted with a stability instrument which uses approved stability software capable of verifying compliance with the applicable intact and damage stability requirements. This requirement may be waived for the following tankers if loaded in accordance with the approved conditions in the trim and stability booklet:

- Tankers on a dedicated service, with a limited number of permutations of loading
- Tankers where stability verifications is made remotely by a means approved by the Administration
- Tankers loaded within an approved range of loading conditions

See also 5C-8-2/2.6, 5C-8-2/2.7, 5C-9-2/2.6, and 5C-9-2/2.7.

PART 3

CHAPTER 3

Subdivision and Stability

APPENDIX 1

Intact Stability of Tankers During Liquid Transfer Operations

1 General

1.1 Note:

The following requirements as specified in 3-3-1/5.1 for tankers (i.e., vessels designed to carry liquid in bulk) are developed from MSC/Circ. 706 (MEPC/Circ. 304), which contains recommendations for existing oil tankers. The phenomenon of lolling is considered to be a safety issue for double hull tankers, as well as for other tankers having exceptionally wide cargo tanks (i.e. having cargo tank breadths greater than 60% of the vessel's maximum beam), which should be solved for every vulnerable tanker. The solution should not be limited only to tankers subject to MARPOL.

1.3 Operations to be Addressed

The Appendix applies to any tanker that is not subject to MARPOL Convention Annex I Regulation 27. Alternatively, such tankers may comply with MARPOL Convention Annex I Regulation 27.

3

Every tanker is to comply with the intact stability criteria specified in 3-3-A1/3.1 and 3-3-A1/3.3 for any operating draft reflecting actual, partial or full load conditions, including the intermediate stages of liquid transfer operations.

Liquid transfer operations include cargo loading and unloading, ballasting and deballasting, ballast water exchange and tank cleaning operations.

3.1

In port, the initial metacentric height GM_o, corrected for free surface measured at 0 degree heel, is not to be less than 0.15 m (0.5 ft).

3.3

At sea, the intact stability criteria contained in Part A paragraphs 2.2.1 to 2.2.4 of the IMO International Code on Intact Stability 2008 are applicable, or the criteria contained in the national requirements of the flag administration if the national stability requirements provide at least an equivalent degree of safety.

5

For all loading conditions in port and at sea, including intermediate stages of liquid transfer operations, the initial metacentric height and the righting lever curve are to be corrected for the effect of free surfaces of liquids in tanks. Reference may be made to the Unified Interpretation LL61 Method of Correction for the Effect of Free Surface of Liquids in Tanks, set out by the International Association of Classification Societies.

7

The intact stability criteria specified in 3-3-A1/3 preferably is to be met by design of the vessel, i.e., the design should allow for maximum free surface effects in all cargo, ballast and consumables tanks during liquid transfer operations.

9

If the intact stability criteria specified in 3-3-A1/3 are not met through design of the vessel alone, the Master is to be provided with clear instructions covering the operational restrictions and methods necessary to ensure compliance with these criteria during liquid transfer operations. These instructions should be simple and concise, and:

9.1

In a language understood by the officer-in-charge of transfer operations;

9.3

Require no more than minimal mathematical calculations by the officer-in-charge;

9.5

Indicate the maximum number of cargo and ballast tanks which may be slack under any possible condition of liquid transfer;

9.7

Provide pre-planned sequences of cargo/ballast transfer operations, which indicate the cargo and ballast tanks which may be slack to satisfy the stability criteria under any specific condition of liquid transfer, including possible range of cargo densities. The slack tanks may vary during stages of the transfer operations and be any combination which satisfies the stability criteria;

9.9

Provide instructions for pre-planning other sequences of cargo/ballast transfer operations, including use of stability performance criteria in graphical or tabular form which enable comparisons of required and attained stability. These instructions for pre-planning other sequences, in relation to individual vessels, should take account of:

i) The degree of criticality with respect to the number of tanks which can simultaneously have maximum free surface effects at any stage of liquid transfer operations;

ii) The means provided to the officer-in-charge to monitor and assess the effects on stability and hull strength throughout the transfer operations;

iii) The need to give sufficient warning of an impending critical condition by reference to suitable margins (and the rate and direction of change) of the appropriate stability and hull strength parameters. If appropriate, the instructions should include safe procedures for suspending transfer operations until a suitable plan of remedial action has been evaluated.

iv) The use of on-line shipboard computer systems, where fitted, during all liquid transfer operations, processing cargo and ballast tank ullage data and cargo densities to continuously monitor the vessel's stability and hull strength and, when necessary, to provide effective warning of an impending critical situation, possibly automatic shut-down, and evaluation of possible remedial actions;

9.11

Provide for corrective actions to be taken by the officer-in-charge in case of unexpected thecnical difficulties with the recommended pre-planned transfer operations and in case of emergency situations. A general reference to the vessel's shipboard oil pollution emergency plan may be included; and

9.13

the instructions required above be prominently displayed:

i) In the approved trim and stability booklets;

ii) At the cargo/ballast transfer control station;

iii) In any computer software by which intact stability is monitored or calculations performed;

iv) In any computer software by which hull strength is monitored or calculations performed.

PART 3

CHAPTER 3

Subdivision and Stability

APPENDIX 2

Intact Stability Requirements for Offshore Support Vessels

1 General

For every loading condition, which is to be shown in the Trim and Stability Booklet, the righting arm curve (GZ curve) is to be plotted using the VCG corrected for the free surface effects of liquid in tanks.

3 Criteria

3.1 General Criteria

The following stability criteria are to be complied with:

i) The area under the righting lever curve (GZ curve) should not be less than 0.055 meter-radians (10.3 ft-degrees) up to $\theta = 30°$ angle of heel and not less than 0.09 meter-radians (16.9 ft-degrees) up to $\theta = 40°$ or the angle of flooding, 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 (θ_f) is less than 40°, is not to be less than 0.03 meter-radians (5.6 ft-degrees).

ii) The righting lever GZ is to be at least 0.20 m (0.66 ft) at an angle of heel equal to or greater than 30°.

iii) The maximum righting arm is to occur at an angle of heel not less than 25°.

iv) The initial metacentric height, GM_0, is not to be less than 0.15 m (0.49 ft).

3.3 Severe Wind and Rolling Criterion

In addition to 3-3-A2/3.1, The Severe Wind and Rolling Criterion in Part A, Section 2.3 of the 2008 Intact Stability Code is to be complied with. Where the vessel's characteristics render compliance with this criteria impracticable, consideration will be given for compliance with another published weather criteria.

3.5 Alternative Criteria for Offshore Support Vessels

For vessels of 24 m (79 ft) in length and over but not more than 100 m (328 ft) in length where the vessel's characteristics render compliance with 3-3-A2/3.1 impracticable, the following alternative criteria are to be complied with. For vessels greater than 100 m (328 ft) in length where the vessel's characteristics render compliance with 3-3-A2/3.1 impracticable, consideration will be given for compliance with the following alternative criteria. The alternative criteria is not applicable to Special Purpose Ships greater than 100 m (328 ft) in length.

i) The area under the curve of righting levers (GZ curve) is not to be less than 0.070 meter-radians (13.2 ft-degrees) up to an angle of 15° when the maximum righting lever (GZ) occurs at 15° and 0.055 meter-radians (10.3 ft-degrees) up to an angle of 30° when the maximum righting lever (GZ) occurs at 30° or above. Where the maximum righting lever (GZ) occurs at angles of between 15° and 30°, the corresponding area under the righting lever curve is to be:

$0.055 + 0.001(30° - \theta_{max}**)$ meter-radians

$10.3 + 0.187(30° - \theta_{max}**)$ feet-degrees

ii) 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 (θ_f) is less than 40°, is not to be less than 0.03 meter-radians (5.6 ft-degrees).

iii) The righting lever (GZ) is to be at least 0.20 m (0.66 ft) at an angle of heel equal to or greater than 30°.

iv) The maximum righting lever (GZ) is to occur at an angle of heel not less than 15°.

v) The initial transverse metacentric height (GM_0) is not to be less than 0.15 m (0.49 ft).

* θ_f is the angle of heel in degrees at which openings in the hull, superstructure 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_{max} is the angle of heel in degrees at which the righting lever curve reaches its maximum.

5 Standard Loading Conditions

The following conditions of loading are to be examined in the Trim and Stability Booklet:

i) Vessel at the maximum Load Line draft, with full stores and fuel and fully loaded with all liquid and dry cargo distributed below deck and with remaining deadweight distributed as above deck cargo (specified by weight, LCG, VCG and total height above deck) corresponding to the worst service departure condition in which all the relevant stability criteria are met.

ii) Vessel with 10% stores and fuel and fully loaded cargoes of i) above, arrival condition.

iii) Vessel with full stores and fuel and loaded with the maximum design deck cargo (specified by weight, LCG, VCG and total height above deck) and with remaining deadweight distributed below deck in liquid and dry cargo spaces corresponding to the worst service departure condition in which all the relevant stability criteria are met.

iv) Vessel with 10% stores and fuel and fully loaded cargoes of iii) above, arrival condition.

v) Vessel with full stores and fuel in ballast departure condition.

vi) Vessel with 10% stores and fuel in ballast arrival condition.

vii) Vessel in the worst anticipated operating condition (i.e., arrival condition with deck cargo only – 100% deck cargo with 10% stores and fuel).

On a case-by-case basis, specific loading conditions may be excluded if it can be shown that the conditions are not applicable to a specific vessel type and/or operation.

7 Carriage of Pipe as Deck Cargo

Where pipes are carried on deck, a quantity of trapped water equal to a certain percentage of the net volume of the pipe deck cargo should be assumed in and around the pipes. The net volume is to be taken as the internal volume of the pipes, plus the volume between the pipes. This percentage is to be 30% if the freeboard amidships is equal to or less than 0.015*L* and 10% if the free board amidships is equal to or greater than $0.03L$. For intermediate values of the freeboard amidships, the percentage is to be obtained by linear interpolation. In assessing the quantity of trapped water, the positive or negative sheer aft, actual trim and area of operation may be taken into account.

Where pipe is stored on decks located above the freeboard deck, the distance from the freeboard deck to the storage deck is to be added to the freeboard in the above calculation to determine the amount of trapped water.

9 Icing

For vessels operating in areas where ice accretion is likely to occur, icing allowances should be included in the analysis of conditions of loading. The following guidance may be used:

i) The vessel's stability is to be investigated in the worst conditions of loading.

ii) In the absence of area specific ice accretion data, the following ice accretion may be applied:

- The weight of ice on all horizontal surfaces is to be at least 30 kg/m^2 (6.14 lbs/ft^2).
- The weight of ice of the projected vertical area above the waterline is to be at least 15 kg/m^2 (3.07 lbs/ft^2). This accounts for 7.5 kg/m^2 (1.54 lbs/ft^2) on both the port and starboard vertical surfaces.
- Plans showing projected horizontal and vertical areas are to be submitted.

iii) The height of the center of gravity of the accumulated ice is to be located according to the position of the corresponding horizontal surfaces (decks and gangways) and other continuous surfaces on which ice can reasonably be expected to accumulate. The projected lateral area of small discontinuous surfaces such as rails, spars, and rigging with no sails can be accounted for by increasing the calculated area by 5 percent and the static moments of the area by 10 percent.

iv) The icing accretion assumptions, along with guidance for the avoidance of icing conditions, reduction and removal of ice and other actions to ensure the safety of the vessel during icing conditions are to be included in the Trim and Stability Booklet. Section 3 of Annex 2 of the IMO Code on Intact Stability contains operational guidance for fishing vessels during ice accretion and may be used as a reference.

11 Submission of Plans

11.1 Note

Stability calculations and corresponding information for the Master are to be submitted for review and approval. The submission of evidence showing approval by an Administration of stability of the vessel in accordance with the SPS Code may be acceptable.

11.3 Criteria

i) In general, special purpose OSVs are to comply with intact stability of Section 3-3-1 and 3-3-A2/11, as applicable.

ii) The alternative criteria given in 3-3-A2/3.5 may be used for special purpose ships of less than 100 m (328 ft) in length of similar design and characteristics.

13 Additional Criteria for Anchor Handling Vessels

13.1 Intact Stability

For vessels that are used for anchor handling and which at the same time are utilizing their towing capacity and/or tractive power of the winches, calculations are to be made showing the acceptable vertical and horizontal transverse force/tension to which the vessel can be exposed. The calculations are to consider the most unfavorable conditions for vertical and transverse force/tension and as a minimum include the following:

i) Calculations are to be made for the maximum acceptable tension in wire/chain, including the maximum acceptable transverse force/tension that can be accepted in order for the vessel's maximum heeling to be limited to one of the following angles, whichever occurs first:

- Heeling angle equivalent to a GZ value equal to 50% of GZ max
- The angle which results in water on working deck when the deck is calculated as flat
- 15 degrees

ii) The heeling moment is to be calculated as the total effect of the horizontal and vertical transverse components of force/tension in the wire or the chain. The torque arm of the horizontal components is to be calculated as the distance from the height of the work deck at the guide pins to the center of main propulsion propeller or to center of stern side propeller where this projects deeper. The torque arm of the vertical components is to be calculated from the center of the outer edge of the stern roller and with a vertical straining point on the upper edge of the stern roller.

13.3 Loading Conditions

The following loading conditions intended for anchor handling are to be examined in the Trim and Stability Booklet:

i) Vessel at the maximum Load Line draft, with full stores and fuel and fully loaded with all liquid and dry cargo distributed below deck and with remaining deadweight distributed as above deck weight (anchors, chain, etc., specified by weight, LCG, VCG and total height above deck) corresponding to the worst service departure condition in which all the relevant stability criteria are met.

ii) Vessel with 10% stores and fuel and fully loaded cargoes of i) above, arrival condition.

iii) Vessel at the maximum Load Line draft, with full stores, a full set of rig anchors on deck to be deployed during single trip (and rig chains, where appropriate) and fuel loaded to the maximum deadweight, corresponding to the worst service departure condition in which all the relevant stability criteria are met.

iv) Vessel with 10% stores and fuel and fully loaded cargoes of iii) above, arrival condition.

v) Vessel in worst anticipated operating condition.

These conditions are to include the following items:

- The loads on the deck (including the weight of anchors, chains and lines) and winch reels (loaded with heaviest possible line types).
- The vertical force from the tension, upon which calculations of trim and curve for righting arm are based. • The weight of the anchors and lines.
- The righting arm curve (GZ curve) is to be plotted using the VCG corrected for the free surface of all slack tanks (see 3-3-1/9), including any roll reduction tanks in use. Consideration is to be given to fuel oil and fresh water used as well as any ballast water necessary during the operations.
- Where the vessel is fitted with rig chain locker(s) below the main deck, the opening(s) is to be considered as a downflooding point for the stability calculations in 3-3-A2/13 and 3-3-A2/15.3.
- Where the vessel is fitted with open rig chain lockers on the main deck, effective means to drain these lockers are to be provided. Where not, the lockers are to be considered flooded and the appropriate free surface effects included in all stability calculations.

13.5 Stability Guidance for the Master

The trim and stability booklet, required by 3-3-1/15, is to include the following guidance:

i) Information stating the maximum force/tension in wire or chain, as well as corresponding lateral point of direction according to the calculations, is to be provided in the trim and stability booklet and be displayed next to the control desk or at another location where the navigator on duty easily can see the information from his command post.

ii) The displayed information is to be in the form of simple sketches showing the vessel's righting moment/arm curves in addition to a table stating the relevant combinations of force/tension and point of direction which gives the maximum acceptable heeling moment.

iii) Any tank restrictions (i.e. ballast tank and/or roll reduction tank usage, fuel oil burn off sequences, etc.) determined by the stability calculations.

During anchor handling operations, all weather-tight access and emergency hatches, and doors on the work deck, are to be kept closed, except when actually being used for transit under safe conditions.

15 Additional Criteria for Towing Vessels

15.1 Criteria *(1 July 2020)*

The intact stability of each vessel receiving a towing notation is to be evaluated for all towing conditions, demonstrating compliance with the IMO Code on Intact Stability 2008, as amended by IMO Res.MSC.415(97) for ships engaged in towing operations.

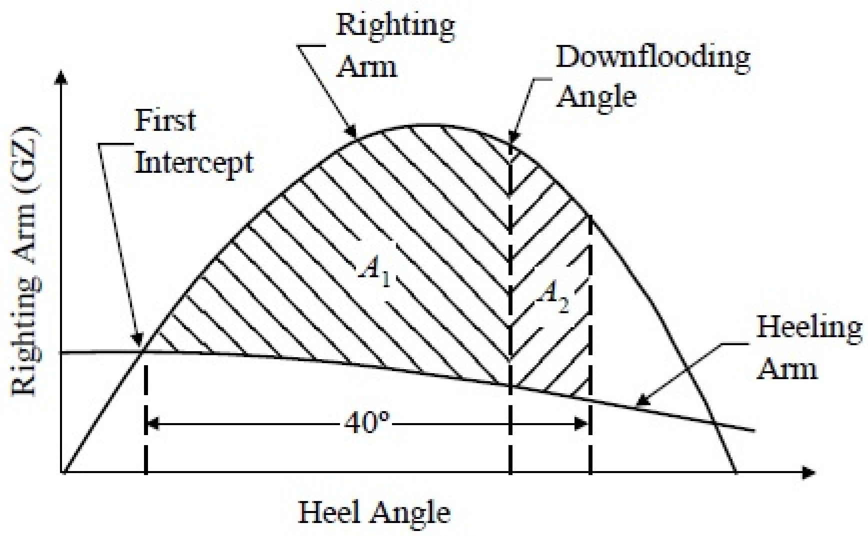
Alternatively, the intact stability criteria in 3-3-A2/15.3, may be used where a vessel is not subject to the IMO Code on Intact Stability 2008.

The results of the analysis are to be submitted for review.

15.3 Towing Operating

The heeling arm curve due to towline pull is to be calculated in accordance with 3-3-A2/15.5. The area of the residual dynamic stability (area between righting and heeling arm curves beyond the angle of the first intercept) up to an angle of heel of 40° beyond the angle of the first intercept ($A_1 + A_2$), or the angle of downflooding, Where this angle is less than 40° beyond the angle of the first intercept (A_1), is not to be less than 0.09 meter-radians. (See 3-3-A2/15.3 FIGURE 1)

FIGURE 1
Righting Arm and Heeling Arm Curves



15.5 Heeling Arm Curve

The towline pull force is to be calculated using the corresponding percentage of the maximum bollard pull force, depending on the type of propulsion (see 3-3-A2/15.5 TABLE 1), at right angles to the vessel's fore and aft axes. The heeling moment due to towline pull are to be calculated by multiplying the towline pull force by the distance from the top of the towing bitt to the intersection of propeller shaft centerline and rudder axis. The resultant moment are to be converted to a heeling arm and plotted on the same graph as the righting arm/GZ curve (corrected for free surface). The heeling arm curve can be taken to vary with the cosine of the heeling angle.

The bollard pull force is to be derived from the actual test. For the purposes of preliminary stability evaluations prior to the bollard pull test, the bollard pull force may be estimated, depending on the type of propulsion and shaft power (SHP), as per 3-3-A2/15.5 TABLE 1.

TABLE 1
Towline Pull Force

Type of Propulsion	*Towline Pull Force as Percentage of Max Bollard Pull Force*	*Bollard Pull Force Estimate based on Shaft Power kN/kW (tf/kW, lbs/SHP)*
Twin screw with open propellers, or other types not listed below	50%	5029 (513, 30)
Twin screw with open propellers and flank rudders	50%	5029 (513, 30)
Twin screw with conventional non-movable nozzles	50%	5867 (598, 35)
Water Tractor Tug with twin propeller Z-drives (steerable propellers with nozzles)	70%	5867 (598, 35)
Water Tractor with twin cycloidal propellers (vertical axis)	70%	5029 (513, 30)

15.7 Stability Guidance for the Master

The Master of the vessel is to receive information in the Trim and Stability Booklet regarding cargo and/or ballast limitations, list of protected flooding openings that need to be kept closed, wind and/or wave restrictions, etc., necessary to ensure that the stability is in compliance with the criteria given in 3-3-A2/15.3.

Where any loading condition requires water ballast for compliance with the criteria in 3-3-A2/15.3, the quantity and disposition are to be stated in the guidance to the Master.

17 Additional Criteria for Vessels Equipped to Lift

Each vessel equipped to lift is to satisfy the additional intact stability requirements in the following subsections. Stability calculations and corresponding information for the Master are to be submitted for review and approval. The submission of evidence showing approval by an Administration of stability of the vessel for the lifting operations in accordance with a recognized standard may be accepted.

The dynamic load chart for each crane is to be included in the Trim and Stability Booklet and posted at the crane operator's station in the clear view for the operator.

17.1 Specific Applicability

This appendix applies to each vessel that:

i) Is equipped for heavy lifting of cargo or other objects; and

ii) Has a maximum heeling moment due to hook load greater than or equal to:

$$(0.67)(\Delta)(GM)(F/B) \quad \text{meter} - \text{metric} \quad \text{tons} \quad (\text{foot} - \text{long} \quad \text{tons})$$

where:

Δ = displacement of the vessel with the hook load included, in metric (long) tons

GM = metacentric height with hook load included, in meters (feet)

F = freeboard to the deck edge amidships, in meters (feet)

B = beam, in meters (feet)

17.3 Definition

As used in this Appendix.

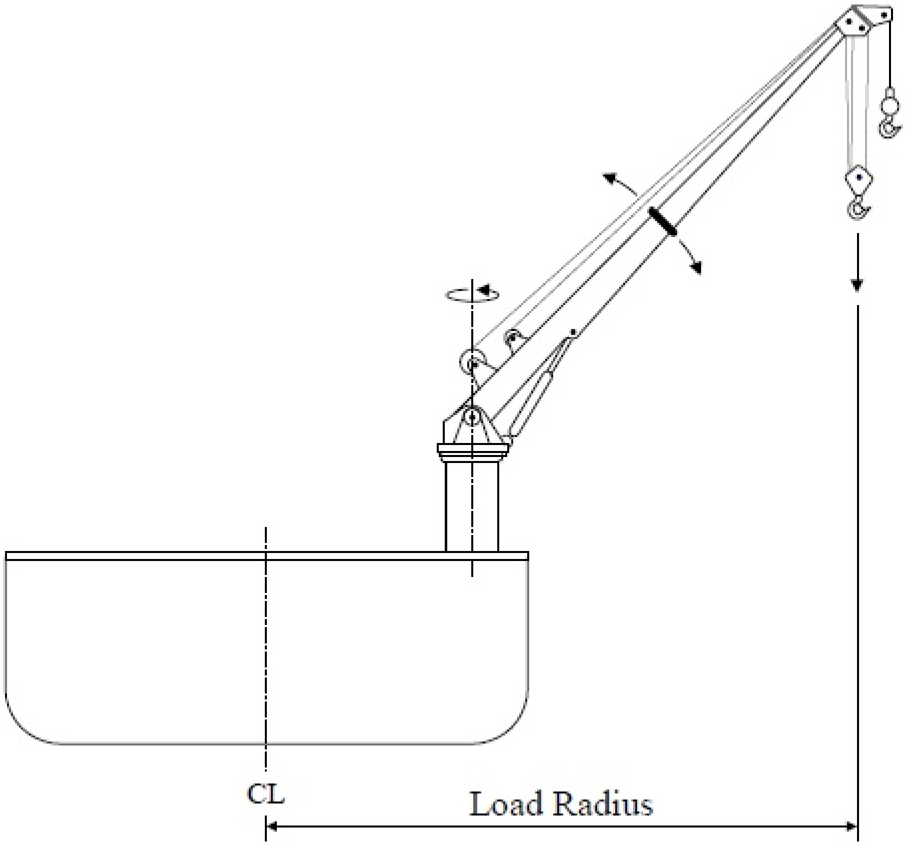
i) Hook load means the weight of the object lifted by the crane.

ii) Load radius means the distance illustrated in 3-3-A2/17.3 FIGURE 2

iii) Crane Heeling Moment is the maximum heeling moment developed by multiplying the weight of the hook load and boom by the horizontal distance from vessel's centerline to the hook load and boom center of gravity, considering the full range of crane elevations and weights. The resulting heeling moment is to be converted to a heeling arm at zero degrees by dividing it by the vessel displacement. The heeling arm is to be assumed constant for all heel angles.

iv) Equilibrium heel angle is the angle of heel under the combined effects of the hook load, counter-ballasting and a beam wind.

FIGURE 2
Load Radius



17.5 Counter-ballasted and Non-counter-ballasted Vessels

17.5.1

Each vessel that is equipped to lift is to comply, by design calculations, with this section under the following conditions:

i) Either for each loading condition (see 3-3-A2/5) and pre-lift condition, or the range of conditions, including pre-lift conditions, delineated by the lifting operations guidelines contained in the trim and stability booklet; and

ii) Crane Heeling Moment, and

iii) The effect of beam wind on the projected area of the vessel (including deck cargo) should be evaluated for 25.7 m/s (50 knots) wind speed. Should a lesser wind speed be used, that wind speed shall be listed in the trim and stability booklet as an operational restriction during lifting operations.

The wind heeling moment shall be calculated as:

$P \times A \times H \quad \mathrm{N-m(kgf-m, lbf-ft)}$

where

P = wind pressure, calculated as per below

A = projected lateral area, in square meters (square feet), of all exposed surfaces (including deck cargo), in the upright condition

H = vertical distance, in meters (feet), from the center of A to t he center of the underwater lateral area or approximately to the one-half draft point

This wind heeling moment is to remain constant for all heel angles.

$P = fV_k^2 C_h C_s \quad \mathrm{N/m^2}\left(\mathrm{kgf/m^2, lbf/ft^2}\right)$

where

f = 0.611 (0.0623, 0.00338)

V_k = wind velocity in m/s (m/s, knots)

C_s = 1.0, shape coefficient

C_h = height coefficient from 3-3-A2/Table 2

TABLE 2
Values of C_h

H (meters)	*H (feet)*	C_h
0.0–15.3	0–50	1.00
15.3–30.5	50–100	1.10
30.5–46.0	100–150	1.20
46.0–61.0	150–200	1.30
61.0–76.0	200–250	1.37
76.0–91.5	250–300	1.43
91.5 and above	300 and above	1.48

17.5.2 *(1 July 2021)*

Each vessel is to have a righting arm curve with the following characteristics:

i) The area under the righting arm curve from the equilibrium heel angle (based upon the wind heeling moment) up to the smallest of the following angles must be at least 0.080 meter-radians (15 foot-degrees):

- The second intercept
- The downflooding angle
- 40 degrees

ii) The lowest portion of the weather deck and downflooding point should not be submerged at the equilibrium heel angle.

iii) The heeling angle based on the crane heeling moment and effect of the beam wind shall not exceed the maximum heel angle from the crane manufacturer.

The righting arm curve is to be corrected for the increase in the vertical center of gravity due to the lifting operation. (The increase in the VCG is due to the boom being in the elevated position, and the hook load acting at the elevated end of the boom.).

For lifting operations conducted under environmental and operational limitations, stability criteria in 2.9.4 of Resolution MSC.415(97) Amendements to Part B of the 2008 IS Code is to be complied with.

17.7 Additional Standards – Counter-ballasted Vessels *(1 July 2021)*

The following recommended criteria are based on crane operations taking place in favorable weather conditions. The analysis should be carried out for the counter-ballast case when the vessel is floating with a heel and trim not exceeding the maximum cross angle. The maximum cross angle is the angle corresponding to the crane operational restrictions.

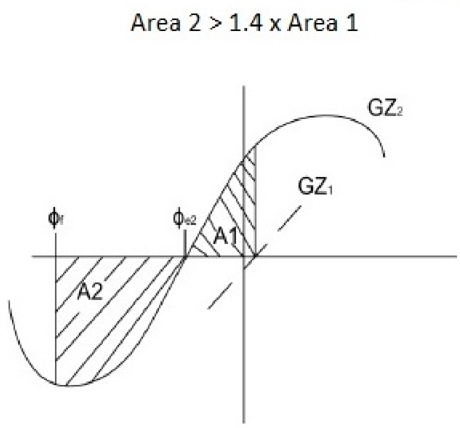
The righting arm curve is to be corrected for the increase in the vertical center of gravity due to the load. (The increase in the VCG is due to the boom being in the elevated position, and the hook load acting at the elevated end of the boom.).

i) For any condition of loading and crane heeling moment, the first intercept of the heeling arm curve with the righting arm curve (equilibrium point) is to occur prior to submergence of the deck edge. The following requirements are also to be met, with the vessel at the maximum allowable vertical center of gravity, to provide adequate stability in case of sudden loss of crane load:

ii) The area in the side of ship opposite to the lift (Area 2) is not to be less than 40% in excess of residual area on the side of the lift (Area 1) as shown in 3-3-A2/17.7 FIGURE 3.

iii) The angle of the first intercept between the righting lever curve after loss of crane load and the maximum permissible counter ballast lever curve is not to exceed 15° (angle of equilibrium after loss of crane load).

FIGURE 3
Criteria after Accidental Loss of Crane Load *(1 July 2021)*



where:

GZ_1 = net righting lever (GZ) curve for the condition before loss of crane load, corrected for crane heeling moment and for the righting moment provided by the counter ballast if applicable;

GZ_2 = net righting lever (GZ) curve for the condition after loss of crane load, corrected for the transverse moment provided by the counter ballast if applicable;

φ_{e2} = the angle of static equilibrium after loss of crane load;

φ_f = the angle of down-flooding or the heel angle corresponding to the second intersection between heeling and righting arm curves, whichever is less; and

PART 3

CHAPTER 3
Subdivision and Stability

APPENDIX 3
Intact Stability Requirements for Fishing Vessels

1 Intact Stability

The intact stability of each fishing vessel is to be evaluated and the results for all loading conditions indicated in 3-3-A3/9, verifying compliance with the intact stability criteria in 3-3-A3/3, 3-3-A3/5 and 3-3-A3/7 and taking into account the design considerations indicated in 3-3-A3/11, are to be submitted.

Where it may be critical, the longitudinal intact stability of the loading conditions is to be investigated.

The maximum allowable KG (or minimum required GM) curve is to confirm compliance with the intact criteria in 3-3-A3/3, 3-3-A3/5 and 3-3-A3/7. This curve (or series of curves) is to cover the full range of operation (Load Line/maximum draft to arrival condition, 3-3-A3/9.1.vii), and the full range of anticipated trims). The supporting calculations for this curve shall be submitted for review.

Where it is desired to use intact stability criteria which differ from the following, special consideration may be given upon submission of the details and service experience.

3 Criteria

3.1 General

The intact stability of the fishing vessel is to meet the criteria in Part B Section 2.1.3.1 of the IMO Intact Stability Code, 2008, supplemented by a required 60 degree range of positive stability. This criterion is summarized below and illustrated in 3-3-A3/3.1 FIGURE 1A.

i) The area under the righting arm curve is not to be less than 0.055 meter-radians (10.3 ft-degrees) up to an angle of heel of 30 degrees.

ii) The area under the righting arm curve between the angles of heel of 30 degrees and 40 degrees or between 30 degrees and the angle of downflooding (θ_f), where downflooding occurs at less than 40 degrees, is not to be less than 0.030 meter-radians (5.6 ft-degrees)

iii) The area under the righting arm curve is not to be less than 0.090 meter-radians (16.9 ft-degrees) up to an angle of heel of 40 degrees or the angle of downflooding (θ_f), where this angle is less than 40 degrees.*

iv) The righting arm is to be at least 0.2 m (0.66 ft) at an angle greater than or equal to 30 degrees.

v) The maximum righting arm is to occur at an angle of heel preferably exceeding 30 degrees but not less than 25 degrees.

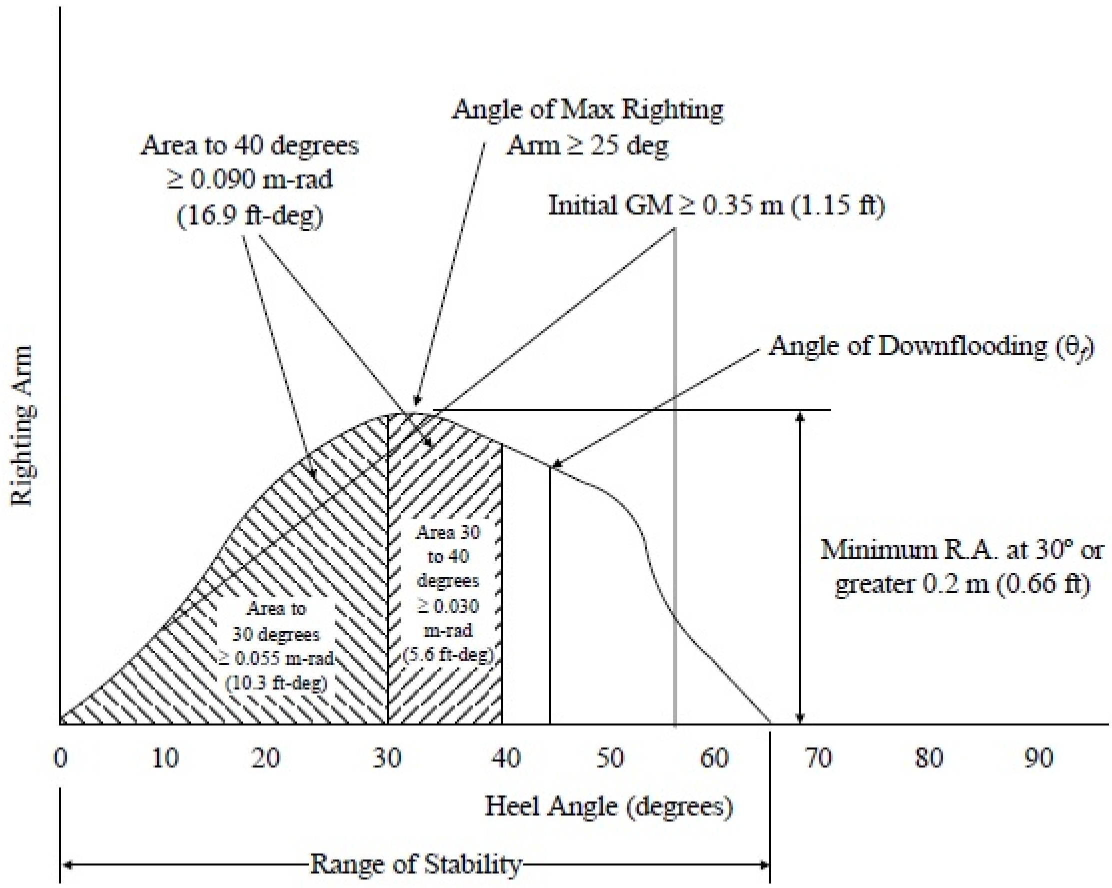
vi) Initial GM is not to be less than 0.35 m (1.15 ft). The required initial GM may be reduced to at least 0.15 m (0.5 ft) for vessels having a full length superstructure or for any vessel with a length of 70 m (229.7 ft) or greater.

vii) A minimum range of stability of 60 degrees is to be provided.

viii) For fishing vessels less than 24 m (79 ft), the stability criteria is specially considered.

Note: *This criterion requires that the sum of the area under the righting arm curve to 30 degrees and the righting arm curve between 30 degrees and 40 degrees or 30 degrees and the angle of downflooding be greater than 0.090 meter-radians (16.9 ft-degrees). This means that either or both of these areas is to be greater than that specified in 3-3-A3/3.1.ii) and 3-3-A3/3.1.iii).

FIGURE 1A
Intact Stability Criteria for Fishing Vessels



3.3 Alternate Criteria

Where the vessel's characteristics are such that the above criteria in 3-3-A3/3.1 cannot be met, the following criteria may be used:

i) The area under the righting arm curve is not to be less than 0.070 meter-radians (13.1 ft-degrees) up to an angle of 15 degrees when the maximum righting arm occurs at 15 degrees, and 0.055 meter-radians (10.3 ft-degrees) up to an angle of 30 degrees when the maximum righting arm occurs at 30 degrees or above. Where the maximum righting arm occurs at angles of between 15 degrees and 30 degrees, the corresponding area under the righting arm curve is to be:

$0.055 + 0.001(30 - \theta_{max})$ meter-radians **

$10.3 + 0.187(30 - \theta_{max})$ ft-degrees

** θ_{max} is the angle of heel in degrees at which the righting arm curve reaches its maximum.

ii) The area under the righting arm curve between the angles of heel and 30 degrees and 40 degrees, or between 30 degrees and θ_f, where this angle is less than 40 degrees, is to be not less than 0.03 meter-radians (5.6 ft-degrees).

iii) The righting arm is to be at least 0.2 m (0.66 ft) at an angle of heel equal to or greater than 30 degrees.

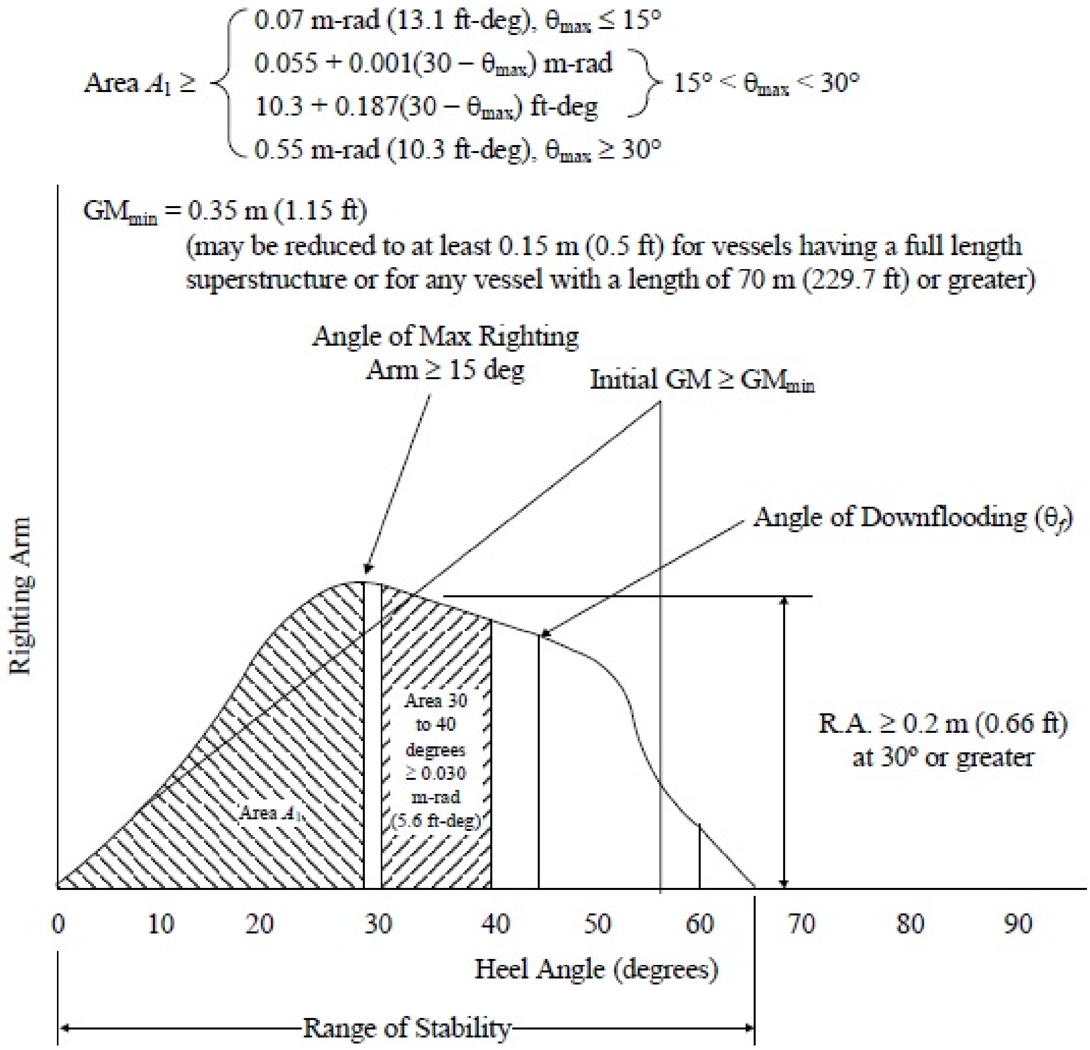
iv) The maximum righting arm is to occur at an angle of heel not less than 15 degrees.

v) The initial GM is to be not less than 0.35 m (1.15 ft). The required initial GM may be reduced to at least 0.15 m (0.5 ft) for vessels having a full length superstructure or for any vessel with a length of 70 m (229.7 ft) or greater.

vi) A minimum range of stability of 60 degrees is to be provided.

vii) For fishing vessels less than 24 m (79 ft), the criteria indicated above is specially considered.

FIGURE 1B
Alternate Intact Stability Criteria for Fishing Vessels



5 Severe Wind and Rolling Criteria

5.1 General *(1 July 2020)*

The fishing vessel is to meet the severe wind and rolling criteria, indicated in Part B Section 2.1.4 of the IMO Intact Stability Code, 2008, as summarized below and illustrated in 3-3-A3/5.1 FIGURE 2.

i) The vessel is assumed to be subjected to a steady wind pressure acting perpendicular to the vessel's centerline which results in a steady wind heeling arm (L_{w1}).The vessel heel to an angle of equilibrium (θ_0) is not to exceed 16 degrees or 80% of the angle of deck edge immersion, whichever is less.

ii) From the resultant angle of equilibrium (θ_0), the vessel is assumed to roll due to wave action to an angle of roll (θ_1) to windward.

iii) The vessel is then subjected to a gust wind pressure which results in a gust wind heeling arm (L_{w2}).

iv) Under these circumstances, area "b" is to be equal to or greater than area "a".

v) Free surface effects are to be accounted for in the standard conditions of loading, as discussed in 3-3-1/9.

vi) The angles in 3-3-A3/5.1 FIGURE 2 are defined as follows:

θ_0 = angle of heel under action of steady wind (i.e., the intersection of the wind heeling arm curve, L_{w1}, and the righting arm curve)

θ_1 = angle of roll to windward due to wave action

θ_2 = angle of downflooding (θ_f) or 50 degrees or θ_{c2}, whichever is less

θ_3 = angle of heel 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_{c1} = angle of first intercept of wind heeling arm curve, L_{w2}, and righting arm curve

θ_{c2} = angle of second intercept of wind heeling arm curve, L_{w2}, and righting arm curve

vii) The wind heeling arms L_{w1} and L_{w2}, referred to above, are constant values at all angles of inclination and are to be calculated as shown below:

$$L_{w1} = \frac{PAZ}{\Delta} \quad \text{m (ft)}$$

$$L_{w2} = 1.5L_{w1} \text{ m (ft)}$$

where

P = 0.0514 t/m^2 (0.0047 Lt/ft^2) for vessels 45 m (147.6 ft) in length and over
For vessels between 24.0 m (79 ft) and 45 m (147.6 ft) in length, the values of P are to be taken from the following table:

h (m)	1	2	3	4	5	6 and up
p (t/m^2)	0.0322	0.0394	0.0438	0.0469	0.0494	0.0514
p (LT/ft^2)	0.00294	0.00360	0.00400	0.00428	0.00452	0.00470

A = projected lateral area of the portion of the vessel and deck cargo above the waterline, m^2 (ft^2)

Z = vertical distance from the center of A to the center of the underwater lateral area or approximately to a point at one half the draft, m (ft)

h = vertical distance from the center of the projected lateral area of the vessel above the waterline to the waterline, m (ft)

Δ = displacement, metric tons (long tons)

viii) The angle of roll (θ_1) is to be calculated as follows:

$$\theta_1 = 109kX_1X_2\sqrt{rs} \quad \text{degrees}$$

where

X_1 = factor as shown in 3-3-A3/5.1 TABLE 1

X_2 = factor as shown in 3-3-A3/5.1 TABLE 2

k = factor as follows:

= 1.0 for round bilge vessel having no bilge or bar keels

= 0.7 for a vessel having sharp bilges

= as shown in 3-3-A3/5.1 TABLE 3 for a vessel having bilge keels, a bar keel or both

r = $0.73 + 0.6 \quad OG/d$

with

OG = distance between the center of gravity and waterline, m (ft) (+ where center of gravity is above the waterline, – where it is below)

d = mean design draft of the vessel, m (ft)

s = factor as shown in 3-3-A3/5.1 TABLE 4.

Rolling Period $T = \frac{2.0CB}{\sqrt{GM}}$ sec. (SI/MKS units)

$T = \frac{1.108CB}{\sqrt{GM}}$ sec. (U.S. units)

wh
ere

C = $0.373 + 0.023(B/d) - 0.043(L/100)$ (SI/MKS units)

= $0.373 + 0.023(B/d) - 0.000131L$ (U.S. units)

The symbols in Tables 1 to 4, below, and formula for the rolling period are defined as follows:

L = waterline length of the vessel, m (ft)

B = molded breath amidships of the vessel, m (ft)

d = mean design draft of the vessel, m (ft)

C_b = block coefficient

A_k = total overall area of bilge keels, or area of the lateral projection of the bar keel, or sum of these areas, m^2 (ft^2)

GM = metacentric height corrected for free surface effect, m (ft)

The angle of roll for vessels provided with active anti-rolling devices is to be determined without taking into account the operation of these devises. For vessels with anti-roll tanks, the full free surface effect of the tanks is to be used to determine the GM value used in calculating the angle of roll.

FIGURE 2
Severe Wind and Rolling Criteria

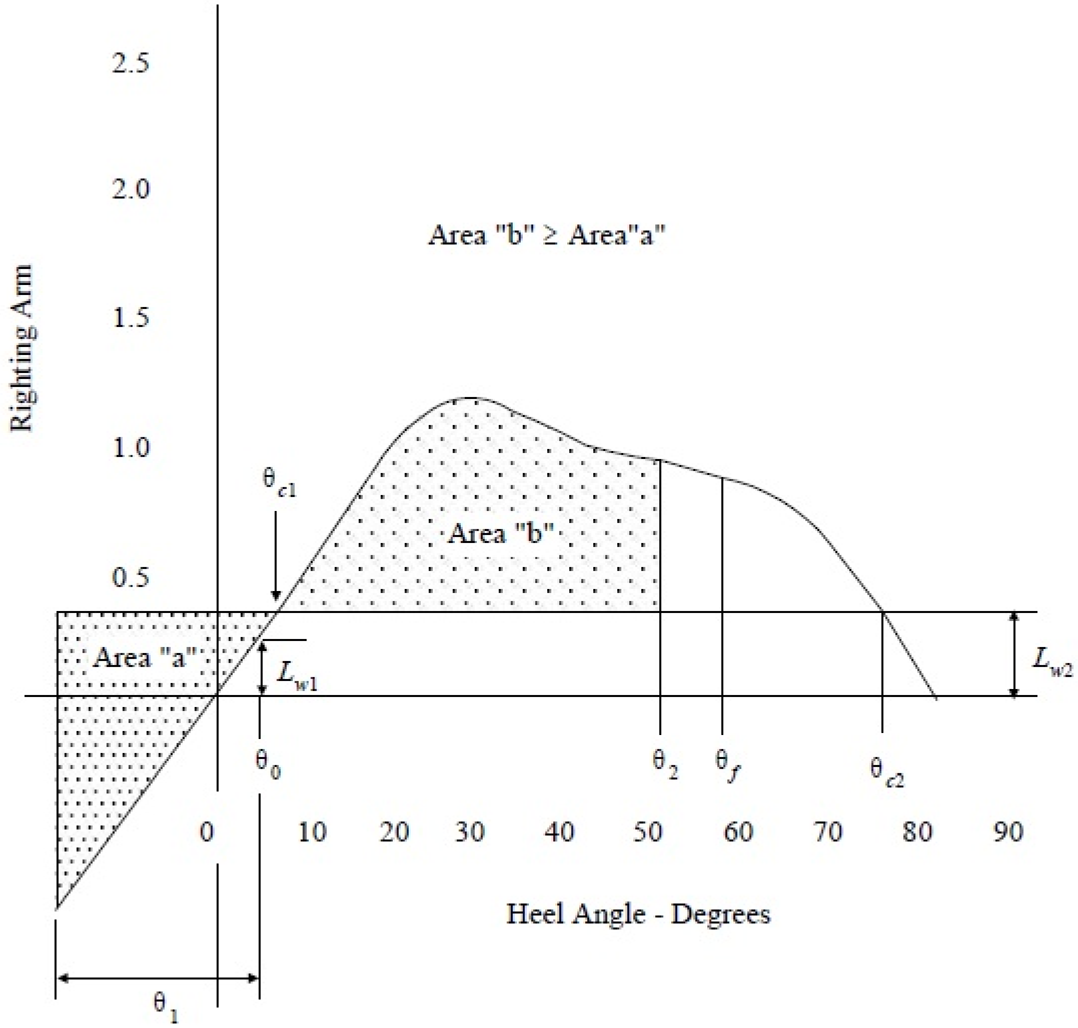


TABLE 1
Values of factor X_1

B/d	X_1
≤2.4	1.00
2.5	0.98
2.6	0.96
2.7	0.95
2.8	0.93
2.9	0.91
3.0	0.90
3.1	0.88
3.2	0.86

B/d	X_1
3.3	0.84
3.4	0.82
≥ 3.5	0.80

TABLE 2
Values of factor X_2

C_b	X_2
≤0.45	0.75
0.50	0.82
0.55	0.89
0.60	0.95
0.65	0.97
≥0.70	1.00

TABLE 3
Values of factor k

$\frac{Ak100}{LB}$	k
0.0	1.00
1.0	0.98
1.5	0.95
2.0	0.88
2.5	0.79
3.0	0.74
3.5	0.72
≥ 4.0	0.70

TABLE 4
Values of factor *s*

T	s
≤6	0.100
7	0.098
8	0.093
12	0.065
14	0.053
16	0.044

T	*s*
18	0.038
≥ 20	0.035

(Intermediate values in 3-3-A3/Table 1 through 3-3-A3/Table 4 should be obtained by linear interpolation.)

7 Treatment of Lifting Weights and Heeling Moments Due to Fishing Gear

7.1 General

When a weight is lifted from the deck or a fishing net filled with fish is lifted from the water, the weight then acts at the tip of the boom and is to be considered in developing the VCG and the righting arm curves.

The stability information shall contain the details of the lifting gear including the maximum heeling moments and other information for the crew to avoid exceeding the allowable lifting loads and/or heeling moments used in the stability calculations.

7.3 Definitions

As used in this section:

i) Hook load means the weight of the object (i.e., fishing net with catch, crab pot, etc.) lifted by the crane.

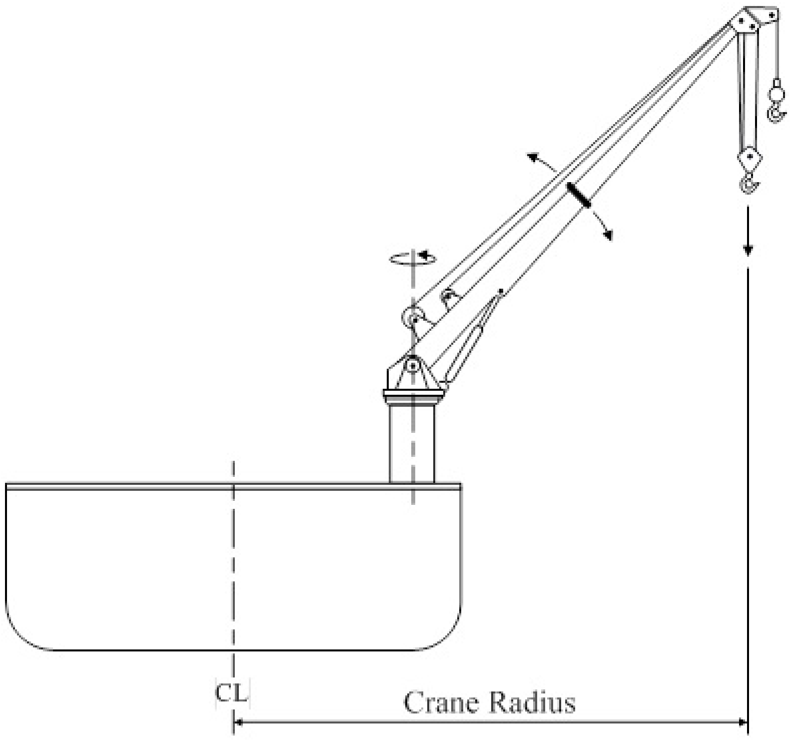
ii) Crane radius means the distance illustrated in 3-3-A3/7.3 FIGURE 3.

iii) Crane Heeling Moment is the maximum heeling moment developed by multiplying the weight of the hook load and boom by the horizontal distance from vessel's centerline to the hook load and boom center of gravity, respectively, considering the full range of crane elevations and weights. The resulting heeling moment is to be converted to a heeling arm at zero degrees by dividing it by the vessel displacement. The heeling arm is to be assumed constant for all heel angles.

If multiple cranes are used simultaneously, the Crane Heeling Moment shall include the maximum heeling moment created by each crane.

iv) The equilibrium heel angle is the angle of heel under the combined effects of the hook load, counter-ballasting and a beam wind.

FIGURE 3
Crane Radius



7.5 Heeling Moment Due to Onboard Crane Use

7.5.1

The stability of each vessel that uses onboard crane(s) for fishing operations shall be evaluated for the effects of the heeling moments. Stability calculations are to include the following considerations when showing compliance with the requirements in 3-3-A3/7.5.2:

i) Crane Heeling Moment, and

ii) The effect of beam wind on the projected area of the vessel (including deck cargo) should be evaluated for 25.7 m/s (50 kn) wind speed. Should a lesser wind speed be used, that wind speed shall be listed in the trim and stability booklet as an operational restriction during lifting operations.

The heeling arm, which shall remain constant for all heel angles, shall be calculated as:

$$HA = (P \times A \times H) / \Delta$$

where

A	=	projected lateral area, in square meters (square feet), of all exposed surfaces (including deck cargo), in the upright condition
H	=	vertical distance, in meters (feet), from the center of A to the center of the underwater lateral area or approximately to the one-half draft point.
Δ	=	displacement of the vessel with the hook load included, in metric tons (long tons)
P	=	wind pressure, calculated as:
	=	$fV_k^2 C_h C_s$ N/m^2 (kgf/m^2, lbf/ft^2)

f = 0.611 (0.0623, 0.00338)

V_k = wind velocity in m/s (m/s, kn)

C_s = 1.0, shape coefficient

C_h = height coefficient from 3-3-A3/7.5.1.ii TABLE 5

TABLE 5
Values of C_h

H (Meters)	*H (Feet)*	C_h
0.0–15.3	0–50	1.00
15.3–30.5	50–100	1.10
30.5–46.0	100–150	1.20
46.0–61.0	150–200	1.30
61.0–76.0	200–250	1.37
76.0–91.5	250–300	1.43
91.5 and above	300 and above	1.48

7.5.2

As illustrated in 3-3-A3/7.5.2 FIGURE 4, each vessel must have a righting arm curve with the following characteristics:

i) The area under the righting arm curve from the equilibrium heel angle up to the smallest of the following angles must be at least 0.080 meter-radians (15 foot-degrees):

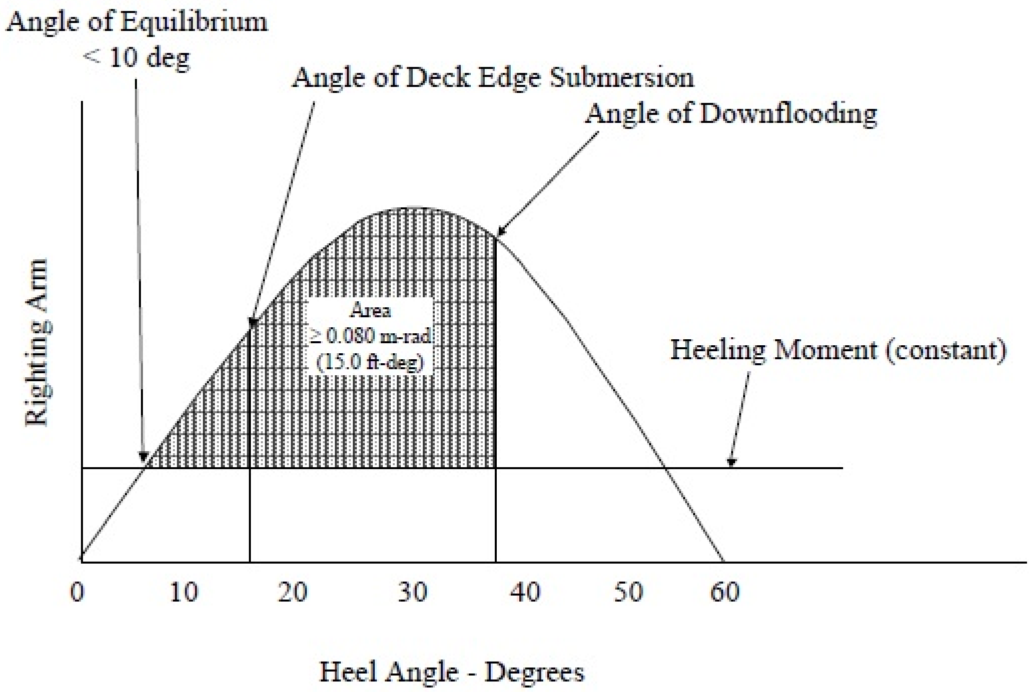
a) The downflooding angle

b) 40 degrees

ii) The deck edge should not be submerged at the equilibrium heel angle.

iii) The equilibrium heel angle shall not exceed 10 degrees.

FIGURE 4
Lifting Criteria

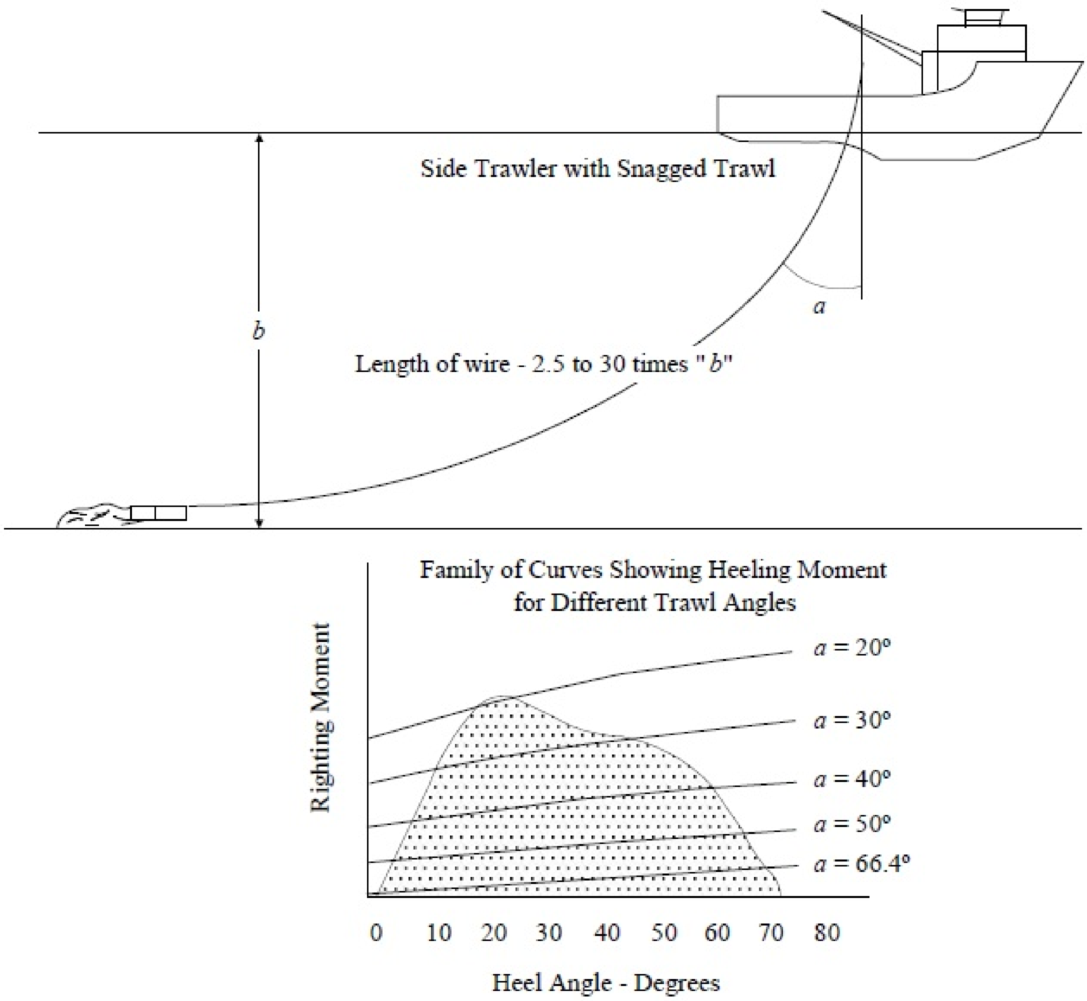


7.7 Heeling Moment Due to Fishing Gear

i) The expected maximum heeling moments imposed by trawling or seining, for instance, are to be evaluated by the designer and included in the stability analysis.

ii) The effect of a trawl snagging on the bottom (and the vessel's attempt to clear the snag) is to be considered. When the trawl becomes snagged the potential heeling moment can exceed the righting moment. 3-3-A3/7.7.ii FIGURE 5 shows a family of heeling moment curves for a given propeller thrust and vessel trawl geometry imposed on a righting arm curve. The illustration is not intended to be numerically specific, but is instead presented to show how operational practices must be considered in developing stability information. The heeling moment increases for decreasing trawl angles a, where a is the angle which the trawl wire makes with the vertical. The magnitude of the heeling moment is a function of the trawl angle, which is in turn a function of the wire length and the water depth. Since normal practice is to shorten up the trawl wire and use power to break the trawl free, the angle at which the wire trails can be significantly reduced as the vessel moves towards the location of the snag. The stability information is to warn the operators that attempting to release a fastened trawl by rapidly increasing the engine thrust or suddenly increasing the power on the winch may cause the vessel to capsize. Consideration is to be given to the need for quick-release devices on winches and other lifting equipment.

FIGURE 5
Calculating the Effect of a Fastened Trawl



9 Standard Loading Conditions

9.1 Loading Conditions

The following assumed loading conditions are to be investigated for each fishing vessel as a minimum:

i) Departure condition from port with full fuel, water, stores, ice, fishing gear (including pot load or other gear on deck), etc.

ii) Arrival at the fishing grounds with reduced fuel, water and stores, ice, fishing gear (including pot load or other gear on deck) and no catch (the amount of fuel, water and stores based on the distance to the fishing area).

iii) At the fishing grounds with 50 percent fuel, water and stores, cargo holds empty and either the maximum deck load on deck or the holds 50 percent full, whichever is consistent with the vessel's fishing method).

iv) Departure from the fishing grounds with reduced fuel, water, and stores and full catch.

v) Departure from the fishing grounds with reduced fuel, water, and stores and 20 percent of full catch.

vi) Arrival at home port with 10 percent fuel, water and stores, and full catch including any weights to be lifted or suspended and their effects on stability.

vii) Arrival at home port with 10 percent fuel, water, and stores and 20 percent of full catch.

viii) Other loading conditions in which the vessel may be operated, such as other partial catch and tank loading combinations, with deck loads, using boxes to store fish, while lifting, in ballast and during periods of icing.

9.3 Load Considerations

The following considerations are to be included in assessing loading conditions.

i) In addition to the loading conditions noted above, loading conditions are to be calculated for any other unusual loads or operating practices not considered by the criteria which may have an effect on the vessel being designed.

ii) Operating conditions which may seriously impair the stability of the vessel are to be brought to the attention of the operator and recommended practical corrective measures are to be included in the stability information furnished to the operator.

iii)) When calculating operating conditions, the weight of all fishing gear on deck in that condition (i.e., wet nets, tackle, pots, traps, etc.) is to be included.

iv) Where the vessel operates in areas where ice accretion is likely to occur, the icing loads in 3-3-A3/11.7 are to be included.

v) The cargo may be assumed to be homogeneous unless this is inconsistent with practice.

vi) Deck cargo is to be included.

vii) The free surface of slack ballast tanks or fish wells is to be accounted for if it is present in normal operations.

viii) Where normal practice is to stow fish so that one end of the hold is loaded higher, then the increase in VCG is to be accounted for.

11 Design and Operating Factors Affecting Stability *(1 July 2020)*

The following design considerations, environmental forces and operating conditions which affect the stability of each fishing vessel are to be considered when developing the stability calculations and appropriate instructions are to be included in the stability information furnished to the master.

11.1 Calculation of Righting Arms

i) The hull designs of fishing vessels, with house forward and working areas aft, generally cause the vessel to change draft and trim significantly as it is heeled. When calculating the loading conditions, the righting arms are to be determined assuming the initial trim and using constant trimming moments (free to trim).

ii) Superstructures and deck houses may be included in the buoyant volume where the structure is weathertight and of sufficient strength, and where all openings in the sides and ends are weathertight, and all portlights and windows, including those fitted in doors, have deadlight covers.

iii) Stern ramps are to be deducted from the buoyant volume.

iv) Bulwarks are not to be included in the buoyant volume.

11.3 Ballast

i) Ballast is normally used to improve the stability of the vessel. However, depending on the location of the ballast, it can either raise or lower the center of gravity of a vessel. Ballast may also decrease the reserve buoyancy of a given vessel and can adversely change the trim of the vessel.

ii) Where it is the intent to ballast during ballast operations, the free surface effect will exist during the interim period until the ballast tank is pressed up is to be considered in developing the stability data.

iii) The installation of permanent ballast is to be verified by the attending Surveyor. Permanent ballast is not to be removed without notifying ABS and evaluating the effect on stability.

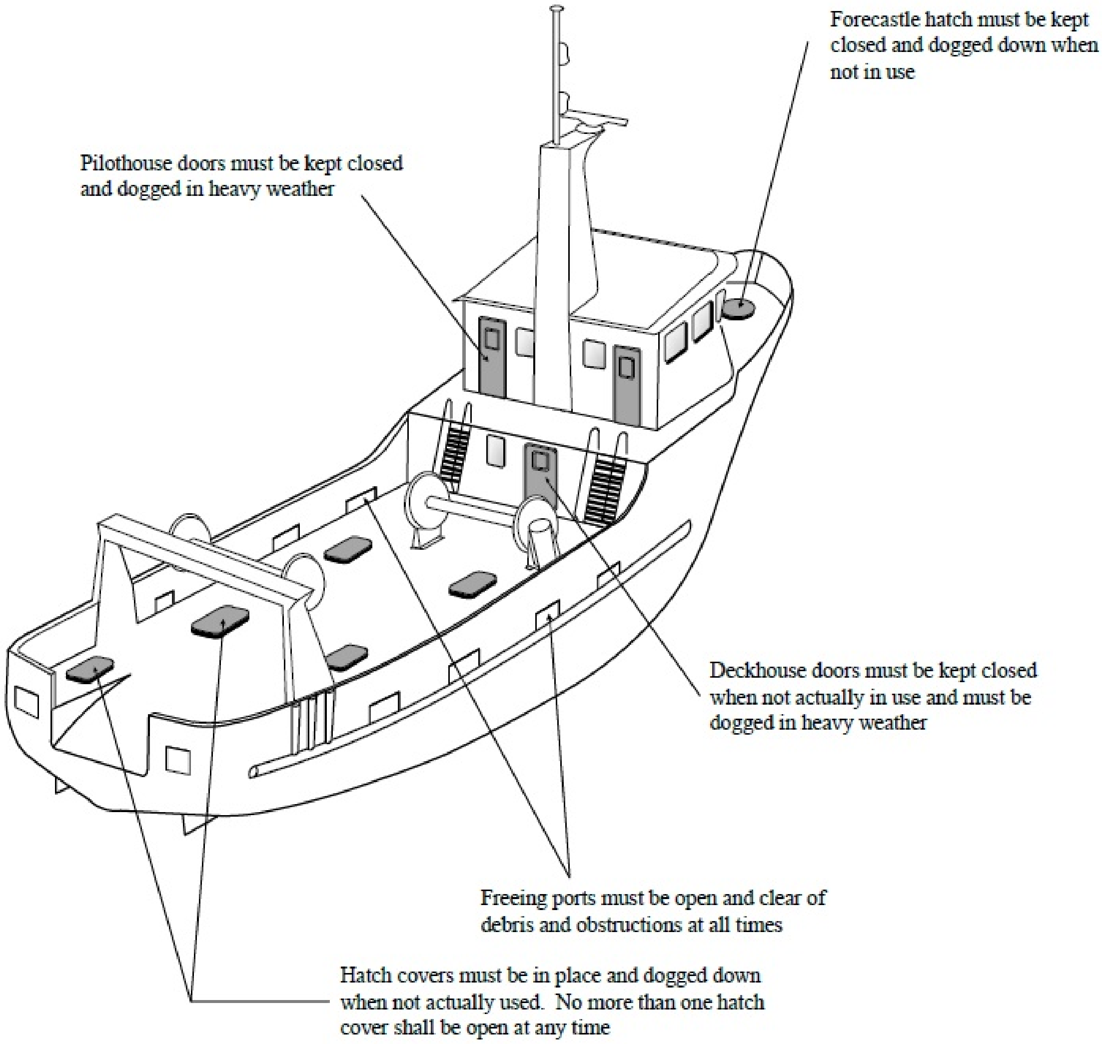
11.5 Watertight Integrity and Flooding

i) The importance of providing watertight closures that can be quickly closed and easily maintained is to be considered in developing a hull which can meet or exceed the stability criteria and provide an efficient fishing platform.

ii) All closures which must be opened at sea are to be kept as far inboard and as high as possible in order to maximize the angle at which downflooding occurs. Doors in forecastle, poop, and deckhouse end bulkheads are often located near the side of the vessel and could be immersed at low angle of heel. Wherever possible these closures are to be kept close to the centerline, then the angle of downflooding is considerably increased with a resultant increase in safety.

iii) Instructions to the master are to be provided to keep all watertight closures closed except when actually being used. These closures are to be clearly labeled “This opening is to be kept closed except when actually being used.” or similar. A diagram showing the location to all watertight closures is to be placed aboard the vessel in the Stability Information provided to the operator. An example of this is shown in 3-3-A3/11.5.iii FIGURE 6.

FIGURE 6
Diagram of Key Watertight Closures



11.7 Icing

i) Where the vessel operates in areas where ice accretion is likely to occur, the vessel's conditions of loading given in 3-3-A3/9 shall include the icing allowance in either 3-3-A3/11.7.ii) or 3-3-A3/11.7.iii) when they are evaluated for compliance with the applicable intact and damage stability requirements.

ii) The minimum weights of ice are:

a) The weight of ice on all horizontal surfaces is to be at least 30 kg/m^2 (6.14 lbs/ft^2).

b) The weight of ice of the projected vertical area above the waterline is to be at least 15 kg/m^2 (3.07 lbs/ft^2). This accounts for 7.5 kg/m^2 (1.54 lbs/ft^2) on both the port and starboard vertical surfaces.

Plans showing projected horizontal and vertical areas are to be submitted.

iii) The weight of ice recommended by the Administration where the vessel is intended to operate (such as the Transport Canada – Marine Safety requirements for vessels operating in their waters), may be substituted for 3-3-A3/11.7.ii).

iv) The height of the center of gravity of the accumulated ice is to be located according to the position of the corresponding horizontal surfaces (decks and gangways) and other continuous surfaces on which ice can reasonably expected to accumulate. The projected lateral area of small discontinuous surfaces such as rails, spars, and rigging with no sails can be accounted for by increasing the calculated area by 5 percent and the static moments of the area by 10 percent.

11.9 Water on Deck

The IMO Guidance as a means of evaluating the residual stability of the vessel with water on deck is repeated below.

i) The ability of the vessel to withstand the heeling effect due to the presence of water on deck is to be demonstrated by showing that with the vessel in the worst operating condition, the ratio of area "b" to area "a" shown in 3-3-A3/11.9 FIGURE 7 is not to be less than 1.0. That is, it satisfies the following equation in the worst operating condition:

$$C_{wod} = \frac{\text{area "b"}}{\text{area "a"}} \geq 1.0$$

ii) The angle which limits area "b" is to be equal to the downflooding angle θ_f or 40 degrees, whichever is less.

iii) The value of the heeling moment M_{wod} (or the corresponding heeling arm) due to the presence of water on deck is to be determined assuming that the deck well is filled to the top of the bulwark at its lowest point and the vessel heeled up to the angle at which this point is immersed (see 3-3-A3/11.9 FIGURE 8). For the determination of M_{wod} the following formula is to be used:

$$M_{wod} = KM_w$$

where

M_w = static heeling moment due to water on deck

K = coefficient

a) Where M_{wod} is determined by static approach, K= 1.0 may be applied.

b) Where M_{wod} is determined by quasi-static approach, K may take into account the rolling period of the vessel and the dynamic effect of the water flow, including the effect of the disposition and configuration of the deck wells and deckhouses. The value of K is to be satisfactory, taking into account the type of vessel, area of operation, etc. For vessels where the angle of deck edge immersion θ_D is less than 10° to 15°, or the angle of bulwark top immersion θ_B is less than 20° to 25°, a value for K greater than 1.0 may be applied. When θ_D is greater than 20° or θ_B is greater than 30°, a value for K less than 1.0 may be applied.

iv) When calculating M_{wod} the following assumptions are to be made:

a) At the beginning the vessel is in upright position;

b) During heeling, trim and displacement are constant and equal to the values for the vessel without water on deck;

c) The effect of freeing ports is to be ignored.

v) The above provisions may be adjusted, taking into account the seasonal weather conditions and sea states in the areas in which the vessels operate, the type of vessel and its mode of operation.

vi) Other methods for the calculation of the effect of water on deck using the dynamic approach may be adopted.

FIGURE 7
Method of Treatment of Water on Deck

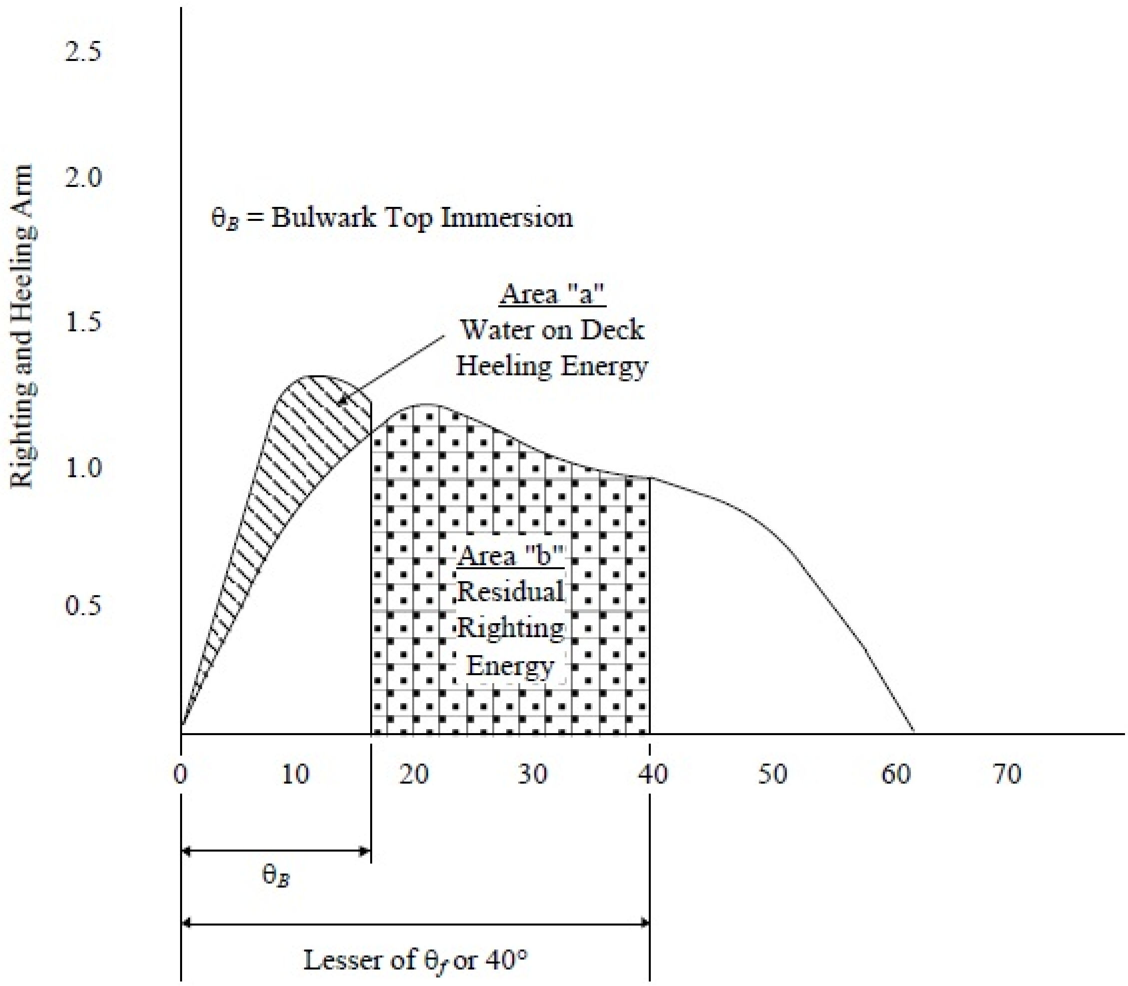
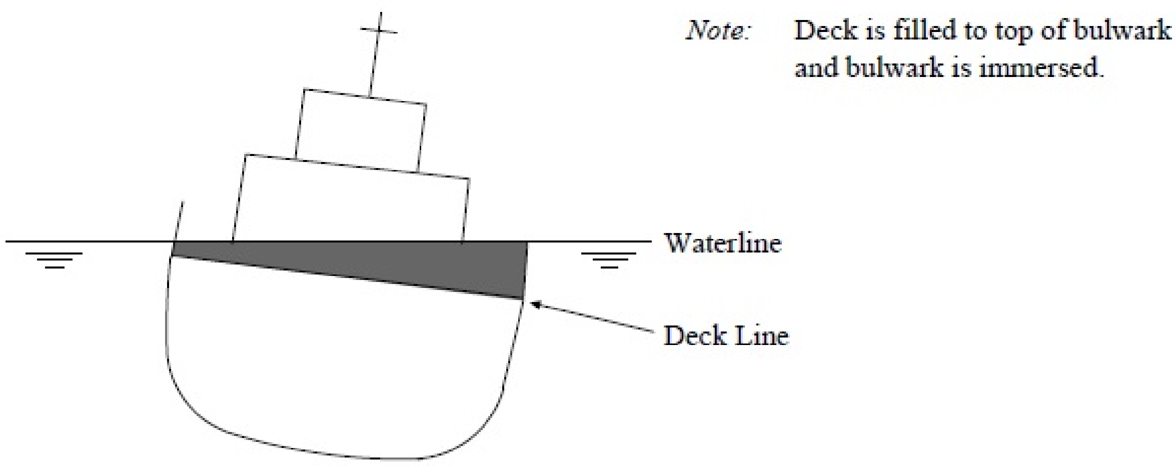


FIGURE 8
Volume of Water to be Included in Calculating Effect of Water on Deck



13 Stability Guidance for the Master

13.1

Each vessel is to be provided with stability information in a format acceptable to ABS. The format may be pictorial, tabular, simplified trim and stability booklet or other format that will provide a rapid means for the crew to evaluate the stability of the vessel.

13.3 *(1 July 2020)*

Each trim and stability book is to contain sufficient information to enable the Master to operate the vessel in compliance with the applicable intact and damage stability requirements in 3-3-A3/5. Information on loading restrictions used to determine compliance with applicable intact and damage stability criteria is to encompass the entire range of operating drafts and the entire range of the operating trims.

The format of the trim and stability booklet and the information included will vary based on the vessel type and operation. Units of measure used in the trim and stability booklet are to agree with the units of measure of the draft markings.

i) The trim and stability booklet shall contain the information specificed in 3-3-1/15.

ii) Intact and damage stability calculations supporting the maximum KG or minimum GM curve are to be contained in a separate document and not included in the trim and stability booklet.

iii) The content and format of a simplified trim and stability booklet or simplified operating guidance is to cover the full operating envelope of the vessel and provide the Master with a rapid and simple means to evaluate the stability of the vessel. The format of the guidance (i.e., tank limitations, load restrictions, lifting restrictions, etc.) is reviewed and accepted by ABS on a case-by-case basis.

PART 3

CHAPTER 3
Subdivision and Stability

APPENDIX 4
Subdivision and Damage Stability Requirements for Bulk Carriers

1 General

1.1 Note

Requirements in the following sections, developed based on the new Regulation XII/4 of SOLAS 1974, as amended, 'Damage Stability Requirements Applicable to Bulk Carriers', are applicable for bulk carriers in the categories described in 3-3-A4/1.1 TABLE 1.

TABLE 1
Bulk Carriers 150 m (492 ft) in Length (L_f) and above to Carry Solid Bulk Cargoes

Construction Date	*Skin Type Single or Double Skin*	*Specific Density ≥ t/m^3 (lb/ft^3)*	*Damaged Hold*
on or after 1 July 1999	Single	1.0 (62.4)	any one cargo hold
on or after 1 July 2006	Double with long'l bhd. located within the lesser of B/5 or 11.5m (37.7 ft)	1.0 (62.4)	any one cargo hold
before 1 July 1999	Single	1.78 (111.07)	foremost cargo hold

Note: B is the bulk carrier breadth as defined in the International Convention on Load Lines in force.

The application of the requirements from the Regulation is extended as a condition of classification for consistency with the new strength/structural requirements under flooded conditions specified in 5C-3-A5a/1 (Longitudinal Strength), 5C-3-A5b/1 (Corrugated Transverse Watertight Bulkheads) and 5C-3-A5c/1 (Permissible Cargo Loads in Holds).

1.3 Applicability

Single side skin bulk carriers of 150 m (492 ft) in length (L_f) and greater, designed to carry solid bulk cargoes having a density of 1.78 t/m^3 (111.07 lb/ft^3) and above, constructed before 1 July 1999, are, when loaded to the summer load line, to be able to withstand flooding of the foremost cargo hold in all loading conditions and remain afloat in a satisfactory condition of equilibrium, as specified in 3-3-A4/3.

Single side skin bulk carriers of 150 m (492 ft) in length (L_f) and greater, designed to carry solid bulk cargoes having a density of 1.0 t/m^3 (62.4 lb/ft.^{3}) and above are, when loaded to the summer load line, to be able to withstand flooding of any one cargo hold of single side skin construction in all loading conditions and remain afloat in a satisfactory condition of equilibrium, as specified in 3-3-A4/3.

Double side Bulk carriers of 150 m (492 ft) in length (L_f) and upwards in which any part of longitudinal bulkhead is located within B/5 or 11.5 m (37.73 ft), whichever is less, inboard from ship's side at right angle to the centerline at the assigned Summer Load Line, designed to carry solid bulk cargoes having a density of 1,000 kg/m^3 (62.4 lb/ft^3) and above, constructed on or after 1 July 2006, shall, when loaded to the Summer Load Line, be able to withstand flooding of any one cargo hold in all loading conditions and remain afloat in a satisfactory condition of equilibrium, as specified in 3-3-A4/3.

3 Damage Stability Criteria

The condition of equilibrium after flooding is to satisfy the condition of equilibrium laid down in Regulation 27 as per the 1988 Protocol to the International Convention on Load Lines, 1966, as amended.

The assumed flooding need only take into account flooding of the cargo hold space. The permeability of a loaded hold is to be assumed as 0.9 and the permeability of an empty hold is to be assumed as 0.95, unless permeability relevant to a particular cargo is assumed for the volume of a flooded hold occupied by cargo and permeability of 0.95 is assumed for the remaining empty volume of the hold.

5 Bulk Carriers with a Reduced Freeboard

Alternatively, bulk carriers which have been assigned a reduced freeboard in compliance with the provisions of paragraph (8) of the Regulation Equivalent to Regulation 27 of the International Convention on Load Lines, 1966, adopted by Resolution A.320(IX), as amended by Resolution A.514(13) may be considered as complying with 3-3-A4/1.3.

On bulk carriers which have been assigned reduced freeboard in compliance with the provisions of Regulation 27(8) set out in Annex B of the Protocol of 1988 relating to the International Convention on Load Lines, 1966, the condition of equilibrium after flooding shall satisfy the relevant provisions of that Protocol.

PART 3

CHAPTER 3
Subdivision and Stability

APPENDIX 5
Damage Stability Requirements for Offshore Supply Vessels

1 General

Taking into account, as initial conditions before flooding, all of the standard loading conditions as referred to in 3-3-A2/5 and the damage assumptions in 3-3-A5/3, the vessel is to comply with the damage stability criteria as specified in 3-3-A5/5.

3 Damage Assumptions

The following damage assumptions are to be applied:

i) Damage is to be assumed to occur anywhere in the vessel's length between transverse watertight bulkheads. The longitudinal extent of damage is:

a) For a vessel the keel of which is laid or which is at a similar stage of construction* before 22 November 2012:

with length (L_f**) not greater than 43 m (141 ft): 10% of L_f; and

with length (L_f) greater than 43 m (141 ft): 3 m (10 ft) plus 3% of L_f;

b) For a vessel the keel of which is laid or which is at a similar stage of construction on or after 22 November 2012:

with length (L_f) not greater than 43 m (141 ft): 10% of L_f;

with length (L_f) greater than 43 m (141 ft) and less than 80 m (262.5 ft): 3 m (10 ft) plus 3% of L_f; and

with length (L_f) from 80 m (262.5 ft) to 100 m (328 ft): $1/3L_f^{2/3}$;

* A similar stage of construction means the stage at which:

1) construction identifiable with a specific ship begins; and

2) assembly of that ship has commenced comprising at least 50 tonnes (49 Long tons) or one per cent of the estimated mass of all structural material, whichever is less.

** L_f is the freeboard length, as defined in 3-1-1/3.3.

ii) The vertical extent of damage is to be assumed from the underside of the cargo deck, or the continuation thereof, for the full depth of the vessel.

iii) The transverse extent of damage is:

a) For a vessel the keel of which is laid or which is at a similar stage of construction before 22 November 2012:

760 mm (30 in.) measured inboard from the side of the vessel perpendicularly to the centerline at the level of the summer load waterline;

b) For a vessel the keel of which is laid or which is at a similar stage of construction on or after 22 November 2012:

with length (L_f) less than 80 m (262.5 ft): 760 mm (30 in.); and

with length (L_f) from 80 m to 100 m (262.5 ft to 328 ft): $B/20$, but not less than 760 mm (30 in.);

Notes:

1 For a vessel the keel of which is laid or which is at a similar stage of construction:

1.1 Before 22 November 2012:
A transverse watertight bulkhead extending from the vessel's side to a distance inboard of 760 mm (30 in.) or more at the level of the summer load line joining longitudinal watertight bulkheads is to be considered as a transverse watertight bulkhead for the purpose of the damage calculations.

1.2 On or after 22 November 2012:
For a vessel with length (L_f) less than 80 m (262.5 ft), a transverse watertight bulkhead extending from the vessel's side to a distance inboard of 760 mm (30 in.) or more at the level of the summer load line joining longitudinal watertight bulkheads is to be considered as a transverse watertight bulkhead for the purpose of the damage calculations. For a vessel with length (L_f) from 80 m to 100 m (262.5 ft to 328 ft), a transverse watertight bulkhead extending from the vessel's side to a distance inboard of $B/20$ or more but not less than 760 mm (30 in.) at the level of the summer load line joining longitudinal watertight bulkheads is to be considered as a transverse watertight bulkhead for the purpose of the damage calculations.

2 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 to be floodable for each case of damage.

3 If damage of a lesser extent than that specified in 3-3-A5/3.i), 3-3-A5/3.ii), and 3-3-A5/3.iii) results in a more severe condition, such lesser extent is to be assumed.

4 Where a transverse watertight 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 m (10 ft), the double bottom or side tanks adjacent to the stepped portion of the transverse watertight bulkhead is to be considered as flooded simultaneously.

5 If the distance between adjacent transverse watertight bulkheads or the distance between the transverse planes passing through the nearest stepped portions of the bulkheads is less than the longitudinal extent of damage given in *i*), only one of these bulkheads should be regarded as effective.

6 The forecastle space need not be assumed damaged if the continuation of the cargo deck forward is capable of being secured watertight.

7 For a vessel operating in well stimulation service, the assumed damage occurs anywhere in the vessel's length at any transverse watertight bulkhead.

5 Criteria

5.1 OSV – General

The following damage stability criteria are to be satisfied for offshore support vessels except for those of characters indicated in 3-3-A5/5.3:

i) The final waterline, taking into account sinkage, heel and trim, is to be below the lower edge of any opening through which progressive flooding may take place. Such openings are to include air pipes and those openings which are capable of being closed by means of weather-tight doors or hatch covers and exclude those openings closed by means of watertight manhole covers and flush scuttles, small watertight cargo tank hatch covers which maintain the high integrity of the deck, remotely operated watertight sliding doors, and side scuttles of the non-opening type.

ii) In the final stage of flooding, the angle of heel due to unsymmetrical flooding is not to exceed 15°. This angle may be increased up to 17° if no deck immersion occurs.

iii) The stability in the final stage of flooding is to be investigated and may be regarded as sufficient if the righting lever curve has a positive range of at least 20° beyond the position of equilibrium in association with a maximum residual righting lever of at least 100 mm (3.9 in.) within this range. Unprotected openings are not to become immersed at an angle of heel within the prescribed minimum range of residual stability unless the space in question has been included as a floodable space in calculations for damage stability. Within this range, immersion of any of the openings referred to in 3-3-A5/5.1.i) and any other openings capable of being closed weather-tight may be authorized.

iv) The vessel shall maintain sufficient stability during intermediate stages of flooding.

5.3 OSV – Special Purpose

Special Purpose offshore support vessels (see definitions in 5D-1-2) are to satisfy the following damage stability criteria:

5.3.1

The subdivision and damage stability of special purpose ships should in general be in accordance with SOLAS Chapter II-1 where the ship is considered a passenger ship, and special personnel are considered passengers, with an R-value calculated in accordance with SOLAS regulation II-1/6.2.3 as follows:

i) Where the ship is certified to carry 240 persons or more, the R-value is assigned as R;

ii) Where the ship is certified to carry not more than 60 persons, the R-value is assigned as 0.8R; and

iii) For more than 60 (but not more than 240) persons, the R-value should be determined by linear interpolation between the R-values given in *i)* and *ii)* above

5.3.2

For special purpose ships to which *i)* applies, the requirements of SOLAS regulations II-1/8 and II-1/8-1 and of SOLAS Chapter II-1, parts B-2, B-3 and B-4 should be applied as though the ship is a passenger ship and the special personnel are passengers. However, SOLAS regulations II-1/14 and II-1/18 are not applicable.

5.3.3

For special purpose ships to which *ii)* or *iii)* applies, except as provided in 3-3-A5/5.3.4 below, the provisions of SOLAS Chapter II-1, Parts B-2, B-3 and B-4 should be applied as though the ship is a cargo ship and the special personnel are crew. However, SOLAS regulations II-1/8 and II-1/8-1 need not be applied and SOLAS regulations II-1/14 and II-1/18 are not applicable.

5.3.4

All special purpose ships should comply with SOLAS regulations II-1/9, II-1/13, II-1/19, II-1/20, II-1/21 and II-1/35-1, as though the ship is a passenger ship.

5.3.5

The partial indices A_s, A_p and A_ℓ are to be not less than $0.9R$.

7 Permeability

The permeability** of compartments assumed to be damaged is to be as follows:

Spaces	*Permeability*
Appropriated to stores	0.60
Occupied by accommodation	0.95
Occupied by machinery	0.85
Void spaces	0.95
Intended for dry cargo	0.95

The permeability of tanks is to be consistent with the amount of liquid carried, as shown in the loading conditions specified in 3-3-A5/1. The permeability of empty tanks is to be assumed to be not less than 0.95.

** Permeability of a space means the ratio of the volume within that space, which should be assumed to be occupied by water to the total volume of that space. The total volume should be calculated to the molded lines and no reduction in total volume should be taken into account due to structural members (i.e., stiffeners, etc.).

9 Free Surface

The free surface effects are to be calculated in accordance with 3-3-A2/9. Additionally, the free surface effect of a damaged non-consumable tank may be omitted from the damage stability calculations.

11 Subdivision

The machinery spaces, working, cargo and accommodation spaces in the hull are to be separated by bulkheads made watertight up to the freeboard deck.

A collision bulkhead is to be fitted forward, complying with the relevant provisions of 3-2-9/3.1 applicable to cargo ships. In vessels having a long superstructure at the fore end, the collision bulkhead is to extend weather-tight up to the superstructure deck.

An aft peak bulkhead is to be fitted and made watertight up to the freeboard deck. The aft peak bulkhead may be stepped below the freeboard deck provided the degree of safety of the vessel with regard to subdivision is not diminished.

Arrangements made to maintain the watertight integrity of the watertight subdivisions in way of openings therein are to comply with the relevant provisions of Section 3-2-9 applicable to cargo ships.

PART 3

CHAPTER 3
Subdivision and Stability

APPENDIX 6
Damage Stability Requirements for Fishing Vessels

1 Applicability

Vessels 90m in Length and over, shall comply with the requirements of the ABS *Marine Vessel Rules*. See also 5C-18-1/3. Vessels of 100 m (328 ft) or greater in length and where the total number of persons onboard is 100 or more, shall be capable of remaining afloat with positive stability, after flooding of any one compartment assumed damaged.

3 General

Taking into account, as initial conditions before flooding, all of the standard loading conditions (without icing) as referred to in 3-3-A3/9 and the damage assumptions in 3-3-A6/5, the vessel is to comply with the damage stability criteria as specified in 3-3-A6/7.

The maximum allowable KG (or minimum required GM curve) in the trim and stability booklet are to compliance with the damage criteria in 3-3-A3/7. This curve(s) is to cover the full range of operations (Load Line draft to arrival condition, 3-3-A3/9.1.ii)) and the full range of operational trims. The supporting calculations for this curve are to be submitted for ABS review.

5 Damage Assumptions

The following damage assumptions are to be applied:

i) Damage is to be assumed to occur anywhere in the vessel's length between transverse watertight bulkheads. The longitudinal extent of damage is: $(1/3)L_f^{2/3}$ m, where L_f is the freeboard length, as defined in 3-1-1/3.3.

ii) The vertical extent of damage is to be assumed from the base line upwards without limit.

iii) The transverse extent of damage is to be assumed as $B/5$ m, measured inboard from the side of the vessel perpendicularly to the centerline at the level of the summer load line.

Notes:

1. The flooding should be restricted to any single compartment between adjacent transverse bulkheads. If there are steps or recesses in a transverse bulkhead of not more than 3.05 m (10 ft) in length located within the transverse extent of assumed damage, such transverse bulkhead may be considered intact and the adjacent compartments may be flooded singly. Where the step or recess within the transverse extent of damage exceeds 3.05 (10 ft) m in length in a transverse bulkhead, the two compartments adjacent to this bulkhead should be considered as flooded. The step formed at the junction of the aftpeak bulkhead and the afterpeak tank top should not be considered as a step.
2. If pipes, ducts or tunnels are situated within the assumed extents of damage, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed to be floodable for each case of damage.
3. If damage of a lesser extent than that specified in 3-3-A6/5i), 3-3-A6/5ii) and 3-3-A6/5iii) results in a more severe condition, such lesser extent is to be assumed.
4. Where a transverse watertight 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 m (10 ft), the double bottom or side tanks adjacent to the stepped portion of the transverse watertight bulkhead is to be considered as flooded simultaneously.
5. If the distance between adjacent transverse watertight bulkheads or the distance between the transverse planes passing through the nearest stepped portions of the bulkheads is less than the longitudinal extent of damage given in 3-3-A6/5.i, only one of these bulkheads should be regarded as effective.

7 Criteria

The following damage stability criteria are to be satisfied:

i) The final waterline, taking into account sinkage, heel, and trim, is to be below the lower edge of any opening through which progressive flooding may take place. Such openings are to include air pipes and those openings which are capable of being closed by means of weather-tight doors or hatch covers and exclude those openings closed by means of watertight manhole covers and flush scuttles, small watertight cargo tank hatch covers which maintain the high integrity of the deck, remotely operated watertight sliding doors, and side scuttles of the non-opening type.

ii) In the final stage of flooding, the angle of heel due to unsymmetrical flooding is not to exceed 20°.

iii) The stability in the final stage of flooding is to be investigated and may be regarded as sufficient if the righting lever curve has a positive range of at least 20° beyond the position of equilibrium in association with a maximum residual righting lever of at least 100 mm (3.9 in.) within this range. The area under the righting arm curve within this range shall not be less than 0.0175 m-rad. Unprotected openings are not to become immersed at an angle of heel within the prescribed minimum range of residual stability unless the space in question has been included as a floodable space in calculations for damage stability. Within this range, immersion of any of the openings referred to in 3-3-A6/7.i and any other openings capable of being closed weather-tight may be authorized.

iv) The initial metacentric height of the damaged vessel in the final condition of flooding for the upright position shall not be less than 50 mm.

v) Unsymmetrical flooding shall be kept to a minimum consistent with efficient arrangements. Where it is necessary to correct large angles of heel, the means shall be automatic. The vessel shall maintain sufficient stability during intermediate stages of flooding.

9 Permeability

The permeability** of compartments assumed to be damaged is to be as follows:

Spaces	*Permeability*
Appropriated to Stores	0.60
Accommodations	0.95
Machinery Spaces	0.85
Void Spaces	0.95
Spaces for Dry Cargo	0.95
Empty Fish Hold	0.95
Full Fish Hold	0.50
Tanks	0.95

** Permeability of a space means the ratio of the volume within that space, which should be assumed to be occupied by fluid, to the total volume of that space.

11 Free Surface

The free surface effects are to be calculated in accordance with 3-3-A3/11.5. Additionally, the free surface effect of a damaged non-consumable tank may be omitted from the damage stability calculations.

13 Subdivision

The machinery spaces, working, cargo and accommodation spaces in the hull are to be separated by bulkheads made watertight up to the freeboard deck.

A collision bulkhead is to be fitted forward, complying with the relevant provisions of 3-2-9/3.1 applicable to cargo ships. In vessels having a long superstructure at the fore end, the collision bulkhead is to extend weather-tight up to the superstructure deck.

An aft peak bulkhead is to be fitted and made watertight up to the freeboard deck. The aft peak bulkhead may be stepped below the freeboard deck provided the degree of safety of the vessel with regard to subdivision is not diminished.

Arrangements made to maintain the watertight integrity of the watertight subdivisions in way of openings therein is to comply with the relevant provisions of Section 3-2-9 applicable to cargo ships.

PART 3

CHAPTER 3

Subdivision and Stability

APPENDIX 7

Computer Software for Onboard Stability Calculations

1 General

1.1 Scope

The scope of stability calculation software is to be in accordance with the stability information as approved by the flag Administration or ABS on behalf of the flag Administration. The software is at least to include all information and perform all calculations or checks as necessary to ensure compliance with the applicable stability requirements.

The approved stability software is not a substitute for the approved stability information, and is used as a supplement to the approved stability information to facilitate stability calculations.

1.3 Design

The input/output information is to be easily comparable with the approved stability information so as to avoid confusion and possible misinterpretation by the operator relative to the approved stability information.

An operation manual is to be provided for the onboard computer stability software.

The language in which the stability information is displayed and printed out, and in which the operation manual is written is to be the same as used in the vessel's approved stability information. The primary language is to be English.

The onboard computer for stability calculations is to be vessel specific equipment and the results of the calculations are to be applicable only to the vessel for which it has been approved.

In case of modifications implying changes in the main data or internal arrangement of the vessel, the specific approval of any original stability calculation software is no longer valid. The software is to be modified accordingly and submitted for re-approval.

3 Calculation Systems

This Appendix covers either system, a passive system that requires manual data entry or an active system, which replaces the manual with the automatic entry with sensors reading and entering the contents of tanks, etc., provided the active system is in the off-line operation mode. However, an integrated system, which controls or initiates actions based on the sensor-supplied inputs is not within the scope of this Appendix.

5 Types of Stability Software

Four types of calculations performed by stability software are acceptable depending upon a vessel's stability requirements:

- Type 1 Software calculating intact stability only (for vessels not required to meet a damage stability criterion)
- Type 2 Software calculating intact stability and checking damage stability on basis of a limit curve (for vessels applicable to SOLAS Part B-1 damage stability calculations, etc.) or checking all the stability requirements (intact and damage stability) on the basis of a limit curve
- Type 3 Software calculating intact stability and damage stability by direct application of preprogrammed damage cases based on the relevant Conventions or Codes for each loading condition (for some tankers, etc.)
- Type 4 Software calculating damage stability associated with an actual loading condition and actual flooding case, using direct application of user defined damage, for the purpose of providing operational information for safe return to port (SRtP).

Damage stability of both Type 3 and Type 4 stability software is to be based on a hull form model, that is, directly calculated from a full three-dimensional geometric model.

7 Functional Requirements

7.1 Calculation Program

The calculation program is to present relevant parameters of each loading condition in order to assist the Master in their judgment on whether the vessel is loaded within the approval limits. The following parameters are to be presented for a given loading condition:

- Deadweight data
- Lightship data
- Trim
- Draft at the draft marks and perpendiculars
- Summary of loading condition displacement, VCG, LCG and, if applicable, TCG
- Downflooding angle and corresponding downflooding opening (not applicable for Type 2 software which uses limit curve for checking all the stability requirements. However, if intact stability criteria are given in addition to the limit curve, the limit values, the obtained values and the conclusion is to be indicated).
- Compliance with stability criteria: Listing of all calculated stability criteria, the limit values, the obtained values and the conclusions (criteria fulfilled or not fulfilled) (not applicable for Type 2 software which uses limit curve for checking all the stability requirements. However, if intact stability criteria are given in addition to the limit curve, the limit values, the obtained values and the conclusion is to be indicated).

7.3 Direct Damage Stability Calculations *(1 July 2021)*

If direct damage stability calculations are performed, the relevant damage cases for both sides of the ship according to the applicable requirements are to be pre-defined for automatic check of a given loading condition.

7.5 Warning

A clear warning is to be given on screen and in hard copy printout if any of the loading limitations are not satisfied any of the loading limitations are not complied with.

As applicable, loading limitations are to include, but may not be limited to:

- Trim, draft, liquid densities, tank filling levels, initial heel
- Use of limit KG/GM curves in conjunction with above for Type 2
- Restrictions to the stowage height for timber where timber load lines are assigned

7.7 Data Printout

The data are to be presented on screen and in hard copy printout in a clear unambiguous manner.

7.9 Date and Time

The date and time of a saved calculation are to be part of the screen display and hard copy printout.

7.11 Information of Program

Each hard copy printout is to include identification of the calculation program with version number.

7.13 Units

Units of measurement are to be clearly identified and used consistently within a loading calculation.

7.15 Computer Model

For Type 3 and Type 4 software, the system is to be pre-loaded with a detailed computer model of the complete hull, including appendages, all compartments, tanks and the relevant parts of the superstructure considered in the damage stability calculation, wind profile, down-flooding and up-flooding openings, cross-flooding arrangements, internal compartment connections and escape routes, as applicable and according to the type of stability software.

For Type 1 and Type 2 software, in case a full three dimensional model is used for stability calculations, the requirements of the computer model are to be as per the paragraph above to the extent as applicable and according to the type of stability software.

7.17 Further Requirements for Type 4 Stability Software

7.17.1

The normal (Type 1, 2 and 3) and SRtP (Type 4) software need not be "totally separated". Where the normal and SRtP software are not totally separated:

- The function of switching between normal software and Type 4 software is to be provided.
- The actual intact loading condition is to be the same for both functions (normal operation and SRtP); and
- The SRtP module needs only to be activated in case of an incident.

Approval of Type 4 (SRtP) software is for stability only.

7.17.2

In passenger vessels which are subject to SRtP and have an onboard stability computer and shore-based support, such software need not be identical.

7.17.3

Each internal space is to be assigned its permeability as shown below, unless a more accurate permeability has been reflected in the approved stability information.

Spaces	*Permeability*			
	Default	*Full*	*Partially Filled*	*Empty*
Container Spaces	0.95	0.70	0.80	0.95
Dry Cargo spaces	0.95	0.70	0.80	0.95
Ro-Ro spaces	0.95	0.90	0.90	0.95
Cargo liquids	0.95	0.70	0.80	0.95
Intended for consumable liquids	0.95	0.95	0.95	0.95
Stores	0.95	0.60	0.60	0.95
Occupied by machinery	0.85			
Void spaces	0.95			
Occupied by accomodation	0.95			

7.17.4

The system is to be capable of accounting for applied moments such as wind, lifeboat launching, cargo shifts and passenger relocation.

7.17.5

The system is to account for the effect of wind by using the method in SOLAS regulation II-1/7-2.4.1.2 as the default, but allow for manual input of the wind speed/pressure if the on-scene pressure is significantly different (P = 120 N/m^2 equates to Beaufort 6; approximately 13.8 m/s or 27 knots).

7.17.6

The system is to be capable of assessing the impact of open main watertight doors on stability (e.g., for each damage case provided for verification, additional damage stability calculation is to be done and presented, taking into account any watertight door located within the damaged compartment(s)).

7.17.7

The system is to utilize the latest approved lightship weight and center of gravity information.

7.17.8

The output of the software is to be such that it provides the master with sufficient clear unambiguous information to enable quick and accurate assessment of the stability of the vessel for any actual damage, the impact of flooding on the means of escape and the controls of devices necessary for managing and/or controlling the stability of the vessel.

When the actual loading condition is input in the SRtP software, the following output (intact stability) is to be available:

- Deadweight data
- Lightship data

- Trim
- Heel
- Draft at the draft marks and perpendiculars
- Summary of loading condition displacement, VCG, LCG and, if applicable, TCG
- Downflooding angle and corresponding downflooding opening
- Free surfaces
- GM value
- GZ values relevant to an adequate range of heeling (not less than 60°) available indicatively at the following intervals: 0 5 10 15 20 25 30 40 50 60 deg
- Compliance with relevant intact stability criteria (i.e., 2008 IS Code): listing of all calculated intact stability criteria, the limiting values, the obtained values and the evaluation (criteria fulfilled or not fulfilled)
- GM/KG limiting curve according to SOLAS, Ch II-1, Regulation 5-1

When the actual loading condition is associated to the actual damage case(s) due to the casualty, the following output (damage stability) is to be available:

- Trim
- Heel
- Draft at the draft marks and perpendiculars
- Progressive flooding angle and corresponding progressive flooding openings
- GM value
- GZ values relevant to an adequate range of heeling (not less than 60°) available indicatively at the following intervals: 0 5 10 15 20 25 30 40 50 60 deg
- Compliance with stability criteria: listing of all calculated stability criteria, the limit values, the obtained values and the conclusions (criteria fulfilled or not fulfilled)
- The survivability criteria for Type 4 software (SRtP) are left to the discretion of the Administration
- Relevant flooding points (unprotected or weathertight) with the distance from the damage waterline to each point
- List of all flooded compartments with the permeability considered
- Amount of water in each flooded compartment
- Escape route immersion angles
- A profile view, deck views and cross-sections of the vessel indicating the flooded water-plane and the damaged compartments

7.17.9

For ro-ro passenger vessels, there are to be algorithms in the software for estimating the effect of water accumulation on deck (WOD) (e.g., 1. In addition to the predefined significant wave height, taken from the approved stability document, there is to be possibility for the crew to input manually the significant wave height of the vessel navigation area in the system, 2. In addition to the predefined significant wave height, taken from the approved stability document, calculations with two additional significant wave heights are to be submitted for checking the correctness of the algorithms in the software for estimating the effect of WOD). *

Note: * This paragraph applies to Ro-Ro Passenger vessels subject to the Stockholm Agreement (IMO Circular Letter No. 1891)

9 Acceptable Tolerances

Depending on the type and scope of programs, the acceptable tolerances are to be determined differently, according to 3-3-A7/9.1 or 3-3-A7/9.3. In general, deviation from these tolerances is not to be accepted unless a satisfactory explanation for the difference is submitted for review and the same is satisfactorily confirmed by ABS that there would be no adverse effect on the safety of the vessel.

Examples of pre-programmed input data include the following:

- Hydrostatic data: Displacement, LCB, LCF, VCB, KMt and MCT vs. draft
- Stability data: KN or MS values at appropriate heel/trim angles vs. displacement, stability limits or allowable VCG.
- Compartment data: Volume, LCG, VCG, TCG and FSM/Grain heeling moments vs. level of the compartment's contents.

Examples of output data include the following:

- Hydrostatic data: Displacement, LCB, LCF, VCB, KMt and MCT versus draft, as well as actual drafts, trim.
- Stability data: FSC (free surface correction), GZ-values, KG, GM, KG/GM limits, allowable grain heeling moments, derived stability criteria (e.g., areas under the GZ curve), weather criteria.
- Compartment data: Calculated Volume, LCG, VCG, TCG and FSM/Grain heeling moments vs. level of the compartment's contents

The computational accuracy of the calculation program results is to be within the acceptable tolerances specified in 3-3-A7/9.1 or 3-3-A7/9.3, of the results using an independent program or the approved stability information with identical input.

9.1 Calculation Program of the Approved Stability Information

Programs which use only pre-programmed data from the approved stability information as the basis for stability calculations are to have zero tolerances for the printouts of input data.

Output data tolerances are to be close to zero. However, small differences associated with calculation rounding or abridged input data are acceptable. Additionally differences associated with the use of hydrostatic and stability data for trims that differ from those in the approved stability information are acceptable subject to review by ABS.

9.3 Independent Program for Assessment of Stability

Programs which use hull form models as their basis for stability calculations are to have tolerances for the printouts of basic calculated data established against either data from the approved stability information or data obtained using the approval authority’s model. Acceptable tolerances shall be in accordance with 3-3-A7/9.3 TABLE 1.

TABLE 1
Acceptable Tolerances

Hull Form Dependent	*Acceptable Tolerance* (1)
Displacement	± 2%
Longitudinal center of buoyancy, from AP	± 1% or 50 cm, whichever is greater
Vertical center of buoyancy	± 1% or 5 cm, whichever is greater
Transverse center of buoyancy	± 0.5% of *B* or 5 cm whichever is greater
Longitudinal center of flotation, from AP	± 1% or 50 cm, whichever is greater

Hull Form Dependent	***Acceptable Tolerance*** (1)
Moment to trim 1 cm	± 2%
Transverse metacentric height	± 1% or 5 cm, whichever is greater
Longitudinal metacentric height	± 1% or 50 cm, whichever is greater
Cross curves of stability	± 5 cm
Compartment Dependent	*Acceptable Tolerance* (1)
Volume or deadweight	± 2%
Longitudinal center of gravity, from AP	± 1% or 50 cm, whichever is greater
Vertical center of gravity	± 1% or 5 cm, whichever is greater
Transverse center of gravity	± 0.5% of *B* or 5 cm, whichever is greater
Free surface moment	± 2%
Shifting moment	± 5%
Level of contents	± 2%
Trim and Stability	*Acceptable Tolerance* (1)
Drafts (forward, aft, mean)	± 1% or 5 cm, whichever is greater
GMt	± 1% or 5 cm, whichever is greater
GZ values	± 5% or 5 cm, whichever is greater
Downflooding angle	± 2°
Equilibrium angles	± 1°
Distance to unprotected openings or margin line from WL, if applicable	± 5% or 5 cm, whichever is greater
Areas under righting arm curve	± 5% or 0.0012 mrad

Notes:

1 Deviation in % = {(base value-applicant's value)/base value} ×100
where the "base value" may be from the approved stability information or the society's computer model.

2 Where differences in calculation methodology exist between the programs used in the comparison, this may be a basis for accepting deviations greater than that specified in the table above provided a software examination is carried out in sufficient detail to clearly document that such differences are technically justifiable.

3 Deviation from these tolerances are not to be accepted unless ABS considers that there is a satisfactory explanation for the difference and that it is clearly evident from ABS's stability calculations that the deviation does not impact compliance with the required stability criteria for the vessel under consideration.

11 Approval Procedure

11.1 Conditions of approval of the onboard software for stability calculations

The onboard software used for stability calculations is subject to approval, which is to include:

- Verification of type approval, if any,
- Verification that the data used is consistent with the current condition of the vessel (see 3-3-A7/11.5),

- Verification and approval of the test conditions, and
- Verification that the software is appropriate for the type of vessel and stability calculations required.
- Verification that the software is installed so that failure of the primary computer or server does not prevent the stability calculation from being carried out (this is to be demonstrated onboard as noted below)
- Verification of functional requirements under 3-3-A7/7.

The satisfactory operation of the software for stability calculations is to be verified by testing upon installation on the primary computer or server and at least one back-up computer or redundant server onboard (see 3-3-A7/15). A copy of the approved test conditions and the operation manual for the computer/software are to be available onboard.

11.3 General Approval (optional)

Upon receipt of application for general approval of the calculation program, ABS may provide the applicant with test data consisting of two or more design data sets, each of which is to include a vessel's hull form data, compartmentation data, lightship characteristics and deadweight data, in sufficient detail to accurately define the vessel and its loading condition.

Acceptable hull form and compartmentation data may be in the form of surface coordinates for modeling the hull form and compartment boundaries (e.g., a table of offsets) or in the form of precalculated tabular data (e.g., hydrostatic tables, capacity tables) depending upon the form of data used by the software being submitted for approval. Alternatively, the general approval may be given based on at least two test vessels agreed upon between the applicant and ABS.

In general, the software is to be tested for two types of vessels for which approval is requested, with at least one design data set for each of the two types. Where approval is requested for only one type of vessel, a minimum of two data sets for different hull forms of that type of vessel are required to be tested.

For calculation software which is based on the input of hull form data, design data sets are to be provided for three types of vessels for which the software is to be approved, or a minimum of three data sets for different hull forms if approval is requested for only one type of vessel. Representative vessel types which require different design data sets due to their hull forms, typical arrangements, and nature of cargo include: tanker, bulk carrier, container carrier, and other dry cargo and passenger vessels.

The test data sets are to be used by the applicant to run the calculation program for the test vessels. The results obtained, together with the hydrostatic data and cross-curve data developed by the program, if appropriate are to be submitted to ABS for the assessment of the program's computational accuracy. ABS is to perform parallel calculations using the same data sets and a comparison of these results will be made against the applicant's submitted program's results.

11.5 Specific Approval

ABS is to verify the accuracy of the computational results and actual vessel data used by the calculation program for the particular vessel on which the program will be installed.

Upon receipt of application for data verification, ABS and the applicant are to agree on a minimum of four loading conditions, taken from the vessel's approved stability information, which are to be used as the test conditions.

For vessels carrying liquids in bulk, at least one of the conditions is to include partially filled tanks. For vessels carrying grain in bulk, one of the grain loading conditions is to include a partially filled grain compartment. Within the test conditions each compartment is to be loaded at least once. The test conditions normally are to cover the range of load drafts from the deepest envisaged loaded condition to the light ballast condition and are to include at least one departure and one arrival condition.

For Type 4 stability software for SRtP, ABS is to examine at least three damage cases, each of them associated with at least three loading conditions taken from the vessel's approved stability information. Output of the software is to be compared with results of corresponding load/damage case in the approved damage stability booklet or an alternative independent software source.

ABS is to verify that the following data, submitted by the applicant, is consistent with arrangements and most recently approved lightship characteristics of the vessel according to current plans and documentation on file with ABS, subject to possible further verification onboard:

- Identification of the calculation program including version number.
- Main dimensions, hydrostatic particulars and, if applicable, the vessel profile.
- The position of the forward and after perpendiculars, and if appropriate, the calculation method to derive the forward and after drafts at the actual position of the vessel's draft marks.
- Vessel lightweight and center of gravity derived from the most recently approved inclining experiment or lightweight survey.
- Lines plan, offset tables or other suitable presentation of hull form data if necessary for ABS to model the vessel.
- Compartment definitions, including frame spacing, and centers of volume, together with capacity tables (sounding/ullage tables), free surface corrections, if appropriate
- Cargo and Consumables distribution for each loading condition.

Verification by ABS does not absolve the applicant and shipowner of responsibility for ensuring that the information programmed into the onboard computer software is consistent with the current condition of the vessel.

13 Operation Manual

A simple and straightforward operation manual is to be provided, containing descriptions and instructions, as appropriate, for at least the following:

- Installation
- Function keys
- Menu displays
- Input and output data
- Required minimum hardware to operate the software
- Use of the test loading conditions
- Computer-guided dialogue steps
- List of warnings

15 Installation Testing

To ensure correct working of the computer after the final or updated software has been installed, it is the responsibility of the vessel's master to have test calculations carried out according to the following pattern in the presence of the Surveyor:

- From the approved test conditions at least one load case (other than lightship) is to be calculated.

  Note: Actual loading condition results are not suitable for checking the correct working of the computer.

- Normally, the test conditions are permanently stored in the computer.

Steps to be performed:

- Retrieve the test load case and start a calculation run; compare the stability results with those in the documentation.
- Change several items of deadweight (tank weights and the cargo weight) sufficiently to change the draft or displacement by at least 10%. The results are to be reviewed to ensure that they differ in a logical way from those of the approved test condition.
- Revise the above modified load condition to restore the initial test condition and compare the results. Confirm that the relevant input and output data of the approved test condition have been replicated.
- Alternatively, one or more test conditions shall be selected and the test calculation performed by entering all deadweight data for each selected test condition into the program as if it were a proposed loading. The results shall be verified as identical to the results in the approved copy of the test conditions.

17 Periodical Testing

It is the responsibility of the vessel's master to check the accuracy of the onboard computer for stability calculations at each Annual Survey by applying at least one approved test condition.

If the Surveyor is not present for the computer check, a copy of the test condition results obtained by the computer check is to be retained onboard as documentation of satisfactory testing for the Surveyor's verification.

At each Special Periodical Survey, this checking for all approved test loading conditions is to be done in presence of the surveyor.

The testing procedure is to be carried out in accordance with 3-3-A7/15.

19 Other Requirements

The following features are to be provided to the software:

- Protection against unintentional or unauthorized modification of programs and data is to be provided.
- The program is to monitor operations and activate an alarm when the program is incorrectly or abnormally used.
- The program and any data stored in the system are to be protected from corruption by loss of power.
- Error messages with regard to limitations such as filling a compartment beyond capacity, or exceeding the assigned load line, etc. are to be included.

PART 3

CHAPTER 4
Fire Safety Measures

CONTENTS

PART 3

CHAPTER 4
Fire Safety Measures

SECTION 1
Structural Fire Protection

1 General

1.1 SOLAS Application

For classification purposes, the fire safety measures contained in the International Convention for the Safety of Life at Sea, 1974 (1974 SOLAS) as amended, are applicable to vessels of type, size and service coming under that Convention.

This Chapter does not relax the requirements in other Chapters of these Rules.

1.3 Regulation

Regulation means the regulation contained in 1974 SOLAS as amended. An abbreviated notation is used, e.g. Regulation II-2/5.2 means Regulation 5.2 of Chapter II-2.

1.5 Definitions

See Regulation II-2/3.

1.7 Materials Containing Asbestos

Installation of materials which contains asbestos is prohibited.

3 Offshore Support Vessels

For offshore support vessels that can be considered as cargo vessels as defined in Regulation II-2/3.7, the relevant requirements in Regulations 4 to 11; Regulation 13; and Regulations 19 and 20, Chapter II-2 of 1974 SOLAS, as amended, are applicable.

Vessels intended to carry hazardous and noxious liquid substances in bulk are to comply with the IMO Resolution A.673(16) as amended by MSC.236(82) requirements *Guidelines for the Transport and Handling of Limited Amounts of Hazardous and Noxious Liquid Substances in Bulk on Offshore Support Vessels* and the governing Administrative Regulations.

5 Passenger Vessels

For Passenger vessels, the requirements in Part 5C, Chapter 7 are applicable.

7 Cargo Vessel

7.1 General Requirements

For all cargo vessels as defined in Regulation 3.7, the relevant requirements in Part B: Regulation 4, 5, 6; Part C: Regulations 7, 8, 9, 10, 11; Part D: Regulation 13; and Part G: Regulations 19 and 20, Chapter II-2 of 1974 SOLAS, as amended, are applicable.

7.3 Additional Requirements for Tankers

For tankers as defined in Regulation 3.48, Chapter II-2 of 1974 SOLAS, as amended, the following requirements are additional to 3-4-1/7.1.

7.3.1 Low Flash Point Cargoes

For tankers intended for the carriage of cargoes having a flash point of 60°C (140°F) or less, the relevant requirements in Part A: Regulation 1; Part B: Regulation 4; Part C: Regulations 9, 10, 11; and Part E: Regulations 16, Chapter II-2 of 1974 SOLAS, as amended, are applicable. Furthermore, the requirements of Chapters 2, 14 and 15 of the Fire Safety Systems Code are also applicable.

For tankers with bow or stern loading and unloading connections, the provisions of SOLAS Regulations II-2/4.5.1.6, II-2/4.5.2.1 to II-2/4.5.2.3 inclusive and II-2/9.2.4.2.5 are to apply, unless alternative arrangements are acceptable to the Administration. This applies to the exterior boundaries of superstructures and deckhouses enclosing accommodation spaces which face the cargo shore connection, the overhanging decks which support such accommodation, the outboard sides of the superstructures and deckhouses for the specific distances from the boundaries which face the cargo shore connection.

7.3.2 High Flash Point Cargoes

For tankers intended for the carriage of cargoes having a flash point above 60°C (140°F), the requirements in 3-4-1/7.1 are applicable, except that in lieu of the fixed fire extinguishing system required by Regulation II-2/10.7.1.3 they are to be fitted with a fixed deck foam system which is to comply with Chapter 14 of the Fire Safety Systems Code.

9 Fiber Reinforced Plastic (FRP) Gratings

Where approved by the Administration, the use of Fiber Reinforced Plastic (FRP) gratings is to be in accordance with Appendix 3-4-A1.

11 Review Procedures

11.1 Administration Review

When the vessel is issued a Passenger Ship Safety Certificate, Cargo Ship Safety Equipment Certificate or Cargo Ship Safety Construction Certificate by the flag Administration or its agent other than ABS, such Certificate will be accepted as evidence that the vessel is in accordance with the applicable criteria in 1974 SOLAS as amended.

Where the Administration undertakes any part of the review and ABS is issuing the above Certificate, the acceptance by the Administration will be required before the certificate is issued.

Compliance with the Rule requirements in addition to those in 1974 SOLAS as amended is to be verified by ABS.

11.3 ABS Review

In all other cases, the required information and plans are to be submitted to ABS for review.

PART 3

CHAPTER 4
Fire Safety Measures

APPENDIX 1
Fiber Reinforced Plastic (FRP) Gratings

1 General

1.1

FRP gratings may be used in other machinery spaces, cargo areas, and on-deck areas. FRP gratings are not accepted in accommodation, service, control spaces, and areas where smoke and toxicity is a concern. The floor plating and gratings in Category A machinery spaces is to be made of steel. Refer to 3-4-A1/9 TABLE 1.

FRP gratings are to meet the performance requirements of and are to be tested in accordance with ASTM F3059, *Standard Specification for Fiber-Reinforced Polymer (FRP) Gratings Used in Marine Construction and Shipbuilding.*

1.3

Changes in either the type, amount, and/or architecture, of either the reinforcement materials, resin matrix, coatings, or manufacturing processes require separate testing in accordance with the procedures below. Manufacturers are required to provide evidence, such as enrollment in a follow-up program, that the FRP gratings being installed are the same as those which were tested and approved.

3 FRP Grating Material Systems

3.1

Where required, all fire integrity, flame spread, smoke, and toxicity testing are to be conducted on each material system.

5 Fire Test Requirements

5.1 Structural Fire Integrity

The structural fire integrity requirements are intended for self-supporting personnel platforms or walkways, and are not intended for grating overlaid on steel decking or used in other applications such as pipe guards, sea chest screenings, safety guards, etc.

The structural fire integrity matrix in 3-4-A1/9 TABLE 1 establishes the structural fire integrity characteristics that FRP gratings are to have based on location and service. Where a specific application satisfies more than one block in the matrix, the highest level of fire integrity is required. The test procedures required to qualify FRP gratings to one of levels are described in 3-4-A1/7. The location and service of the FRP gratings are to be determined on the basis of the following considerations for each of the four performance levels:

5.1.1 Level 1 (L1)

FRP gratings meeting the L1 performance criteria are intended to be satisfactory for use in escape routes or access for firefighting, emergency operation or rescue, after having been exposed to a significant hydrocarbon or cellulosic fire incident. In addition, they are also acceptable for the services and functions described for levels L2 and L3.

5.1.2 Level 2 (L2)

FRP gratings meeting the L2 performance criteria are intended to be satisfactory for use in open deck areas where groups of people are likely to assemble, such as temporary safe refuge or lifeboat embarkation areas. In addition, they are also acceptable for the services and functions described for level L3.

5.1.3 Level 3 (L3)

FRP gratings meeting the L3 performance criteria are intended to be satisfactory for use in egress routes and any areas that may require access for firefighting, rescue or emergency operations during exposure to or shortly after exposure to a transitory hydrocarbon or cellulosic fire.

5.1.4 Level 0 (L0)

L0 FRP gratings are to be tested in accordance with ASTM E84 with a flame spread index not to exceed 20 and a smoke developed index not to exceed 450. L0 FRP gratings have no fire integrity. L0 FRP gratings may be used for personnel walkways, catwalks, ladders, platforms, or access areas in cargo holds and tanks.

5.3 Flame Spread

All FRP gratings, are to have low flame spread characteristics as determined by the following test procedure:

5.3.1

Tested to ASTM E84 with a flame spread rating not to exceed 20.

5.5 Smoke Generation

All FRP gratings are to have low smoke characteristics as determined by the following test procedure:

5.5.1

Tested to ASTM E84 with a smoke developed index limit not to exceed 450.

7 Structural Fire Integrity Test Procedures

Structural fire integrity tests are to be in accordance with ASTM F3059-15 according to the structural fire integrity performance levels (L1, L2, L3, L0).

9 Structural Fire Integrity Matrix

TABLE 1
Structural Fire Integrity Matrix

Location	*Service*	*Fire Integrity*
Machinery Spaces of Category A(1)	Steel Grating	-
Other Machinery Spaces	Walkways or areas which may be used for escape, or access for firefighting, emergency operation or rescue	L1 (2)
	Personnel walkways, catwalks, ladders, platforms or access areas other than those described above	L3
Cargo Pump Rooms	All personnel walkways, catwalks, ladders, platforms or access areas	L1
Cargo Holds	Walkways or areas which may be used for escape, or access for firefighting, emergency operation or rescue	L1
	Personnel walkways, catwalks, ladders, platforms or access areas other than those described above	L0
Cargo Tanks	All personnel walkways, catwalks, ladders, platforms or access areas	L0(3, 6)
Fuel Oil Tanks	All personnel walkways, catwalks, ladders, platforms or access areas	L0(3)
Ballast Water Tanks	All personnel walkways, catwalks, ladders, platforms or access areas	L0(4)
Cofferdams, void spaces, double bottoms, pipe tunnels, etc.	All personnel walkways, catwalks, ladders, platforms or access areas	L0(4)
Accommodation, service, and control spaces	All personnel walkways, catwalks, ladders, platforms or access areas	Not permitted
Lifeboat embarkation or temporary safe refuge stations in open deck areas	All personnel walkways, catwalks, ladders, platforms or access areas	L2
Open Decks or semi-enclosed areas	Operational areas and access routes for deck foamfirefighting systems on tank vessels	L2
	Walkways or areas which may be used for escape, or accessfor firefighting systems and AFFF hose reels, emergencyoperation, or rescue on MODUs and production platformsincluding safe access to tanker bows	L2
	Walkways or areas which may be used for escape, or access for firefighting, emergency operation or rescue other tan those described above	L3 (5)
	Personnel walkways, catwalks, ladders, platforms or access areas other than those described above	L3

Notes:

1) Machinery spaces of category A is as defined in 4-7-1/11.15.

2) If the machinery space does not contain any internal combustion machinery, other oil-burning, oil-heating, or oil-pumping units, fuel oil filling stations, or other potential hydrocarbon fire sources and has not more than 2.5 kg/m^2 (0.51 lb/ft^2) of combustible storage, gratings of L3 integrity may be used in lieu of L1.

3) If these spaces are normally entered when underway, gratings of L1 integrity are to be required.

4) If these spaces are normally entered when underway, gratings of L3 integrity shall be required.

5) Vessels fitted with deck foam or dry powder firefighting systems require gratings of L2 integrity for the firefighting system operational areas and access routes.

6) With regard to the use of FRP/GRP grating inside LNG/LPG tanks, although the gratings are not to be used at cryogenic temperatures, the manufacturer has to demonstrate the suitability for the intended purpose showing that low temperature does not affect the material characteristics when used.

11 Other Authorized Uses

The ABS Surveyor may authorize the use of FRP gratings without Main Office approval in applications where structural fire integrity of the FRP gratings is not a concern, provided they meet the applicable flame spread and smoke generation requirements set forth in 3-4-A1/5.3 and 3-4-A1/5.5Applications where the uses of FRP gratings have been authorized in the past, without any structural fire integrity requirement, include the following:

i) Sea chest coverings;

ii) Small sundeck awnings and supports;

iii) Lifeboat bilge flooring;

iv) Electrical control flooring;

v) Pipe guards on deck, in cargo holds, and in engine rooms;

vi) Removable guards over hawse holes, anchor hawse pipes, and scuppers;

vii) Personnel barriers, such as protection for electrical panels; and

viii) Ship staging and work platforms (Occupational Safety and Health Administration (OSHA) requirements may also apply).

PART 3

CHAPTER 5
Equipment

CONTENTS

PART 3

CHAPTER 5
Equipment

SECTION 1
Anchoring, Mooring, and Towing Equipment

1 General *(1 July 2018)*

All vessels are to have a complete equipment of anchors and chains. The symbol Ⓔ placed after the symbols of classification in the *Record*, thus: ✠ **A1** Ⓔ, will signify that the equipment of the vessel is in compliance with the requirements of these Rules, or with requirements corresponding to the service limitation noted in the vessel's classification, which have been specially approved for the particular service. The mass per anchor of bower anchors, given in 3-5-1/19.7 TABLE 1A (in SI, MKS Units) and 3-5-1/19.7 TABLE 1B (in US Units), is for anchors of equal mass. The mass of individual anchors may vary 7% plus or minus from the tabular mass, provided that the combined mass of all anchors is not less than that required for anchors of equal mass.

For tankers and bulk carriers that anchor outside a harbor or similar area of sheltered waters, the ABS *Guide for the Optional Class Notation Deep Water Anchoring for Oil Tankers and Bulk Carriers*, with the optional notation **DWA**, enables owners, operators, and designers to assess the adequacy of anchoring equipment in these locations.

Cables which are intended to form part of the equipment are not to be used as check chains when the vessel is launched. The inboard ends of the cables of the bower anchors are to be secured to the vessel's structure such, as to be able to be released in the case of distress or emergency (see 3-5-1/13). Two bower anchors and their cables are to be connected and positioned, ready for use. Means are to be provided for stopping each cable as it is paid out, and the windlass should be capable of heaving in either cable. The length of chain cable required by 3-5-1/Tables 1A and 1B can be equally distributed between the two bower anchors connected and ready for use. Where the chain is arranged such that one anchor has a longer length for mooring, it is to be verified that the windlass has sufficient capability for heaving in the longer length of chain. Arrangements are to be provided for securing the anchors and stowing the cables. See 3-5-1/14.

The strength of supporting hull structures in way of shipboard fittings used for mooring operations and towing operations as well as supporting hull structures of winches and capstans at the bow, sides, and stern are to comply with the requirements of 3-2-7/4.

3 Equipment Mass and Size

Equipment mass and size are to be in accordance with the following sections as applicable.

3.1 Equipment Number (EN) *(1 July 2022)*

The requirements herein are intended for temporary mooring of a vessel within a harbor or sheltered area when the vessel is awaiting berth, tide, etc. The *ABS Guide for the Optional Notation Deep Water Anchoring for Oil Tankers and Bulk Carriers* or the IACS Recommendation No. 10 'Anchoring, Mooring and Towing Equipment' may be referred to for recommendations concerning anchoring equipment for vessels in deep and unsheltered water.

The equipment is therefore not designed to hold a vessel off fully exposed coasts in rough weather or to stop a ship that is moving or drifting. In this condition, the loads on the anchoring equipment increase to such a degree that its components may be damaged or lost owing to the high energy forces generated, particularly in large vessels. The anchoring equipment required herewith is designed to hold a vessel in good holding ground in conditions such as to avoid dragging of the anchor. In poor holding ground, the holding power of the anchors is significantly reduced.

The "Equipment Number" (EN) equation is based on an assumed maximum current speed of 2.5 m/s (8.2 ft/s), a maximum wind speed of 25 m/s (49 knots) and a minimum scope of 6, the scope being the ratio of length of chain paid out to the water depth. For vessels with a Rule length greater than 135 m (443 ft), alternatively the required anchoring equipment can be considered applicable to a maximum current speed of 1.54 m/s (4.9 ft/s), a maximum wind speed of 11 m/s (21 knots) and waves with maximum significant height of 2 m (6.6 ft). Anchors and chains are to be in accordance with 3-5-1/Tables 1A and 1B and the numbers, mass and sizes of these are to be regulated by the equipment number (*EN*) obtained from the following equation:

$$\mathrm{EN} = k\Delta^{2/3} + m(Bh + S_{fun}) + nA$$

where

k	=	1.0 (1.0, 1.012)
m	=	2 (2, 0.186)
n	=	0.1 (0.1, 0.00929)
Δ	=	molded displacement, as defined in 3-1-1/13.1
B	=	molded breadth, as defined in 3-1-1/5
h	=	effective height, in m (ft), from the Summer Load waterline to the top of the uppermost house
	=	$a + h_1 + h_2 + h_3 + \ldots$ See Notes 1, 2 and 3.
a	=	vertical distance at hull side, in m (ft), from the Summer Load waterline amidships to the upper deck.
$h_1, h_2, h_3 \ldots$	=	height shown in 3-5-1/3.1 FIGURE 1A, in m (ft), measured at the centerline of each tier of houses having a breadth greater than $B/4$, as applicable. For the lowest tier, h_1 is to be measured at the centerline from the upper deck or from a notional deck line where there is local discontinuity in the upper deck, see 3-5-1/3.1 FIGURE 1A for an example.
S_{fun}	=	effective front projected area, in m^2 (ft^2), of the funnel
	=	$A_{FS} - S_{shield}$
A_{FS}	=	front projected area, in m^2 (ft^2), of the funnel calculated between the upper deck at the centerline, or the notional deck line where there is local discontinuity in the upper deck, and the top of the effective height h_F. See 3-5-1/3.1 FIGURE 1A and Note 5. A_{FS} is taken equal to zero if the funnel breadth is less than or equal to $B/4$ at all elevations along the funnel height.

h_F = effective height, in m (ft), of the funnel measured from the upper deck at the centerline, or the notional deck line where there is local discontinuity in the upper deck, and the top of the funnel. See 3-5-1/3.1 FIGURE 1A and Note 5.
The top of the funnel may be taken at the level where the funnel breadth reaches B/4.

S_{shield} = the section of front projected area A_{FS}, in m^2 (ft^2), which is shielded by all deck houses having breadth greater than B/4. If there is more than one shielded section, the individual shielded sections (i.e., S_{shield_1}, S_{shield_2}, etc.), as shown in 3-5-1/3.1 FIGURE 1A, are to be added together. To determine S_{shield}, the deckhouse breadth is assumed B for all deck houses having breadth greater than B/4 as shown for S_{shield_1} and S_{shield_2} in 3-5-1/3.1 FIGURE 1A.

A = side projected area, in m^2 (ft^2), of the hull, superstructures, houses and funnels above the Summer Load waterline which are within the Rule length of the ship and also have a breadth greater than B/4. The side projected area of the funnel is considered in A when A_{FS} is greater than zero. In this case, the side projected area of the funnel is to be calculated between the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the top of the effective height h_F. See Notes 1, 2, 3, 4 and 5.

Notes:

1 The sheer and trim may be neglected. Superstructures or deck houses having a breadth at any point not greater than B/4 may be excluded.

2 Screens and bulwarks more than 1.5 m (4.9 ft) in height are to be regarded as parts of houses in the calculation.

3 The heights of hatch coamings and that of any deck cargos such as containers may be disregarded, except as specified by 3-5-1/9.3 for mooring lines.

4 Where bulwark is more than 1.5 m (4.9 ft) in height, area A_2 within the Rule length as illustrated in 3-5-1/3.1 FIGURE 1B), is to be included in A .

5 When several funnels are fitted on the ship, A_{FS}, h_F and A are taken as follows:

- A_{FS}: sum of the front projected area of each funnel, in m^2 (ft^2), calculated between the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the effective height h_F. A_{FS} is to be taken equal to zero if the sum of each funnel breadth is less than or equal to B/4 at all elevations along the funnels height.
- h_F: effective height of the funnel, in m (ft), measured from the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the top of the highest funnel. The top of the highest funnel may be taken at the level where the sum of each funnel breadth reaches B/4.
- A: Side projected area, in m^2 (ft^2), of the hull, superstructures, houses and funnels above the Summer Load waterline which are within the Rule length of the ship. The total side projected area of the funnels is to be considered in the side projected area of the ship, A , when A_{FS} is greater than zero. The shielding effect of funnels in transverse direction may be considered in the total side projected area (i.e., when the side projected areas of two or more funnels fully or partially overlap, the overlapped area needs only to be counted once).

FIGURE 1A
Effective Heights and Widths of Deck Houses *(1 July 2022)*

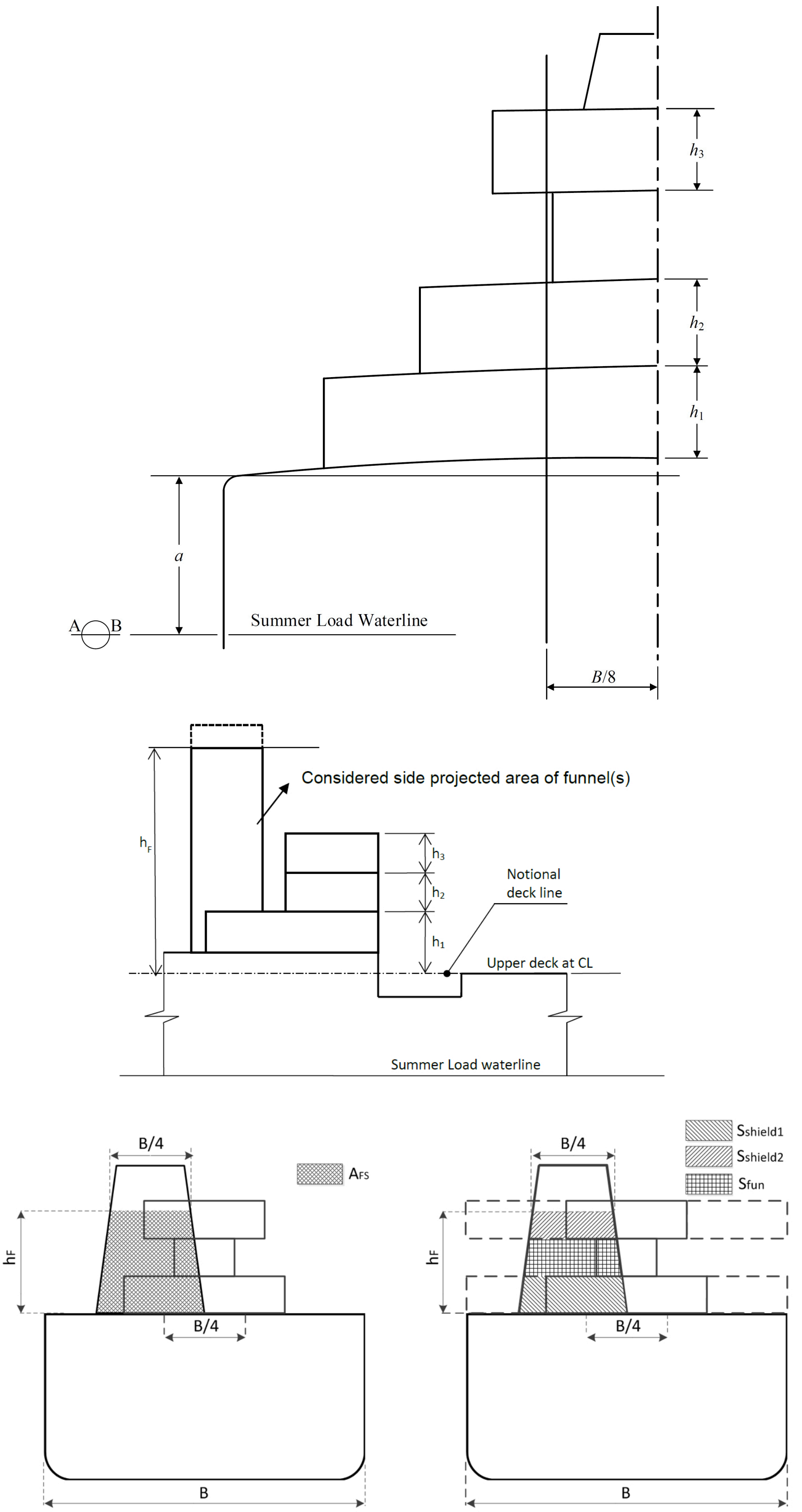
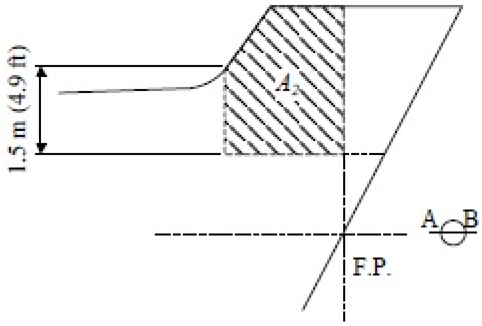


FIGURE 1B
Profile Area



3.3 Equipment Number (EN) for Vessels Under 90 Meters (295 Feet) In Length *(1 July 2018)*

3.3.1 Vessels for Unrestricted Service and Having EN of 205 or Above

Where the EN obtained from 3-5-1/3.1 equals to 205 or above, the calculated EN is to be used in association with 3-5-1/Tables 1A and 1B.

3.3.2 Vessels Having EN Less Than 205 or Intended for Towing Service *(1 July 2018)*

For the following under 90m (295 ft) vessels the basic EN obtained from 3-5-1/3.1 is to be readjusted and to be used in conjunction with 3-5-1/Tables 1A and 1B:

i) Vessels having Basic EN less than 205

ii) Vessels Intended for Towing Service

The adjusted EN for use with 3-5-1/Tables 1A and 1B may be calculated in accordance with the following:

$$\mathrm{EN} = k\Delta^{2/3} + m(Ba + \sum bh) + nA$$

where

b = breadth, in m (ft), of the widest superstructure or deckhouse on each tier.

h = height, in m (ft), of each tier of deckhouse or superstructure having a width of B/4 or greater. In the calculation of h, sheer, camber and trim may be neglected. See 3-5-1/3.1 FIGURE 1A.

k, m, n, Δ, B, a and A are as defined in 3-5-1/3.1.

3.5 Vessels Having Unconventional Topside Arrangements or Operational Profiles

Vessels having unconventional topside arrangements or operational profiles are subject to special considerations with regard to EN calculation. Such considerations may include but not limited to:

i) Additional wind areas of widely separated deckhouses or superstructures are to be accounted for;

ii) Equipment sizing is based on direct calculation but not to be taken less than that required by 3-5-1/3.1 and 3-5-1/3.3, as applicable.

3.7 Equipment without the Symbol Ⓔ *(1 July 2020)*

For vessels under 90 m (295 ft) having EN less than 205 or vessels intended for towing, where the symbol Ⓔ is not desired, see Section 3-5-3.

5 Material and Tests *(1 July 2018)*

Material and testing for anchors and chains on vessels receiving the Ⓔ symbol are to be in accordance with the requirements of Chapter 2 of the ABS *Rules for Materials and Welding (Part 2)* for the respective sizes of anchors and chains. See Sections 2-2-1 and 2-2-2 of the above referenced Part 2. Materials and tests for wire rope on vessels under 90 m (295 ft) are to be in accordance with a national or other recognized standard.

Where the symbol Ⓔ is not desired in accordance with 3-5-1/3.7, the testing is to be carried out in accordance with the approved specification, and the manufacturer's test certificate to that effect is to be submitted to the Surveyor.

7 Anchor Types

i) Anchors are to be of the stockless type. The mass of the head of a stockless anchor, including pins and fittings, is not to be less than three-fifths of the total mass of the anchor.

ii) Where specifically requested by the Owners, ABS is prepared to consider the use of special types of anchors, which are of proven superior holding capacity. This may result in a mass reduction of up to a maximum of 25% from the mass specified in 3-5-1/Tables 1A and 1B. In such cases, the notation **RW** (reduced weight) is to be indicated in the *Record*.

9 Mooring and Towing Equipment *(1 July 2018)*

9.1 All Vessels *(1 July 2018)*

Hawsers, towlines, and requirements for associated equipment and arrangements as described in 3-5-1/9.9 and 3-5-1/9.11 are generally not required as a condition of classification, except as indicated in 3-5-1/15.5. The hawsers and towlines listed in 3-5-1/19.7 TABLE 2 and 3-5-1/19.7 TABLE 3 are as a minimum guide.

9.3 Mooring Lines *(2022)*

The mooring lines for vessels with Equipment Number EN of less than or equal to 2000 are given in 3-5-1/9.3.1. For other vessels, the mooring lines are given in 3-5-1/9.3.2.

The Equipment Number EN is to be calculated in compliance with 3-5-1/3. Deck cargoes at the ship nominal capacity condition are to be included for the determination of side-projected area *A*. The nominal capacity condition is defined in 3-2-7/4.3.1.

Sections 3-5-1/9.3.1 and 3-5-1/9.3.2 specify the minimum recommended number and minimum strength of mooring lines. As an alternative to 3-5-1/9.3.1 and 3-5-1/9.3.2, the minimum recommendation for mooring lines may be determined by direct mooring analysis in line with the procedure given in IACS Recommendation 10/Appendix A.

The designer should consider verifying the adequacy of mooring lines based on assessments carried out for the individual mooring arrangement, expected shore-side mooring facilities and design environmental conditions for the berth.

9.3.1 Mooring Lines for Vessels with EN ≤ 2000

The minimum mooring lines for vessels having an Equipment Number EN of less than or equal to 2000 are given in 3-5-1/19.7 TABLE 2 is intended as a guide.

For vessels having an *A/EN* ratio greater than 0.9 for SI or MKS units (9.7 for US units), the number of hawsers given in 3-5-1/19.7 TABLE 2 is to be increased by the number given below:

A/EN Ratio		*Increase number of hawsers by*
SI Units MKS Units	*U.S. Units*	
Above 0.9 up to 1.1	above 9.7 up to 11.8	1
Above 1.1 up to 1.2	above 11.8 up to 12.9	2
above 1.2	above 12.9	3

9.3.2 Mooring Lines for Vessels with EN > 2000 *(2022)*

The ship design minimum breaking load and number of mooring lines for vessels with an Equipment Number EN > 2000 are given in 3-5-1/9.3.2(a) and 3-5-1/9.3.2(b), respectively, and is intended as a guide. The length of mooring lines is given by 3-5-1/9.3.3.

The ship design minimum breaking load of mooring lines and the number of head, stern, and breast lines (see Note below defining head, stern, and breast lines) for vessels with an Equipment Number EN > 2000 are based on the side-projected area A_1. Side projected area A_1 is to be calculated similar to the side-projected area$A$ according to 3-5-1/3 but considering the following conditions:

- The ballast draft is to be considered for the calculation of the side-projected area A_1. For ship types having small variation in the draft (e.g., passenger and RO/RO vessels), the side projected area A_1may be calculated using the summer load waterline.
- Wind shielding of the pier may be considered for the calculation of the side-projected area A_1 unless the vessel is intended to be regularly moored to jetty type piers. A height of the pier surface of 3 m (9.8 ft) over waterline may be assumed (i.e., the lower part of the side-projected area with a height of 3 m (9.8 ft) above the waterline) for the considered loading condition and may be disregarded for the calculation of the side-projected area A_1.
- Deck cargoes at the ship nominal capacity condition are to be included for the determination of side-projected area A_1. For the condition with cargo on deck, the summer load waterline may be considered. Deck cargoes may not need to be considered if ballast draft condition generates a larger side-projected area A_1 than the full load condition with cargoes on deck. The larger of both side-projected areas is to be chosen as side-projected area A_1. The nominal capacity condition is defined in 3-2-7/4.3.1.

The mooring lines as given here under are based on a maximum current speed of 1.0 m/s (3.3 ft/s) and the following maximum wind speed v_w, in m/s (ft/s):

v_w	=	$25.0 - 0.002(A_1 - 2000)$ m/s	for passenger vessels, ferries, and car carriers with 2000 m^2 < $A_1 \leq$ 4000 m^2
	=	21.0 m/s	for passenger vessels, ferries, and car carriers with A_1 > 4000 m^2
	=	25.0 m/s	for other vessels
	=	$82.0 - 0.00061(A_1 - 21528)$ ft/s	for passenger vessels, ferries, and car carriers with 21528 ft^2 < $A_1 \leq$ 43056 ft^2
	=	68.9 ft/s	for passenger vessels, ferries, and car carriers with A_1 > 43056 ft^2
	=	82.0 ft/s	for other vessels

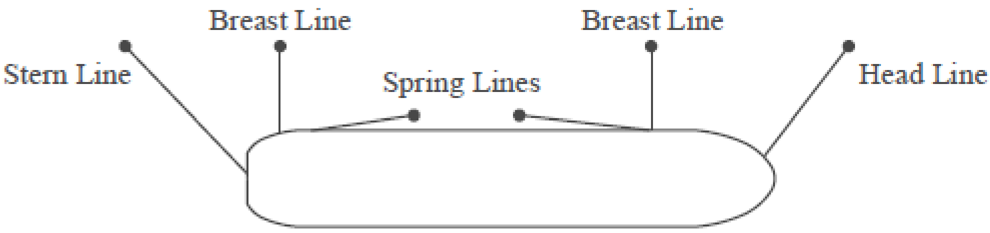
The wind speed is considered representative of a 30 second mean speed from any direction and at a height of 10 m (32.8 ft) above the ground. The current speed is considered representative of the maximum current speed acting on bow or stern (±10°) and at a depth of one-half of the mean draft. Furthermore, it is considered that vessels are moored to solid piers that provide shielding against cross current.

Additional loads caused by, e.g., higher wind or current speeds, cross currents, additional wave loads, or reduced shielding from non-solid piers may need to be particularly considered. Furthermore, it should be observed that unbeneficial mooring layouts can considerably increase the loads on single mooring lines.

Notes:

The following is defined with respect to the purpose of mooring lines, see also figure below:

- Breast line: A mooring line that is deployed perpendicular to the vessel, restraining the vessel in the off-berth direction.
- Spring line: A mooring line that is deployed almost parallel to the vessel, restraining the vessel in the fore or aft direction.
- Head/Stern line: A mooring line that is oriented between longitudinal and transverse direction, restraining the vessel in the off-berth and in fore or aft direction. The amount of restraint in the fore or aft and off-berth directions depends on the line angle relative to these directions.



9.3.2(a) Ship Design Minimum Breaking Load (2022)

The ship design minimum breaking load, in kN (kgf, lbf), of the mooring lines is to be taken as:

$$\mathrm{MBL_{SD}} = 0.1A_1 + 350 \quad \text{kN}$$

$$\mathrm{MBL_{SD}} = 10.20A_1 + 35690 \quad \text{kgf}$$

$$\mathrm{MBL_{SD}} = 2.089A_1 + 78680 \quad \text{lbf}$$

The ship design minimum breaking load may be limited to 1275 kN (130,000 kgf, 286,600 lbf). However, in this case the moorings are to be considered as not sufficient for environmental conditions given by 3-5-1/9.3.2. For these vessels, the acceptable wind speed v_w* can be estimated as follows:

$$v_w^* = v_w\sqrt{\frac{\mathrm{MBL_{SD}^*}}{\mathrm{MBL_{SD}}}}$$

where

v_w	=	wind speed as per 3-5-1/9.3.2
$\mathrm{MBL_{SD}^*}$	=	ship design minimum breaking load of the mooring lines intended to be supplied
$\mathrm{MBL_{SD}}$	=	ship design minimum breaking load according to the above formula

However, the ship design minimum breaking load is not to be taken less than that corresponding to an acceptable wind speed of 21 m/s (68.9ft/s):

$$\mathrm{MBL}^*_{\mathrm{SD}} \geq \left(\frac{21}{v_w}\right)^2 \cdot \mathrm{MBL}_{\mathrm{SD}} \quad \text{for} \quad v_w \quad \text{in} \quad \mathrm{m/s}$$

$$\mathrm{MBL}^*_{\mathrm{SD}} \geq \left(\frac{68.9}{v_w}\right)^2 \cdot \mathrm{MBL}_{\mathrm{SD}} \quad \text{for} \quad v_w \quad \text{in} \quad \mathrm{ft/s}$$

If lines are intended to be supplied for an acceptable wind speed v_w* higher than v_w as per 3-5-1/9.3.2, the ship design minimum breaking load is to be taken as:

$$\mathrm{MBL}^*_{\mathrm{SD}} = \left(\frac{v_w{}^*}{v_w}\right)^2 \cdot \mathrm{MBL}_{\mathrm{SD}}$$

9.3.2(b) Number of Mooring Lines (2022)

The total number of head, stern, and breast lines (see Note in 3-5-1/9.3.2) is to be taken as:

n	=	$8.3 \cdot 10^{-4} \cdot A_1 + 6$	for A_1 in m^2
n	=	$7.71 \cdot 10^{-5} \cdot A_1 + 6$	for A_1 in ft^2

For oil tankers, chemical tankers, bulk carriers, and ore carriers the total number of head, stern, and breast lines is to be taken as:

n	=	$8.3 \cdot 10^{-4} \cdot A_1 + 4$	for A_1 in m^2
n	=	$7.71 \cdot 10^{-5} \cdot A_1 + 4$	for A_1 in ft^2

The total number of head, stern, and breast lines is to be rounded to the nearest whole number.

The number of head, stern, and breast lines may be increased or decreased in conjunction with an adjustment to the ship design minimum breaking load of the lines. The adjusted ship design minimum breaking load, $\mathrm{MBL}^{**}_{\mathrm{SD}}$, is to be taken as:

$\mathrm{MBL}^{**}_{\mathrm{SD}}$	=	$1.2 \cdot \mathrm{MBL}_2 \cdot n/n** \leq \mathrm{MBL}_2$	for increased number of lines
$\mathrm{MBL}^{**}_{\mathrm{SD}}$	=	$\mathrm{MBL}_2 \cdot n/n**$	for reduced number of lines

where MBL_2 is $\mathrm{MBL}_{\mathrm{SD}}$ or $\mathrm{MBL}^*_{\mathrm{SD}}$ specified in 3-5-1/9.3.2(a), as appropriate, $n**$ is the increased or decreased total number of head, stern and breast lines and n the number of lines for the considered vessel type as calculated by the above formulas without rounding

Similarly, the ship design minimum breaking load of head, stern, and breast lines may be increased or decreased in conjunction with an adjustment to the number of lines.

The total number of spring lines n_S (see Note in 3-5-1/9.3.2) is not to be taken as less than:

- Two lines, where EN < 5000
- Four lines, where EN ≥ 5000

The ship design minimum breaking load of spring lines is to be the same as that of the head, stern, and breast lines. If the number of head, stern, and breast lines is increased in conjunction with an adjustment to the ship design minimum breaking load of the lines, the number of spring lines is to be taken as follows, but rounded up to the nearest even number:

$$n_S^* = \left(\mathrm{MBL}_2/\mathrm{MBL}_{\mathrm{SD}}^{**}\right) \; n_S$$

where MBL_2, $\mathrm{MBL}_{\mathrm{SD}}^{**}$ and n_S are defined above, and n_S^* is the increased number of spring lines.

9.3.3 Length of Mooring Lines

The length of mooring lines for vessels with *EN* of less than or equal to 2000 may be taken from 3-5-1/19.7 TABLE 2. For vessels with *EN* > 2000 the length of mooring lines may be taken as 200 m.

The lengths of individual mooring lines may be reduced by up to 7% of the above given lengths, but the total length of mooring lines should not be less than would have resulted had all lines been of equal length.

9.5 Tow Line *(2022)*

The tow lines are given in 3-5-1/19.7 TABLE 3 and are intended as a vessel's own tow line of a vessel being towed by a tug or other vessel. For the selection of the tow line from 3-5-1/19.7 TABLE 3, the Equipment Number (*EN*) is to be taken according to 3-5-1/9.3.

The designer should consider verifying the adequacy of towing lines based on assessments carried out for the individual towing arrangement.

9.7 Mooring and Tow Line Construction *(2022)*

Tow lines and mooring lines may be of wire, natural fiber,or synthetic fiber construction or of a mixture of wire and fiber. For synthetic fiber ropes it is recommended to use lines with reduced risk of recoil (snap-back) to mitigate the risk of injuries or fatalities in the case of breaking mooring lines.

Notwithstanding the requirements given in 3-5-1/9.3 and 3-5-1/9.5, no fiber rope is to be less than 20 mm (0.79 in) in diameter. For polyamide ropes, the line design break force is to be increased by 20% and for other synthetic ropes by 10% to account for strength loss due to, among others, aging and wear. Line design break force means the minimum force that a new, dry, spliced, mooring line will break at. This is for all synthetic cordage materials.

9.9 Mooring Winches *(1 July 2018)*

9.9.1 *(2022)*

Each winch is to be fitted with brakes with a holding capacity sufficient to prevent unreeling of the mooring line when the rope tension is equal to 80% of the ship design minimum breaking load of the rope as fitted on the first layer. The winch is to be fitted with brakes that will allow for the reliable setting of the brake rendering load.

9.9.2 *(2022)*

For powered winches the maximum hauling tension which can be applied to the mooring line (the reeled first layer) is not be less than 1/4.5 times, nor be more than $^1/_3$ times the rope's ship design minimum breaking load. For automatic winches, these figures apply when the winch is set to the maximum power with automatic control.

9.9.3

For powered winches on automatic control, the rendering tension that the winch can exert on the mooring line (the reeled first layer) is not to exceed 1.5 times, nor be less than 1.05 times the hauling tension for that particular power setting of the winch. The winch is to be marked with the range of rope strength for which it is designed.

9.11 Mooring and Towing Arrangement *(1 July 2018)*

9.11.1 Mooring Arrangement

Mooring lines in the same service (e.g. breast lines, see Note in 3-5-1/9.3.2) should be of the same characteristic in terms of strength and elasticity.

As far as possible, a sufficient number of mooring winches are to be fitted to allow for all mooring lines to be belayed on winches. This allows for an efficient distribution of the load to all mooring lines in the same service and for the mooring lines to shed load before they break. If the mooring arrangement is designed such that mooring lines are partly to be belayed on bitts or bollards, these lines are considered to be not as effective as the mooring lines belayed on winches.

Mooring lines are to have a lead as straight as is practicable from the mooring drum to the fairlead.

At points of change in direction, sufficiently large radii of the contact surface of a rope on a fitting are to be provided to minimize the wear experienced by mooring lines and as recommended by the rope manufacturer for the rope type intended to be used.

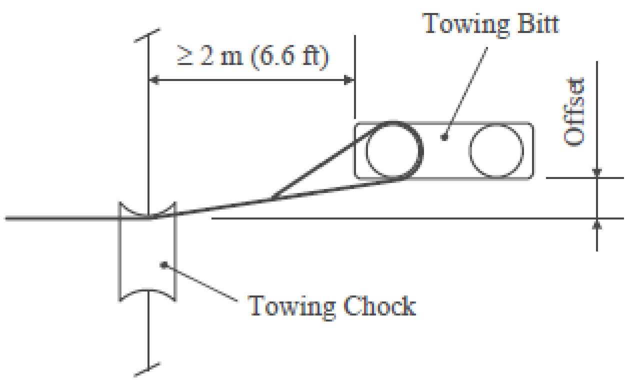
9.11.2 Towing Arrangement

Towing lines, in general, should be led through a closed chock. The use of open fairleads with rollers or closed roller fairleads is to be avoided.

For towing purposes, at least one chock is to be provided close to centerline of the vessel forward and aft. It is also beneficial to provide additional chocks on port and starboard side at the transom and at the bow.

Towing lines are to have a straight lead from the towing bitt or bollard to the chock.

For the purpose of towing, bitts or bollards serving a chock are to be located slightly offset and, as far as practicable, a distance of at least 2 m (6.6 ft) away from the chock, see figure below:



As far as practicable, warping drums are to be positioned not more than 20 m (65.6 ft) away from the chock, measured along the path of the line.

Attention is to be given to the arrangement of the equipment for towing and mooring operations in order to prevent interference of mooring and towing lines as far as practicable. It is beneficial to provide dedicated towing arrangements separate from the mooring equipment.

For emergency towing arrangements for tankers reference is be made to 3-5-1/15.7. For all vessels other than tankers it is recommended to provide towing arrangements fore and aft of sufficient strength for 'other towing' service as defined in 3-2-7/4.3.2.

11 Windlass or Winch Supporting Hull Structure and Chain Stopper *(2022)*

Construction and installation of all windlasses used for anchoring are to be carried out in accordance with 4-1-1/5 and Section 4-5-1. Where fitted, an independent chain stopper and its components are to be adequate for the load imposed. The arrangements and details of the chain stopper are to be submitted for review.

The windlass supporting hull structures are to meet the requirements in 3-5-1/11.1.

11.1 Supporting Hull Structure *(2022)*

The windlass is to be bolted down to a substantial foundation which is to meet the following load cases and associated criteria.

11.1.1 Design Loads *(2022)*

11.1.1(a) Load on Windlass Support Structure. (2022)

The following load is to be applied in the direction of the chain.

With cable stopper not attached to windlass:	0.45 B.S.
With cable stopper attached to windlass:	0.8 B.S.
Without cable stopper:	0.8 B.S.

where

BS = minimum breaking strength of the chain, as indicated in 2-2-2/27 TABLE 2 and 2-2-2/27 TABLE 3 of the *Rules for Materials and Welding (Part 2)*.

11.1.1(b) Load on Cable Stopper and Support Structure .

A load of 0.8 BS is to be applied in the direction of the chain.

11.1.1(c) Allowable Stresses. (2022)

The allowable stress for the structures supporting the windlass and cable stopper are as follows:

i) For strength assessment by means of beam theory or grillage analysis:

- Normal stress: 100% of the specified minimum yield stress of the material
- Shear stress: 60% of the specified minimum yield stress of the material

The normal stress is the sum of bending stress and axial stress. The shear stress to be considered corresponds to the shear stress acting perpendicular to the normal stress. No stress concentration factors are to be taken into account.

ii) For strength assessment by means of finite element analysis:

- Von Mises stress: 100% of the specified minimum yield stress of the material

For strength assessment by means of finite element analysis, the mesh is to be fine enough to represent the geometry as realistically as possible. The ratio of element length to width is not to exceed 3. Girders are to be modelled using shell or plane stress elements. Symmetric girder flanges may be modelled by beam or truss elements. The element height of girder webs is not to exceed one-third of the web height. In way of small openings in girder webs, the web thickness is to be reduced to a mean thickness over the web height. Large openings are to be modelled. Stiffeners may be modelled using shell, plane stress, or beam elements. The mesh size of stiffeners is to be fine enough to obtain proper bending stress. If flat bars are modelled using shell or plane stress elements, dummy rod elements are to be modelled at the free edge of the flat bars and the stresses of the dummy elements are to be evaluated. Stresses are to be read from the center of the individual element. For shell elements, the stresses are to be evaluated at the mid plane of the element.

11.1.1(d) Required Scantlings *(2022)*

The net minimum scantlings of the supporting hull structure are to comply with the requirements given in 3-5-1/11.1.1(c). The required gross scantlings are determined according to 3-2-7/4.7.

11.1.2 Sea Loads

For vessels with length, L (as defined in 3-1-1/3.1), of 80 meters (263 feet) or more, where the height of the exposed deck in way of the item is less than $0.1L$ or 22 m above the summer load waterline, whichever is the lesser, the windlass supporting structures located on the exposed fore deck within the forward $0.25L$ are to meet the following requirements Where the mooring winch is integral with the windlass, it is to be considered as a part of the windlass for the purpose of said paragraph.

11.1.2(a) Pressures. *(1 July 2018)*

The following pressures and associated areas are to be applied (see 3-5-1/11 FIGURE 2):

- 200 kN/m^2 (20.4 tf/m^2, 4178 lbs/ft^2) normal to the shaft axis and away from the forward perpendicular, over the projected area in this direction. Where the cable is stored on the windlass drum, the entire projected area of the drum's flange is to be accounted for.
- 150 kN/m^2 (15.3 tf/m^2, 3133 lbs/ft^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 is defined as:

  f = $1 + B/H$, but need not be taken as greater than 2.5

  B = width of windlass measured parallel to the shaft axis (see 3-5-1/11 FIGURE 2)

  H = overall height of windlass (see 3-5-1/11 FIGURE 2).

11.1.2(b) Forces.

Forces in the bolts, chocks and stoppers securing the windlass to the deck are to be calculated. The windlass is supported by N groups of bolts, each containing one or more bolts, see 3-5-1/11 FIGURE 2.

i) *Axial Forces*

The aggregate axial force R_i in respective group of bolts (or bolt) i, positive in tension, may be calculated from the following equations:

$$R_{xi} = P_x h x_i A_i / I_x$$

$$R_{yi} = P_y h y_i A_i / I_y$$

$$R_i = R_{xi} + R_{yi} - R_{si}$$

where

P_x = force, kN (tf, Ltf), acting normal to the shaft axis

P_y = force, kN (tf, Ltf), 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, cm (in.)
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, cm (in.)
A_i	=	cross-sectional area of all bolts in group i, cm^2 (in^2)
I_x	=	$A_i x_i^2$ for N bolt groups
I_y	=	$A_i y_i^2$ for N bolt groups
R_{si}	=	static reaction at bolt group i, due to weight of windlass.

ii) *Shear Forces*

Aggregated shear forces, F_{xi}, F_{yi}, applied to the respective bolt group, i, of bolts, and the resultant combined force, F_i, may be calculated from:

$$F_{xi} = (P_x - \alpha g M)/N$$

$$F_{yi} = \left(P_y - \alpha g M\right)/N$$

$$F_i = \left(F_{xi}^2 + F_{yi}^2\right)^{0.5}$$

where

α	=	coefficient of friction (0.5)
M	=	mass of windlass, in tonnes (Ltons)
g	=	gravity: 9.81 m/s^2 (32.2 ft/sec^2)
N	=	number of groups of bolts

The axial tensile/compressive and lateral forces from the above equations are also to be considered in verifying the supporting structure.

11.1.2(c) Stresses in Bolts.

Tensile axial stresses in the individual bolts in each group of bolts 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 "fitted" bolts are to be calculated and compared to the stress under proof load. Where pourable resins are incorporated in the holding down arrangements, due account is to be taken in the calculations.

11.1.2(d) Allowable Stresses. *(2022)*

i) *Bolts.* The safety factor against bolt proof strength is to be not less than 2.0.

ii) *Supporting Structures.* The stresses acting on the above deck framing and the hull structure supporting the windlass and chain stopper are not to be greater than the following allowable values:

a) For strength assessment by means of beam theory or grillage analysis:

- Normal stress: 100% of the specified minimum yield stress of the material
- Shear stress: 60% of the specified minimum yield stress of the material

The normal stress is the sum of bending stress and axial stress. The shear stress to be considered corresponds to the shear stress acting perpendicular to the normal stress. No stress concentration factors are to be taken into account.

b) For strength assessment by means of finite element analysis:

- Von Mises stress: 100% of the specified minimum yield stress of the material

For strength assessment by means of finite element analysis, the mesh is to be fine enough to represent the geometry as realistically as possible. The ratio of element length to width is not to exceed 3. Girders are to be modelled using shell or plane stress elements. Symmetric girder flanges may be modelled by beam or truss elements. The element height of girder webs is not to exceed one-third of the web height. In way of small openings in girder webs, the web thickness is to be reduced to a mean thickness over the web height. Large openings are to be modelled. Stiffeners may be modelled using shell, plane stress, or beam elements. The mesh size of stiffeners is to be fine enough to obtain proper bending stress. If flat bars are modelled using shell or plane stress elements, dummy rod elements are to be modelled at the free edge of the flat bars and the stresses of the dummy elements are to be evaluated. Stresses are to be read from the center of the individual element. For shell elements, the stresses are to be evaluated at the mid plane of the element.

iii) The net minimum scantlings of the supporting hull structure are to comply with the requirements given in 3-5-1/11.1.2(d).ii. The required gross scantlings are determined according to 3-2-7/4.7.

11.3 Winches for Used Anchoring (Vessels Under 90 m (295 ft)) *(1 July 2018)*

For vessels under 90 m (295 ft), construction and installation of all winches used for anchoring are to be carried out in accordance with the following requirements, to the satisfaction of the Surveyor. In general, the design is to conform to an applicable standard or code of practice. As a minimum, standards or practices are to indicate strength, performance and testing criteria.

The winch is to be well bolted down to a substantial bed. Where wire ropes are used in lieu of chain cables, winches capable of controlling the wire rope at all times are to be fitted.

The manufacturer or builder is to submit, in accordance with 4-1-1/5, the plans and calculations from following subsections, as applicable.

11.3.1 Plans

i) Arrangement and details of the winch, drums, brakes, shaft, gears, coupling bolts, wildcat, sheaves, pulleys and foundation

ii) Electric one line diagram

iii) Piping system diagrams

iv) Control arrangements

Plans or data are to show complete details including power ratings, working pressures, welding details, material specifications, pipe and electric cable specifications, etc.

11.3.2 Calculations

Detailed stress calculations for the applicable system components listed in 3-5-1/11.3.1 above. The calculations are to be based on the breaking strength of the chain or wire rope, are to indicate maximum torque or load to which the unit will be subjected and also show compliance with either applicable sections of the Rules, such as Section 4-3-1 and 4-3-1-A1, for the gears and shafts, or to other recognized standard or code of practice.

11.5 Trial

Trial requirements refer to 3-7-2/1.

FIGURE 2
Direction of Forces and Weight

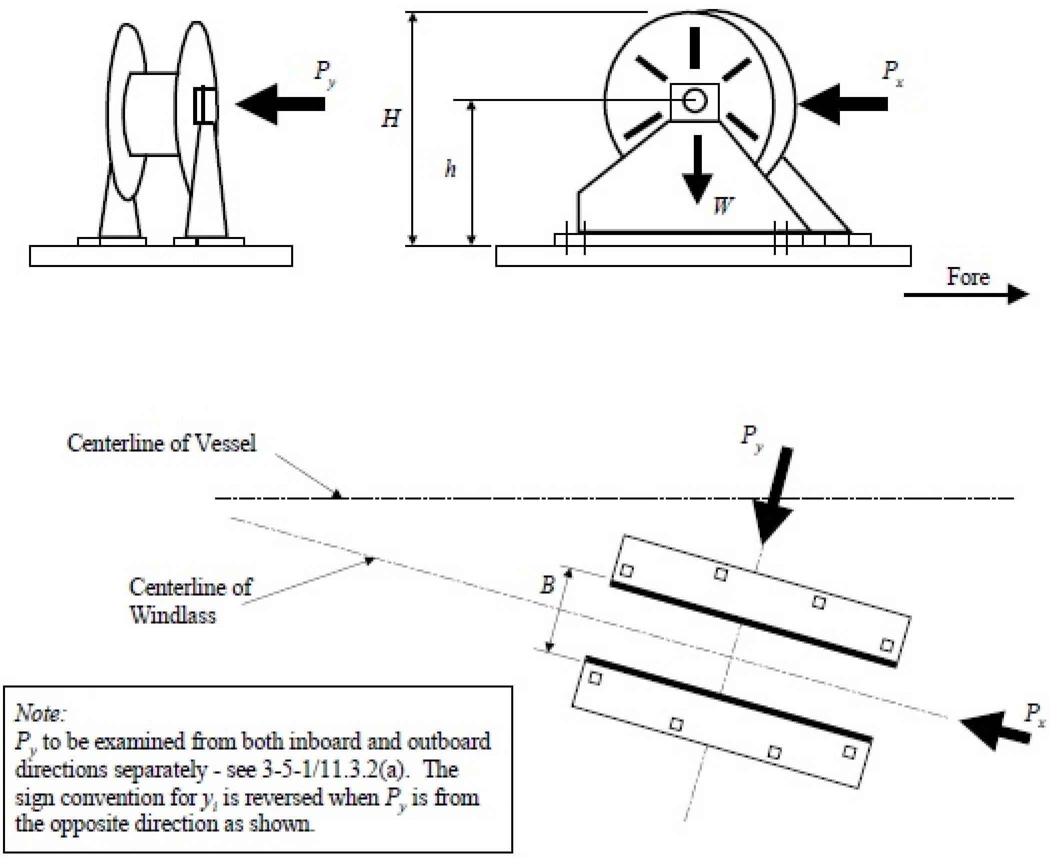
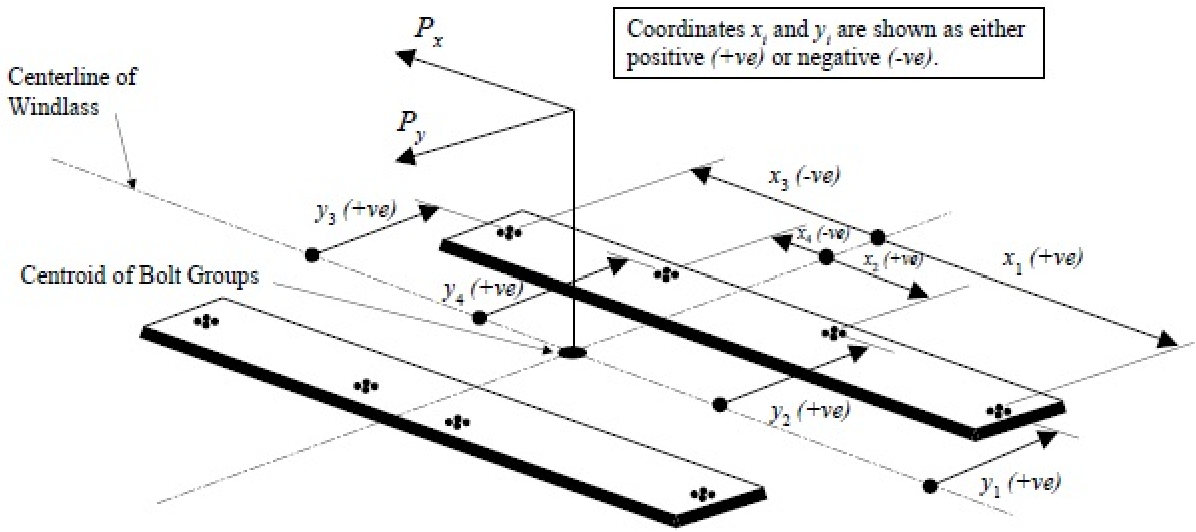


FIGURE 3
Sign Convention



12 Hawse Pipes *(2021)*

Hawse pipes are to be comply with the following:

i) To be of ample size and strength in accordance with the following equations or other recognized design practices:

- Minimum hawse pipe inner diameter = 9.5 x *d* (mm) [(1)];
- Minimum top plate thickness = 0.3 x *d* (mm);
- Minimum bottom plate thickness = 0.4 x *d* (mm);
- Where the hawse pipe is made of one plate, minimum plate thickness = (0.35 x *d*) - 0.5 (mm).

Where *d* is the diameter of the anchor chain.

Note:

1 8.5 x *d* (mm) may be acceptable for large diameter of anchor chain if proposed inner diameter of hawse pipe is greater than 33 x $(G)^{1/3}$ (mm) , where *G* is anchor weight (kg).

ii) To have full rounded flanges and the least possible lead, in order to minimize the nip on the cables.

iii) They are to be securely attached to thick doubling or insert plates by continuous welds the size of which are to be in accordance with Section 3-2-19 for the plating thickness and type of joint selected.

iv) When in position, they are to be thoroughly tested for watertightness by means of a hose in which the water pressure is not to be less than 2.06 bar (2.1 kgf/cm^2, 30 psi).

v) Hawse pipes for stockless anchors are to provide enough clearances to preclude the anchor jamming. The anchors are to be let go aweigh and heaved up to the satisfaction of the Surveyor, proving the smooth setting, flukes' adherence to the pocket surface and no jamming occurrence.

vi) The anchors are to be shipped and unshipped so that the Surveyor may be satisfied that there is no risk of the anchor jamming in the hawse pipe.

vii) Care is to be taken to ensure a fair lead for the chain from the windlass to the hawse pipes and to the chain pipes.

13 Securing of the Inboard Ends of Chain Cables *(1 July 2018)*

Arrangements are to be provided for securing the inboard ends of the bower anchor chain cables. The chain cables are to be secured to structures by a fastening able to withstand a force not less than 15% nor more than 30% of the breaking load of the chain cable. The fastening is to be provided with a mean suitable to permit, in case of emergency, an easy slipping of the chain cables to sea, operable from an accessible position outside the chain locker.

14 Securing of Stowed Anchors *(1 July 2020)*

Arrangements are to be provided for securing the anchors and stowing the cables. To hold the anchor tight in against the hull or the anchor pocket, respectively, it is recommended to fit anchor lashings (e.g., a "devil's claw"). If fitted, anchor lashings are to be designed to resist a load at least corresponding to twice the anchor mass plus 10 m (32.8 ft) of cable without exceeding 40% of the yield strength of the material.

15 Shipboard Fittings *(2023)*

For vessels which are required to comply with SOLAS, the arrangements and details of shipboard fittings used for mooring operations and/or towing operations at bow, sides and stern are to comply with the requirements in this Section. The requirements for the supporting structures of these deck fittings are specified in 3-2-7/4.

15.1 Bollards and Bitts, Fairleads, Stand Rollers and Chocks *(2023)*

The size of shipboard fittings is to be in accordance with recognized standards (e.g. ISO13795 Ships and marine technology – Ship's mooring and towing fittings – Welded steel bollards for sea-going vessels) or comply with the requirements given in 3-5-1/15.3.1 and 3-5-1/15.3.2. For shipboard fittings not in accordance with recognized standard the corrosion addition, t_c, and the wear allowance, t_w, given in 3-2-7/4.7, respectively, are to be considered.

Details of the shipboard fittings are to be submitted for review. The design load used to assess shipboard fittings and their attachments to the hull are to be in accordance with the requirements as specified in 3-2-7/4.

15.1.1 Mooring Operations *(2022)*

Shipboard fittings may be selected from a recognized national or international standard. The Safe Working Load (SWL) is to be suitable for mooring lines with a minimum breaking strength that is not less than the ship design minimum breaking load according to 3-5-1/19.7 TABLE 2 (see Notes in 3-2-7/4.3.1(b).

Mooring bitts (double bollards) are to be chosen for the mooring line attached in figure-of-eight fashion if the industry standard distinguishes between different methods to attach the line, i.e. figure-of-eight or eye splice attachment.

When the shipboard fitting is not selected from an accepted industry standard, the strength of the fitting and of its attachment to the vessel is to be in accordance with requirements related to mooring in 3-2-7/4.3 and 3-2-7/4.5. Mooring bitts (double bollards) are required to resist the loads caused by the mooring line attached in figure-of-eight fashion, see Note. For strength assessment beam theory or finite element analysis using net scantlings is to be applied, as appropriate. Corrosion additions are to be as defined in 3-2-7/4.7.2. A wear down allowance is to be included as defined in 3-2-7/4.7.3. Consideration may be given to accepting load tests as alternative to strength assessment by calculations.

Note: With the line attached to a mooring bitt in the usual way (figure-of-eight fashion), either of the two posts of the mooring bitt can be subjected to a force twice as large as that acting on the mooring line. Disregarding this effect, depending on the applied industry standard and fitting size, overload may occur.

15.1.2 Towing Operations *(2022)*

Shipboard fittings may be selected from a recognized industry standard and are to be at least based on the following loads:

i) For normal towing operations, the intended maximum towing load (e.g., static bollard pull) as indicated on the towing and mooring arrangements plan

ii) For other towing service, the ship design minimum breaking load of the tow line according to 3-5-1/19.7 TABLE 3 (see Notes in 3-2-7/4.3.2(b))

iii) For fittings intended to be used for, both, normal and other towing operations, the greater of the loads according to *i)* and *ii)*

Towing bitts (double bollards) may be chosen for the towing line attached with eye splice if the industry standard distinguishes between different methods to attach the line, i.e. figure-of-eight or eye splice attachment.

When the shipboard fitting is not selected from an accepted industry standard, the strength of the fitting and of its attachment to the vessel is to be in accordance with requirements related to towing in 3-2-7/4.3 and 3-2-7/4.5. Towing bitts (double bollards) are required to resist the loads caused by the towing line attached with eye splice. For strength assessment beam theory or finite element analysis using net scantlings is to be applied, as appropriate. Corrosion additions are to be as defined in 3-2-7/4.7.2. A wear down allowance is to be included as defined in 3-2-7/4.7.3.

Consideration may be given to accepting load tests as alternative to strength assessment by calculations.

15.3 Safe Working Load (SWL) and Towing Load (TOW) *(1 July 2018)*

The requirements on SWL apply for a single post basis (no more than one turn of one cable).

15.3.1 Mooring Operations *(2022)*

i) The Safe Working Load (SWL) is the safe load limit of shipboard fittings used for mooring purpose.

ii) Unless a greater SWL is requested by the applicant according to 3-2-7/4.3.3, the SWL is not to exceed the ship design minimum breaking load of the mooring line according to 3-5-1/19.7 TABLE 2, see Notes in 3-2-7/4.3.1.

iii) The SWL, in tonnes, of each shipboard fitting is to be marked (by weld bead or equivalent) on the fittings used for mooring. For fittings intended to be used for both, mooring and towing, TOW, in tonnes, according to 3-5-1/15.3.2 is to be marked in addition to SWL.

iv) The above requirements on SWL apply for the use with no more than one mooring line.

v) The towing and mooring arrangements plan mentioned in 3-5-1/15.5 is to define the method of use of mooring lines.

15.3.2 Towing Operations *(2022)*

i) The Safe Towing Load (TOW) is the safe load limit of shipboard fittings used for towing purpose.

ii) TOW used for normal towing operations is not to exceed 80% of the design load per 3-2-7/4.3.2(a).

iii) TOW used for other towing operations is not to exceed 80% the design load according to 3-2-7/4.3.2(b).

iv) For fittings used for both normal and other towing operations, the greater of the safe towing loads according to *ii)* and *iii)* is to be used.

v) TOW, in tonnes, of each shipboard fitting is to be marked (by weld bead or equivalent) on the fittings used for towing. For fittings intended to be used for both towing and mooring, SWL, in tonnes, according to 3-5-1/15.3.1 is to be marked in addition to TOW.

vi) The above requirements on TOW apply for the use with no more than one line. If not otherwise chosen, for towing bitts (double bollards) TOW is the load limit for a towing line attached with eye-splice.

vii) The towing and mooring arrangements plan mentioned in 3-5-1/15.5 is to define the method of use of towing lines.

15.3.3 Marking and Plan

15.3.3(a) Marking.

The SWL of each shipboard fitting is to be permanently marked (by weld bead or equivalent, but not painting alone) on the fittings used for towing/mooring.

15.3.3(b) Plan.

The towing and mooring arrangements plan mentioned in 3-5-1/15.5 is to define the method and purpose of use of mooring lines and/or towing lines.

15.5 Towing and Mooring Arrangements Plan *(2022)*

The SWL and TOW for the intended use for each shipboard fitting is to be noted in the towing and mooring arrangements plan available on board for the guidance of the Master.

The plan is to include for each shipboard fitting the listed below information:

- Location on the ship;
- Fitting type;
- SWL and TOW;
- Purpose (mooring/harbor towing/other towing); and
- Manner of applying towing or mooring line load including limiting fleet angle (i.e., the angle of change in direction of a line at the fitting).

The above information is to be incorporated into the pilot card in order to provide the pilot proper information on harbor/other towing operations.

In addition, the towing and mooring arrangement plan is to include the following general information:

- the arrangement of mooring lines showing number of lines (N)
- the ship design minimum breaking load of each mooring line (MBL_{SD})
- the acceptable environmental conditions as given in 3-5-1/9.3.2 for the recommended ship design minimum breaking load lines for vessels with Equipment Number $EN > 2000$:
  - 30 second mean wind speed from any direction (v_W or v_W* according to 3-5-1/9.3.2)
  - Maximum current speed acting on bow or stern (±10°)

15.7 Emergency Towing Arrangements

Emergency towing arrangements at both ends on tankers of 20,000 tons (19684 Lton) deadweight and above, including oil tankers, chemical tankers and gas carriers, are to be fitted in accordance with Maritime Safety Committee Resolution MSC 35(63).

Written approval by the flag Administration of the emergency towing arrangements is to be accepted as evidence of compliance with this paragraph.

17 Offshore Mooring Chain for Station Keeping

17.1 Qualification of Manufacturers

Offshore mooring chain is to be manufactured by works approved by ABS, in accordance with 2-2-2/7.1 of the ABS *Rules for Materials and Welding (Part 2)* or in accordance with the ABS *Requirements for Certification of Offshore Mooring Chain*.

17.3 Materials

Materials used for the manufacture of offshore mooring chain are to meet the requirements of 2-2-2/7.1 of the ABS *Rules for Materials and Welding (Part 2)* or in accordance with the ABS *Requirements for Certification of Offshore Mooring Chain*.

17.5 Design, Manufacture, Testing and Certification of Mooring Chain

Offshore mooring chain is to be designed, manufactured, tested and certified in accordance with the requirements of Section 2-2-2 of the ABS *Rules for Materials and Welding (Part 2)* or in accordance with the ABS *Requirements for Certification of Offshore Mooring Chain*.

The common link is to be of stud link type grade 2a, 2b or 3a, 3b Anchor Chain, or grade RQ3, RQ3S, RQ4 Mooring Chain.

19 Chafing Chain for Emergency Towing Arrangements

19.1 Scope

These requirements apply to the chafing chain for chafing gear of two types of Emergency Towing Arrangement (ETA), those with a specified safe working load (SWL) of 1000 kN (ETA1000) for tankers of 20,000 tonnes deadweight and over but less than 50,000 tonnes deadweight and those with a specified safe working load of 2000 kN (ETA2000) for tankers of 50,000 tonnes deadweight and over. Chafing chains other than those specified can be used subject to special agreement with ABS.

19.3 Qualification of Manufacturers

Qualification of chafing chain manufacturers is to comply with 3-5-1/17.1.

19.5 Materials

Materials used for the manufacture of chafing chain are to comply with 3-5-1/17.3.

19.7 Design, Manufacture, Testing and Certification of Chafing Chain

19.7.1

Chafing chain is to be designed, manufactured, tested and certified in accordance with the requirements of Section 2-2-2 of the ABS *Rules for Materials and Welding (Part 2)* or in accordance with the ABS *Requirements for Certification of Offshore Mooring Chain.*

19.7.2

The common link is to be of stud link type grade 2a, 2b or 3a, 3b Anchor Chain, or grade RQ3, RQ3S, RQ4 Mooring Chain.

19.7.3

The arrangement at the end connected to the strongpoint and the dimensions of the chafing chain are determined by the type of ETA. The other end of the chafing chain is to be fitted with a pear-shaped open link allowing connection to a shackle corresponding to the type of ETA and chain cable grade. A typical arrangement of this chain end is shown in 3-5-1/19.7 FIGURE 4.

19.7.4

The chafing chain is to be able to withstand a breaking load not less than twice the SWL. For each type of ETA, the nominal diameter of common link for chafing chains is to comply with the value indicated below.

Type of ETA	*Nominal Diameter of Common Link, d, min.*	
	Grade 2	*Grade 3*
ETA1000	62 mm	52 mm
ETA2000	90 mm	76 mm

FIGURE 4
Typical Outboard Chafing Chain End

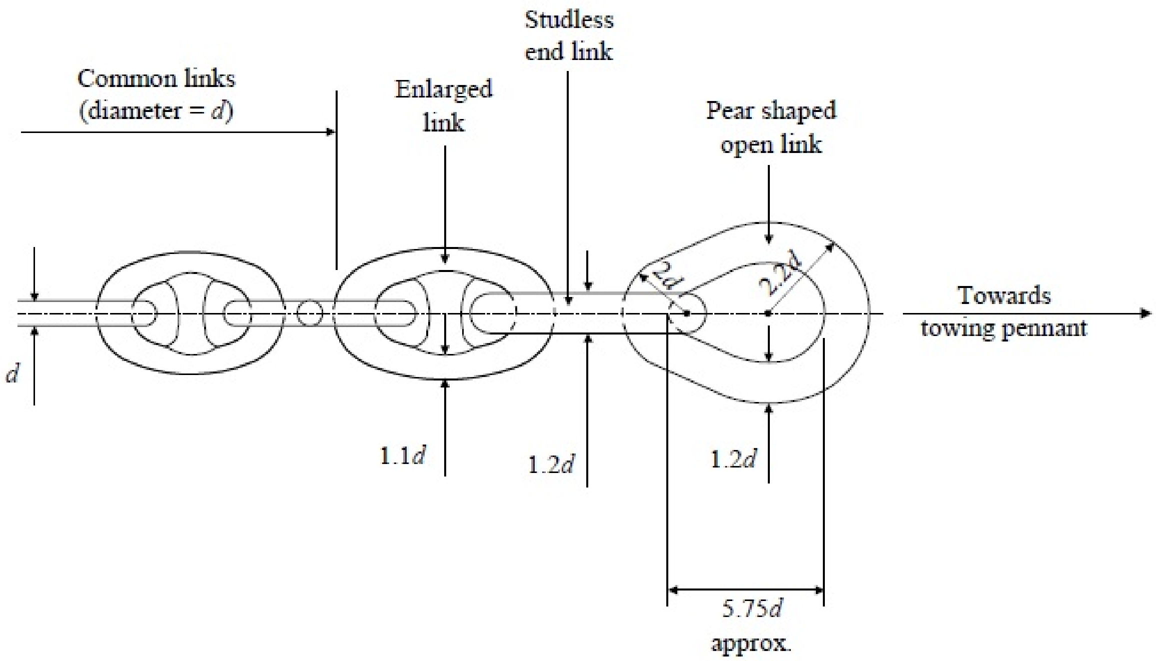


TABLE 1A
Equipment for Self-propelled Ocean-going Vessels *(1 July 2018)*

For intermediate values of equipment number, use equipment complement in sizes and weights given for the lower equipment number in the table.

SI, MKS Units

Equipment Numeral	*Equipment Number*	*Stockless Bower Anchors*		*Chain Cable Stud Link Bower Chain**			
					Diameter		
		Number	*Mass per Anchor, kg*	*Length, m*	*Ordinary-Strength Steel (Grade 1), mm*	*High-Strength Steel (Grade 2), mm*	*Extra High-Strength Steel (Grade 3), mm*
UA1	30	2	75	192.5	12.5	--	--
UA2	40	2	100	192.5	12.5	--	--
UA3	50	2	120	192.5	12.5	--	--
UA4	60	2	140	192.5	12.5	--	--
UA5	70	2	160	220	14	12.5	--
UA6	80	2	180	220	14	12.5	--
UA7	90	2	210	220	16	14	--

Equipment Numeral	*Equipment Number*	*Stockless Bower Anchors*		*Chain Cable Stud Link Bower Chain**			
					Diameter		
		Number	*Mass per Anchor, kg*	*Length, m*	*Ordinary-Strength Steel (Grade 1), mm*	*High-Strength Steel (Grade 2), mm*	*Extra High-Strength Steel (Grade 3), mm*
UA8	100	2	240	220	16	14	--
UA9	110	2	270	247.5	17.5	16	--
UA10	120	2	300	247.5	17.5	16	--
UA11	130	2	340	275	19	16	--
UA12	140	2	390	275	20.5	17.5	--
U6	150	2	480	275	22	19	
U7	175	2	570	302.5	24	20.5	
U8	205	2	660	302.5	26	22	20.5
U9	240	2	780	330	28	24	22
U10	280	2	900	357.5	30	26	24
U11	320	2	1020	357.5	32	28	24
U12	360	2	1140	385	34	30	26
U13	400	2	1290	385	36	32	28
U14	450	2	1440	412.5	38	34	30
U15	500	2	1590	412.5	40	34	30
U16	550	2	1740	440	42	36	32
U17	600	2	1920	440	44	38	34
U18	660	2	2100	440	46	40	36
U19	720	2	2280	467.5	48	42	36
U20	780	2	2460	467.5	50	44	38
U21	840	2	2640	467.5	52	46	40
U22	910	2	2850	495	54	48	42
U23	980	2	3060	495	56	50	44
U24	1060	2	3300	495	58	50	46
U25	1140	2	3540	522.5	60	52	46
U26	1220	2	3780	522.5	62	54	48

Equipment Numeral	*Equipment Number*	*Stockless Bower Anchors*		*Chain Cable Stud Link Bower Chain**			
					Diameter		
		Number	*Mass per Anchor, kg*	*Length, m*	*Ordinary-Strength Steel (Grade 1), mm*	*High-Strength Steel (Grade 2), mm*	*Extra High-Strength Steel (Grade 3), mm*
U27	1300	2	4050	522.5	64	56	50
U28	1390	2	4320	550	66	58	50
U29	1480	2	4590	550	68	60	52
U30	1570	2	4890	550	70	62	54
U31	1670	2	5250	577.5	73	64	56
U32	1790	2	5610	577.5	76	66	58
U33	1930	2	6000	577.5	78	68	60
U34	2080	2	6450	605	81	70	62
U35	2230	2	6900	605	84	73	64
U36	2380	2	7350	605	87	76	66
U37	2530	2	7800	632.5	90	78	68
U38	2700	2	8300	632.5	92	81	70
U39	2870	2	8700	632.5	95	84	73
U40	3040	2	9300	660	97	84	76
U41	3210	2	9900	660	100	87	78
U42	3400	2	10500	660	102	90	78
U43	3600	2	11100	687.5	105	92	81
U44	3800	2	11700	687.5	107	95	84
U45	4000	2	12300	687.5	111	97	87
U46	4200	2	12900	715	114	100	87
U47	4400	2	13500	715	117	102	90
U48	4600	2	14100	715	120	105	92
U49	4800	2	14700	742.5	122	107	95
U50	5000	2	15400	742.5	124	111	97
U51	5200	2	16100	742.5	127	111	97
U52	5500	2	16900	742.5	130	114	100

Equipment Numeral	Equipment Number	Stockless Bower Anchors		Chain Cable Stud Link Bower Chain*			
					Diameter		
		Number	Mass per Anchor, kg	Length, m	Ordinary-Strength Steel (Grade 1), mm	High-Strength Steel (Grade 2), mm	Extra High-Strength Steel (Grade 3), mm
U53	5800	2	17800	742.5	132	117	102
U54	6100	2	18800	742.5	--	120	107
U55	6500	2	20000	770	--	124	111
U56	6900	2	21500	770	--	127	114
U57	7400	2	23000	770	--	132	117
U58	7900	2	24500	770	--	137	122
U59	8400	2	26000	770	--	142	127
U60	8900	2	27500	770	--	147	132
U61	9400	2	29000	770	--	152	132
U62	10000	2	31000	770	--	--	137
U63	10700	2	33000	770	--	--	142
U64	11500	2	35500	770	--	--	147
U65	12400	2	38500	770	--	--	152
U66	13400	2	42000	770	--	--	157
U67	14600	2	46000	770	--	--	162

Note:

* Wire ropes may be used in lieu of chain cables for both anchors on vessels less than 30 m (98.4 ft) in length. For vessels between 30 m (8.4 ft) and 40 m (131.2 ft) in length, wire rope may be used in lieu of chain cable for one anchor, provided normal chain cable is provided for the second anchor.

The wire is to have a breaking strength not less than the grade 1 chain of required size and a length of at least 1.5 times the chain it is replacing.

Between the wire rope and anchor, chain cable of the required size having a length of 12.5 m (41.0 ft), or the distance between anchor in stored position and winch, whichever is less, is to be fitted.

TABLE 1B
Equipment for Self-propelled Ocean-going Vessels *(1 July 2018)*

For intermediate values of equipment number, use equipment complement in sizes and weights given for the lower equipment number in the table.

US Units

		Stockless Bower Anchors		*Chain Cable Stud Link Bower Chain**			
					Diameter		
Equipment Numeral	*Equipment Number*	*Number*	*Mass per Anchor, pounds*	*Length, fathoms*	*Ordinary-Strength Steel (Grade 1), inches*	*High-Strength Steel (Grade 2), inches*	*Extra High-Strength Steel (Grade 3), inches*
UA1	30	2	165	105	$^{1}/_{2}$	--	--
UA2	40	2	220	105	$^{1}/_{2}$	--	--
UA3	50	2	265	105	$^{1}/_{2}$	--	--
UA4	60	2	310	105	$^{1}/_{2}$	--	--
UA5	70	2	350	120	$^{9}/_{16}$	$^{1}/_{2}$	--
UA6	80	2	400	120	$^{9}/_{16}$	$^{1}/_{2}$	--
UA7	90	2	460	120	$^{5}/_{8}$	$^{9}/_{16}$	--
UA8	100	2	530	120	$^{5}/_{8}$	$^{9}/_{16}$	--
UA9	110	2	595	135	$^{11}/_{16}$	$^{5}/_{8}$	--
UA10	120	2	670	135	$^{11}/_{16}$	$^{5}/_{8}$	--
UA11	130	2	750	150	$^{3}/_{4}$	$^{11}/_{16}$	--
UA12	140	2	860	150	$^{13}/_{16}$	$^{11}/_{16}$	--
U6	150	2	1060	150	$^{7}/_{8}$	$^{3}/_{4}$	
U7	175	2	1255	165	$^{15}/_{16}$	$^{13}/_{16}$	
U8	205	2	1455	165	1	$^{7}/_{8}$	$^{13}/_{16}$
U9	240	2	1720	180	$1\,^{1}/_{8}$	$^{15}/_{16}$	$^{7}/_{8}$
U10	280	2	1985	195	$1\,^{3}/_{16}$	1	$^{15}/_{16}$
U11	320	2	2250	195	$1\,^{1}/_{4}$	$1\,^{1}/_{8}$	$^{15}/_{16}$
U12	360	2	2510	210	$1\,^{5}/_{16}$	$1\,^{3}/_{16}$	1
U13	400	2	2840	210	$1\,^{7}/_{16}$	$1\,^{1}/_{4}$	$1\,^{1}/_{8}$
U14	450	2	3170	225	$1\,^{1}/_{2}$	$1\,^{5}/_{16}$	$1\,^{3}/_{16}$
U15	500	2	3500	225	$1\,^{9}/_{16}$	$1\,^{5}/_{16}$	$1\,^{3}/_{16}$
U16	550	2	3830	240	$1\,^{5}/_{8}$	$1\,^{7}/_{16}$	$1\,^{1}/_{4}$
U17	600	2	4230	240	$1\,^{3}/_{4}$	$1\,^{1}/_{2}$	$1\,^{5}/_{16}$
U18	660	2	4630	240	$1\,^{13}/_{16}$	$1\,^{9}/_{16}$	$1\,^{7}/_{16}$
U19	720	2	5020	255	$1\,^{7}/_{8}$	$1\,^{5}/_{8}$	$1\,^{7}/_{16}$

Equipment Numeral	*Equipment Number*	*Stockless Bower Anchors*		*Chain Cable Stud Link Bower Chain**			
		Number	*Mass per Anchor, pounds*	*Length, fathoms*	*Diameter*		
					Ordinary-Strength Steel (Grade 1), inches	*High-Strength Steel (Grade 2), inches*	*Extra High-Strength Steel (Grade 3), inches*
U20	780	2	5420	255	2	1 $^{3}/_{4}$	1 $^{1}/_{2}$
U21	840	2	5820	255	2 $^{1}/_{16}$	1 $^{13}/_{16}$	1 $^{9}/_{16}$
U22	910	2	6280	270	2 $^{1}/_{8}$	1 $^{7}/_{8}$	1 $^{5}/_{8}$
U23	980	2	6740	270	2 $^{3}/_{16}$	1 $^{15}/_{16}$	1 $^{3}/_{4}$
U24	1060	2	7270	270	2 $^{5}/_{16}$	2	1 $^{13}/_{16}$
U25	1140	2	7800	285	2 $^{3}/_{8}$	2 $^{1}/_{16}$	1 $^{13}/_{16}$
U26	1220	2	8330	285	2 $^{7}/_{16}$	2 $^{1}/_{8}$	1 $^{7}/_{8}$
U27	1300	2	8930	285	2 $^{1}/_{2}$	2 $^{3}/_{16}$	2
U28	1390	2	9520	300	2 $^{5}/_{8}$	2 $^{5}/_{16}$	2
U29	1480	2	10120	300	2 $^{11}/_{16}$	2 $^{3}/_{8}$	2 $^{1}/_{16}$
U30	1570	2	10800	300	2 $^{3}/_{4}$	2 $^{7}/_{16}$	2 $^{1}/_{8}$
U31	1670	2	11600	315	2 $^{7}/_{8}$	2 $^{1}/_{2}$	2 $^{3}/_{16}$
U32	1790	2	12400	315	3	2 $^{5}/_{8}$	2 $^{5}/_{16}$
U33	1930	2	13200	315	3 $^{1}/_{16}$	2 $^{11}/_{16}$	2 $^{3}/_{8}$
U34	2080	2	14200	330	3 $^{3}/_{16}$	2 $^{3}/_{4}$	2 $^{7}/_{16}$
U35	2230	2	15200	330	3 $^{5}/_{16}$	2 $^{7}/_{8}$	2 $^{1}/_{2}$
U36	2380	2	16200	330	3 $^{7}/_{16}$	3	2 $^{5}/_{8}$
U37	2530	2	17200	345	3 $^{9}/_{16}$	3 $^{1}/_{16}$	2 $^{11}/_{16}$
U38	2700	2	18300	345	3 $^{5}/_{8}$	3 $^{3}/_{16}$	2 $^{3}/_{4}$
U39	2870	2	19200	345	3 $^{3}/_{4}$	3 $^{5}/_{16}$	2 $^{7}/_{8}$
U40	3040	2	20500	360	3 $^{7}/_{8}$	3 $^{5}/_{16}$	3
U41	3210	2	21800	360	3 $^{15}/_{16}$	3 $^{7}/_{16}$	3 $^{1}/_{16}$
U42	3400	2	23100	360	4	3 $^{9}/_{16}$	3 $^{1}/_{16}$
U43	3600	2	24500	375	4 $^{1}/_{8}$	3 $^{5}/_{8}$	3 $^{3}/_{16}$
U44	3800	2	25800	375	4 $^{1}/_{4}$	3 $^{3}/_{4}$	3 $^{5}/_{16}$
U45	4000	2	27100	375	4 $^{3}/_{8}$	3 $^{7}/_{8}$	3 $^{7}/_{16}$

		Stockless Bower Anchors		*Chain Cable Stud Link Bower Chain**			
					Diameter		
Equipment Numeral	*Equipment Number*	*Number*	*Mass per Anchor, pounds*	*Length, fathoms*	*Ordinary-Strength Steel (Grade 1), inches*	*High-Strength Steel (Grade 2), inches*	*Extra High-Strength Steel (Grade 3), inches*
U46	4200	2	28400	390	$4\,{}^{1}/_{2}$	$3\,{}^{15}/_{16}$	$3\,{}^{7}/_{16}$
U47	4400	2	29800	390	$4\,{}^{5}/_{8}$	4	$3\,{}^{9}/_{16}$
U48	4600	2	31100	390	$4\,{}^{3}/_{4}$	$4\,{}^{1}/_{8}$	$3\,{}^{5}/_{8}$
U49	4800	2	32400	405	$4\,{}^{3}/_{4}$	$4\,{}^{1}/_{4}$	$3\,{}^{3}/_{4}$
U50	5000	2	33900	405	$4\,{}^{7}/_{8}$	$4\,{}^{3}/_{8}$	$3\,{}^{7}/_{8}$
U51	5200	2	35500	405	5	$4\,{}^{3}/_{8}$	$3\,{}^{7}/_{8}$
U52	5500	2	37200	405	$5\,{}^{1}/_{8}$	$4\,{}^{1}/_{2}$	$3\,{}^{15}/_{16}$
U53	5800	2	39200	405	$5\,{}^{1}/_{8}$	$4\,{}^{5}/_{8}$	4
U54	6100	2	41400	405	--	$4\,{}^{3}/_{4}$	$4\,{}^{1}/_{4}$
U55	6500	2	44000	420	--	$4\,{}^{7}/_{8}$	$4\,{}^{3}/_{8}$
U56	6900	2	47400	420	--	5	$4\,{}^{1}/_{2}$
U57	7400	2	50700	420	--	$5\,{}^{1}/_{8}$	$4\,{}^{5}/_{8}$
U58	7900	2	54000	420	--	$5\,{}^{3}/_{8}$	$4\,{}^{3}/_{4}$
U59	8400	2	57300	420	--	$5\,{}^{5}/_{8}$	5
U60	8900	2	60600	420	--	$5\,{}^{3}/_{4}$	$5\,{}^{1}/_{8}$
U61	9400	2	63900	420	--	6	$5\,{}^{1}/_{8}$
U62	10000	2	68000	420	--	--	$5\,{}^{3}/_{8}$
U63	10700	2	72500	420	--	--	$5\,{}^{5}/_{8}$
U64	11500	2	78000	420	--	--	$5\,{}^{3}/_{4}$
U65	12400	2	85000	420	--	--	6
U66	13400	2	92500	420	--	--	$6\,{}^{1}/_{8}$
U67	14600	2	101500	420	--	--	$6\,{}^{3}/_{8}$

Note:
*Wire ropes may be used in lieu of chain cables for both anchors on vessels less than 30 m (98.4 ft) in length. For vessels between 30 m (8.4 ft) and 40 m (131.2 ft) in length, wire rope may be used in lieu of chain cable for one anchor, provided normal chain cable is provided for the second anchor.
The wire is to have a breaking strength not less than the grade 1 chain of required size and a length of at least 1.5 times the chain it is replacing.
Between the wire rope and anchor, chain cable of the required size having a length of 12.5 m (41.0 ft), or the distance between anchor in stored position and winch, whichever is less, is to be fitted.

TABLE 2
Mooring Lines for Self-propelled Ocean-going Vessels with *EN*≤ 2000 *(2022)*

Equipment Number		*Mooring Lines*					
Exceeding	*Not Exceeding*	*Number*	*Minimum length of each line **		*Ship design minimum breaking load ***		
			(m)	*(fathoms)*	*(kN)*	*(kgf)*	*(lbf)*
50	70	3	80	44	37	3750	8300
70	90	3	100	55	40	4000	9000
90	110	3	110	60	42	4500	9400
110	130	3	110	60	48	5000	10800
130	150	3	120	66	53	5400	11900
150	175	3	120	66	59	6000	13300
175	205	3	120	66	64	6500	14400
205	240	4	120	66	69	7000	15500
240	280	4	120	66	75	7500	16900
280	320	4	140	77	80	8000	18000
320	360	4	140	77	85	8500	19100
360	400	4	140	77	96	9500	21600
400	450	4	140	77	107	11000	24100
450	500	4	140	77	117	12000	26300
500	550	4	160	87	134	13500	30100
550	600	4	160	87	143	14500	32100
600	660	4	160	87	160	16500	36000
660	720	4	160	87	171	17500	38400
720	780	4	170	93	187	19000	42000
780	840	4	170	93	202	20500	45400
840	910	4	170	93	218	22000	49000
910	980	4	170	93	235	24000	52800
980	1060	4	180	98	250	25500	56200
1060	1140	4	180	98	272	27500	61100
1140	1220	4	180	98	293	30000	65900

Equipment Number		*Mooring Lines*					
Exceeding	*Not Exceeding*	*Number*	*Minimum length of each line* *		*Ship design minimum breaking load* **		
			(m)	*(fathoms)*	*(kN)*	*(kgf)*	*(lbf)*
1220	1300	4	180	98	309	31500	69500
1300	1390	4	180	98	336	34500	75500
1390	1480	4	180	98	352	36000	79100
1480	1570	5	190	104	352	36000	79100
1570	1670	5	190	104	362	37000	81400
1670	1790	5	190	104	384	39000	86300
1790	1930	5	190	104	411	42000	92400
1930	2000	5	190	104	437	44500	98200

Note:

* 3-5-1/9.3.3 is to be observed

** Ship design minimum breaking load (MBL_{SD}) means the minimum breaking load of new, dry mooring lines or tow lines for which shipboard fittings and supporting hull structures are designed in order to meet mooring restraint requirements or the towing requirements of other towing service.

TABLE 3
Tow Lines for Self-propelled Ocean-going Vessels *(2022)*

Equipment Number		*Tow Lines*				
Exceeding	*Not Exceeding*	*Minimum length of each line*		*Ship design minimum breaking load* *		
		(m)	*(fathoms)*	*(kN)*	*(kgf)*	*(lbf)*
50	70	180	98	98	10000	22000
70	90	180	98	98	10000	22000
90	110	180	98	98	10000	22000
110	130	180	98	98	10000	22000
130	150	180	98	98	10000	22000
150	175	180	98	98	10000	22000
175	205	180	98	112	11400	25100
205	240	180	98	129	13200	29100
240	280	180	98	150	15300	33700
280	320	180	98	174	17700	39000
320	360	180	98	207	21100	46500
360	400	180	98	224	22800	50300
400	450	180	98	250	25500	56200
450	500	180	98	277	28200	62200
500	550	190	104	306	31200	68800

Equipment Number		*Tow Lines*				
Exceeding	*Not Exceeding*	*Minimum length of each line*		*Ship design minimum breaking load **		
		(m)	*(fathoms)*	*(kN)*	*(kgf)*	*(lbf)*
550	600	190	104	338	34500	76000
600	660	190	104	370	37800	83300
660	720	190	104	406	41400	91200
720	780	190	104	441	45000	99200
780	840	190	104	479	48900	107800
840	910	190	104	518	52800	116400
910	980	190	104	559	57000	125600
980	1060	200	109	603	61500	135500
1060	1140	200	109	647	66000	145500
1140	1220	200	109	691	70500	155400
1220	1300	200	109	738	75300	166000
1300	1390	200	109	786	801000	176500
1390	1480	200	109	836	85200	187800
1480	1570	220	120	888	90600	199700
1570	1670	220	120	941	967000	211500
1670	1790	220	120	1024	104400	230000
1790	1930	220	120	1109	113100	249500
1930	2080	220	120	1168	119100	262500
2080	2230	240	131	1259	128400	283000
2230	2380	240	131	1356	138300	305000
2380	2530	240	131	1453	148200	326500
2530	2700	260	142	1471	150000	330500
2700	2870	260	142	1471	150000	330500
2870	3040	260	142	1471	150000	330500
3040	3210	280	153	1471	150000	330500
3210	3400	280	153	1471	150000	330500
3400	3600	280	153	1471	150000	330500
3600	-	300	164	1471	150000	330500

Note:
* Ship design minimum breaking load (MBL_{SD}) means the minimum breaking load of new, dry mooring lines or tow lines for which shipboard fittings and supporting hull structures are designed in order to meet mooring restraint requirements or the towing requirements of other towing service

PART 3

CHAPTER 5
Equipment

SECTION 2
Mooring of Vessels at Single Point Moorings

1 Application

This Section is applicable to conventional vessels fitted with equipment enabling them to be moored by the bow to single point moorings or moored in tandem to FPSO/FSO terminals. Application to other types of tankers will be subject to special consideration.

3 Notation

Vessels provided with mooring arrangements in accordance with the requirements of this Section will be eligible to be assigned the Class Notation **SPMA**.

5 Submission of Design Plans and Data

The following design plans and data are to be submitted:

- Plan showing the mooring arrangement with position of bow fairleads, bow chain stoppers, winches and capstans and pedestal rollers and winch storage drums, if applicable
- Details of bow chain stoppers
- Details of bow fairleads and their attachment to the bulwark
- Details of attachment to deck and supporting structure of the bow chain stoppers, winch or capstans and pedestal rollers and winch storage drums, if applicable.

7 Arrangements

7.1 General

The vessel is to be fitted with bow chain stoppers and bow fairleads as per 3-5-2/7.1 TABLE 1. Additional pedestal roller fairleads may be required for alignment purposes and a winch or capstan for the pick-up rope. The requirements for the supporting deck structure in way of all equipment are to be in accordance with 3-2-7/4.

TABLE 1
Required Arrangements by Vessel Deadweight

Ship Size (tonnes DWT at maximum summer draft)	*Chafing Chain Size*	*Number of Bow Chain Stoppers*	*Minimum SWL (Tonnes)*	*Number of Bow Fairleads (recommended)*
100,000 or less (See Note)	76 mm (3 in.)	1	200 tonnes (440405 lbs)	1
Over 100,000 but not greater than 150,000 (See Note)	76 mm (3 in.)	1	250 (550505 lbs)	1
Over 150,000	76 mm (3 in.)	2	350 (770707 lbs)	2

Note: Ships in this size range may elect to fit two stoppers / fairleads to ensure full range terminal acceptance

7.3 Bow Chain Stoppers

7.3.1 Number, Chain Cable Size, and Minimum SWL

The number, chain cable size, and minimum SWL of bow chain stoppers are to be in accordance with 3-5-2/7.1 TABLE 1. The chain stoppers are to be permanently marked with the SWL to which they have been designed and tested.

7.3.2 Location

Bow chain stoppers are to be located between 2.7 m (8 ft 10 in.) and 3.7 m (12 ft 2 in.) aft of the bow fairlead.

7.3.3 Alignment

Stoppers are to be positioned to give correct alignment with the bow fairlead and the pedestal fairlead or storage drum of the winch.

7.3.4 Securing

A standard 76 mm (3 in.) stud-link chain is to be secured when the chain engaging pawl or bar is in the closed position. When in open position, the chain and associated fittings are to be allowed to pass freely.

7.3.5 Structural Strength

The structural strength of the stopper and supporting structure is to be based on a safety factor of 2.0 against the yield criterion when applying a load equal to SWL given in 3-5-2/7.1 TABLE 1.

7.3.6 Relation to Deck Structure

Stoppers are to be fitted as close as possible to the deck structure, taking due consideration to possible obstacles in order to obtain a free lead through the fairleads.

7.3.7 Fairing of Leading Edge

The leading edge of the bow chain stopper base is to be faired to allow for the unimpeded entry of the chafing chain.

7.3.8 Testing

Upon installation, bow stoppers are to be load tested to the equivalent SWL in the presence of our surveyor and a test certificate is to be issued. The test certificate is to be available for inspection onboard the ship. Alternative testing arrangements will be considered that can be shown to be equivalent to the above load test requirements.

Applicable strength of the supporting structure is to be documented by adequate analyses and submitted for review to a technical office. A copy of the approval letter is to be available onboard.

7.5 Bow Fairleads

7.5.1 Openings

Bow fairlead openings are to measure at least 600 mm × 450 mm. ($23^1/_2$ in. × $17^3/_4$ in.)

7.5.2 Ships with Two Fairleads

For ships fitted with two fairleads, they are to be spaced, from center to center, at least 2.0 m (6 ft $6^3/_4$ in.) apart. In any event, the fairleads are not to be spaced more than 3.0 m (9 ft 10 in.) apart.

7.5.3 Ships with One Fairlead

For ships fitted with one fairlead, it is to be positioned on the centerline.

7.5.4 Shape

Fairleads are to be oval or round in shape and adequately faired when fitted in order to prevent chafing chains from fouling on the lower lip when heaving inboard. Square fairleads are not suitable.

7.5.5 Number of Fairleads

When two bow chain stoppers are fitted, then two bow fairleads are required.

7.5.6 Structural Strength

The structural strength of the bow fairlead is to be based on a safety factor of 2.0 against the yield criterion when applying a load equal to SWL given in 3-5-2/7.1 TABLE 1.

7.7 Pedestal Rollers

7.7.1 Position

Winches or capstans are to be positioned to enable a direct pull to be achieved on the continuation of the direct lead line between the bow fairleads and bow stoppers. Alternatively, a pedestal roller may be positioned between the stopper and the winch or the capstan, in order to achieve direct pull.

7.7.2 Distance between the Bow Stoppers and Pedestal Roller

The distance between the bow stoppers and pedestal roller is to be considered so that an unrestricted line pull is achieved from the bow fairlead and through the bow stopper.

7.7.3 Number and Angle

The number of pedestal rollers used for each bow chain stopper is not to exceed two and the angle of change of direction of the pick-up rope lead is to be minimal.

7.7.4 Structural Strength

The structural strength of the pedestal rollers and supporting structure is to be verified to withstand the design load of 1.25 times the maximum hauling-in force of the winch or capstan and in accordance with 3-5-1/15.

7.9 Winches or Capstans

Winches or capstans are to be capable of exerting a continuous duty pull of not less than 15 tonnes (33030 lbs).

7.11 Winch Storage Drum

If a winch storage drum is used to stow the pick-up rope, it is to be of sufficient size to accommodate 150 m (492 ft) of 80 mm ($3^{3}/_{16}$ in.) diameter rope.

9 Materials

Material for the hull structure is to be in accordance with Chapter 1 of the ABS *Rules for Materials and Welding (Part 2)*. Material for the deck fittings will be accepted on the basis of the manufacturer's certified mill test reports.

PART 3

CHAPTER 5
Equipment

SECTION 3
Equipment without symbol Ⓔ

1 General *(2020)*

The equipment for vessels other than OSVs having EN less than 205 per 3-5-1/3.3.2 or vessels under 90 m in length intended for towing where the symbol Ⓔ is not desired, is to be in accordance with 3-5-1/19.7 TABLE 1A and 3-5-1/19.7 TABLE 1B in association with the EN so calculated, but the following modifications may be accepted. See also 3-5-1/5.

3 Vessels intended for Limited Service

Vessels intended for limited service (see 1-1-3/7 of the ABS *Rules for Conditions of Classification (Part 1)*) and having their own moorage, e.g., ferries, launch, etc. with an equipment number less than 150, obtained from 3-5-1/3.3.2, are to have one anchor of the tabular weight and one-half the tabulated length of anchor chain in 3-5-1/19.7 TABLE 1A and 3-5-1/19.7 TABLE 1B. Alternatively, two anchors of one-half the tabular weight with the total length of anchor chain listed in 3-5-1/19.7 TABLE 1A and 3-5-1/19.7 TABLE 1B may be fitted, provided both anchors are positioned and ready for use and the windlass is capable of heaving in either anchor.

5 Vessels Intended for Towing Service

Vessels intended for towing service are to have at least one anchor of one-half the tabular weight listed in 3-5-1/19.7 TABLE 1A and 3-5-1/19.7 TABLE 1B.

The towing winch can be used for releasing and heaving in the anchor, provided that the anchor is positioned ready for use and is capable of being quickly connected to the winch's wire rope.

PART 3

CHAPTER 6
Navigation

CONTENTS

PART 3

CHAPTER 6
Navigation

SECTION 1
Visibility

1 Navigation Bridge Visibility

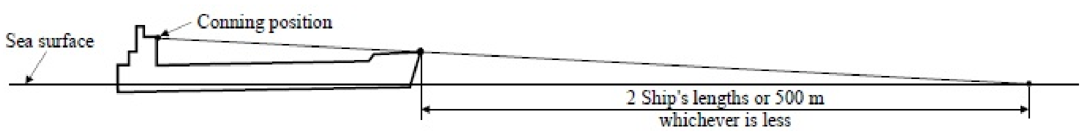
Vessels of not less than 55 m (180 ft) in length overall having the keel laid or in similar stage of construction on or after 1 July 1998 are to meet the following requirements for visibility from navigation bridge, unless they are navigating solely the Great Lakes of North America and their connecting 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 may be given to vessels that operate only on domestic or on short, limited, international voyages.

1.1 Field of Vision

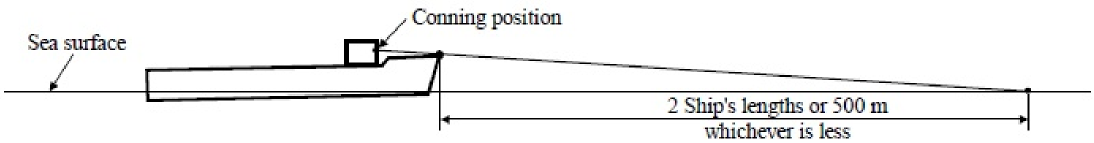
1.1.1 Conning Position

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 (1640 ft), 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 3-6-1/1.1.1(a) FIGURE 1 as applicable.

FIGURE 1



(a)



(b)

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, specialist equipment, support for helicopter deck 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 3-6-1/1.1.1(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. See 3-6-1/1.1.4 FIGURE 3, as applicable.

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. See 3-6-1/1.1.4 FIGURE 4, as applicable.

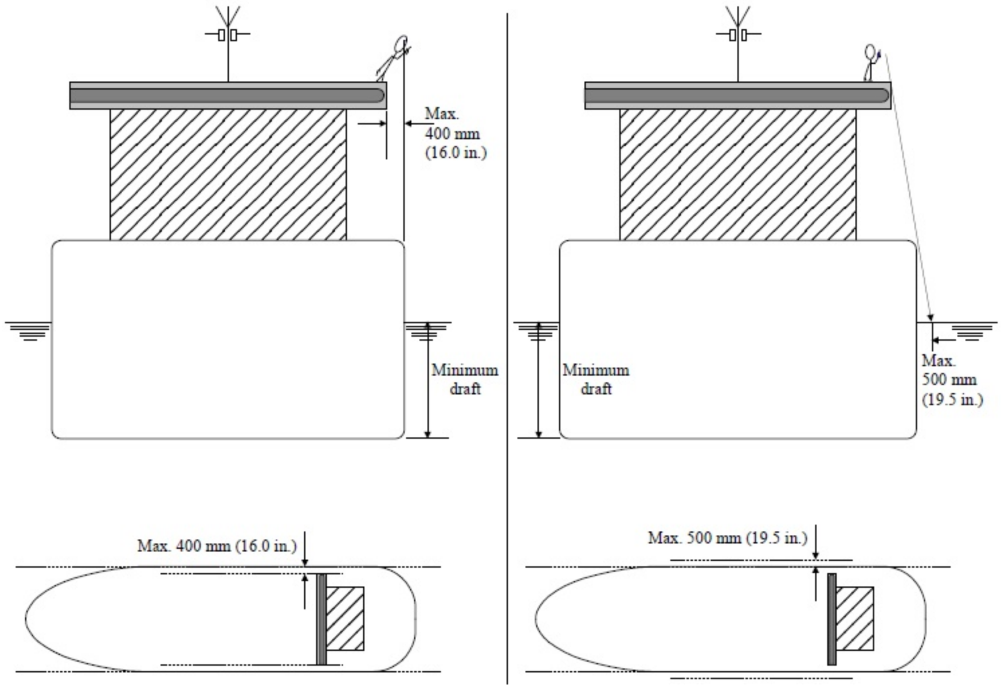
1.1.2(b) The vessel's side is to be visible from the bridge wing.

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 (16 in.), 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 (19.5 in.) and more from the maximum beam throughout the ship’s length is visible from the side of the bridge wing.

See 3-6-1/1.1.2(b).i FIGURE 2.

FIGURE 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, 3-6-1/1.1.2(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 (59 in.) 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.

1.1.3 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 3-6-1/1.1.4 FIGURE 5, as applicable.

1.1.4 Remote Camera System

The use of a remote camera system may be accepted for ships of unconventional design, other than those mentioned in 3-6-1/1.1.2(b).ii above, as means for achieving the view of the ship's side from the bridge wing, provided:

i) The installed remote camera system is to be redundant from the circuit breaker to the camera and screen, including communication cables (i.e., the system is to provide on each side of the ship redundancy of):

- The power cables and circuit breakers from the main switchboard to the camera and the screen;
- The camera;
- The screen;
- The transmission lines from the camera to the display screen; and
- The components associated with these lines and cables;

ii) The remote camera system is powered from the ship's main source of electrical power and is not required to be powered by the emergency source of electrical power;

iii) The remote camera system is capable of continuous operation under environmental conditions as per 4-9-9/15.7 TABLE 1 and 4-9-9/15.7 TABLE 2;

iv) The view provided by the remote camera system is analogous to that from the bridge wing so the ship's side is to be visible, and is also displayed at locations where the maneuvering of the ship may take place;

v) The upper edge of the ship's side abeam is directly visible from locations where the maneuvering of the ship may take place.

FIGURE 3

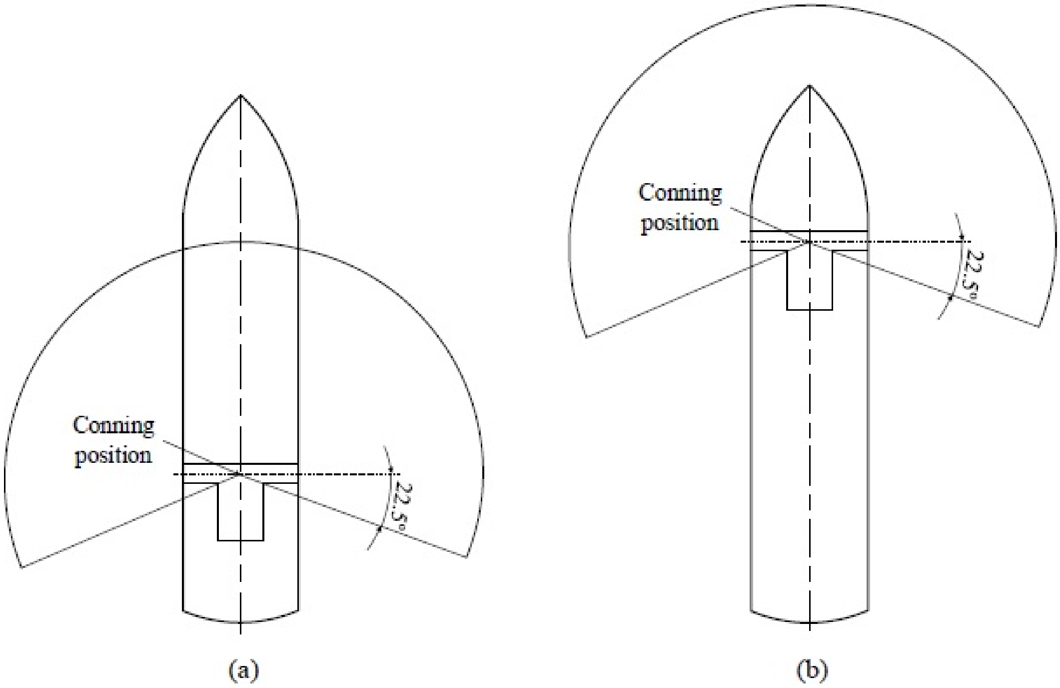
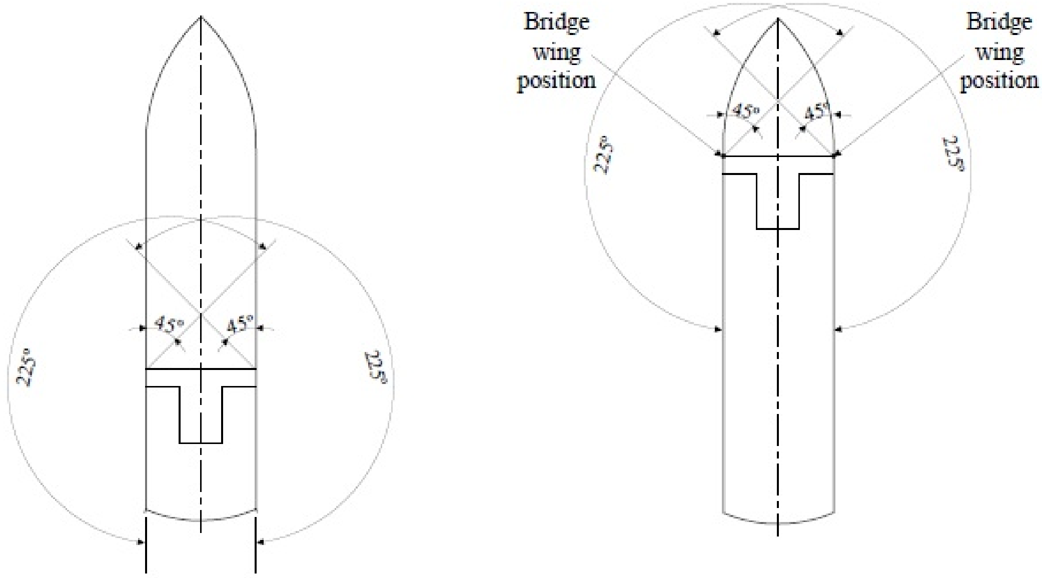
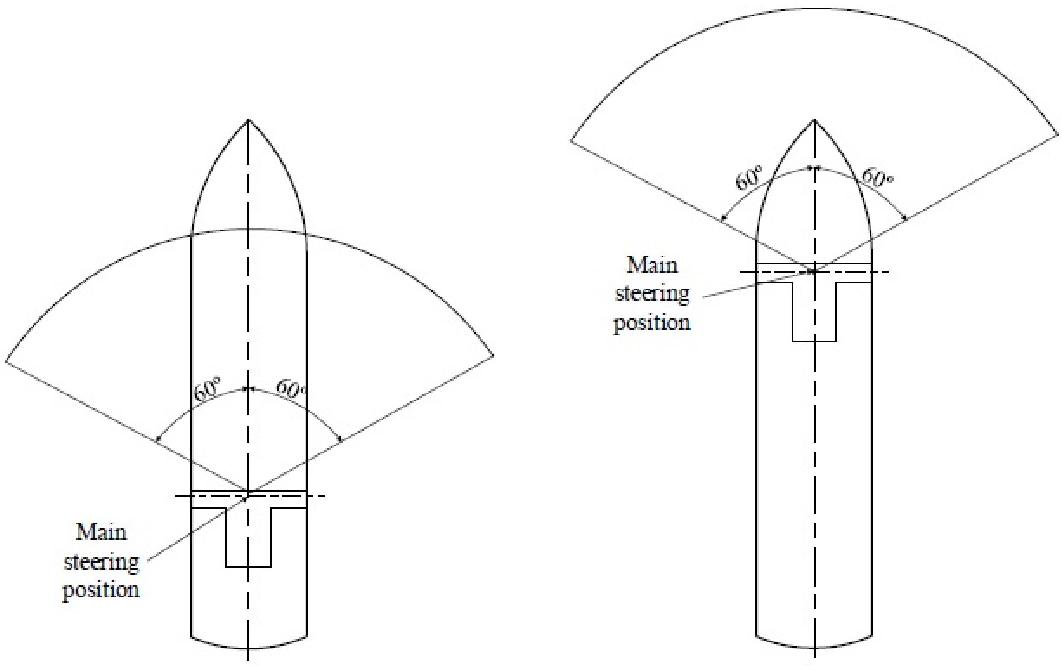


FIGURE 4



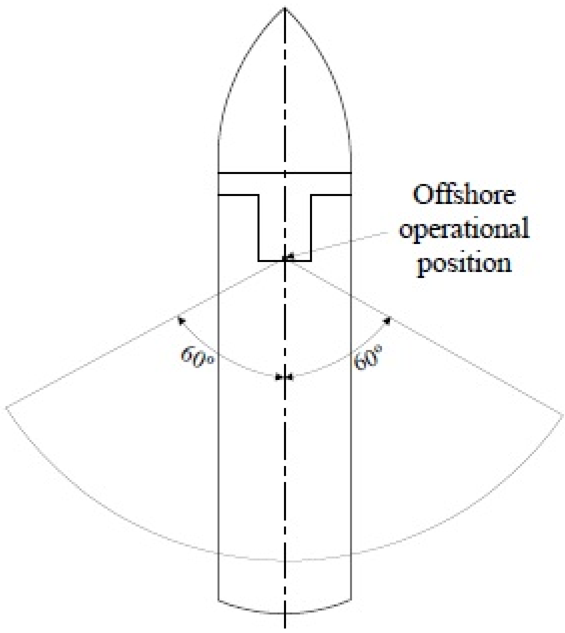
(a) (b)

FIGURE 5



(a) (b)

FIGURE 6



1.3 Windows and their Arrangements

Navigation bridge windows and their arrangements are to meet the following requirements:

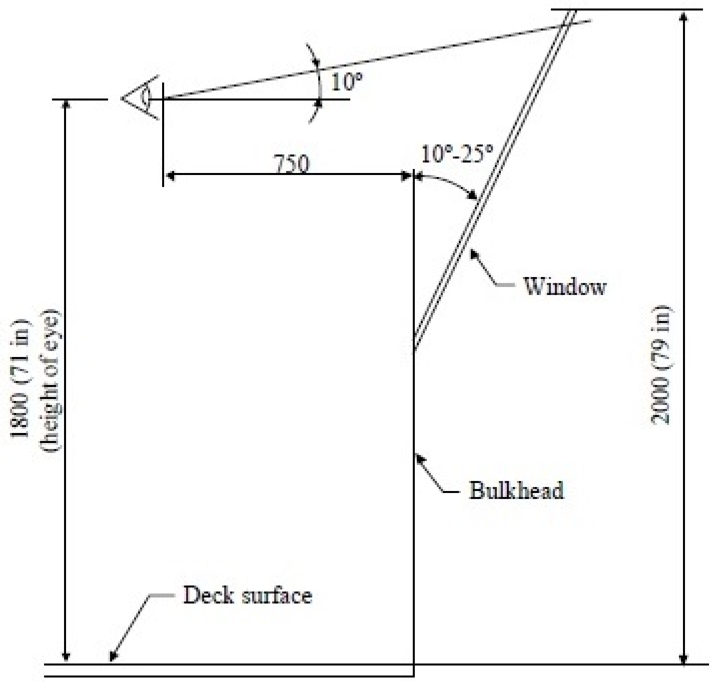
1.3.1 Framing *(2019)*

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 navigation bridge front windows are to be inclined from a vertical plane top out, at an angle of not less than that as indicated in 3-6-1/1.3.2 FIGURE 7, as applicable.

FIGURE 7
Forward Window *(2019)*



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 is to be fitted in front of bridge windows for 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 close to the bridge deck as practical. 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 (5 ft 11 in.) above the bridge deck at the conning position, when the vessel is pitching in heavy seas. ABS, if satisfied that an 1800 mm (5 ft 11 in.) height of eye is unreasonable and impractical, may allow reduction of the height of eye but not to less than 1600 mm (5 ft 3 in.). See 3-6-1/1.3.2 FIGURE 7.

1.5 Unconventional Design

For vessels of unconventional design which cannot comply with the above requirements, arrangements are to be provided to the satisfaction of ABS achieve a level of visibility that is as near as practical to those prescribed in this Section.

1.7 Articulated Tug-Barge Units *(2019)*

Tugboats designed to push barges as part of an Articulated Tug-Barge unit (ATB), are required to meet the requirements of 3-6-1/1.1.1. The length overall is to be based on the length from the barge's stem to the stern of the tug when operating as a combined unit. The visibility is to be determined based on the largest barge that the tugboat is designed to operate with as an articulated unit.

3 Offshore Operations Bridge Visibility

All offshore support vessels are to be provided with an unobstructed as possible and practical view abaft from the Offshore Operations Control Area towards the cargo or work decks and machinery or specialist equipment. On supply vessels it is necessary to control both, the station keeping as well as cargo loading/ unloading operations. On anchor handling/towing vessels it is necessary to control the heading, position, speed as well as deck machinery engaged for towing and/or anchor handling operations. On other types of offshore support vessels it may be necessary to control the station keeping as well as the specific service equipment installed on work deck. Where direct visual observation of machinery and equipment is unavoidably obstructed, a CCTV system suitable for use in the marine environment would be considered acceptable.

3.1 Field of Vision

The view of the cargo or work deck area, including loading/unloading ports on supply vessels, as well as view of the sea surface in close vicinity of the vessel shall not be obstructed. From the Offshore Operations Control Area, the horizontal field of vision should extend over an arc from right astern to at least 60° on each side of the vessel see 3-6-1/1.1.4 FIGURE 6.

3.3 Aft Windows Arrangements

Aft windows and their arrangements are to meet the following requirements:

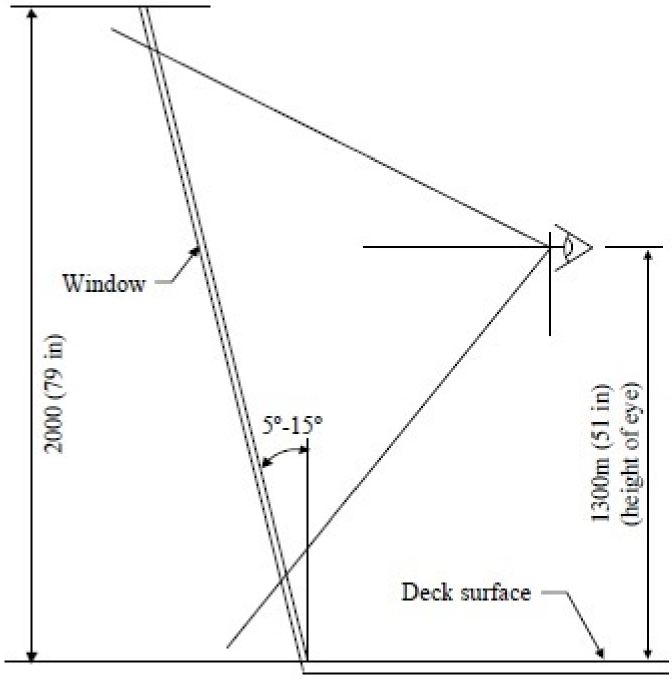
3.3.1 Framing

Framing between navigation bridge aft 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 main commanding/maneuvering and controlling positions.

3.3.2 Inclination Angle

The bridge aft windows are to be inclined from a vertical plane top out, at an angle of not less than 5° and not more than 15°, see 3-6-1/3.3.2 FIGURE 8.

FIGURE 8
Aft Window *(2019)*



3.3.3 Glass

Polarized and tinted windows are not to be fitted.

3.3.4 Clear View

At all times, regardless of the weather conditions, at least two of the above aft windows are to provide a clear view, as described above. The following, or equivalent, is to be provided as well:

3.3.4(a) Sun Screens. Sunscreens are to be with minimum color distortion; are to be readily removable and are not to be permanently installed.

3.3.4(b) Wipers and Fresh Water Wash Systems. Heavy-duty wipers provided with an interval function and fresh water wash systems, being capable of operating independently of each other.

3.3.4(c) De-icing and De-misting Systems. De-icing and de-misting systems are to be provided.

3.3.4(d) Fixed Catwalk. A fixed catwalk with guardrails, fitted aft of the bridge windows is to be provided, enabling manual cleaning of windows in the event of failure of the above systems.

3.3.5 Impact Protection for Windows

Suitable protection of the aft windows against impact from any cargo being lifted onboard the vessel is recommended.

3.3.6 Lower and Upper Edge

The lower edge of the navigation bridge aft windows is to be kept as close to the bridge deck as practical. The upper edge of the navigation bridge aft windows is to be kept as close to the overhead deck as practical.

5 Side Windows Arrangement

Side windows for shore support vessel are constructed to meet the following requirements:

i) To be arranged to minimize blind sectors such as funnels etc. which unavoidably restricts a 360° view of the sea surface from the wheelhouse.

ii) Where windows are installed on bridge wings aligned with ship sides they are to provide the horizontal field of vision as well as visibility of vessel's sides as required in 3-6-1/1.1.2 above, see 3-6-1/1.1.4 FIGURE 4, as applicable.

iii) Where windows are installed on bridge wings not aligned with ship sides then a fixed catwalk with guardrails is to be installed to enable fulfilling this requirement.

PART 3

CHAPTER 7

Testing, Trials and Surveys During Construction - Hull

CONTENTS

PART 3

CHAPTER 7

Testing, Trials and Surveys During Construction - Hull

SECTION 1

Tank, Bulkhead and Rudder Tightness Testing

1 General

Testing to confirm the watertightness of tanks and watertight boundaries and the structural adequacy of tanks which form the watertight subdivisions[(1)] of ships is to be completed. Verification of the weathertightness of structures and shipboard outfitting is to be carried out. The tightness of all tanks and tight boundaries of new ships and those tanks and boundaries whose structural integrity is affected by major conversions or major repairs[(2)] is to be confirmed prior to the delivery of the ship or prior to the completion of the modification or repair as relevant.

Testing procedures of watertight compartments for ships built in compliance with SOLAS 1974 as amended (including ships which are to comply with the requirements in Parts 5A and 5B) are to be carried out in accordance with 3-7-1/3, unless:

i) The shipyard provides documentary evidence of the Owner's agreement to a request to the Flag Administration for an exemption from the application of Chapter II-1, Regulation 11 of SOLAS 1974 as amended, or for an equivalency agreeing that the content of 3-7-1/5 is equivalent to Chapter II-1, Regulation 11 of SOLAS 1974 as amended; and

ii) The above-mentioned exemption/equivalency has been granted by the responsible Flag Administration.

Testing procedures of watertight compartments are to be carried out in accordance with 3-7-1/5 for ships not built in compliance with SOLAS 1974 as amended and those ships built in compliance with SOLAS 1974 as amended for which:

i) The shipyard provides documentary evidence of the Owner's agreement to a request to the Flag Administration for an exemption from the application of Chapter II-1, Regulation 11 of SOLAS 1974 as amended, or for an equivalency agreeing that the content of 3-7-1/5 is equivalent to Chapter II-1, Regulation 11 of SOLAS 1974 as amended; and

ii) The above-mentioned exemption/equivalency has been granted by the responsible Flag Administration.

Notes:

1) Watertight subdivision means the transverse and longitudinal subdivisions of the ship required to satisfy the subdivision requirements of SOLAS Chapter II-1.

2) Major repair means a repair affecting structural integrity.

3 Testing Requirements for Ships Built in Compliance with SOLAS 1974 as Amended (Including Ships that are to Comply with the Requirements in Parts 5A and 5B)

3.1 Application

All gravity tanks which are subjected to vapor pressure not greater than 0.7 bar (0.7 kgf/cm^2, 10 psi) and other boundaries required to be watertight or weathertight are to be tested in accordance with this Subsection and proven to be tight or structurally adequate as follows:

3.1.1

Gravity Tanks for their structural adequacy and tightness,

3.1.2

Watertight Boundaries Other Than Tank Boundaries for their watertightness, and

3.1.3

Weathertight Boundaries for their weathertightness.

For the testing of cargo containment systems of liquefied gas carriers, the requirements in 5C-8-4/20 will apply.

Testing of structures not listed in 3-7-1/3.5.7 TABLE 1 and 3-7-1/3.5.7 TABLE 2 is to be specially considered.

3.3 Test Types and Definitions

3.3.1

The following two types of tests are specified in this requirement.

3.3.1(a) Structural Test. A test to verify the structural adequacy of tank construction. This may be a hydrostatic test or, where the situation warrants, a hydropneumatic test.

3.3.1(b) Leak Test. A test to verify the tightness of a boundary. Unless a specific test is indicated, this may be a hydrostatic/hydropneumatic test or an air test. A hose test may be considered an acceptable form of leak test for certain boundaries, as indicated by Footnote 3 of 3-7-1/3.5.7 TABLE 1.

3.3.2

The definition of each test type is as follows:

Hydrostatic Test: (Leak and Structural)	A test wherein a space is filled with a liquid to a specified head.
Hydropneumatic Test: (Leak and Structural)	A test combining a hydrostatic test and an air test, wherein a space is partially filled with a liquid and pressurized with air.
Hose Test: (Leak)	A test to verify the tightness of a joint by a jet of water with the joint visible from the opposite side.
Air Test: (Leak)	A test to verify tightness by means of air pressure differential and leak indicating solution. It includes tank air test and joint air tests, such as *compressed air fillet weld tests* and *vacuum box tests.*
Compressed Air Fillet Weld Test: (Leak)	An air test of fillet welded tee joints wherein leak indicating solution is applied on fillet welds.

Vacuum Box Test: (Leak)	A box over a joint with leak indicating solution applied on the welds. A vacuum is created inside the box to detect any leaks.
Ultrasonic Test: (Leak)	A test to verify the tightness of the sealing of closing devices such as hatch covers by means of ultrasonic detection techniques.
Penetration Test: (Leak)	A test to verify that no visual dye penetrant indications of potential continuous leakages exist in the boundaries of a compartment by means of low surface tension liquids (i.e. dye penetrant test).

3.5 Test Procedures

3.5.1 General

Tests are to be carried out in the presence of a Surveyor at a stage sufficiently close to the completion of work with all hatches, doors, windows, etc. installed and all penetrations including pipe connections fitted, and before any ceiling and cement work is applied over the joints. Specific test requirements are given in 3-7-1/3.5.4 and 3-7-1/3.5.7 TABLE 1. For the timing of the application of coating and the provision of safe access to joints, see 3-7-1/3.5.5, 3-7-1/3.5.6 and 3-7-1/3.5.7 TABLE 3.

3.5.2 Structural Test Procedures

3.5.2(a) Type and Time of Test. Where a structural test is specified in 3-7-1/3.5.7 TABLE 1 or 3-7-1/3.5.7 TABLE 2, a hydrostatic test in accordance with 3-7-1/3.5.4(a) will be acceptable. Where practical limitations (strength of building berth, light density of liquid, etc.) prevent the performance of a hydrostatic test, a hydropneumatic test in accordance with 3-7-1/3.5.4(b) may be accepted instead.

A hydrostatic test or hydropneumatic test for the confirmation of structural adequacy may be carried out while the vessel is afloat, provided the results of a leak test are confirmed to be satisfactory before the vessel is afloat.

3.5.2(b) Testing Schedule for New Construction or Major Structural Conversion.

i) Tanks which are intended to hold liquids, and which form part of the watertight subdivision of the ship*, shall be tested for tightness and structural strength as indicated in 3-7-1/3.5.7 TABLE 1 and 3-7-1/3.5.7 TABLE 2.

ii) The tank boundaries are to be tested from at least one side. The tanks for structural test are to be selected so that all representative structural members are tested for the expected tension and compression.

iii) The watertight boundaries of spaces other than tanks for structural testing may be exempted, provided that the water-tightness of boundaries of exempted spaces is verified by leak tests and inspections. Structural testing may not be exempted and the requirements for structural testing of tanks in 3-7-1/3.5.2(b).i to 3-7-1/3.5.2(b)iii. shall apply, for ballast holds, chain lockers and a representative cargo hold if intended for in-port ballasting.

iv) Tanks which do not form part of the watertight subdivision of the ship*, may be exempted from structural testing provided that the water-tightness of boundaries of exempted spaces is verified by leak tests and inspections.

Note: * Watertight subdivision means the main transverse and longitudinal subdivisions of the ship required to satisfy the subdivision requirements of SOLAS Chapter II-1.

3.5.3 Leak Test Procedures

For the leak tests specified in 3-7-1/3.5.7 TABLE 1, tank air tests, compressed air fillet weld tests, vacuum box tests in accordance with 3-7-1/3.5.4(d) through 3-7-1/3.5.4(f), or their combination, will be acceptable. Hydrostatic or hydropneumatic tests may also be accepted as leak tests provided that 3-7-1/3.5.5, 3-7-1/3.5.6 and 3-7-1/3.5.7 are complied with. Hose tests will also be acceptable for such locations as specified in 3-7-1/3.5.7 TABLE 1, note 3, in accordance with 3-7-1/3.5.4(c).

The application of the leak test for each type of welded joint is specified in 3-7-1/3.5.7 TABLE 3.

Air tests of joints may be carried out in the block stage provided that all work on the block that may affect the tightness of a joint is completed before the test. See also 3-7-1/3.5.5(a) for the application of final coatings and 3-7-1/3.5.6 for the safe access to joints and the summary in 3-7-1/3.5.7 TABLE 3.

3.5.4 Test Methods

3.5.4(a) Hydrostatic Test. Unless another liquid is approved, hydrostatic tests are to consist of filling the space with fresh water or sea water, whichever is appropriate for testing, to the level specified in 3-7-1/3.5.7 TABLE 1 or 3-7-1/3.5.7 TABLE 2. See also 3-7-1/3.5.7.

In cases where a tank is designed for cargo densities greater than sea water and testing is with fresh water or sea water, the testing pressure height is to simulate the actual loading for those greater cargo densities as far as practicable.

All external surfaces of the tested space are to be examined for structural distortion, bulging and buckling, other related damage and leaks..

3.5.4(b) Hydropneumatic Test. Hydropneumatic tests, where approved, are to be such that the test condition, in conjunction with the approved liquid level and supplemental air pressure, will simulate the actual loading as far as practicable. The requirements and recommendations for tank air tests in 3-7-1/3.5.4(d) will also apply to hydropneumatic tests. See also 3-7-1/3.5.7.

All external surfaces of the tested space are to be examined for structural distortion, bulging and buckling, other related damage and leaks.

3.5.4(c) Hose test. Hose tests are to be carried out with the pressure in the hose nozzle maintained at least at 2 bar (2 kgf/cm^2, 30 psi) during the test. The nozzle is to have a minimum inside diameter of 12 mm (0.5 in.) and be at a perpendicular distance from the joint not exceeding 1.5 m (5 ft). The water jet is to impinge directly upon the weld.

Where a hose test is not practical because of possible damage to machinery, electrical equipment insulation or outfitting items, it may be replaced by a careful visual examination of welded connections, supported where necessary by means such as a dye penetrant test or ultrasonic leak test or the equivalent.

3.5.4(d) Tank air test. All boundary welds, erection joints and penetrations, including pipe connections, are to be examined in accordance with approved procedure and under a stabilized pressure differential above atmospheric pressure not less than 0.15 bar (0.15 kgf/cm^2, 2.2 psi), with a leak indicating solution such as soapy water/detergent or a proprietary brand applied.

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 not to be less than that of the pipe supplying air to the tank. Arrangements involving the use of two calibrated pressure gauges to verify the required test pressure may be accepted taking into account the provisions in F5.1 and F7.4 of IACS Recommendation 140, “Recommendation for Safe Precautions during Survey and Testing of Pressurized Systems”.

Other effective methods of air testing, including compressed air fillet weld testing or vacuum testing, may be considered in accordance with 3-7-1/3.5.4(i).

A double inspection is to be made of tested welds. The first is to be immediately upon applying the leak indication solution; the second is to be after approximately four or five minutes, without further application of leak indication solution, in order to detect those smaller leaks which may take time to appear.

3.5.4(e) Compressed air fillet weld test. In this air test, compressed air is injected from one end of a fillet welded joint and the pressure verified at the other end of the joint by a pressure gauge. Pressure gauges are to be arranged so that an air pressure of at least 0.15 bar (0.15 kgf/cm^2, 2.2 psi) can be verified at each end of all passages within the portion being tested.

For limited portions of the partial penetration or fillet welded joints forming tank boundaries, such as corners and section of the weld adjacent to the testing apparatus, the attending Surveyor may accept the use of Magnetic Particle Inspection or Dye Penetration examination as an alternative to fillet air testing.

Where a leaking test of partial penetration welding is required and the root face is sufficiently large such as 6-8 mm (0.24-0.32 inch), the compressed air test is to be applied in the same manner as for a fillet weld.

3.5.4(f) Vacuum box test. A box (vacuum testing box) with air connections, gauges and an inspection window is placed over the joint with a leak indicating solution applied to the weld cap vicinity. The air within the box is removed by an ejector to create a vacuum of 0.20 bar (0.20 kgf/cm^2, 2.9 psi) – 0.26 bar (0.27 kgf/cm^2, 3.8 psi) inside the box.

3.5.4(g) Ultrasonic test. An ultrasonic echo transmitter is to be arranged inside of a compartment and a receiver is to be arranged on the outside. The watertight/weathertight boundaries of the compartment are scanned with the receiver in order to detect an ultrasonic leak indication. A location where sound is detectable by the receiver indicates a leakage in the sealing of the compartment.

3.5.4(h) Penetration test. A test of butt welds or other weld joints uses the application of a low surface tension liquid at one side of a compartment boundary or structural arrangement. If no liquid is detected on the opposite sides of the boundaries after the expiration of a defined period of time, this indicates tightness of the boundaries. In certain cases, a developer solution may be painted or sprayed on the other side of the weld to aid leak detection.

3.5.4(i) Other test. Other methods of testing, except as provided in 3-7-1/5, may be considered upon submission of full particulars prior to the commencement of testing.

3.5.5 Application of Coating

3.5.5(a) Final Coating. For butt joints welded by an automatic process, the final coating may be applied any time before the completion of a leak test of spaces bounded by the joints, provided that the welds have been carefully inspected visually to the satisfaction of the Surveyor.

Surveyors reserve the right to require a leak test prior to the application of final coating over automatic erection butt welds.

For all other joints, the final coating is to be applied after the completion of the leak test of the joint. See also 3-7-1/3.5.7 TABLE 3.

3.5.5(b) Temporary Coating. Any temporary coating which may conceal defects or leaks is to be applied at the time as specified for the final coating (see 3-7-1/3.5.5(a)). This requirement does not apply to shop primer.

3.5.6 Safe Access to Joints

For leak tests, safe access to all joints under examination is to be provided. See also 3-7-1/3.5.7 TABLE 3.

3.5.7 Hydrostatic or Hydropneumatic Tightness Test

In cases where the hydrostatic or hydropneumatic tests are applied instead of a specific leak test, examined boundaries must be dew-free, otherwise small leaks are not visible.

TABLE 1
Testing Requirements for Tanks and Boundaries

	Tank or Boundary to be Tested	*Test Type*	*Test Head or Pressure*	*Remarks*
1	Double bottom tanks (4)	Leak & Structural (1)	The greater of - top of the overflow, - to 2.4 m (8 ft) above top of tank (2), or - to bulkhead deck	
2	Double bottom voids (5)	Leak	See 3-7-1/3.5.4(d) through 3-7-1/3.5.4(f), as applicable	Including pump room double bottom and bunker tank protection double hull required by MARPOL Annex I
3	Double side tanks	Leak & Structural (1)	The greater of - top of the overflow, - to 2.4 m (8 ft) above top of tank (2), or - to bulkhead deck	
4	Double side voids	Leak	See 3-7-1/3.5.4(d) through 3-7-1/3.5.4(f), as applicable	
5	Deep tanks other than those listed elsewhere in this table	Leak & Structural (1)	The greater of - top of the overflow, or - to 2.4 m (8 ft) above top of tank (2)	
6	Cargo oil tanks	Leak & Structural (1)	The greater of - top of the overflow, - to 2.4 m (8 ft) above top of tank (2), or - to top of tank (2) plus setting of any pressure relief valve	
7	Ballast hold of bulk carriers	Leak & Structural (1)	To top of cargo hatch coaming	See item 16 for hatch covers.
8	Peak tanks	Leak & Structural (1)	The greater of - top of the overflow, or - to 2.4 m (8 ft) above top of tank (2)	After peak to be tested after installation of stern tube.

	Tank or Boundary to be Tested	*Test Type*	*Test Head or Pressure*	*Remarks*
9	.1 Fore peak spaces with equipment	Leak	See 3-7-1/3.5.4(c) through 3-7-1/3.5.4(f), as applicable	
	.2 Fore peak voids	Leak	See 3-7-1/3.5.4(d) through 3-7-1/3.5.4(f), as applicable	
	.3 Aft peak spaces with equipment	Leak	See 3-7-1/3.5.4(c) through 3-7-1/3.5.4(f),, as applicable	
	.4 Aft peak voids	Leak	See 3-7-1/3.5.4(d) through 3-7-1/3.5.4(f), as applicable	After peak to be tested after installation of stern tube.
10	Cofferdams	Leak	See 3-7-1/3.5.4(d) through 3-7-1/3.5.4(f), as applicable	
11	.1 Watertight bulkheads	Leak (8)	See 3-7-1/3.5.4(c) through 3-7-1/3.5.4(f), as applicable (7)	
	.2 Superstructure end bulkheads	Leak	See 3-7-1/3.5.4(c) through 3-7-1/3.5.4(f), as applicable	
	.3 Cable penetrations in watertight bulkheads	Hose	See 3-7-1/3.5.4(c)	
12	Watertight doors below freeboard or bulkhead deck	Leak (6, 7)	See 3-7-1/3.5.4(c) through 3-7-1/3.5.4(f), as applicable	See 3-2-9/9.11 for additional test at the manufacturer.
13	Double plate rudder blades	Leak	See 3-7-1/3.5.4(d) through 3-7-1/3.5.4(f), as applicable	
14	Shaft tunnels clear of deep tanks	Leak (3)	See 3-7-1/3.5.4(c) through 3-7-1/3.5.4(f), as applicable	
15	Shell doors	Leak (3)	See 3-7-1/3.5.4(c) through 3-7-1/3.5.4(f), as applicable	
16	Watertight hatch covers of tanks on combination carriers.	Leak(3, 7)	See 33-7-1/3.5.4(c) through 3-7-1/3.5.4(f), as applicable	Hatch covers closed by tarpaulins and battens excluded
17	Dual purpose tanks/dry cargo hatch covers	Leak(3, 7)	See 3-7-1/3.5.4(c) through 3-7-1/3.5.4(f), as applicable	In addition to structural test in item 6 or 7
18	Chain lockers	Leak & Structural(1)	Top of chain pipe	
19	L.O. sump tanks and other similar tanks/spaces under main engine	Leak(9)	See 3-7-1/3.5.4(c) through 3-7-1/3.5.4(f), as applicable	
20	Ballast ducts	Leak & Structural (1)	The greater of - ballast pump maximum pressure, or - setting of any pressure relief valve	

	Tank or Boundary to be Tested	*Test Type*	*Test Head or Pressure*	*Remarks*
21	Fuel oil tanks	Leak & Structural (1)	The greater of - top of the overflow, or - to 2.4 m (8 ft) above top of tank (2), or - to top of tank (2) plus setting of any pressure relief valve, or - to bulkhead deck	
22	Azimuthing Pod	Leak	See 3-7-1/3.5.4(c) through 3-7-1/3.5.4(f), as applicable	

Notes:

1 Refer to 3-7-1/3.5.2(b).

2 Top of tank is the deck forming the top of the tank, excluding any hatchways

3 Hose Test may also be considered as a medium of the test. See 3-7-1/3.3.2.

4 Including tanks arranged in accordance with the provisions of SOLAS regulation II-1/9.4

5 Including duct keels and dry compartments arranged in accordance with the provisions of SOLAS regulation II-1/11.2 and II-1/9.4 respectively, and/or oil fuel tank protection and pump room bottom protection arranged in accordance with the provisions of MARPOL Annex I, Chapter 3, Part A regulation 12A and Chapter 4, Part A, regulation 22, respectively.

6 Where water tightness of a watertight door has not confirmed by prototype test, testing by filling watertight spaces with water is to be carried out. See SOLAS regulation II-1/16.2 and MSC/Circ.1176.

7 As an alternative to the hose testing, other testing methods listed in 3-7-1/3.5.4(g) through 3-7-1/3.5.4(i) may be applicable subject to adequacy of such testing methods being verified. See SOLAS regulation II-1/11.1. For watertight bulkheads (item 11.1) alternatives to the hose testing may only be used where a hose test is not practicable.

8 A “Leak and structural test”, see 3-7-1/3.5.2(b), is to be carried out for a representative cargo hold if intended for in-port ballasting. The filling level requirement for testing cargo holds intended for in-port ballasting is to be the maximum loading that will occur in-port as indicated in the loading manual.

9 Where L.O. sump tanks and other similar spaces under main engines intended to hold liquid form part of the watertight subdivision of the ship, they are to be tested as per the requirements of Item 5, Deep tanks other than those listed elsewhere in this table.

TABLE 2
Additional Testing Requirements for Vessels or Tanks of Special Service *(2018)*

	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	Leak & Structural	The greater of - the top of overflow, or - to 2.4 m (8 ft.) above top of tank (2)	See 5C-8-4/20 for testing requirements applicable to integral cargo tanks, independent cargo tanks and hull structure supporting membrane or semi-membrane cargo tanks.
2	Edible Liquid Tanks	Independent Tanks	Leak & Structural(1)	The greater of - the top of overflow, or - to 0.9 m (3 ft.) above top of tank (2)	
3	Chemical Carriers	Integral or Independent Tanks	Leak & Structural(1)	The greater of - to 2.4 m (8 ft.) above top of tank (2), or - to top of tank (2) plus setting of any pressure relief valve	Where a cargo tank is designed for the carriage of cargoes with specific gravities larger than 1.0, an appropriate additional head is to be considered.

Notes:

1 See 3-7-1/3.5.2(b).

2 Top of tank is the deck forming the top of the tank, excluding any hatchways.

TABLE 3
Application of Leak Testing, Coating and Provision of Safe Access for Type of Welded Joints

<table>
<tr><th colspan="2" rowspan="2">Type of Welded Joints</th><th rowspan="2">Leak Testing</th><th colspan="2">Coating (1)</th><th colspan="2">Safe Access (2)</th></tr>
<tr><th>Before Leak Testing</th><th>After Leak Testing & Before Structural Test</th><th>Leak Test</th><th>Structural Test</th></tr>
<tr><td rowspan="2">Butt</td><td>Automatic</td><td>Not required</td><td>Allowed (3)</td><td>N/A</td><td>Not required</td><td>Not required</td></tr>
<tr><td>Manual or Semi-automatic (4)</td><td>Required</td><td>Not allowed</td><td>Allowed</td><td>Required</td><td>Not required</td></tr>
<tr><td>Fillet</td><td>Boundary including penetrations</td><td>Required</td><td>Not allowed</td><td>Allowed</td><td>Required</td><td>Not required</td></tr>
</table>

Notes:

1. Coating refers to internal (tank/hold coating), where applied, and external (shell/deck) painting. It does not refer to shop primer.
2. Temporary means of access for verification of the leak testing.
3. The condition applies provided that the welds have been carefully inspected visually to the satisfaction of the Surveyor.
4. Flux Core Arc Welding (FCAW) semiautomatic butt welds need not be tested provided that careful visual inspections show continuous uniform weld profile shape, free from repairs, and the results of the Rule and Surveyor required NDE testing show no significant defects.

5 Testing Requirments for Ships Not Built in Compliance with SOLAS 1974 as Amended

5.1

Testing procedures are to be carried out in accordance with the requirements of 3-7-1/3 in association with the following alternative procedures for 3-7-1/3.5.4(b) "Testing Schedule for New Construction or Major Structural Conversion" and alternative test requirements for 3-7-1/3.5.7 TABLE 1.

5.3

The tank boundaries are to be tested from at least one side. The tanks for structural test are to be selected so that all representative structural members are tested for the expected tension and compression.

5.5

Structural tests are to be carried out for at least one tank of a group of tanks having structural similarity (i.e., same design conditions, alike structural configurations with only minor localized differences determined to be acceptable by the attending Surveyor) on each vessel provided all other tanks are tested for leaks by an air test. The acceptance of leak testing using an air test instead of a structural test does not apply to cargo space boundaries adjacent to other compartments in tankers and combination carriers or to the boundaries of tanks for segregated cargoes or pollutant cargoes in other types of ships.

5.7

Additional tanks may require structural testing if found necessary after the structural testing of the first tank.

5.9

Where the structural adequacy of the tanks of a vessel were verified by the structural testing required in 3-7-1/3.5.7 TABLE 1, subsequent vessels in the series (i.e. sister ships built from the same plans at the same shipyard) may be exempted from structural testing of tanks, provided that:

i) Water-tightness of boundaries of all tanks is verified by leak tests and thorough inspections are carried out

ii) Structural testing is carried out for at least one tank of each type among all tanks of each sister vessel

iii) Additional tanks may require structural testing if found necessary after the structural testing of the first tank or if deemed necessary by the attending Surveyor

For cargo space boundaries adjacent to other compartments in tankers and combination carriers or boundaries of tanks for segregated cargoes or pollutant cargoes in other types of ships, the provisions of paragraph 3-7-1/5.3 shall apply in lieu of paragraph 3-7-1/5.5.

5.11

Sister ships built (i.e., keel laid) two years or more after the delivery of the last ship of the series, may be tested in accordance with 3-7-1/5.5 at the discretion of the Surveyor, provided that:

i) General workmanship has been maintained (i.e., there has been no discontinuity of shipbuilding or significant changes in the construction methodology or technology at the yard and shipyard personnel are appropriately qualified and demonstrate an adequate level of workmanship as determined by the Surveyor).

ii) An NDT plan is implemented and evaluated by the Surveyor for the tanks not subject to structural tests. Shipbuilding quality standards for the hull structure during new construction are to be reviewed and agreed during the kick-off meeting. Structural fabrication is to be carried out in accordance with IACS Recommendation 47, “Shipbuilding and Repair Quality Standard”, or a recognized fabrication standard to the satisfaction of the attending Surveyor prior to the commencement of fabrication/construction. The work is to be carried out in accordance with the Rules and under survey of the Surveyor.

PART 3

CHAPTER 7

Testing, Trials and Surveys During Construction - Hull

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, as specified in 4-5-1/5.1.4, is to be measured and verified, with each anchor and at least 82.5 m (44.5 fathoms) 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.

3 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.

5 Steering Trials

Refer to 4-3-4/21.7, 4-3-4/23.3, and 4-3-4/25.7 as applicable, for technical details of the steering trials.

PART 3

CHAPTER 7
Testing, Trials and Surveys During Construction - Hull

SECTION 3
Surveys

1 Construction, Welding and Fabrication

For surveys of hull construction, refer to the ABS *Guide for Hull Survey for New Construction*.

For surveys of hull construction welding and fabrication, refer to Chapter 4 of the ABS *Rules for Materials and Welding (Part 2)* and the ABS *Guide for Nondestructive Inspection*.

3 Hull Castings and Forgings

For surveys in connection with the manufacture and testing of hull castings and forgings, refer to Chapter 1 of the ABS *Rules for Materials and Welding (Part 2)*.

5 Hull Piping

For surveys in connection with the manufacture and testing of hull piping, refer to Section 4-6-1.