RULES FOR BUILDING AND CLASSING

STEEL VESSELS UNDER 90 METERS (295 FEET) IN LENGTH
2019

PART 3
HULL CONSTRUCTION AND EQUIPMENT

(Updated July 2019)

American Bureau of Shipping
Incorporated by Act of Legislature of
the State of New York 1862

© 2019 American Bureau of Shipping. All rights reserved.
1701 City Plaza Drive
Spring, TX 77389 USA

PART

3

Hull Construction and Equipment

CONTENTS

CHAPTER 1 General 1

Section 1 Definitions 3
Section 2 General Requirements 6

CHAPTER 2 Hull Structures and Arrangements 16

Section 1 Longitudinal Strength 32
Section 2 Shell Plating 44
Section 3 Deck Plating 49
Section 4 Bottom Structure 54
Section 5 Side Frames, Webs and Stringers 66
Section 6 Beams, Deck Girders, Deck Transverses and Pillars 72
Section 7 Watertight Bulkheads and Doors 85
Section 8 Deep Tanks 93
Section 9 Superstructures and Deckhouses 97
Section 10 Keels, Stems, Stern Frames, Shaft Struts, and Propeller Nozzles 106
Section 11 Rudders 116
Section 12 Protection of Deck Openings 164
Section 13 Protection of Shell Openings 212
Section 14 Bulwarks, Rails, Freeing Ports, Portlights, Windows, Ventilators, Tank Vents and Overflows 226
Section 15 Ceiling, Sparring and Protection of Steel 238
Section 16 Weld Design 240
Section 17 Machinery Space and Tunnel 249
Section 18 Guidance on Finite Element Analysis 252

Appendix 1 Loading Manuals and Loading Instruments 40
Appendix 2 Guidelines for Calculating Bending Moment and Shear Force in Rudders and Rudder Stocks 154
Appendix 3 Portable Beams and Hatch Cover Stiffeners of Variable Cross Section 210

CHAPTER 3 Subdivision and Stability 257

Section 1 General Requirements 259

Appendix 1 Intact Stability of Tankers During Liquid Transfer Operations 262
Appendix 2 Onboard Computers for Stability Calculations 265

CHAPTER 4 Fire Safety Measures 275
Section 1 Structural Fire Protection 276

Appendix 1 Fiber Reinforced Plastic (FRP) Gratings 278

CHAPTER 5 Equipment 281
Section 1 Anchoring, Mooring and Towing Equipment 283

CHAPTER 6 Navigation 304
Section 1 Visibility 305

CHAPTER 7 Testing, Trials and Surveys During Construction – Hull 310
Section 1 Tank, Bulkhead and Rudder Tightness Testing 311
Section 2 Trials 320
Section 3 Surveys 321

This Page Intentionally Left Blank

PART

3

CHAPTER 1 General

CONTENTS

SECTION 1 Definitions 3

1 Application 3
3 Length 3
3.1 Scantling Length (L) 3
3.3 Freeboard Length (L_f) 3
5 Breadth (B) 3
7 Depth 4
7.1 Molded Depth (D) 4
7.3 Scantling Depth (D_s) 4
9 Draft for Scantlings (d) 4
11 Molded Displacement and Block Coefficient 4
11.1 Molded Displacement (Δ) 4
11.3 Block Coefficient (C_b) 4
13 Decks 4
13.1 Freeboard Deck 4
13.3 Bulkhead Deck 4
13.5 Strength Deck 5
13.7 Superstructure Deck 5
13.9 Deckhouses 5
15 Deadweight and Lightship Weight 5
17 Gross Tonnage 5
17.1 International Tonnage 5
17.3 National Tonnage 5
19 Units 5

FIGURE 1 3

SECTION 2 General Requirements 6

1 Materials 6
1.1 General 6
1.3 Selection of Material Grade 6
1.5 Note for the Users 6
1.7 Ships Exposed to Low Air Temperatures 8
1.9 Design Temperature t_D 9
1.11 Cold Cargo for Ships Other Than Liquefied Gas Carriers 10
3 Workmanship 10
5 Design 11

5.1 Continuity....11
5.3 Openings....11
5.5 Brackets....11
7 Structural Sections....12
7.1 Deep Supporting Members....12
7.3 Frames, Beams and Stiffeners....12
7.5 Hold Frames of Single Side Skin Bulk Carriers....13
9 Structural Design Details....13
9.1 General....13
9.3 Termination of Structural Members....13
9.5 Fabrication....14

TABLE 1 Material Grades....7
TABLE 2 Material Class of Structural Members....7
TABLE 3 Application of Material Classes and Grades – Structures Exposed at Low Temperatures....8
TABLE 4 Material Grade Requirements for Classes I, II and III at Low Temperatures....9
TABLE 5 Brackets....11
TABLE 6 Hull Components and Equipment List for Steel Vessels Under 90 Meters....15

FIGURE 1 Commonly Used Definitions of Temperatures....10
FIGURE 2 Bracket....12

PART
3

CHAPTER **1 General**

SECTION **1 Definitions**

1 Application

The following definitions apply throughout these Rules.

3 Length

3.1 Scantling Length (L) *(2018)*

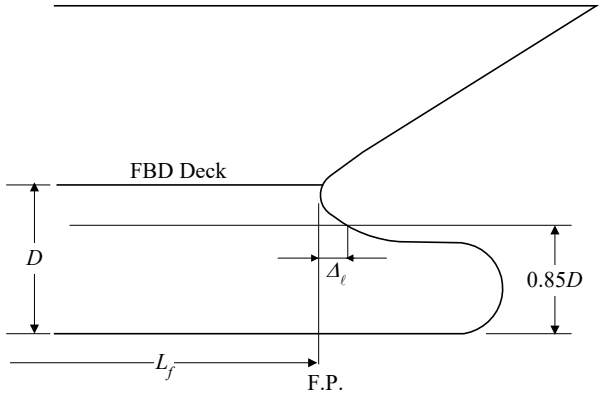
L is the distance in meters (feet) on the summer load line from the fore side of the stem to the centerline of the rudder stock. For use with the Rules, L is not to be less than 96% and need not be greater than 97% of the extreme length on the summer load line. The forward end of L is to coincide with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

3.3 Freeboard Length (L_f) *(2018)*

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 aftmost point of the stem is above the waterline, the forward end of the length, L_f, is to be taken at the aftmost point of the stem above that waterline. See 3-1-1/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)

D is the molded depth at side in meters (feet) measured at the middle of L from the molded base line to the top of the freeboard-deck beams. 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)

The depth, D_s, for use with scantling requirements is measured to the strength deck, as defined in 3-1-1/13.5.

9 Draft for Scantlings (d)

d is the draft in meters (feet) measured at the middle of the length, L, from the molded keel or the rabbet line at its lowest point to the estimated summer load waterline, the design load waterline or $0.66D$, whichever is greater.

11 Molded Displacement and Block Coefficient

11.1 Molded Displacement (Δ)

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

11.3 Block Coefficient (C_b)

C_b is the block coefficient obtained from the following equation:

$$C_b = \Delta/1.025LB_{wl}d \qquad \text{(SI \& MKS units)}$$

$$C_b = 35\Delta/LB_{wl}d \qquad \text{(US units)}$$

where

Δ = molded displacement, as defined in 3-1-1/11.1

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

d = draft, as defined in 3-1-1/9

B_{wl} = the greatest molded breadth at summer load line

13 Decks

13.1 Freeboard Deck *(2018)*

The freeboard deck is normally the uppermost complete deck exposed to weather and sea, which has permanent means of closing all openings in the weather part thereof, and below which all openings in the vessel's side are equipped with permanent means for watertight closure. In cases 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 the Rules may be taken as the lowest actual deck from which the draft can be obtained under those regulations.

13.3 Bulkhead Deck

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

13.5 Strength Deck

The strength deck is the deck which forms the top of the effective hull girder at any part of its length. See Section 3-2-1.

13.7 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 the Rules, refers to the first such deck above the freeboard deck.

13.9 Deckhouses

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.

15 Deadweight and Lightship Weight *(2018)*

For the purpose of these Rules, the deadweight, *DWT*, is the difference in metric tons (long tons) between the displacement of the vessel in water having a specific gravity of 1.025 at the summer load line and the lightship weight. For the purpose of these Rules, lightship weight is the displacement of a vessel in metric tons (long tons) without cargo, fuel, lubricating oil, ballast water, fresh water and feed water in tanks, consumable stores, and passengers and crews and 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.

17 Gross Tonnage

17.1 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".

17.3 National Tonnage

As an alternative to 3-1-1/17.1 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)*).

19 Units

These Rules are written in three systems of units, i.e., 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 the 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 Materials

1.1 General

These Rules are intended for vessels of welded construction using steels complying with the requirements in Chapter 1 of the ABS *Rules for Materials and Welding (Part 2)*.

1.1.1 Steel

Use of steels other than Grade A and AH in Chapter 1 of the ABS *Rules for Materials and Welding (Part 2)* and plate over 20 mm (0.79 in.) in important locations will be specially considered.

1.1.2 Aluminum Alloys

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

1.1.3 Design Consideration

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

1.1.4 Guidance for Repair

Where special welding procedures are required for the special steels used in the construction, including any low temperature steel and those materials not in Chapter 1 of the ABS *Rules for Materials and Welding (Part 2)*, a set of plans showing the following information for each steel should be placed aboard the vessel:

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

These plans are in addition to those normally placed aboard which are to show all material applications.

1.3 Selection of Material Grade *(2019)*

For vessels 61 m (200 ft) and over in length, steel materials for particular locations are not to be lower grades than those required by 3-1-2/Table 1 for the material class given in 3-1-2/Table 2.

For vessels under 61 m (200 ft) in length, material is to be per 3-1-2/1.1.1. 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 15 mm (0.6 in.) for sections."

1.5 Note for the Users

The attention of users is drawn to the fact that when fatigue loading is present, the effective strength of higher-strength steel in a welded construction may not be greater than that of ordinary-strength steel. Precautions against corrosion fatigue may also be necessary.

TABLE 1
Material Grades *(2017)*

Plate Thickness t mm (in.)	*Material Class*	
	I	*II*
$t \le 15$ ($t \le 0.60$)	A[1], AH	A, AH
$15 < t \le 20$ ($0.60 < t \le 0.79$)	A, AH	A, AH
$20 < t \le 25$ ($0.79 < t \le 0.98$)	A, AH	B, AH
$25 < t \le 30$ ($0.98 < t \le 1.18$)	A, AH	D, DH
$30 < t \le 35$ ($1.18 < t \le 1.38$)	B, AH	D, DH
$35 < t \le 40$ ($1.38 < t \le 1.57$)	B, AH	D, DH
$40 < t \le 100$ ($1.57 < t \le 4.0$)	D, DH	E, EH

Note:

1 *(2017)* 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 15 mm (0.6 in.) for sections.

TABLE 2
Material Class of Structural Members *(2017)*

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
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
(1 July 2015) 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.

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

4 *(2017)* 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.

5 *(1 July 2015)* Steering equipment components other than rudders, as described in Section 3-2-11.

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

For ships intended to operate in areas with low air temperatures [below –10°C (14°F)], the materials in exposed structures are to be selected based on the design temperature t_D, to be taken as defined in 3-1-2/1.9.

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 3-1-2/Table 3) and materials of cargo tank boundary plating for which 3-1-2/1.11 is applicable are not to be of lower grades than those corresponding to Classes I, II and III, as given in 3-1-2/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/Table 3) and structures below the lowest ballast water line, 3-1-2/1.3 applies.

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 meters (820 feet).

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

4 Not to be less than Grade D/DH.

5 *(2017)* 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 3-1-2/1.11.

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

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

Class I

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

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

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	-, -	-, -

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

Plating materials for sternframes, rudder horns, rudders and shaft brackets are not to be of lower grades than those corresponding to the material classes given in 3-1-2/1.3.

1.9 Design Temperature t_D *(2017)*

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
- *Average:* Average during one day and night
- *Lowest:* Lowest during year

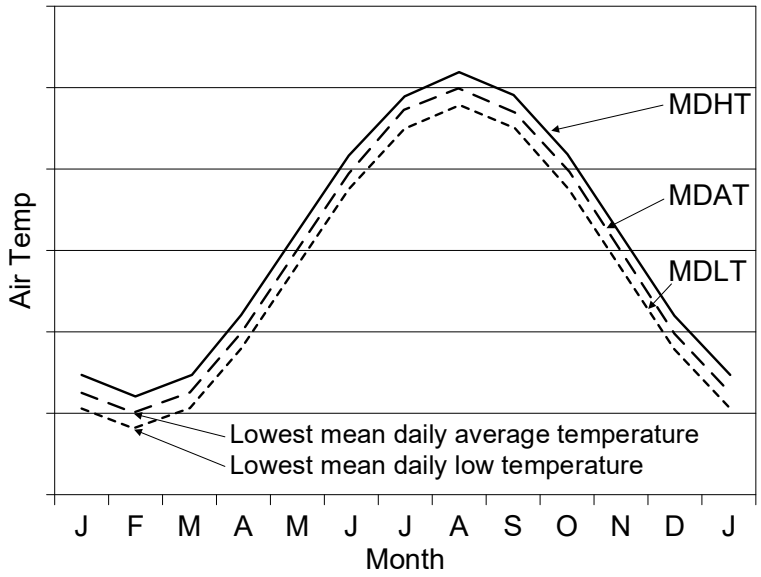
For seasonally restricted service the lowest value within the period of operation applies.

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/Figure 1 illustrates the temperature definition.

FIGURE 1
Commonly Used Definitions of Temperatures *(2017)*



MDHT = Mean Daily High (or maximum) Temperature

MDAT = Mean Daily Average Temperature

MDLT = Mean Daily Low (or minimum) Temperature

1.11 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 (14°F) (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/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/Table 3

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

3 Workmanship

All workmanship is to be of commercial marine quality and acceptable to the Surveyor. Welding is to be in accordance with the requirements of Chapter 4 of the *Rules for Materials and Welding (Part 2)* and Section 3-2-16 of these Rules. Plates which have been subjected to excessive furnacing are to undergo a satisfactory heat treatment before being worked into a hull.

5 Design

5.1 Continuity

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.

5.3 Openings

In general, major openings such as doors, 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.

5.5 Brackets

Where brackets are fitted having thicknesses as required by 3-1-2/Table 5 and faces at approximately 45 degrees with the bulkhead deck or shell and the bracket is supported by a bulkhead, deck or shell and the bracket is supported by a bulkhead, deck or shell structural member, the length of each member, ℓ, may be measured at a point 25% of the extent of the bracket beyond the toe of the bracket, as shown in 3-1-2/Figure 2, when a reduction of the span is so permitted in each section. 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 $\qquad\qquad$ $x = 1.4y + 1.2$ 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 amount of overlap generally is to be 25.5 mm (1 in.).

TABLE 5
Brackets

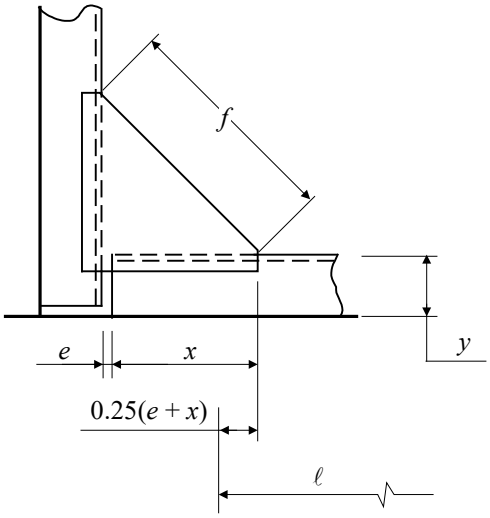
Metric

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
Over 26 to 36	3/8	5/16	2 1/2
Over 36 to 54	7/16	3/8	3

FIGURE 2
Bracket



7 Structural Sections

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

7.1 Deep Supporting Members

The required section modulus of members, such as girders, webs, etc., supporting frames, beams and stiffeners, is to be obtained on an effective width of plating basis, in accordance with this subsection. The section is to include the structural member in association with an effective width of plating not exceeding one-half the sum of spacing on each side of the member or 33% of the unsupported span ℓ, whichever is less. For girders and webs along hatch openings, an effective breadth of plating not exceeding one-half the spacing or 16.5% of the unsupported span, ℓ, whichever is less, is to be used. The section modulus of a shape, bar or fabricated section not attached to plating is that of the member only.

7.3 Frames, Beams and Stiffeners

7.3.1 Section Modulus

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

7.3.2 Web Thickness

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

Members with flange $50C_1C_2$

Members without flange $15C_1C_2$

C_1 = 0.95 (horizontal web within tank)

= 1.0 (all other cases)

C_2 = 1.0 (ordinary strength steel)

= 0.92 (HT32)

= 0.90 (HT36)

7.5 Hold Frames of Single Side Skin Bulk Carriers *(1998)*

The 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), in addition to the requirements of Section 3-2-5, are to comply insofar as is practical with the requirements for hold frames given in the following sections of the Rules.

- 5C-4-2/11.1, "Strength of Frame and Supporting Structure," of the ABS *Rules for Building and Classing Steel Vessels (Steel Vessel Rules)*
- 3-2-16/Table 1, "Welding Requirements," of these Rules

9 Structural Design Details

9.1 General

The designer is to give consideration to the following:

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

ii) The proportions of built-up members to comply with established standards for buckling strength.

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

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

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

Standard construction details based on the above considerations are to be indicated on the plans or in a booklet submitted for review and comment.

9.3 Termination of Structural Members *(1998)*

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

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

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

Bracket toes and sniped end members are to be kept within 25 mm (1.0 in.) of the adjacent member, unless the bracket or member is supported by another member on the opposite side of the plating. The depth of toe or sniped end is generally not to exceed 15 mm (0.60 in.).

Where a strength deck or shell longitudinal terminates without 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 3-2-5/1.3, beyond the last floor or web that supports the longitudinal.

The end attachments of non-load bearing members may, in general, be snipe ended. The snipe end is to be not more than 30° and is to be kept generally within 40 mm (1.57 in.) of the adjacent member unless it is supported by a member on the opposite side of the plating. The depth of the toe is generally not to exceed 15 mm (0.6 in.).

9.5 Fabrication *(1 July 2011)*

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

TABLE 6
Hull Components and Equipment List for Steel Vessels Under 90 Meters *(2012)*

This components and equipment list has been annotated to agree with ABS *Rules for Building and Classing Steel Vessels Under 90 meters (295 feet) in Length*. This list is not to be considered exhaustive: should additional equipment not listed to be fitted on board, the same will be specially considered for compliance with the Rules. In case of conflict between the content of this list and the applicable Rules and regulations, the latter are to be considered applicable.

Notes:

1 Please refer to the specific Rule requirement for the applicable latest revision.

2 ABS Surveyor may require additional certification on any equipment as considered necessary on a case-by-case basis.

Symbol	*Meaning*
d	DESIGN REVIEW – (Design Review Required)
m	MATERIAL TESTING – (Material Testing is to be witnessed by an ABS Surveyor)
s	MANUFACTURING SURVEYS – (Product is to be inspected during fabrication by an ABS Surveyor)
t	TYPE/PROTOTYPE – (Testing conducted on an actual sample or a prototype model is required, as applicable)
obs	ON BOARD SURVEYS – Operational, hydrostatic non-destructive testing, or other required tests are to be witnessed by an ABS surveyor after installation on board vessel
g	MANUFACTURER'S DOCUMENTATION – (Manufacturer should supply documentation to guarantee that the material or the equipment complies with an acceptable Standard, (e.g., Standard tests reports, Ex Certification, etc.)

No.	*Equipment*	*d*	*m*	*s*	*t*	*obs*	*g*	*Remarks*
1	Hull Steels of Grade A, B, D and E, F		X					
2	Higher Strength Hull Steel AH/DH/EH 32, 36 & 40		X					
3	Aluminum Hull Materials		X					
4	Hull Steel Castings and Forgings	X	X	X				
5	Stern Frame Castings	X	X	X				
6	Neck and Pintle Bush Bearing	X					X	
7	Rudder Stock	X	X	X				
8	Rudder Pintles	X	X	X				
9	Rudder Coupling Bolts and Keys	X				X	X	
10	Upper and Lower Rudder Casting		X	X	X			
11	Rudder Carrier Casting		X	X	X			
12	Rudder Carrier Bearing		X	X	X			
13	Fixed Propeller Nozzles with Inner Diameter of 5 meters (16.4 feet) or Less			X		X		
14	Fixed Propeller Nozzles With Inner Diameter Greater than 5 meters (16.4 feet)	X		X		X		
15	Anchor Windlass	X				X	X	
16	Anchor – Ⓔ		X	X	X			
17	Anchor Chain – Ⓔ		X	X	X			
18	Anchor and Anchor Chain – EN Less than 205 or Tow						X	
19	Bollard, Fairlead and Chocks	X					X	
20	Structural Fire Protection (If Applicable)	X			X	X	X	
21	Onboard Computer for Stability (If Applicable)	X			X	X	X	
22	Loading Manual	X						
23	Portlights and Windows	X		X	X	X	X	Confirm the recognized standards
24	Watertight Doors	X		X		X		

PART
3

CHAPTER **2 Hull Structures and Arrangements**

CONTENTS

SECTION 1 Longitudinal Strength 32

1 General 32

3 Longitudinal Hull Girder Strength 32

3.1 Minimum Section Modulus 32

3.3 Vessels 61 m (200 ft) in Length and Over 33

3.5 Hull Girder Moment of Inertia 36

5 Decks 37

5.1 Strength Decks 37

5.3 Effective Lower Decks 37

7 Longitudinal Strength with Higher-Strength Materials 37

7.1 General 37

7.3 Hull Girder Moment of Inertia 37

7.5 Hull Girder Section Modulus 37

9 Loading Guidance 38

9.1 Loading Manual and Loading Instrument 38

9.3 Allowable Stresses 38

11 Section Modulus Calculation 38

11.1 Items Included in the Calculation 38

11.3 Effective Areas Included in the Calculation 38

11.5 Section Modulus to the Deck or Bottom 39

11.7 Section Modulus to the Top of Hatch Coamings 39

13 Continuous Longitudinal Hatch Coamings and Above-Deck Girders 39

FIGURE 1 Sign Convention 33

FIGURE 2 Distribution Factor M 34

FIGURE 3 Distribution Factor F_1 35

FIGURE 4 Distribution Factor F_2 35

SECTION 2 Shell Plating 44

1 General 44

3 Bottom Shell Plating 44

3.1 Extent of Bottom Plating 44

3.3 Bottom Shell Plating 44

3.5 Bottom Forward 45

5 Side Shell Plating 45

5.1 General 45

5.3 Side Shell for Vessels Subject to Impact Loadings 46

5.5 Side Shell Plating at Ends 46
5.7 Forecastle and Poop Side Plating 46
7 Bow and Stern Thruster Tunnels 46
9 Local Strengthening for Research Vessels 47
11 Compensation 47
13 Breaks 47
15 Bilge Keels 47
16 Bilge Plating 47
17 Higher-strength Materials 48
17.1 General 48
17.3 Bottom Plating of Higher-strength Material 48
17.5 Side Plating of Higher-strength Material 48
17.7 End Plating 48

SECTION 3 Deck Plating 49
1 General 49
3 Deck Plating 49
3.1 All Decks 49
3.3 Strength Decks within the Midship 0.8L 50
3.5 All Strength Deck Plating Outside the Line of Openings and Other Effective Deck Plating 50
5 Compensation 50
7 Wheel Loading 51
9 Higher-strength Material 52
9.1 Thickness 52
9.3 Wheel Loading 52

FIGURE 1 Wheel Loading Curves of K 52

SECTION 4 Bottom Structure 54
1 Double Bottoms 54
1.1 General 54
1.3 Center Girder 54
1.5 Side Girders 55
1.7 Floors 55
1.9 Frames 55
1.11 Struts 56
1.13 Inner-bottom Plating 56
1.15 Sea Chests 57
1.17 Access, Lightening, Air, and Drainage Holes 57
3 Single Bottoms with Floors and Keelsons 57
3.1 General 57
3.3 Center Keelsons 57
3.5 Side Keelsons 58
3.7 Floors 58

5 Single Bottoms with Longitudinal or Transverse Frames 60
5.1 General 60
5.3 Bottom Girders and Transverses 61
5.5 Center Girder 62
5.7 Frames 62
7 Fore-end Strengthening 63
7.1 General 63
7.3 Extent of Strengthening 63
7.5 Longitudinal Framing 63
7.7 Transverse Framing 64
9 Higher-strength Materials 64
9.1 General 64
9.3 Inner-bottom Plating 64
9.5 Bottom and Inner-bottom Longitudinals 65
9.7 Center Girders, Side Girders and Floors 65
11 Machinery Space 65
11.1 General 65
11.3 Engine Foundations 65
11.5 Thrust Foundations 65
11.7 Shaft Stools and Auxiliary Foundations 65

TABLE 1 Location of Flat of Bottom Forward 63
TABLE 2 Spacing of Floors 64

FIGURE 1 Plate Floors 59
FIGURE 2 Round Bottom Floors with Deadrise 60
FIGURE 3 Transverse Bottom Frames with Longitudinal Side Girders 60
FIGURE 4 Longitudinal Frames with Transverse Webs 61

SECTION 5 Side Frames, Webs, and Stringers 66
1 General 66
1.1 Basic Considerations 66
1.3 End Connections 66
3 Longitudinal Side Frames 66
3.1 Section Modulus 66
5 Transverse Side Frames 67
5.1 Section Modulus 67
5.3 Tween-deck Frames 69
5.5 Peak Frames 69
7 Side Web Frames 70
7.1 Section Modulus 70
7.3 Tween-deck Web Frames 70
7.5 Proportions 70
7.7 Tripping Brackets and Stiffeners 70
9 Vessel Side Frames Subject to Impact Loads 71

11 Side Stringers 71
11.1 Section Modulus 71
11.3 Proportions 71
11.5 Tripping Brackets and Stiffeners 71

FIGURE 1 Transverse Side Frame 68
FIGURE 2 Transverse Side Frame 68
FIGURE 3 Hold and Tween Deck Frames 68

SECTION 6 Beams, Deck Girders, Deck Transverses, and Pillars 72
1 Beams 72
1.1 Spacing 72
1.3 Section Modulus 72
1.5 Special Heavy Beams 73
1.6 Deck Fittings Support Structures 74
1.7 Container Loading 78
3 Deck Girders and Deck Transverses 79
3.1 General 79
3.3 Deck Girders and Transverses Clear of Tanks 79
3.5 Proportions 79
3.7 Tripping Brackets and Stiffeners 79
3.9 Deck Girders and Transverses in Tanks 80
3.11 Hatch Side Girders 80
3.13 Container Loading 80
3.15 End Attachments 80
3.17 Hatch-end Beams 80
5 Stanchions and Pillars 82
5.1 General 82
5.3 Permissible Load 82
5.5 Calculated Load 82
5.6 Additional Pillars 83
5.7 Stanchions in Double Bottoms and Under Tank Tops 83
5.9 Bulkheads 83
5.11 Attachments 83
7 Higher-strength Materials 83
7.1 General 83
7.3 Beams, Girders and Transverses of Higher-strength Materials 84

TABLE 1 Values of f 79

FIGURE 1 Application of Design Loads 75
FIGURE 2 Sample Arrangement 76
FIGURE 3 Attachment Point of Mooring Line 77
FIGURE 4 Attachment Point of Towing Line 77
FIGURE 5 Hatch-end Beams 81

SECTION 7 Watertight Bulkheads and Doors....85
1 General....85
1.1 Openings and Penetrations....85
3 Arrangement of Watertight Bulkheads....85
3.1 Collision Bulkheads....85
3.3 Engine Room....86
3.5 Chain Lockers....86
3.7 Hold Bulkheads....87
5 Construction of Watertight Bulkheads....87
5.1 Plating....87
5.3 Stiffeners....88
5.5 Girders and Webs....89
5.7 Corrugated Bulkheads....90
7 Watertight Doors....91
7.1 Vessels Requiring Subdivision and Damage Stability....91
7.3 Other Vessels....92
7.5 Construction....92
9 Testing....92

FIGURE 1 Reference Point of Vessels with Bulbous Bow....86
FIGURE 1A....87
FIGURE 1B....87
FIGURE 2 Corrugated Bulkhead....90
FIGURE 3 Corrugated Bulkhead End Connections....91

SECTION 8 Deep Tanks....93
1 General Arrangement....93
3 Construction....93
5 Construction of Deep-tank Bulkheads....93
5.1 Plating....93
5.3 Stiffeners....94
5.5 Corrugated Bulkheads....95
5.7 Girders and Webs....95
5.11 Anti-rolling Tank Bulkheads....95
7 Tank Top Plating....96
9 Higher-strength Materials....96
9.1 General....96
9.3 Plating....96
9.5 Stiffeners....96
11 Drainage and Air Escape....96
13 Testing....96

SECTION 9 Superstructures and Deckhouses....97
1 Superstructure Scantlings....97
1.1 Side and Top Plating....97
1.3 Framing and Internal Bulkheads....97

1.5 Breaks in Continuity 97
1.7 Structural Support 97
3 Exposed Bulkheads of Superstructures and Deckhouses 97
3.1 General 97
3.3 Stiffeners 98
3.5 Plating 99
3.7 End Attachments 100
3.9 Raised-quarter-deck Bulkheads 100
5 Enclosed Superstructures 100
5.1 Closing Appliances 100
5.3 Sills of Access Openings 100
5.5 Means of Access 100
7 Open Superstructures 101
9 Deckhouses 101
10 Aluminum Deckhouses 101
10.1 Scantling Correction 101
10.3 Material Factors 102
10.5 Attachments 102
11 Helicopter Decks 103
11.1 General 103
11.3 Structure 103
11.5 Safety Net 104
11.7 Aluminum Decks 104
11.9 Means of Escape and Access 104

TABLE 1 Values of a 99
TABLE 2 Values of f 99
TABLE 3 Allowable Factors of Safety Based on Y for Helicopter Decks 105

SECTION 10 Keels, Stems, Stern Frames, Shaft Struts, and Propeller Nozzles 106
1 Keels 106
1.1 Bar Keels 106
1.3 Plate Keels 106
3 Stems 106
3.1 Bar Stems 106
3.3 Cast or Forged Stems 107
3.5 Plate Stems 107
5 Sternposts 107
5.1 Bar Sternposts 107
5.3 Cast, Forged, or Fabricated Sternposts 107
7 Stern Frames 107
7.1 Below the Boss 107
7.3 Above the Boss 108
7.5 Secondary Members 108
9 Stern Frames with Shoepieces 109

11 Shoepieces 109
11.1 General 109
11.3 Design Stress 109
11.5 Minimum Scantlings 110
13 Rudder Horns 110
15 Rudder Gudgeons 111
17 Shaft Struts 111
17.1 General 111
17.3 V Strut 111
17.5 I Strut 111
17.7 Strut Length 112
19 Propeller Nozzles 112
19.1 Application 112
19.3 Design Pressure 112
19.5 Nozzle Cylinder 113
19.7 Nozzle Section Modulus 113
19.9 Welding Requirement 115
21 Propulsion Improvement Devices (PID) as Hull Appendages 115
21.1 Application Scope 115
21.3 Plans and Documentation 115
21.5 Design and Arrangement 115
21.7 Structural End Connection 115
23 Inspection of Castings 115

TABLE 1 Coefficient c 112
TABLE 2 Coefficient ε 112
TABLE 3 Coefficient c_n 113
TABLE 4 Corrosion Allowance t_c 113

FIGURE 1 Stern Frame 109
FIGURE 2 Shoepiece 110
FIGURE 3 Propeller Nozzle Section View 114

SECTION 11 Rudders and Steering Equipment 116
1 General 116
1.1 Application 116
1.3 Materials for Rudder, Rudder Stock and Steering Equipment 116
1.5 Expected Torque 117
1.7 Rudder Stops 117
3 Rudder Design Force 117
3.1 Rudder Blades without Cutouts 117
3.3 Rudder Blades with Cutouts 118
3.5 Rudders Blades with Twisted Leading-Edge 118
5 Rudder Design Torque 121
5.1 General 121
5.3 Rudder Blades without Cutouts 121

5.5 Rudders Blades with Cutouts 122
5.7 Rudders with Twisted Leading Edge 122
5.9 Trial Conditions 122
7 Rudder Stocks 122
7.1 Upper Rudder Stocks 122
7.3 Lower Rudder Stocks 122
7.4 Rudder Trunk and Rudder Stock Sealing 123
7.5 Bending Moments 125
9 Flange Couplings 126
9.1 General 126
9.3 Horizontal Couplings 126
9.5 Vertical Couplings 127
11 Tapered Stock Couplings 128
11.1 Coupling Taper 128
11.3 Keyed Fitting 129
11.5 Keyless Fitting 130
11.7 Locking Nut 131
13 Pintles 131
13.1 General 131
13.3 Diameter 132
13.4 Push-up Pressure and Push-up Length 132
13.5 Shear and Bearing Forces 133
15 Supporting and Anti-Lifting Arrangements 133
15.1 Bearings 133
15.3 Rudder Carrier 134
15.5 Anti-Lifting Devices 135
17 Double Plate Rudder 135
17.1 Strength 135
17.3 Side, Top and Bottom Plating 139
17.5 Diaphragm Plates 139
17.7 Connections of Rudder Blade Structure with Solid Parts 139
17.9 Welding and Design Details 142
17.11 Watertightness 142
19 Single Plate Rudders 142
19.1 Mainpiece Diameter 142
19.3 Blade Thickness 143
19.5 Arms 143
21 Steering Nozzles 143
21.1 Application Scope 143
21.3 Design Force 144
21.5 Design Torque 145
21.7 Nozzle Stock 145
21.9 Design Pressure 146
21.11 Plate Thickness 147
21.13 Section Modulus 147
21.15 Locking Device 147
21.17 Welding Requirement 147

23 Azimuthal Thruster 147
23.1 Application Scope 147
23.3 Plans and Documents 148
23.5 Locking Device 148
23.7 Design Force 148
23.9 Design Torque 150
23.11 Design Pressure 150
23.13 Nozzle Scantlings 150
23.15 Steering Tube 151
23.17 Section Modulus 151
23.19 Thruster Nozzle Top Connections 151
23.21 Nozzle Strut 151
23.23 Direct Analysis 152
23.25 Welding and Nondestructive Testing 153

TABLE 1A Coefficient k_c for Ordinary Rudders 119
TABLE 1B Coefficient k_c for High-Lift/Performance Rudders 119
TABLE 2 Coefficient k_ℓ 121
TABLE 3 Coefficient α 121
TABLE 4 Minimum Bearing Force $B_{\min}$ 132
TABLE 5 Bearing Reaction Force 135
TABLE 6 Allowable Bearing Surface Pressure 135
TABLE 7 Thickness of Side Plating and Vertical Diaphragm Plates 142
TABLE 8 Coefficient c_m 146

FIGURE 1A Rudder Blade without Cutouts 120
FIGURE 1B Rudder Blade with Cutouts 120
FIGURE 2 Fillet Shoulder Radius 124
FIGURE 3 Welded Joint Between Rudder Stock and Coupling Flange 127
FIGURE 4 Tapered Couplings 128
FIGURE 5 136
FIGURE 6 137
FIGURE 7 137
FIGURE 8 138
FIGURE 9 Cross-section of the Connection Between Rudder Blade Structure and Rudder Stock Housing 141
FIGURE 10 Nozzle Geometry 145
FIGURE 11 An Illustration of Azimuthal Thruster 149

SECTION 12 Protection of Deck Openings 164
1 General 164
3 Additional Requirements for Bulk Carriers, Ore Carriers and Combination Carriers 164

5 Positions and Design Pressures 164
5.1 Positions of Deck Openings 164
5.3 Vertical Weather Design Pressures 164
5.5 Horizontal Weather Design Pressures 166
7 Hatchway Coamings, Companionway Sills and Access Sills 168
7.1 Coaming and Sill Heights 168
7.3 Coaming Plates 168
7.5 Coaming Stiffeners 168
7.7 Continuous Longitudinal Hatch Coamings 169
9 Hatchways Closed by Portable Covers and Secured Weathertight by Tarpaulins and Battening Devices 169
9.1 Pontoon Covers 169
9.3 Wooden Hatch Covers 170
9.5 Steel Hatch Covers 171
9.7 Bearing Surface 171
9.9 Materials Other Than Steel 171
11 Hatchways Closed by Covers of Steel Fitted with Gaskets and Clamping Devices 171
11.1 Strength of Covers 171
11.3 Local Net Plate Thickness 173
11.5 Net Scantlings of Secondary Stiffeners 174
11.7 Net Scantlings of Primary Supporting Members 175
11.9 Cargo Loads 176
11.11 Container Loads 177
11.13 Loads due to Elastic Deformations of the Vessel's Hull 179
11.15 Strength Calculations 179
11.17 Buckling Strength of Hatch Cover Structures 181
11.19 Details of Hatch Covers 194
11.21 Hatch Coaming Strength Criteria 195
11.23 Closing Arrangements 199
11.25 Corrosion Addition and Steel Renewal 202
13 Hatchways Closed by Portable Covers in Lower Decks or within Fully Enclosed Superstructures 203
13.1 General 203
13.3 Portable Beams and Wood Covers 203
13.5 Steel Covers 203
13.7 Wheel Loading 204
14 Small Hatches on the Exposed Fore Deck 204
14.1 Application 204
14.3 Strength 204
14.5 Primary Securing Devices 204
14.7 Requirements for Primary Securing 205
14.9 Secondary Devices 205
15 Hatchways within Open Superstructures 207
17 Hatchways within Deckhouses 207
19 Container Loading 208

21 Machinery Casings 208
21.1 Arrangement....208
21.3 Exposed Casings on Freeboard or Raised Quarter Decks....208
21.5 Exposed Casings on Superstructure Decks 208
21.7 Casings within Open Superstructures....209
21.9 Casings within Enclosed Superstructures, Deckhouses, or below Freeboard Decks....209
23 Miscellaneous Openings in Freeboard and Superstructure Decks 209
23.1 Manholes and Scuttles 209
23.3 Other Openings 209
23.5 Escape Openings 209
23.7 Chain Pipe Opening....209

TABLE 1 Minimum Design Load $p_{H\min}$ 167
TABLE 2 Coaming and Sill Heights....168
TABLE 3 ffective Breadth e_m of Plating of Primary Supporting Members 180
TABLE 4 Correction Factor F_1 182
TABLE 5 Coefficients e_1, e_2, e_3 and Factor B 183
TABLE 6 Buckling and Reduction Factors for Plane Elementary Plate Panels 184
TABLE 7 Moments of Inertia 194
TABLE 8 Permissible Nominal Surface Pressure p_n 201
TABLE 9 Corrosion Additions t_S for Hatch Covers and Hatch Coamings 202
TABLE 10 Scantlings for Small Steel Hatch Covers on the Fore Deck 205

FIGURE 1 Positions 1 and 2....165
FIGURE 2 Positions 1 and 2 for an Increased Freeboard....166
FIGURE 3 Determination of Normal Stress of the Hatch Cover Plating 173
FIGURE 4 Forces due to Container Loads....178
FIGURE 5 Partial Loading of a Container Hatch Cover 179
FIGURE 6 General Arrangement of Panel 181
FIGURE 7 Stiffening Parallel to Web of Primary Supporting Member ...186
FIGURE 8 Stiffening Perpendicular to Web of Primary Supporting Member 187
FIGURE 9 Dimensions of Stiffeners 193
FIGURE 10 Examples for Typical Coaming Stay Configurations....197
FIGURE 11 Example for Arrangement of Coaming Plates 198
FIGURE 12 Lifting Forces at a Hatch Cover 200
FIGURE 13 Arrangement of Stiffeners 206
FIGURE 14 Example of Primary Securing Method 207

SECTION 13 Protection of Shell Openings 212

1 Cargo, Gangway, or Fueling Ports 212
1.1 Construction 212
1.3 Location 212
3 Bow Doors, Inner Doors, Side Shell Doors and Stern Doors 212
3.1 General 212
3.3 Arrangement 213
5 Securing, Locking and Supporting of Doors 213
5.1 Definitions 213
7 Securing and Supporting Devices 213
7.1 Bow Doors 213
7.3 Side Shell and Stern Doors 214
9 Securing and Locking Arrangement 214
9.1 General 214
9.3 Operation 214
9.5 Indication/Monitoring 214
11 Watertightness 216
11.1 Bow Doors 216
11.3 Inner Doors 216
11.5 Side Shell and Stern Doors 216
11.7 Testing at Watertight Door Manufacturer 216
13 Bow Door Scantlings 216
13.1 General 216
13.3 Primary Structure 216
13.5 Secondary Stiffeners 216
13.7 Plating 216
13.9 Securing and Supporting Devices 217
13.11 Visor Door Lifting Arms and Supports 217
15 Inner Door Scantlings 217
15.1 General 217
15.3 Primary Structure 217
15.5 Securing and Supporting Devices 218
17 Side Shell Door and Stern Door Scantlings 218
17.1 General 218
17.3 Primary Structure 218
17.5 Secondary Stiffeners 218
17.7 Plating 218
17.9 Securing and Supporting Devices 218
19 Bow Door Design Loads 219
19.1 External Pressure 219
19.3 External Forces 220
19.5 Visor Door Forces, Moments and Load Cases 221
19.7 Side-Opening Door Load Cases 223
21 Inner Door Design Loads 223
21.1 External Pressure 223
21.3 Internal Pressure 223

23 Side Shell and Stern Doors....223
23.1 Design Forces for Primary Members....223
23.3 Design Forces for Securing or Supporting Devices of Doors Opening Inwards....223
23.5 Design Forces for Securing or Supporting Devices of Doors Opening Outwards....223
25 Allowable Stresses....224
25.1 Primary Structure and Securing and Supporting Devices....224
25.3 Steel Securing and Supporting Devices Bearing Stress....224
25.5 Tensile Stress on Threaded Bolts....224
27 Operating and Maintenance Manual....225
27.1 Manual....225
27.3 Operating Procedures....225

FIGURE 1 Entry and Flare Angles....219
FIGURE 2 Definition of α_m and β_m....221
FIGURE 3 Visor Type Bow Door....222

SECTION 14 Bulwarks, Rails, Freeing Ports, Portlights, Windows, Ventilators, Tank Vents, and Overflows....226
1 Bulwarks and Guard Rails....226
1.1 Height....226
1.3 Strength of Bulwarks....226
1.5 Guard Rails....226
3 Access and Crew Protection....227
3.1 General....227
3.3 Access to Bow on Tankers....227
5 Freeing Ports....230
5.1 Basic Area....230
5.3 Trunks, Deckhouses, and Hatchway Coamings....230
5.5 Superstructure Decks....230
5.7 Open Superstructures....230
5.9 Details of Freeing Ports....230
7 Portlights....231
7.1 Application....231
7.3 Location....231
7.5 Construction....231
9 Windows....231
9.1 Location....231
9.3 Deadlights and Storm Covers....232
9.5 Construction....232
9.7 Testing....233
11 Ventilators, Tank Vents, and Overflows....233
11.1 General....233
11.3 Ventilators....234
11.5 Tank Vents and Overflows....234
11.7 Ventilators, Tank Vents and Overflows on the Fore Deck....234

TABLE 1 Acceptable Arrangement for Access 228
TABLE 2 233
TABLE 3 233
TABLE 4 760 mm (30 in.) High Tank Vents and Overflows Thickness and Bracket Standards 236
TABLE 5 900 mm (35.4 in.) High Ventilator Thickness and Bracket Standards 237

FIGURE 1 Guardrail Stanchion 227

SECTION 15 Ceiling, Sparring, and Protection of Steel 238
1 Ceiling 238
3 Sparring 238
5 Protection of Steel Work 238
5.1 All Spaces 238
5.3 Salt Water Ballast Space 238
5.5 Oil Spaces 238
5.7 Cargo Holds on Bulk Carriers (including Combination Carriers) 239

FIGURE 1 Extent of Coatings 239

SECTION 16 Weld Design 240
1 Fillet Welds 240
1.1 General 240
1.3 Tee Connections 240
1.5 Tee Type End Connections 241
1.7 Tee Joints at Boundary Connections 241
1.9 Ends of Unbracketed Stiffeners 241
1.11 Reduced Weld Size 241
1.13 Lapped Joints 241
1.15 Plug Welds or Slot Welds 242
3 Full or Partial Penetration Corner or Tee Joints 242
5 Alternatives 242

TABLE 1 Weld Sizes and Spacing – Millimeters 243
TABLE 1 Weld Sizes and Spacing – Inches 246

SECTION 17 Machinery Space and Tunnel 249
1 General 249
1.1 Arrangement 249
1.3 Testing of Tunnels 249
3 Machinery Foundations 249
3.1 Engine Foundations 249
3.3 Boiler Foundations 250

3.5 Thrust Foundations....250
3.7 Shaft Bearing and Auxiliary Machinery Foundations....250
5 Tunnels and Tunnel Recesses....250
5.1 Plating....250
5.3 Stiffeners....250
5.5 Beams, Pillars and Girders....251
5.7 Tunnels through Deep Tanks....251

SECTION 18 Guidance on Finite Element Analysis....252
1 General....252
1.1 Submittal Items....252
3 Structural Modeling....253
3.1 Finite Element Types....253
3.3 Model Types....253
3.5 Modeling Guidance....253
5 Boundary Conditions....254
7 Loads....254
9 Acceptance Criteria....255
9.1 Allowable Stresses....255
9.3 Buckling Strength....256

TABLE 1 Finite Element Type....253
TABLE 2 Stress Limits for Plate Element Models....256

APPENDIX 1 Loading Manuals and Loading Instruments....40
1 General....40
1.1 Application....40
3 Definitions....40
3.1 Loading Guidance....40
3.3 Category I Vessels....40
3.5 Category II Vessels....41
5 Required Loading Guidance....41
5.1 Loading Manual....41
5.3 Modifications....41
7 Loading Manual....41
7.1 Required Information....41
7.3 Loading Conditions....41
7.5 Language....42
9 Loading Instrument....42
9.1 Type....42
9.3 Required Verifications....42
9.5 Language....42
11 Annual Surveys....42

TABLE 1 Loading Conditions in the Loading Manual....43

APPENDIX 2 Guidelines for Calculating Bending Moment and Shear Force in Rudders and Rudder Stocks 154

1 Application 154

3 Spade Rudders 154

3.1 Rudder 154

3.3 Lower Stock 155

3.5 Moment at Top of Upper Stock Taper 156

3.7 Bearing Reaction Forces 156

5 Rudders Supported by Shoepiece 159

5.1 Shear Force, Bending Moment and Reaction Forces 159

7 Rudders Supported by a Horn with One Pintle 160

7.1 Shear Force, Bending Moment and Reaction Forces 160

9 Rudders Supported by a Horn Arranged with Two Pintles (Supports) 161

9.1 Shear Force, Bending Moment and Reaction Forces 161

FIGURE 1 Spade Rudder 158

FIGURE 2 Rudder Supported by Shoepiece 159

FIGURE 3 Rudder Supported by a Horn with One Pintle 161

FIGURE 4 Rudder Supported by a Horn Arranged with Two Pintles (Supports) 163

APPENDIX 3 Portable Beams and Hatch Cover Stiffeners of Variable Cross Section 210

1 Application 210

FIGURE 1 SM and I of Construction Elements 211

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 1 Longitudinal Strength

1 General

Vessels are to have longitudinal hull girder section modulus in accordance with the requirements of this section. The equation in this section is, in general, valid for all vessels having breadths, B, which do not exceed two times their depths, D, as defined in Section 3-1-1. Vessels whose proportions exceed these limits will be subject to special consideration.

3 Longitudinal Hull Girder Strength

3.1 Minimum Section Modulus

The minimum required hull girder section modulus, SM, at amidships, is to be determined in accordance with the following equation:

$$SM = C_1 C_2 L^2 B (C_b + 0.7) \qquad \text{m-cm}^2 \text{ (ft-in}^2\text{)}$$

where

C_1	=	$30.67 - 0.98L$	$12 \le L < 18$ 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
	=	$0.0451L + 3.65$	$61 \le L < 90$ m
C_1	=	$30.67 - 0.299L$	$40 \le L < 59$ 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
	=	$0.0137L + 3.65$	$200 \le L < 295$ ft
C_2	=	0.01 (0.01, 0.000144)	
L	=	length of vessel, as defined in 3-1-1/3, in m (ft)	
B	=	breadth of vessel, as defined in 3-1-1/5, in m (ft)	
C_b	=	block coefficient at design draft, based on the length, L, measured on the design load waterline. C_b is not to be taken as less than 0.60.	

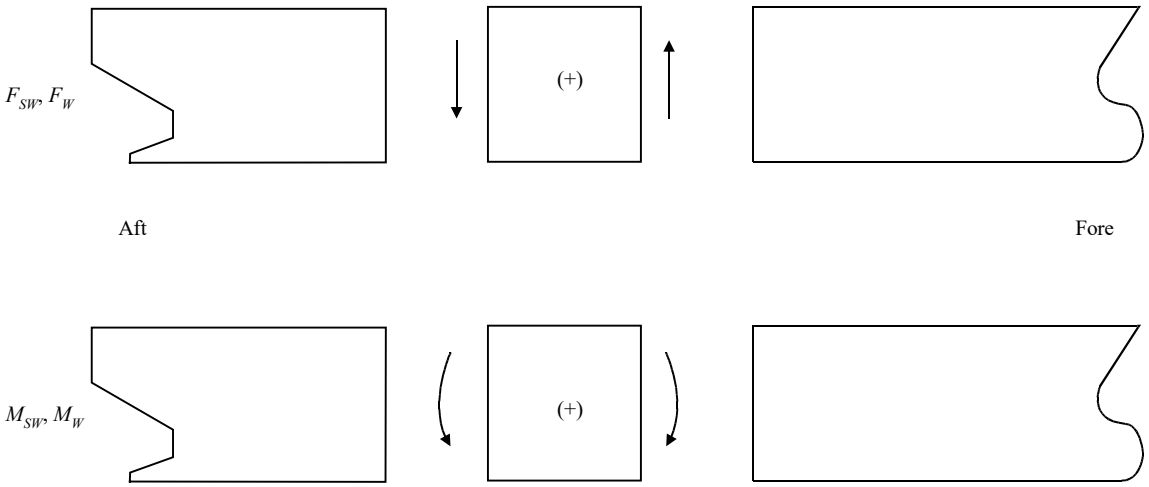
3.3 Vessels 61 m (200 ft) in Length and Over

In addition to meeting the above criteria in 3-2-1/3.1, 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

The sign convention bending moment and shear force is as shown in 3-2-1/Figure 1.

FIGURE 1
Sign Convention



3.3.2 Still-water Bending Moment and Shear Force

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

3.3.3 Wave Loads

3.3.3(a) Wave Bending Moment Amidships. 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 = $0.044L + 3.75$ SI/MKS units ($0.0134L + 3.75$ US customary units)

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

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

C_b = block coefficient at summer load waterline, based on L, as defined in 3-1-1/3

3.3.3(b) Envelope Curve of Wave Bending Moment. The wave bending moment along the length of the vessel L may be obtained by multiplying the midship value by the distribution factor M given in 3-2-1/Figure 2.

3.3.3(c) Wave Shear Force. The envelopes of maximum shearing forces induced by waves, F_w, as shown in 3-2-1/Figure 3 and 3-2-1/Figure 4, may be obtained from the following equations:

$$F_{wp} = +kF_1C_1LB(C_b + 0.7) \times 10^{-2} \qquad \text{For positive shear force}$$

$$F_{wn} = -kF_2C_1LB(C_b + 0.7) \times 10^{-2} \qquad \text{For negative shear force}$$

where

F_{wp}, F_{wn} = maximum shearing force induced by wave, in kN (tf, Ltf)

C_1 = as defined in 3-2-1/3.3.3(a)

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

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

C_b = block coefficient at summer load waterline, based on L, as defined in 3-1-1/3

k = 30 (3.059, 0.2797)

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

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

FIGURE 2
Distribution Factor *M*

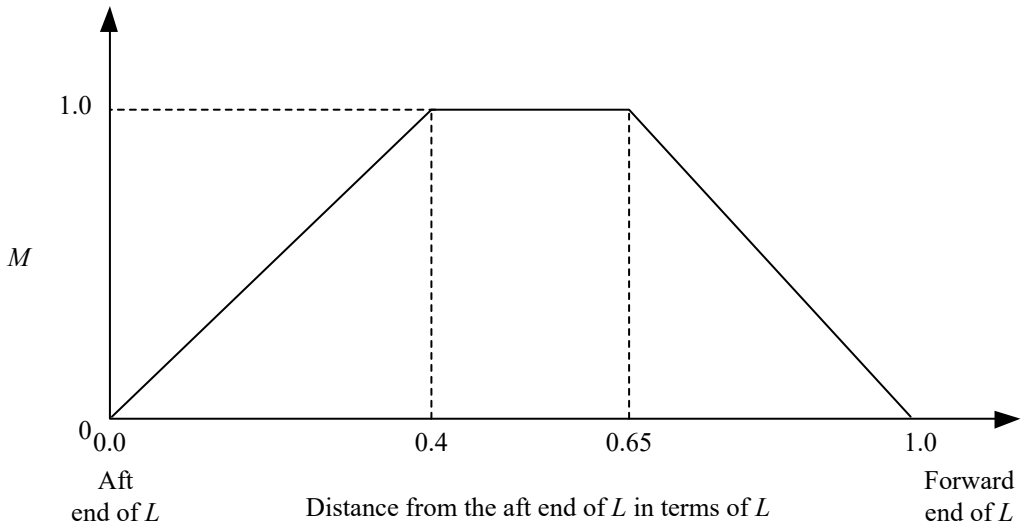


FIGURE 3
Distribution Factor F_1

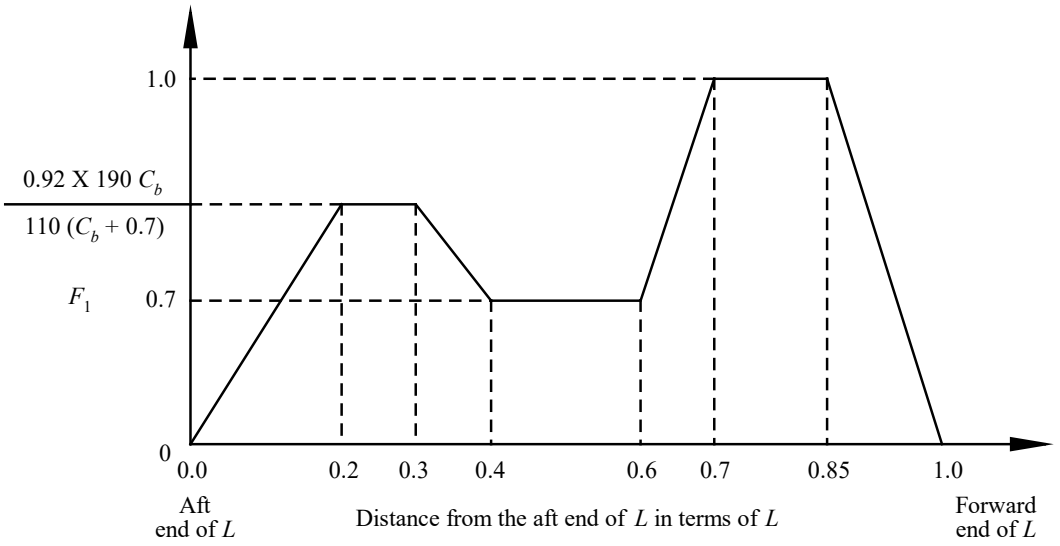
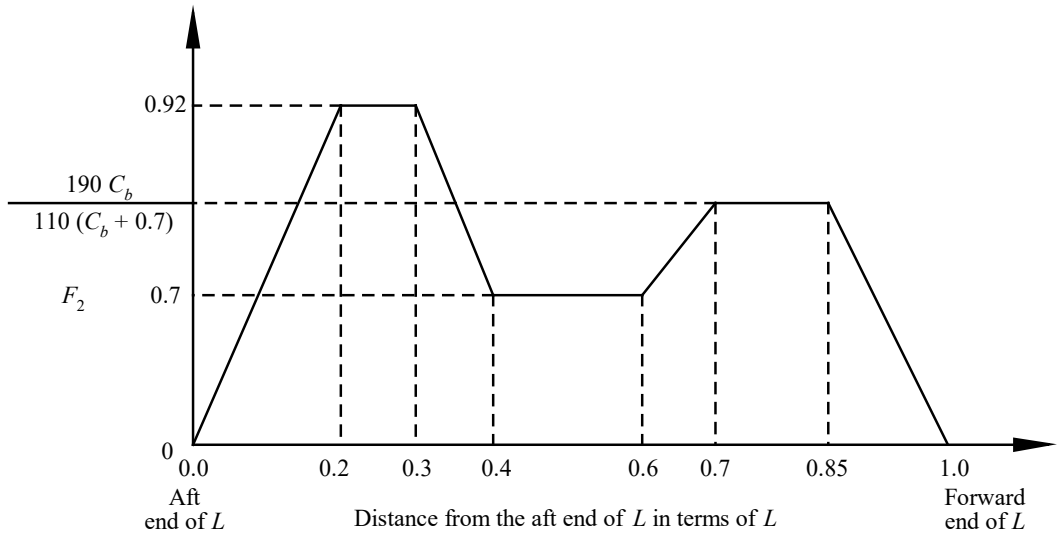


FIGURE 4
Distribution Factor F_2



3.3.4 Section Modulus

The required hull girder section modulus for 0.4L amidships is to be obtained from the following equation, or 3-2-1/3.1, whichever is greater.

$$SM = M_t/f_p \qquad \text{m-cm}^2 \text{ (ft-in}^2\text{)}$$

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, as follows.

$M_t = M_{sw} + M_w$

M_{sw} = still water bending moment, in accordance with 3-2-1/3.3.2

M_w = maximum wave-induced bending moment, in accordance with 3-2-1/3.3.3(a)

f_p = nominal permissible bending stress

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

3.3.5 Shearing Strength

In calculating the nominal total shear stresses 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 thicknesses of the side shell and longitudinal bulkhead, where fitted, are to be such that the nominal total shear stresses, as obtained from 3-2-1/3.3.5(a) or 3-2-1/3.3.5(c), are not greater than 11.0 kN/cm^2 (1.122 tf/cm^2, 7.122 Ltf/in^2). Where the side shell or longitudinal bulkhead is constructed of higher strength material, the permissible shear stresses may be increased by the factor, 1/Q.

3.3.5(a) 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:

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

where

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

m = 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 section 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)

F_w = F_{wp} or F_{wn}, as specified by 3-2-1/3.3.3(c), depending upon loading

3.3.5(b) Modification of Hull Girder Shearing Force for Vessels Carrying Cargo in Alternate Holds or with Other Non-Uniform Loading. Where cargo is carried in alternate holds, the hull girder shearing force in still water, F_{sw}, to be used for calculating shear stresses in the side shell plating may be modified to account for the shear loads transmitted through the double bottom structure to the traverse bulkhead.

3.3.5(c) Shearing Strength for Vessels with Two or Three Longitudinal Bulkheads. For vessels having continuous longitudinal bulkheads, the total shear stresses in the side shell and longitudinal bulkhead plating 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 of the *Steel Vessel Rules* 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. One acceptable method is shown in Appendix 5C-2-A1 of the *Steel Vessel Rules*.

3.5 Hull Girder Moment of Inertia

The hull-girder moment of inertia of the vessel amidships, I, is to be not less than obtained from the following equation:

$$I = L(SM)/33.3 \qquad \text{m}^2\text{-cm}^2 \text{ (ft}^2\text{-in}^2\text{)}$$

where

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

SM = hull girder section modulus required for the vessel in 3-2-1/3.1 or 3-2-1/3.3.4

5 Decks

5.1 Strength Decks

The uppermost deck to which the side shell plating extends for any part of the length of the vessel is to be considered the strength deck for that portion of the length, except in way of comparatively short superstructures. In such a case, the deck on which the superstructures are located is to be considered the strength deck in way of the superstructure. In general, the effective sectional area of the deck for use in calculating the section modulus is to exclude hatchways and other large openings through the deck but may include seam overlaps.

The deck sectional areas used in the section modulus calculations are to be maintained throughout the midship 0.4L in vessels. They may be reduced to one-half the normal requirement at 0.15L from the ends. In way of a superstructure beyond the midship 0.4L, the strength deck area may be reduced to approximately 70% of the normal requirement at that location.

5.3 Effective Lower Decks

To be considered effective for use in calculating the hull girder section modulus, the thickness of the deck plating is to comply with the requirements of Section 3-2-3. The sectional areas of lower decks used in calculating the section modulus are to be obtained as described in 3-2-1/5.1. 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.

7 Longitudinal Strength with Higher-Strength Materials

7.1 General

Vessels in which the effective longitudinal material of either the upper or lower flanges of the main hull girder, or both, are constructed of materials having mechanical properties greater than those of ordinary strength hull structural steel [see Section 2-1-2 of the ABS *Rules for Materials and Welding (Part 2)*], are to have longitudinal strength generally in accordance with the preceding paragraphs of this section, but the value of the hull girder section modulus may be modified as permitted by the following paragraphs. Applications of higher-strength material are to be continuous over the length of the vessel to locations where the stress levels will be suitable for the adjacent mild steel structure. Higher strength steel is to be extended to suitable locations below the strength deck and above the bottom, so that the stress levels will be satisfactory for the remaining ordinary strength steel structure. The strength deck and bottom structure are to be longitudinally framed. The longitudinal framing members are to be essentially of the same material as the plating they support and are to be continuous throughout the required extent of higher strength steel. Calculations showing that adequate strength has been provided against buckling are to be submitted for review and care is to be exercised against the adoption of reduced thicknesses of materials which may be subject to damage during normal operations.

7.3 Hull Girder Moment of Inertia *(2012)*

The hull-girder moment of inertia is to be not less than required by 3-2-1/3.5 using the mild steel section modulus obtained from 3-2-1/3.3.4.

7.5 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, as obtained from 3-2-1/3.1 or 3-2-1/3.3.4, may be reduced by the factor Q.

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

where

Q = 0.78 for Grade H32

Q = 0.72 for Grade H36

Q = 0.68[1] for H40 strength steel

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

Note:

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*

Q factor for steels having other yield point or yield strength will be specially considered.

9 Loading Guidance *(1 July 1998)*

9.1 Loading Manual and Loading Instrument *(2009)*

All vessels that are contracted for construction on or after July 1998 are to be provided with a loading manual. Loading instruments are not required by these Rules. However, when fitted, a loading instrument is to be in accordance with Appendix 3-2-A1.

9.3 Allowable Stresses

9.3.1 At Sea

See 3-2-1/3.3.4 for bending stress and 3-2-1/3.3.5 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 3-2-1/7.5.

9.3.2 In Port

The allowable 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 3-2-1/7.5.

11 Section Modulus Calculation

11.1 Items Included in the Calculation

In general, the following items may be included in the calculation of the section modulus, provided they are continuous or effectively developed within midship, 0.4L, and gradually tapered beyond the midship, 0.4L. 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.

- Deck plating (strength deck and other effective decks)
- Shell and inner bottom plating
- Deck and bottom girders
- Plating and longitudinal stiffeners of longitudinal bulkheads
- All longitudinals of deck, sides, bottom and inner bottom
- Continuous longitudinal hatch coamings. See 3-2-1/13.

11.3 Effective Areas Included in the Calculation

In general, the net sectional areas of longitudinal strength members are to be used in the hull girder section modulus calculations, except that small isolated openings need not be deducted, provided the openings and the shadow area breadths of the other openings in any one transverse section do not reduce the 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 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 the lines tangential to the corners of the opening intersecting each other to form an included angle of 30 degrees.

11.5 Section Modulus to the Deck or Bottom

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

11.7 Section Modulus to the Top of Hatch Coamings

For continuous longitudinal hatch coamings, in accordance with 3-2-1/13, the section modulus to the top of the coaming is to be obtained by dividing the moment of inertia 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 y_t is not less than the distance to the molded deck line at side.

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

where

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

x = distance, in m (ft), from the top of the continuous coaming to the centerline of the vessel

B = breadth of the 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 consideration.

13 Continuous Longitudinal Hatch Coamings and Above-Deck Girders

Where strength deck longitudinal coamings of length greater than $0.14L$ are effectively supported by longitudinal bulkheads or deep girders, the coamings are to be longitudinally stiffened, in accordance with 3-2-12/7.7. The section modulus amidships to the top of the coaming is to be as required by 3-2-1/3.1, 3-2-1/3.3, and 3-2-1/11.7, but the section modulus to the deck at side, excluding the coaming, need not be determined in way of such coaming.

Continuous longitudinal girders on top of the strength deck are to be similarly considered. Their scantlings are also to be in accordance with Section 3-2-6.

PART
3

CHAPTER 2 Hull Structures and Arrangements

APPENDIX 1 Loading Manuals and Loading Instruments *(1 July 1998)*

Note: These requirements are intended to satisfy Regulation 10(1) of the International Convention on Load Lines, 1966.

1 General

1.1 Application

The requirements in Appendix 3-2-A1 apply to all classed vessels 65 m (213 ft) and above in length (L_f) that are contracted for construction on or after 1 July 1998.

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 with sufficient information to enable the master of the vessel to arrange for the loading and ballasting of the vessel in such a way as to avoid the creation of any unacceptable stresses in the vessel's structure.

3.1.2 Loading Instrument

A loading instrument is an instrument by means of which it can be easily and quickly ascertained that the still water bending moments, shear forces and, where applicable, the still water torsional moments and lateral loads at the specified points along the length of the vessel will not exceed the specified values in any loaded or ballast condition.

3.3 Category I Vessels

Category I vessels are any one of the following vessels.

3.3.1

Vessels with large deck openings where combined stresses due to vertical and horizontal hull girder bending and torsional and lateral loads need to be considered.

3.3.2

Vessels designed for non-homogeneous loading where the cargo and/or ballast may be unevenly distributed, except those belonging to 3-2-A1/3.5.3.

3.3.3

Chemical carriers and gas carriers.

3.5 Category II Vessels

Category II vessels are any one of the following vessels.

3.5.1

Vessels with such arrangement as will result in small possibilities for variation in the distribution of cargo and ballast.

3.5.2

Vessels on regular and fixed trading pattern where the loading manual gives sufficient guidance.

3.5.3

Vessels of which the design takes into account the uneven distribution of cargo or ballast.

5 Required Loading Guidance *(2003)*

5.1 Loading Manual

All vessels are to be provided with a loading manual reviewed and stamped by ABS, in accordance with 3-2-A1/7, with the exception that a loading manual is not required for Category II vessels where the deadweight does not exceed 30% of the displacement at the summer load line.

5.3 Modifications

Where the 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 to be placed aboard to replace the existing manual. The loading instrument is to be re-verified in accordance with 3-2-A1/9.3 or newly installed and verified in such cases.

Where the 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 *(2017)*

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 based on which the design of the vessel is approved.

ii) The results of the calculations of still water bending moments, shear forces.

iii) Permissible limits of still water bending moment and shear force and, where applicable, limitations due to torsional and lateral loads.

iv) Maximum allowable tank top loading.

v) If cargoes other than bulk cargoes are contemplated, such cargoes are to be listed together with any specific instructions for loading.

vi) Maximum allowable load on deck and hatch covers. If the vessel is not approved to carry load on deck or hatch covers, that fact is to be clearly stated in the loading manual.

vii) Information on the heavy ballast draft forward used for the fore-end strengthening required in 3-2-4/7.

7.3 Loading Conditions

The above information is to be based on the intended service conditions. See 3-2-A1/Table 1 for the selection of loading conditions.

7.5 Language

The loading manual is to be prepared in, or include, a language understood by the user. English may be considered as a language understood by the user.

9 Loading Instrument

9.1 Type

A loading instrument is to be digital. 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 the Surveyor's personal verification:

i) That the instrument is type approved, where applicable

ii) That the instrument is based on the final data of the vessel

iii) That the number and position of read-out points are satisfactory

iv) That the relevant limits for all read-out points are satisfactory

v) That the operation of the instrument after installation onboard, in accordance with the approved test conditions has been satisfactory

vi) That approved test conditions are available onboard

vii) 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 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 of the *Rules for Survey After Construction (Part 7)* are to be complied with as follows: At each Annual Survey, loading manual is to be verified onboard and, where applicable, loading instrument is to be verified in working order. The operation manual for loading instrument is also to be verified onboard.

TABLE 1
Loading Conditions in the Loading Manual

1.	The loading manual is to include at least	
1.1	full load conditions, subdivided into departure and arrival conditions,	
1.2	ballast conditions, subdivided into departure and arrival conditions (see also 1.5)	
1.3	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 and, where applicable, 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.

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 by the equations for thickness of side and bottom plating as required by this section, nor less than required by Section 3-2-1 for longitudinal strength and Section 3-2-8 for deep tank plating with h not less than the vertical distance to the freeboard deck at side.

3 Bottom Shell Plating

3.1 Extent of Bottom Plating

The term "bottom plating" refers to the plating from the keel to the upper turn of the bilge or upper chine.

3.3 Bottom Shell Plating

The thickness of the bottom shell plating throughout is not to be less than that obtained from the following equations:

3.3.1

$$t = \frac{s\sqrt{h}}{254} + 2.5 \quad \text{mm}$$

$$t = \frac{s\sqrt{h}}{460} + 0.10 \quad \text{in.}$$

where

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

s = frame spacing, in mm (in.)

h = depth, D, in m (ft), as defined in 3-1-1/7.1, 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 vessel, in m (ft), as defined in 3-1-1/3

3.3.2

$$t = \frac{s}{R}\sqrt{\frac{SM_R}{SM_A}} \cdot \frac{1}{\sqrt{Q}} \quad \text{mm (in.)}$$

where

t and s are as defined above.

R = 45 with transverse framing

= 55 with longitudinal framing

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

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

Q = as defined in 3-2-1/7.5

3.5 Bottom Forward

For vessels of 61 m (200 ft) in length and above, where the heavy weather ballast draft or operating draft forward is less than 0.04L, the plating on the flat of bottom forward, forward of the location given in 3-2-4/Table 1 is to be not less than required by the following equation:

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

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

where

s = frame spacing, in mm (in.)

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

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

5 Side Shell Plating

5.1 General *(1998)*

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

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

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

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

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

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.

5.3 Side Shell for Vessels Subject to Impact Loadings *(2014)*

For vessels subject to impact loadings during routine operations, the side shell is to be 25% greater in thickness than that obtained from the equation in 3-2-2/5.1.

5.5 Side Shell Plating at Ends

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

$$t = 0.0455L + 0.009s \quad \text{mm}$$

$$t = 0.000545L + 0.009s \quad \text{in.}$$

where

s = frame spacing, in mm (in.)

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

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

5.7 Forecastle and Poop Side Plating

5.7.1 Forecastle Side Plating

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

$$t = 0.038(L + 30.8) + 0.006s \quad \text{mm}$$

$$t = 0.00045(L + 103.3) + 0.006s \quad \text{in.}$$

5.7.2 Poop Side Plating

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

$$t = 0.0296(L + 39.5) + 0.006s \quad \text{mm}$$

$$t = 0.00035(L + 132.9) + 0.006s \quad \text{in.}$$

where

s = spacing of frames, in mm (in.)

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

7 Bow and Stern Thruster Tunnels

The thickness of the tunnel plating is to be not less than that required by 3-2-2/5.5, nor is the thickness to be less than that 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.), but is to be taken as not less than 968 mm (38 in.)

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

9 Local Strengthening for Research Vessels

In vessels used for research, wear plates or rollers are recommended at all places where research methods or gear will subject the shell plating to accelerated wear. Special strengthening may be required in areas where small boats are regularly launched, retrieved or stowed. Special strengthening may also be required in areas where the vessel makes contact with another vessel when pursing, hauling, brailing, pumping, loading, unloading or running together.

11 Compensation

Compensation is to be provided for openings in the shell plating where required to maintain the longitudinal and transverse strength of the hull. All openings are to have well-rounded corners. Those in the upper side shell are to be located a suitable distance below the deck edge. Cargo and gangway openings are to be kept well clear of other discontinuities in the hull girder. Local provision is to be made to maintain the longitudinal and transverse strength of the hull.

Thick plating or doublers of sufficient breadth to prevent damage from the flukes of stockless anchors are to be fitted around the hawse pipes.

13 Breaks

Breaks in vessels having partial superstructures are to be specially strengthened to limit the local increases in stresses at these points. The stringer plates and sheer strakes at the lower level are to be increased in thickness well beyond the break in both directions. The thickness is to be increased 25% in way of breaks of superstructures. The side plating of the superstructure is to be increased in thickness and the side plating is to extend well beyond the end of the superstructure in such fashion as to provide a long gradual taper. Where the breaks of the forecastle or poop are appreciably beyond the midship $0.5L$, these requirements may be modified. Gangways, large freeing ports, side shell doors, and other openings in the shell or bulwarks are to be kept well clear of the breaks, and any holes which must unavoidably be cut in the plating are to be kept as small as possible and are to be circular or oval in form.

15 Bilge Keels

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

Butt welds in the bilge keel and doubler are to be full penetration and are to be kept clear of master erection butts. In general, shell butts are to be flush in way of the doubler. Doubler butts are to be flush in way of the bilge keel. In general, scallops and cutouts are not to be used. Where desired, a crack-arresting hole at least 25 mm (1 in.) in diameter may be drilled in the bilge keel butt weld as close as practicable to the doubler.

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

16 Bilge Plating *(2016)*

For longitudinally stiffened bilge plate, the plate thickness is not to be less than required in 3-2-2/3 and 3-2-2/5, 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.

17 Higher-strength Materials

17.1 General

In general, applications of higher-strength materials are to take into consideration the suitable extension of the higher-strength material above and below the bottom and deck, respectively, as required by 3-2-1/7.1. 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 bottom and side-shell plating, where constructed of higher-strength materials, are to be not less than required for purposes of longitudinal hull girder strength; nor are they to be less than required by the foregoing paragraphs of this section when modified as indicated by the following paragraphs.

17.3 Bottom Plating of Higher-strength Material

Bottom shell plating, where constructed of higher-strength material and where longitudinally framed, is to be not less in thickness than that obtained from the following equation:

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

where

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

t_{ms} = thickness, in mm (in.), of ordinary-strength steel, as required by preceding paragraphs of this section, or from the requirements of other sections of the Rules, appropriate to the vessel type.

C = 4.3 mm (0.17 in.)

Q = as defined in 3-2-1/7.5

17.5 Side Plating of Higher-strength Material

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

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

where t_{hts}, t_{ms}, C and Q are as defined in 3-2-2/17.3 for bottom plating.

17.7 End Plating

End-plating thickness, including 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 Deck Plating

1 General

The thickness of the deck plating is not to be less than that required to obtain the hull-girder section modulus given in Section 3-2-1, nor less than required by this section.

3 Deck Plating

The thickness of plating on each deck is to be not less than the greater of those obtained from the following equations. The required thickness is not to be less than 5.0 mm (0.20 in.), except for platform decks in enclosed passenger spaces where the thickness is not to be less than 4.5 mm (0.18 in.). Thickness of strength deck inside line of openings may be reduced by 1.0 mm (0.04 in.) from t obtained by 3-2-3/3.3 below.

3.1 All Decks

$$t = \frac{s\sqrt{h}}{254} + 2.5 \quad \text{mm}$$

$$t = \frac{s\sqrt{h}}{460} + 0.10 \quad \text{in.}$$

where

t = thickness, in mm (in.)

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

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

= *for a deck or portion of deck forming a tank top*, the greater of the following distances:

- two-thirds of the distance from the tank top to the top of the overflow, or
- two-thirds of the distance from the tank top to the bulkhead deck or freeboard deck.

= *for a lower deck on which cargo or stores are carried,* the tween-deck height at side; where the cargo weights are greater than normal [7010 N/m^3 (715 kgf/m^3, 45 lbf/ft^3)], h is to be suitably adjusted.

= *for an exposed deck on which cargo is carried,* 3.66 m (12 ft). Where it is intended to carry deck cargoes in excess of 25850 N/m^2 (2636 kgf/m^2, 540 lbf/ft^2), this head is to be increased in proportion to the added loads which will be imposed on the structure

Elsewhere, the value of h is to be not less than that obtained from the appropriate equation below, where L is the length of vessel in m (ft), as defined in 3-1-1/3.

3.1.1 Exposed Freeboard Deck Having No Deck Below

$h = 0.028L + 1.08$ m

$h = 0.028L + 3.57$ ft

3.1.2 Exposed Freeboard Deck Having a Deck Below, Forecastle Deck, Superstructure Deck Forward of Amidships 0.5L

$h = 0.028L + 0.66$ m

$h = 0.028L + 2.14$ ft

3.1.3 Freeboard Deck within Superstructure, Any Deck Below Freeboard Deck, Superstructure Deck Between 0.25L Forward of and 0.20L Aft of Amidships

$h = 0.014L + 0.87$ m

$h = 0.014L + 2.86$ ft

3.1.4 All Other Locations

$h = 0.014L + 0.43$ m

$h = 0.014L + 1.43$ ft

3.3 Strength Decks within the Midship 0.8L *(2002)*

For vessels of length equal to or greater than 61 meters, the strength deck plating within the midship 0.8L shall meet the following requirement:

$t = 0.009s + 2.4$ mm

$t = 0.009s + 0.095$ in.

where

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

3.5 All Strength Deck Plating Outside the Line of Openings and Other Effective Deck Plating *(2002)*

For vessels of length equal to or greater than 61 meters, the strength deck plating within the midship 0.8L shall meet the following requirement:

$$t = \frac{s}{R}\sqrt{\frac{SM_R}{SM_A}} \cdot \frac{1}{\sqrt{Q}} \quad \text{mm (in.)}$$

where

t = thickness, in mm (in.)

s = beam or longitudinal spacing, in mm (in.), not to be taken less than 610 mm (24 in.)

R = 60 for longitudinal framing, 45 for transverse framing

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

SM_A = hull girder section modulus, in cm^2-m (in^2-ft), measured to the deck in question

Q = material factor for the material used in determining SM_R, as defined in 3-2-1/7.5

5 Compensation

Compensation is to be provided for openings in the strength deck and other effective decks to maintain the longitudinal and transverse strength. 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 a radius of 600 mm (24 in.). In other decks, the radius is to be 0.09375 times the width of the opening, but need not exceed radius of 450 mm (18 in.). Openings are to be a suitable distance from the deck edge, from cargo hatch covers, from superstructure breaks and from other areas of structural discontinuity.

7 Wheel Loading *(2014)*

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 deck plating is to be not less than that obtained from the following equation:

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

where

k = 8.05 (25.2, 1)

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/Figure 1

n = 1.0 where $\ell/s > 2.0$ and 0.85 where $\ell/s = 1.0$. For intermediate values of ℓ/s, n is to be obtained by interpolation

C = 1.5 for wheel loads of vehicles stowed at sea and 1.1 for vehicles operating in port

W = static wheel load, in kN (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

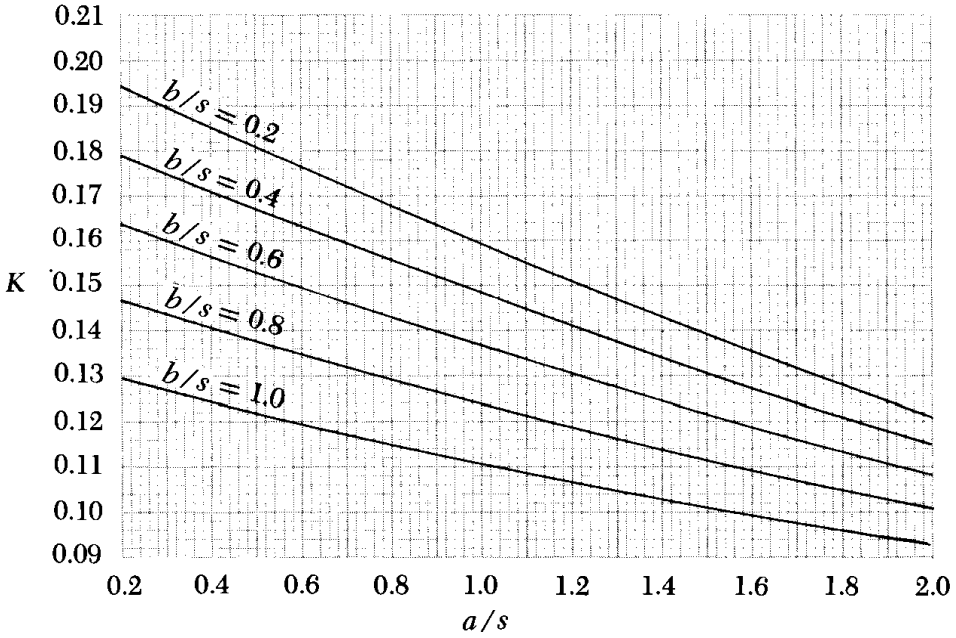
s = spacing of deck beams or deck longitudinals, in mm (in.)

ℓ = length of the plate panel, in mm (in.)

For wheel loading, the strength deck plating thickness is to be not less than 110% of that required by the above equation, and platform deck plating thickness is to be not less than 90% of that required by the above equation.

Where the wheels are close together, special consideration will be given to the use of the combined imprint and load. Where the intended operation is such that only the larger dimension of the wheel imprint is perpendicular to the longer edge of the plate panel, b above may be taken as the larger wheel imprint dimension, in which case, a is to be the lesser one.

FIGURE 1
Wheel Loading Curves of K



9 Higher-strength Material

9.1 Thickness

In general, applications of higher strength materials are to take into consideration the suitable extension of the higher strength material below the deck, forward and aft. Care is to be taken to avoid the adoption of reduced thickness of material such as might be subject to damage during normal operation. The thickness of deck plating for longitudinally framed decks, where constructed of higher-strength material, is to be not less than required for longitudinal strength, nor is it to be less than that obtained from the following equation:

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

where

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

t_{ms} = thickness of ordinary-strength steel, in mm (in.), as required 3-2-3/3.1 and 3-2-3/3.3

C = 4.3 mm (0.17 in.)

Q = is as defined in 3-2-1/7.5

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

9.3 Wheel Loading

Where deck 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 that obtained from the following equation:

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

where

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

t_{ms} = thickness of ordinary-strength steel, as obtained from 3-2-3/7

Y = as defined in 3-2-7/5.1

M = 235 (24, 34000)

PART
3

CHAPTER 2 **Hull Structures and Arrangements**

SECTION 4 **Bottom Structure**

1 Double Bottoms

1.1 General *(2019)*

Inner bottoms are to be fitted fore and aft between the peaks or as near thereto as practicable in vessels of ordinary design of 500 GT or over. Where, for special reasons, it may be desired to omit the inner bottom, the arrangements are to be clearly indicated on the plans when first submitted for approval. A double bottom need not be fitted in way of deep tanks, provided the safety of the vessel in the event of bottom damage is not thereby impaired. It is recommended that the inner bottom be arranged to protect the bilges as much as possible and that it be extended to the sides of the vessel.

Shell longitudinals and frames in way of deep tanks are to have not less strength than is required for stiffeners on deep tank bulkheads.

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 Center Girder

(2017) A center girder is to be fitted extending as far forward and aft as practicable. The plates are to be continuous within the midship three-quarters length; elsewhere, they may be intercostal between floors. 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 more than 61 m (200 ft) 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.

1.3.1 Thickness Amidships

The thickness of the center girder within the midship one-half length is not to be less than that obtained from the following equation.

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

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

where

t = thickness, in mm (in.)

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

1.3.2 Thickness at Ends

The thickness of the center girder forward and aft of the midship one-half length may be reduced to 85% of the girder thickness amidships.

1.3.3 Depth

The depth of the center girder is not to be less than that obtained from the following equation:

$$h_g = 32B + 190\sqrt{d} \quad \text{mm}$$

$$h_g = 0.384B + 4.13\sqrt{d} \quad \text{in.}$$

where

h_g = depth, in mm (in.)

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

d = draft for scantlings, in m (ft), as defined in 3-1-1/9

1.5 Side Girders

Where the distance between the center girder and the side shell exceeds 4.57 m (15 ft), intercostal side girders are to be fitted approximately midway between the center girder and the side shell. The minimum thickness of the intercostal side girders is not to be less than obtained from the following equation.

$$t = 0.036L + c \quad \text{mm}$$

$$t = 0.00043L + c \quad \text{in.}$$

where

t = thickness, in mm (in.)

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

c = 4.7 mm (0.18 in.)

1.7 Floors *(2016)*

Solid floors are to be fitted at every frame (600 mm to 800 mm) under machinery, under the outer ends of bulkhead stiffener brackets, under transverse bulkheads and at the forward end (see 3-2-4/7.5 or 3-2-4/7.7, as applicable). Elsewhere, the solid floors are to have a maximum spacing of 3.66 m (12 ft) in association with intermediate open floors or longitudinal framing. The thickness of solid floors is to be equal to the thickness of side girders obtained in 3-2-4/1.5, except that for widely spaced floors in association with longitudinal framing, c is to be taken as 6.2 mm (0.24 in.).

1.9 Frames

In transversely framed vessels, open floors consisting of frames and reverse frames are to be fitted at all frames where solid floors are not fitted. Center and side brackets are to overlap the frames and reverse frames for a distance equal to $0.05B$. They are to be of the thickness required for side girders in the same location and are to be flanged on their outer edges. Alternatively, longitudinal framing is to be fitted in association with widely spaced floors. The section modulus, SM, of each frame, reverse frame or bottom, or inner bottom longitudinal 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

s = frame spacing, in m (ft)

ℓ = unsupported span between supporting members, in m (ft). Where brackets are fitted in accordance with 3-1-2/5.5 and are supported by bulkheads, inner bottom, or side shell, the length, ℓ, may be measured as permitted therein.

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 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 not less than $0.01L + 0.15$ m or 0.46 m ($0.01L + 0.5$ ft or 1.5 ft), whichever is greatest.

c for transverse frames and reverse frames:

= 0.8 clear of tanks

= 1.0 in way of tanks

= 0.5 with struts

c for longitudinal frames:

= 1.0 without struts

= 0.55 with struts

c for inner bottom longitudinals:

= 0.85 without struts

= 0.45 with struts

Frames and reverse frames in way of tanks are not to be less than that required clear of tanks if that be greater.

1.11 Struts *(2015)*

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 3-2-6/5.3. The calculated load, *W,* is to be determined by:

$$W = nphs \quad \text{kN (tf, Ltf)}$$

where

n = 10.5 (1.07, 0.03)

p = sum of the half lengths, in m (ft), on each side of the strut, of the frames supported

h = as defined in 3-2-4/1.9

s = frame spacing, in m (ft)

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

1.13 Inner-bottom Plating

The thickness of the inner-bottom plating throughout the length of the vessel is to be not less than that obtained from the following equation. Where applicable, the plating is to meet deep tank requirements.

$$t = 0.037L + 0.009s + c \quad \text{mm}$$

$$t = 0.000445L + 0.009s + c \quad \text{in.}$$

where

t = thickness, in mm (in.)

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

s = frame spacing, in mm (in.)

c = 1.5 mm (0.06 in.) in engine space

= –0.5 mm (–0.02 in.) elsewhere

Where no ceiling is fitted under cargo hatchways, except for vessels intended for the exclusive carriage of containers on the inner bottom, the thickness of the inner-bottom plating is to be increased 2.0 mm (0.08 in.). For vessels with longitudinally-framed inner bottoms, the minimum thickness of inner-bottom plating may be reduced by 1 mm (0.04 in.).

For vessels regularly engaged in trades where the cargo is handled by grabs or similar mechanical appliances, it is recommended that flush inner-bottom plating be adopted throughout the cargo space, and that the plating be suitably increased, but the increase need not exceed 5 mm (0.20 in.). It is also recommended that the minimum thickness be not less than 12.5 mm with 610 mm (0.50 in. with 24 in.) frame spacing and 19 mm with 915 mm (0.74 in. with 36 in.) frame spacing. Intermediate thicknesses may be obtained by interpolation.

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 that obtained from 3-2-3/7.

Margin plates which are approximately horizontal are to have thicknesses not less than the adjacent inner bottom plating. Where they are nearly vertical, they are to be not less than the required inner bottom plating in the engine space and are to extend the full depth of the inner bottom.

1.15 Sea Chests *(1 July 2019)*

Where the double bottom structure forms part of a sea chest, the thickness of the plating is to be not less than the required thickness of the shell plating, using the approximate value of stiffener spacing, s.

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.

1.17 Access, Lightening, Air, and Drainage Holes

Access holes in double bottom tank tops and lightening holes in nontight members are to be sufficient in size and number to assure accessibility to all parts of the double bottom. The proposed locations and sizes of the holes are to be indicated on the drawings submitted for approval. Tank top access hole covers are to be of steel or equivalent material, and where no ceiling is fitted in a cargo hold, the covers are to be protected against damage by the cargo. Air and drainage holes are to be cut in all nontight parts of the double bottom structure to assure the free escape of gases to the vents and the free drainage of liquids to the suctions.

3 Single Bottoms with Floors and Keelsons

3.1 General

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 3-2-4/3 or 3-2-4/5, as may be applicable.

3.3 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.

3.3.1 Center-girder Plate Thickness Amidships

$$t = 0.063L + 5 \quad \text{mm}$$

$$t = 0.00075L + 0.2 \quad \text{in.}$$

3.3.2 Center-girder Plates Thickness at Ends

t = 85% of center keelson thickness amidships

3.3.3 Horizontal Top-plate Area Amidships

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

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

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

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

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

where

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

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

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

3.5 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 3-2-4/3.3, if that be less.

3.5.1 Side Keelson and Intercostal Thickness Amidships

$$t = 0.063L + 4 \quad \text{mm}$$

$$t = 0.00075L + 0.16 \quad \text{in.}$$

3.5.2 Side Keelson and Intercostal Thickness at Ends

t = 85% of center thickness amidships

3.5.3 Side Keelson and Intercostal, Horizontal Top Plate Area Amidships

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

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

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

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

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

t, L and A are as defined in 3-2-4/3.3.

3.7 Floors

3.7.1 Section Modulus

With transverse framing, a floor as shown in 3-2-4/Figure 1 is to be fitted on every frame and is to be of the scantlings necessary to obtain a section modulus, *SM,* not less than that obtained from the following equation:

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

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

where

c = 0.55

h = draft, d, in m (ft), as defined in section 3-1-1/9, 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 3-1-2/5.5 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.

3.7.2 Depth

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

$$h_f = 62.5\ell \quad \text{mm}$$

$$h_f = 0.75\ell \quad \text{in.}$$

where

h_f = floor depth, in mm (in.)

ℓ = unsupported span of floors, in m (ft). Where brackets are fitted in accordance with 3-1-2/5.5, the length, ℓ, may be measured as permitted therein.

3.7.3 Thickness

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

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

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

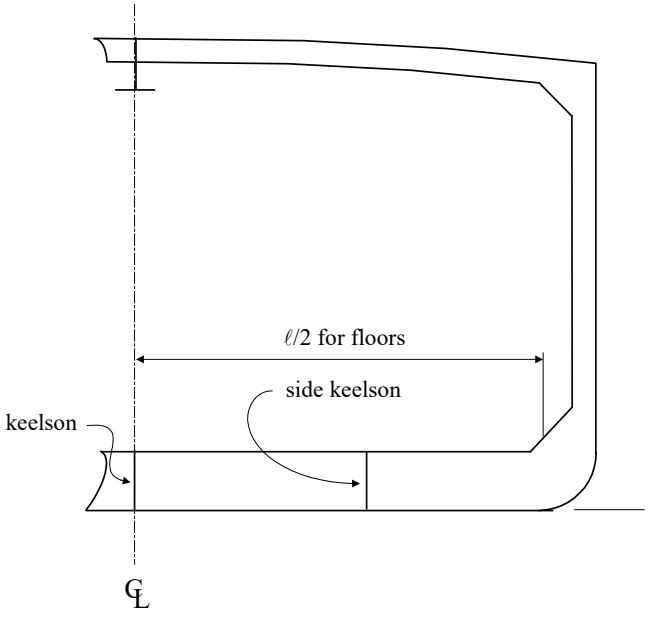
where

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 1
Plate Floors



5 Single Bottoms with Longitudinal or Transverse Frames

5.1 General

Where longitudinal frames supported by bottom transverses or transverse frames supported by longitudinal girders and bottom transverses are proposed in lieu of keelsons referred to in 3-2-4/3, 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/Figure 2, 3-2-4/Figure 3 and 3-2-4/Figure 4.

FIGURE 2
Round Bottom Floors with Deadrise

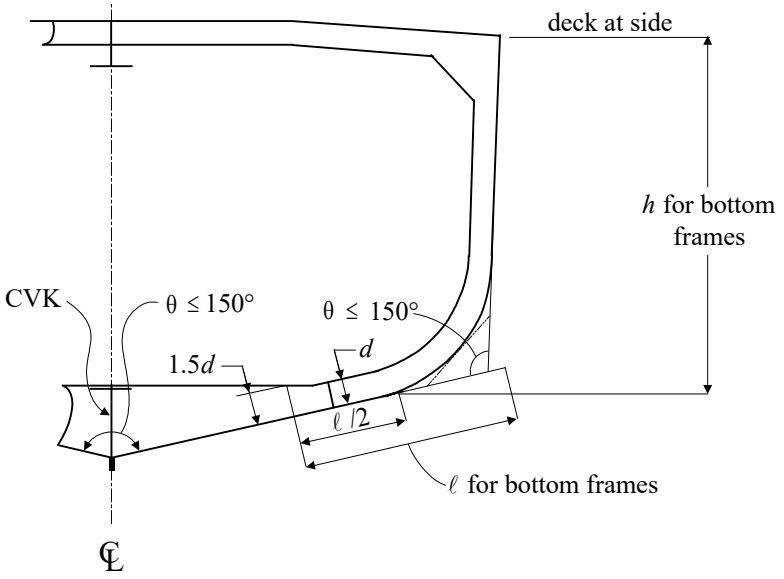


FIGURE 3
Transverse Bottom Frames with Longitudinal Side Girders

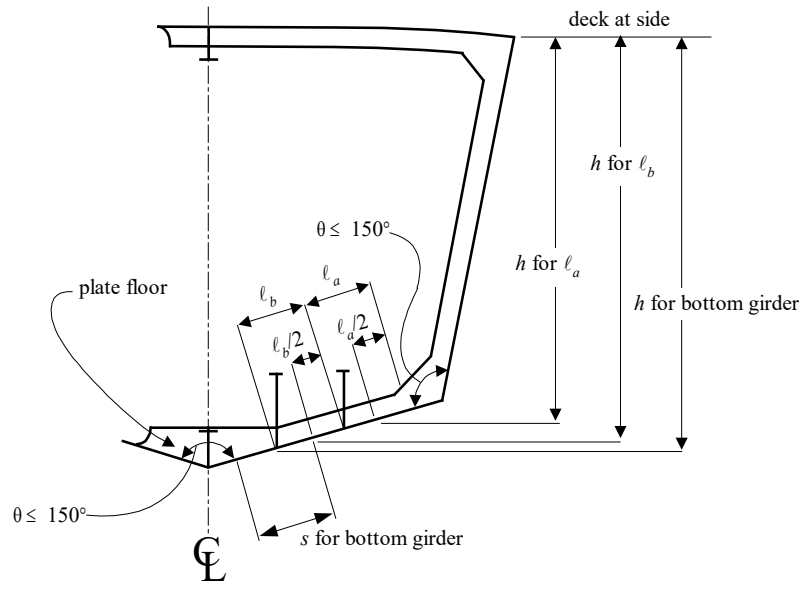
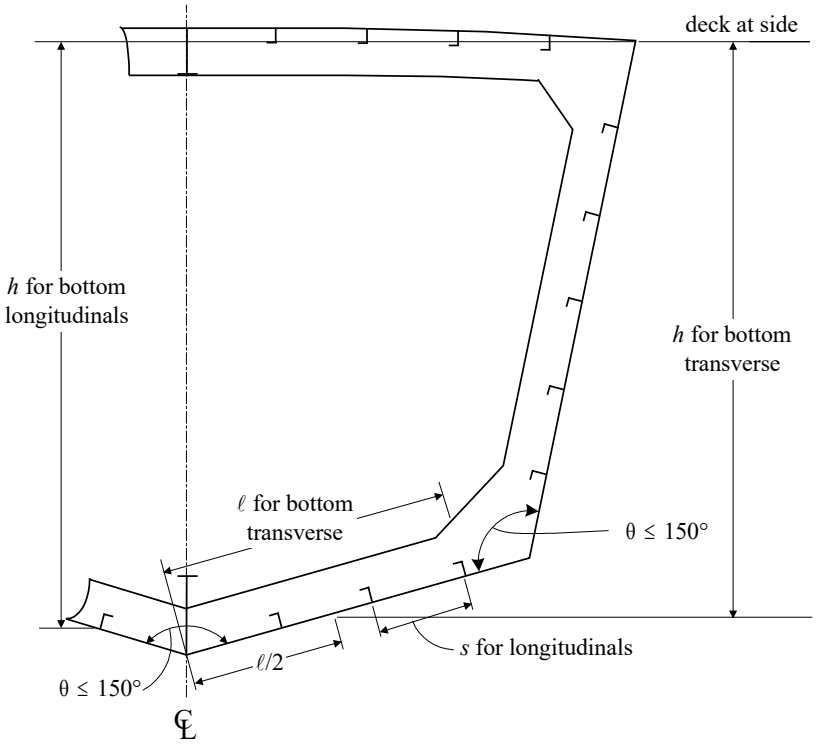


FIGURE 4
Longitudinal Frames with Transverse Webs



5.3 Bottom Girders and Transverses

5.3.1 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). Where brackets are fitted in accordance with 3-1-2/5.5 and are supported by bulkheads, inner bottom or side shell, the length, ℓ, may be measured as permitted therein.

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

5.3.2 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 3-2-4/5.3.1.

5.3.3 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 3-2-4/5.3.2.

5.3.4 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.

5.5 Center Girder

In general, a center girder is to be fitted, complying with 3-2-4/5.3; however, alternative arrangements that provide suitable support for docking will be considered.

5.7 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:

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

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

where

c = 0.80 for transverse frames clear of tanks

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

= 1.00 for transverse frames in way of tanks

s = frame spacing in, m (ft)

ℓ = unsupported span, in m (ft), Where brackets are fitted in accordance with 3-1-2/5.5 and are supported by bulkheads, inner bottom or side shell, the length, ℓ, may be measured as permitted therein.

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.

7 Fore-end Strengthening

7.1 General

For vessels 61 m (200 ft) in length and over, where the heavy weather ballast draft forward is less than 0.04L, strengthening of the flat of bottom forward is to be in accordance with 3-2-4/7.3, 3-2-4/7.5, 3-2-4/7.7 and 3-2-2/3.5. Information on the heavy weather ballast draft forward used for the required fore-end strengthening is to be furnished to the master for guidance. The heavy weather ballast draft is also to be indicated on the shell expansion plan.

7.3 Extent of Strengthening

The flat of bottom forward is defined as being forward of the locations indicated in 3-2-4/Table 1. For intermediate values of C_b, the locations are to be obtained by interpolation. Aft of these locations, a suitable transition is to be provided 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 1.

TABLE 1
Location of Flat of Bottom Forward

C_b is the block coefficient at the summer load waterline, based on L, as defined in 3-1-1/3.

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

7.5 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 1 is to be not less than required by the following equation, nor less than required by 3-2-4/5.7.

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

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

where

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

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

s = spacing of longitudinals, in m (ft)

ℓ = distance between floors, in m (ft)

The spacing of floors forward of 0.25L forward of amidships is to be not greater than that given in 3-2-4/Table 2, nor greater than the spacing amidships.

TABLE 2
Spacing of Floors

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

Notes:

d_f is the heavy weather ballast draft 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.

s is the spacing of the transverse side frames, or $s = 2.08L + 438$ (mm) [$0.025L + 17.25$ (in.)], where the side shell is longitudinally framed.

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

7.7 Transverse Framing

Where the heavy weather ballast draft forward is less than 0.04L, 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 locations in 3-2-4/Table 1 does not exceed 2.13 m (7 ft) and so that the spacing of alternating half- and full-depth girders forward of the location in 3-2-4/Table 1 does not exceed 1.07 m (3.5 ft). Where the heavy weather ballast draft forward is 0.04L or more, the arrangement of solid floors and side girders may be in accordance with 3-2-4/1.7 and 3-2-4/1.5.

9 Higher-strength Materials

9.1 General

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

9.3 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 3-2-4/1.13 or for tank top plating 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 3-2-4/1.13, in mm (in.), increased where required for no ceiling

C = 3 mm (0.12 in.) or 5 mm (0.20 in.) where the plating is required by 3-2-4/1.13 to be increased for no ceiling

Q = as defined in 3-2-1/7.5

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 3-2-4/1.13 are applicable to t_{hts}.

9.5 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, are to be determined as indicated in 3-2-4/1.9, except that the value may be reduced by the factor Q, as defined in 3-2-1/7.5.

9.7 Center Girders, Side Girders and Floors

Center girders, side girders and floors, where constructed of higher-strength materials, are generally to comply with the requirements of 3-2-4/1.3, 3-2-4/1.5 or 3-2-4/1.7, but may be modified as permitted by the following equation:

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

where

t_{hts}, t_{ms} and C are defined in 3-2-4/9.3.

Q is as defined in 3-2-1/7.5.

11 Machinery Space

11.1 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. (See also 4-3-1/21.)

11.3 Engine Foundations

11.3.1 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.

11.3.2 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.

11.5 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.

11.7 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 Side Frames, Webs, and Stringers

1 General

1.1 Basic Considerations

Frames or webs and stringers are not to have less strength than is required for watertight bulkhead stiffeners, or girders, in the same location in association with heads to the bulkhead deck. In way of deep tanks, frames or webs and stringers are not to have less strength than is required for stiffeners or girders on deep-tank bulkheads. The calculated section modulus is based upon the intact sections being used. Where a hole is cut in the flange of any member or a large opening is made in the web of the member, the net section is to be used in determining the section modulus of the member in association with the plating to which it is attached.

1.3 End Connections

At the ends of unbracketed frames, both the web and the flange are to be welded to the supporting member. At bracketed end connections, continuity of strength is to be maintained at the connection to the bracket and at the connection of the bracket to the supporting member. Welding is to be in accordance with 3-2-16/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 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.

3 Longitudinal Side Frames

3.1 Section Modulus

The section modulus, SM, of each longitudinal side frame above the chine or upper turn of bilge is to be not 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 frame to the freeboard deck at side, but not less than $0.02L + 0.46$ m ($0.02L + 1.5$ ft)

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 bulkheads, the length, ℓ, may be measured as permitted therein.

5 Transverse Side Frames

5.1 Section Modulus

The section modulus, *SM*, of each transverse side frame 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 1, 3-2-5/Figure 2 and 3-2-5/Figure 3.

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

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

where

c = 0.915 for frames having no tween decks above

= $0.90 + 5.8/\ell^3$ $(0.90 + 205/\ell^3)$ 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 $bh_1/33$ ($bh_1/100$).

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

h_1 = 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), h_1 is to be adjusted accordingly.

FIGURE 1
Transverse Side Frame

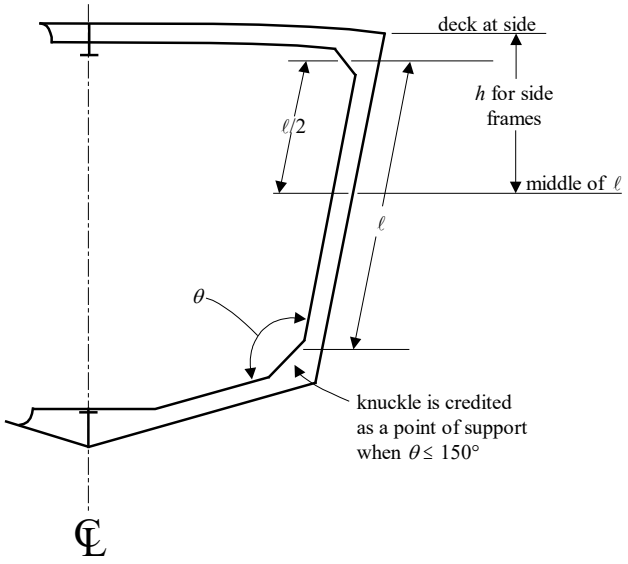


FIGURE 2
Transverse Side Frame

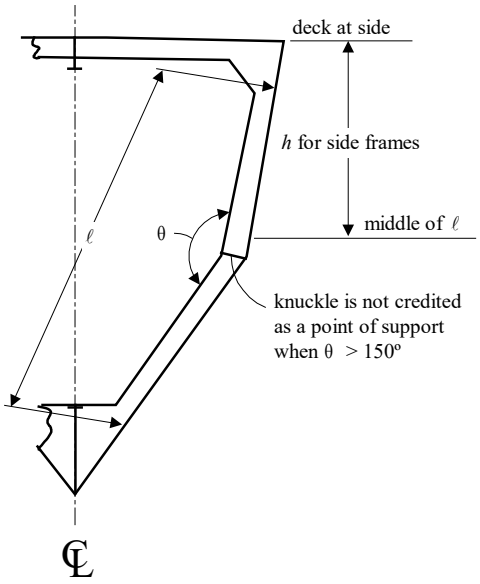
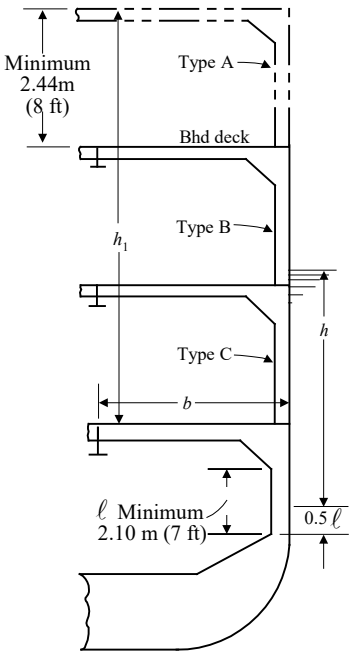


FIGURE 3
Hold and Tween Deck Frames



5.3 Tween-deck Frames

The section modulus, SM, of each transverse side frame 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 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 = 0.90

h = $0.032L$ – 0.68 m ($0.032L$ – 2.23 ft) type A frame

= $0.049L$ – 0.81 m ($0.049L$ – 2.66 ft) type B frame

= $0.052L$ – 0.13 m ($0.052L$ – 0.43 ft) type C frame

= in no case less than the vertical distance, in m (ft), from the mid-length of the frame to the freeboard deck, but not less than $0.02L$ + 0.46 m ($0.02L$ + 1.5 ft)

s = frame spacing, in m (ft)

ℓ = tween deck height or unsupported length along frame, whichever is greater, in m (ft), not to be taken less than 2.13 m (7.0 ft). For frame types, see 3-2-5/Figure 3. Forward of $0.125L$, frames above the bulkhead or freeboard deck are to be type B frames.

Longitudinal tween deck frames are to meet the requirements of 3-2-5/3. The section modulus of each longitudinal tween deck frame forward of $0.125L$ from the stem is to be not less than required by 3-2-5/5.1 for transverse frames in the same location, taking ℓ as the unsupported span along the frame length.

5.5 Peak Frames

5.5.1 General

For vessels 61 m (200 ft) or greater in length, peak frames are to be efficiently connected to deep floors of not less thickness than that obtained from 3-2-4/1.7 for floors in engine spaces. The floors are to extend as high as necessary to give lateral stiffness to the structure and are to be properly stiffened on their upper edges. Care is to be taken in arranging the framing and floors to assure no wide areas of unsupported plating adjacent to the stem. Breast hooks are to be arranged at rectangular intervals at and between the stringers above and below the waterline. In general, the frames above the lowest deck are to be as required by 3-2-5/5, but in vessels having large flare with unusually long frames, stringers and webs above the lowest deck or suitably increased frames may be required.

5.5.2 Section Modulus

For vessels 61 m (200 ft) or greater in length, the section modulus of each peak frame is to be not 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 = 1.13 for forepeak frames

= 0.90 for aftpeak frames

h = $0.110L$ – 1.990 m ($0.110L$ – 6.53 ft) for forepeak frames

= $0.062L$ – 1.122 m ($0.062L$ – 3.68 ft) for aftpeak frames

s = frame spacing, in m (ft)

ℓ = straight line unsupported span, in m (ft), not to be taken less than 2.1 m (7.0 ft)

L = length as defined in 3-1-1/3, but is not to be taken less than 30 m (98.5 ft)

7 Side Web Frames

7.1 Section Modulus

The section modulus, SM, of each side web frame supporting longitudinal framing or shell stringers above the chine or upper turn of bilge, in association with the plating to which the web frame is attached, is not to be 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 = 0.915 aft of the forepeak

= 1.13 in the forepeak of vessel 61 m (200 ft) or greater in length.

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

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 0.5ℓ, whichever is greater, plus $bh_1/45K$ ($bh_1/150K$).

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

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 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), h_1 is to be adjusted accordingly.

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

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

7.3 Tween-deck Web Frames

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

7.5 Proportions *(2018)*

The depth of each web frame is to be not less than 125ℓ mm (1.5ℓ in.) or, unless effective compensation is provided for cutouts, 2.5 times the cutout for frame or longitudinal if greater. The thickness of the web of web frame or stringer is to be not less than 0.01 times the depth plus 3 mm (0.12 in.) but need not exceed 11.5 mm (0.46 in.), ℓ is as defined in 3-2-5/7.1.

7.7 Tripping Brackets and Stiffeners

7.7.1 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.

7.7.2 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.

9 Vessel Side Frames Subject to Impact Loads *(2014)*

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 from 3-2-5/7.1. All side structural members in the impact region are to have end connections with brackets and adequate double continuous fillet welds at the end. Scallop welds are not to be used in connections between side frames and shell plating.

11 Side Stringers

11.1 Section Modulus

The section modulus, SM, of each side stringer in association with the plating to which the side stringer 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

= 1.13 in the forepeak of vessel 61 m (200 ft) or greater in length.

h = vertical distance, in m (ft), from the middle of s to the freeboard deck at side, but not less than $0.02L + 0.46$ m ($0.02L + 1.5$ ft).

= for stringers above the lowest deck or at a similar height in relation to the design draft, not less than given in 3-2-5/5.3 appropriate to the tween deck location.

= for stringers in the peaks of vessels 61 m (200 ft) or greater in length, not less than given in 3-2-5/5.5.

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 in accordance with 3-1-2/5.5 and are supported by transverse bulkheads, the length, ℓ, may be measured as permitted therein.

11.3 Proportions

Side 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. In general, the depth is not to be less than 2.5 times the depth of the slots, or the slots are to be fitted with filler plates. The thickness of each stringer is to be not less than $0.014L + 7.2$ mm ($0.00017L + 0.28$ in.) where L is as defined in 3-1-1/3.

11.5 Tripping Brackets and Stiffeners

11.5.1 Stiffeners

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

11.5.2 Tripping Brackets

The arrangements of tripping brackets are to be in accordance with 3-2-5/7.7.2.

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 6 Beams, Deck Girders, Deck Transverses, and Pillars

1 Beams

1.1 Spacing

Beams may be fitted either transversely or longitudinally. Transverse beams, where provided, are to be fitted at each transverse side frame at the tops of tanks, tunnel tops, and bulkhead recesses. Elsewhere, these beams are not to be more than two frame spaces apart and those in different tiers are to be fitted on the same frames.

1.3 Section Modulus

The section modulus, SM, of each transverse or longitudinal beam, in association with the plating to which it is attached, is not to be less than that obtained from the following equations:

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

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

where

c	=	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

k = $SM_R Y/I_A$

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

Y = distance, in m (ft), from the neutral axis to the deck being considered, always taken as 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 = beam spacing, in m (ft)

ℓ = unsupported span, in m (ft). At the tops of tanks and bulkhead recesses, the maximum span permissible between supports is 4.57 m (15 ft). Where brackets are fitted in accordance with 3-1-2/5.5, the length, ℓ, may be measured as permitted therein.

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

= *for a deep tank top,* is the greatest of the following: two-thirds of the distance from the top of the tank to the top of the overflow, or

- two-thirds of the distance from the top of the tank to the bulkhead deck or freeboard deck, or
- the height to the load line, or
- $0.01L + 0.15$ m ($0.01L + 0.5$ ft)

= *for a lower deck on which cargo or stores are carried,* the tween-deck height at side. Where the cargo weights differ from 7010 N/m^3 (715 kgf/m^3, 45 lbf/ft^3), h is to be proportionately adjusted.

= *for an exposed deck on which cargo is carried,* 3.66 m (12 ft). Where it is intended to carry deck cargoes in excess of 25850 N/m^2 (2636 kgf/m^2, 540 lbf/ft^2), this head is to be increased in proportion to the added loads which will be imposed on the structure.

Elsewhere, the value of h is obtained from the appropriate equation below, where L = length of the vessel, in m (ft), as defined in 3-1-1/3.

1.3.1 Exposed Freeboard Deck Having no Deck Below

$h = 0.02L + 0.76$ m

$h = 0.02L + 2.5$ ft

1.3.2 Exposed Freeboard Deck Having a Deck Below, Forecastle Deck, Superstructure Deck Forward of Amidships 0.5L

$h = 0.02L + 0.46$ m

$h = 0.02L + 1.5$ ft

1.3.3 Freeboard Deck within Superstructure, any Deck Below Freeboard Deck, Superstructure Deck Between 0.25L Forward of and 0.30L Aft of Amidships

$h = 0.01L + 0.61$ m

$h = 0.01L + 2.0$ ft

1.3.4 All Other First Tier Above Freeboard Deck Locations

$h = 0.01L + 0.30$ m

$h = 0.01L + 1.0$ ft

1.3.5 Second Tier Above Freeboard Deck; Deckhouse Top or Short Superstructure*

$h = 0.01L + 0.15$ m

$h = 0.01L + 0.5$ ft

* Where used only as weather covering, may be used as 3-2-6/1.3.6, but L need not be taken greater than 45.70 m (150 ft).

1.3.6 Third Tier Above Freeboard Deck Deckhouse Top or Short Superstructure*

$h = 0.01L$ m

$h = 0.01L$ ft

* Where used only as weather covering, may be used as 3-2-6/1.3.6, but L need not be taken greater than 45.70 m (150 ft).

1.5 Special Heavy Beams

Special reinforced beams are to be fitted under concentrated loads such as the ends of deckhouses, masts, winches, auxiliary machinery, etc. Beams at the heads of web frames are to be suitably increased in strength and stiffness.

1.6 Deck Fittings Support Structures *(1 July 2018)*

1.6.1 General

The strength of supporting hull structures in way of shipboard fittings used for mooring operations 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:

1.6.1(a) Normal Towing. Normal towing is the towing operations necessary for maneuvering in ports and sheltered waters associated with the normal operations of the vessel.

1.6.1(b) Other Towing. 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 for mooring and/or towing, winches and capstans are to be located on stiffeners and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the mooring and/or towing load. The same attention is to be paid to recessed bitts, if fitted, of their structural arrangements and strength of supporting structures. 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.

1.6.2 Design Loads

Unless greater safe working load (SWL) and/or safe towing load (TOW) of shipboard fittings is specified by the applicant [see 3-2-6/1.6.2(c)], the minimum design load to be used is the greater values obtained from 3-2-6/1.6.2(a) or 3-2-6/1.6.2(b), whichever is applicable:

1.6.2(a) Mooring Operations. The minimum design load for shipboard fittings for mooring operations is the applicable value obtained from 3-2-6/1.6.2(a)i) or 3-2-6/1.6.2(a)ii):

i) *Mooring Line Force.* The minimum design load applied to supporting hull structures for shipboard fittings is to be 1.15 times the minimum breaking strength of the mooring line according to 3-5-1/17.3. See Notes 1 and 2.

ii) *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 minimum breaking strength of the mooring line according to 3-5-1/17.3. See Notes 1 and 2. For supporting hull structures of capstans, 1.25 times the maximum hauling-in force is to be taken as 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 loading manual is to be taken into account for selection of mooring lines and the loads applied to shipboard fittings and supporting hull structure.

2 The increase of the minimum breaking strength for synthetic ropes according to 3-5-1/9.4 needs not to be taken into account for the loads applied to shipboard fittings and supporting hull structure.

1.6.2(b) Towing Operations. The minimum design load for shipboard fittings for towing operations is the applicable value obtained from 3-2-6/1.6.2(b)i) through 3-2-6/1.6.2(b)iii), as applicable.

i) *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.

ii) *Other Towing Service.* The minimum breaking strength of the tow line according to the 3-5-1/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)

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

Notes:

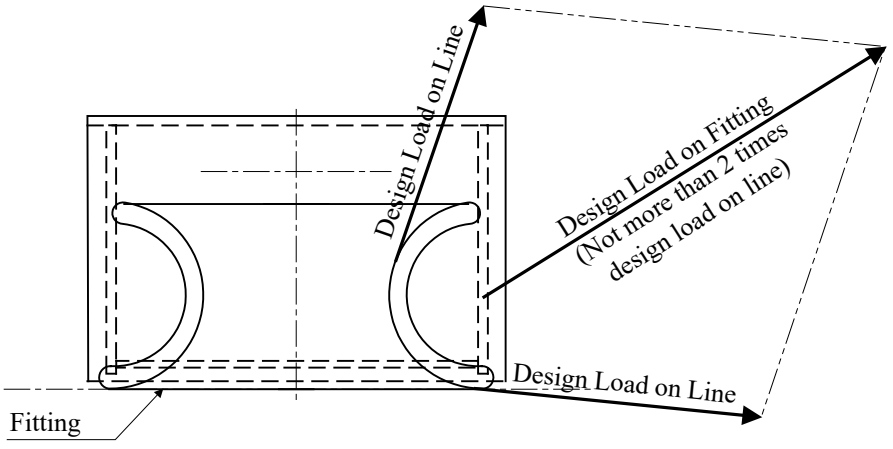
1 Side projected area including that of deck cargoes as given by the loading manual is to be taken into account for selection of towing lines and the loads applied to shipboard fittings and supporting hull structure.

2 The increase of the minimum breaking strength for synthetic ropes according to 3-5-1/17.7 needs not to be taken into account for the loads applied to shipboard fittings and supporting hull structure.

iii) For fittings intended to be used for, both, normal and other towing operations, the greater of the design loads according to 3-2-6/1.6.2(b)i) and 3-2-6/1.6.2(b)ii).

1.6.2(c) Application of Design Loads. 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 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 *(2007)*



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 3-2-6/1.6.2 and 3-5-1/19.5.1.

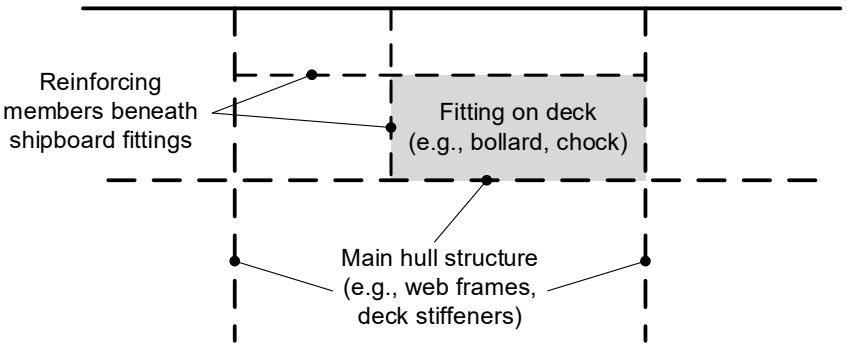
When a safe towing load, TOW, greater than that determined according to 3-5-1/19.5.2 is requested by the applicant, the design load is to be increased in accordance with the appropriate TOW/design load relationship given by 3-2-6/1.6.2 and 3-5-1/19.5.2.

1.6.3 Supporting Structures

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

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 3-2-6/Figure 2 for a sample arrangement. Proper alignment of fitting and supporting hull structure is to be verified.

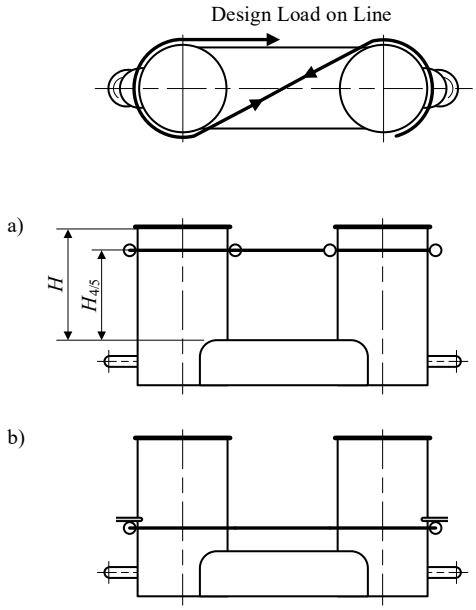
FIGURE 2
Sample Arrangement *(1 July 2018)*



1.6.3(b) Line Forces. 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.

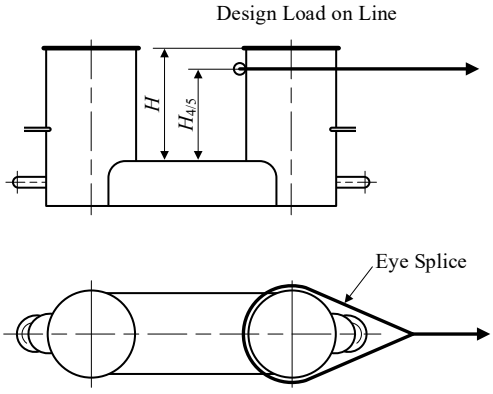
i) *Mooring Operations.* The acting point of the mooring force on shipboard fittings is to be taken at the attachment point of a mooring line or at a change in its direction. For bollards and bitts the attachment point of the mooring line is to be taken $^4/_5$ of the tube height above the base, see a) in 3-2-6/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 3-2-6/Figure 3 below.

FIGURE 3
Attachment Point of Mooring Line *(1 July 2018)*



ii) *Towing Operations.* 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 3-2-6/Figure 4 below.

FIGURE 4
Attachment Point of Towing Line *(1 July 2018)*



1.6.3(c) Allowable Stresses. Allowable stresses under the design load conditions as specified in 3-2-6/1.6.2 are as follows:

i) *For strength assessment with beam theory or grillage analysis:*

- 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.

ii) For strength assessment with finite element analysis:

- Equivalent stress: 100% of the specified minimum yield point of the material.

For strength calculations by means of finite elements, the geometry is to be idealized 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. 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.

1.6.4 Scantlings *(1 July 2019)*

1.6.4(a) Net Scantlings. The net minimum scantlings of the supporting hull structure are to comply with the requirements given in 3-2-6/1.6.3. The net thicknesses, t_{net}, are the member thicknesses necessary to obtain the above required minimum net scantlings. The required gross thicknesses are obtained by adding the total corrosion additions, t_c, given in 3-2-6/1.6.4(b) and, where applicable, the wear allowance, t_w, given in 3-2-6/1.6.4(c) to t_{net}.

1.6.4(b) Corrosion Addition. The 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.).

1.6.4(c) Wear Allowance. In addition to the corrosion addition given in 3-2-6/1.6.4(b) 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.

1.7 Container Loading

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

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

$$SM = M/f$$

where

M = maximum bending moment due to maximum static container loading in kN-cm (kgf-cm, Ltf-in)

f = permissible maximum bending stress, as given in 3-2-6/Table 1.

In determining the maximum bending moment, members may be considered fixed-ended, provided the member is continuous over the adjacent spans or is effectively attached to a bulkhead stiffener or frame or has suitable end connections. 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 3-2-6/1.3, 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 3-2-1/1.3.1 through 3-2-1/1.3.6, is to be added to the above required section modulus.

TABLE 1
Values of f

	kN/cm^2	kgf/cm^2	Ltf/in^2
Effective longitudinal members	12.36	1262	8
Transverse members and longitudinal members inside the line of openings	13.90	1420	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 that obtained from the following equation:

$$A = F/q$$

where

F = shearing force at the point under consideration, kN (kgf, Ltf)

q = allowable average shear stress in the web, not to exceed 10.35 kN/cm^2 (1057 kgf/cm^2, 6.7 Ltf/in^2)

3 Deck Girders and Deck Transverses

3.1 General

Girders and transverses are to be fitted as required to support beams and longitudinals. Additional girders are to be fitted as required under masts, king posts, deck machinery or other heavy concentrated loads.

3.3 Deck Girders and Transverses Clear of Tanks

Section modulus, *SM,* of each longitudinal deck girder and deck transverse clear of tanks is not to be less than that obtained from the following equation:

$$SM = 7.8cbh\ell^2 \quad cm^3$$

$$SM = 0.0041cbh\ell^2 \quad in^3$$

where

c = 0.60

b = mean breadth of area of deck supported (for girders), or spacing of deck transverses (for transverses), in m (ft)

h = height, in m (ft), as required by 3-2-6/1.3 for the beams supported

ℓ = unsupported span, in m (ft). Where brackets are fitted at bulkhead supports, in accordance with 3-1-2/5.5, the length, ℓ, may be measured as permitted therein.

3.5 Proportions

The minimum depth of a deck girder or transverse supporting member is to be 58.3ℓ mm (0.7ℓ in.), where ℓ is as defined in 3-2-6/3.3; the depth is also not to be less than 2.5 times the cutout for the beam or longitudinal unless effective compensation is provided for the cutouts. The minimum thickness is to be 1 mm per 100 millimeters (0.01 in. per inch) of depth plus 4 mm (0.16 in.).

3.7 Tripping Brackets and Stiffeners

Tripping brackets are to be fitted on girders and transverses at a spacing of about 3 m (10 ft). Stiffeners are to be fitted as may be required.

3.9 Deck Girders and Transverses in Tanks

The requirements for deck girders or transverse supporting members in tanks may be obtained in the same manner as given in 3-2-6/3.3, 3-2-6/3.5 and 3-2-6/3.7, except that c is equal to 0.915. The minimum depth of a girder or transverse supporting member is to be 83.3ℓ mm (1.0ℓ in.), where ℓ is as defined in 3-2-6/3.3.

3.11 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 (3-2-6/3.3 and 3-2-6/3.9). Such girders along lower deck hatches under trunks in which covers are omitted are to be increased in proportion to the extra load which may be required to be carried due to the loading up into the trunks. The structure on which the hatch covers are seated is to be effectively supported.

Where deep coamings are fitted above decks, such as at weather decks, the girder below deck may be modified so as to obtain a section modulus in cm^3 (in^3), when taken in conjunction with the coaming up to and including the horizontal coaming stiffener, of not less than 35% more than the required girder value, as derived from 3-2-6/3.3. Where hatch side girders are not continuous under deck beyond the hatchways to the bulkheads, brackets extending for at least two frame spaces beyond the ends of the hatchways are to be fitted.

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

3.13 Container Loading

Where it is intended to carry containers, the structure is to comply with 3-2-6/1.7.

3.15 End Attachments

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

3.17 Hatch-end Beams

Each hatch-end beam, similar to that shown in 3-2-6/Figure 5, which is supported by a centerline pillar without a pillar at the corner of the hatchway, is to have a section modulus, SM, not less than that obtained from the following equations:

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

$$SM = K(AB + CD)h\ell \quad cm^3$$

$$SM = 0.000527K(AB + CD)h\ell \quad in^3$$

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

$$SM = KABh\ell \quad cm^3$$

$$SM = 0.000527KABh\ell \quad in^3$$

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 3-2-6/1.3, 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 $F/N \le 0.6$

= $4.28 - 2.17\ (F/N)$ when $F/N > 0.6$

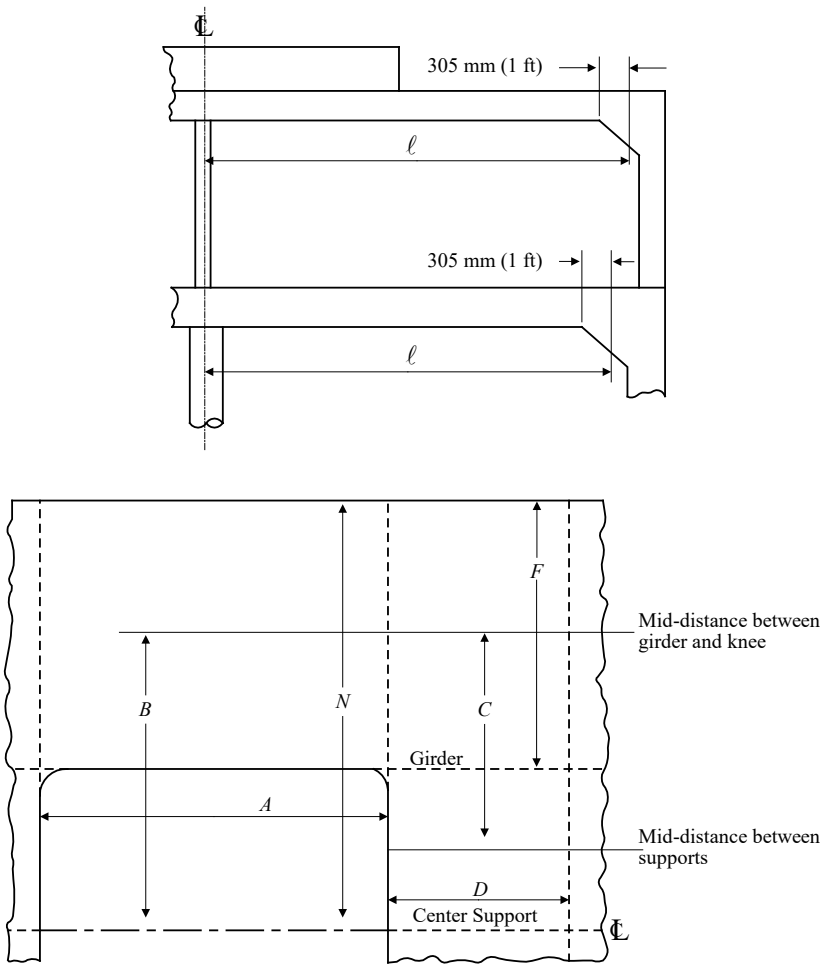
N = one-half the breadth of the vessel in way of the hatch-end beam

F = distance from the side of the vessel to the hatch-side girder

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

Brackets at the end of hatch-end beams are to be generally as described in 3-1-2/5.5. 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 5
Hatch-end Beams



5 Stanchions and Pillars

5.1 General

Supports under pillars are to be sufficient strength to distribute the loads effectively. Tween-deck pillars are to be arranged directly above those below, or effective means are to be provided for transmitting their loads to supports below. Tripping brackets are to be fitted on members in way of pillars, both when the pillar is over and under the member.

5.3 Permissible Load *(2019)*

The permissible load a pillar can carry is to be equal to or greater than the pillar load, W, as determined in 3-2-6/5.5. The permissible load may be obtained from the following equation:

$$W_a = (k - n\ell/r)A$$

where

W_a	=	load, in kN (tf, Ltf)	
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
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
ℓ	=	unsupported length of the pillar, in m (ft)	
r	=	least radius of gyration of pillar, in cm (in.)	
A	=	area of pillar, in cm^2 (in^2)	

The foregoing equation applies where ℓ/r, with ℓ and r in the same units, is less than 130.

5.5 Calculated Load

The load on a pillar is to be obtained from the following equation:

$$W = nbhs$$

where

W	=	load, in kN (tf, Ltf)
n	=	7.04 (0.715, 0.02)
b	=	mean breadth, in m (ft), of area supported
h	=	height, in m (ft), above the deck supported, as defined below
s	=	mean length, in m (ft), of area supported

For a pillar below an exposed deck on which cargo is carried, h is the distance from the deck supported to a point 3.66 m (12 ft) above the exposed deck. Where it is intended to carry deck cargoes in excess of 2636 kilograms per square meter (540 pounds per square foot), this head is to be increased in proportion to the added loads which will be imposed on the structure.

For a pillar below the freeboard deck, h is to be measured to a point not less than $0.02L + 0.76$ m ($0.02L + 2.5$ ft) above the freeboard deck.

For a pillar below the superstructure deck, h is to be measured to a point not less than $0.02L + 0.46$ m ($0.02L + 1.5$ ft) above the superstructure deck.

The height, h, for any pillar is not to be less than the given height in 3-2-6/1.3 for the beams at the top of the pillar plus the sum of the heights given in the same paragraphs for the beams of all complete cargo decks and one-half the heights given for all partial superstructure decks above.

L is the length of vessel, in m (ft), as defined in 3-1-1/3.

5.6 Additional Pillars *(2019)*

Additional pillars which are not directly in line with those above, or which are not on the lines of 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 the use with the equation proportionate to the actual loads transmitted to the pillars through the systems of girders with modifications to the design value of h as described in 3-2-6/5.5.

5.7 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:

$$W = nbhs$$

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 3-2-6/1.3, 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)

5.9 Bulkheads

Bulkheads supporting girders or bulkheads fitted in lieu of girders are to be stiffened to provide supports not less effective than required for pillars.

5.11 Attachments

Wide-spaced tubular or solid pillars are to bear solidly at head and heel and are to be attached by welding, 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 specially developed to provide sufficient welding to withstand the tension load.

7 Higher-strength Materials

7.1 General

In general, applications of higher-strength materials for deck beams, girders and transverses 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. Longitudinal members are to be of essentially the same material as the plating they support.

7.3 Beams, Girders and Transverses of Higher-strength Materials

Each beam, girder and transverse of higher-strength material, in association with the higher-strength plating to which it is attached, is 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 3-2-1/7.5

PART
3

CHAPTER 2 **Hull Structures and Arrangements**

SECTION 7 **Watertight Bulkheads and Doors**

1 General

All vessels having lengths, L, equal to or exceeding 15 m (50 ft) are to be provided with watertight bulkheads in accordance with this section. The plans submitted are to clearly show the location and extent of each watertight bulkhead. Watertight bulkheads constructed in accordance with the Rules will be recorded in the *Record* as **WT** (watertight), the symbols being prefixed in each case by the number of such bulkheads.

1.1 Openings and Penetrations *(2006)*

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 deck are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity. Relaxation in the watertightness of openings above the freeboard deck may be considered, provided it is demonstrated that any progressive flooding can be easily controlled and that the safety of the vessel is not impaired.

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

3 Arrangement of Watertight Bulkheads

3.1 Collision Bulkheads

3.1.1 General *(2019)*

A collision bulkhead is to be fitted on all vessels. It is to be intact, that is, without openings, except as permitted in 4-4-1/9.11. It is to extend 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 superstructure deck. The extension need not be fitted directly over the bulkheads below, provided the location of the extension meets the following requirements and the part of the deck which forms the step is made effectively weathertight.

On vessels with bow-doors, that part of their sloping loading ramps that form part of the extension of a collision bulkhead and are more than 2.3 m (7.5 ft) above the freeboard deck may extend forward of the limit below.

Collision bulkhead requirements for passenger vessels are as indicated in Part 5C, Chapter 7 of the *Steel Vessel Rules*.

3.1.2 Location *(1 July 2010)*

The collision bulkhead is to be located at any point not less than $0.05L_f$ abaft the reference point. At no point on vessels having 500 or more gross tonnage, except as specially permitted, is it to be further than $0.08L_f$ or $0.05L_f$ + 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_f, except that in the case of vessels having any part of the underwater body, such as the bulbous bow, extending forward of the forward end of L_f, the required distances are to be measured from a reference point located a distance forward of the forward end of L_f. This distance, x, is the lesser of the following (see 3-2-7/Figure 1):

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

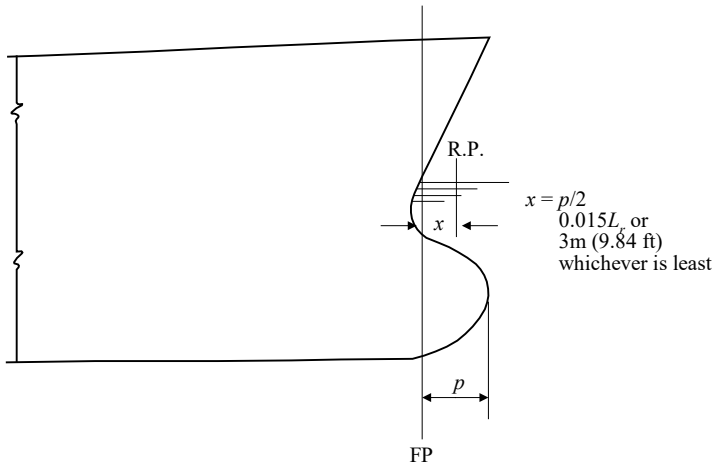
ii) $0.015L_f$

iii) 3 m (9.84 ft)

where L_f is as defined in 3-1-1/3.3.

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

FIGURE 1
Reference Point of Vessels with Bulbous Bow



3.3 Engine Room

The engine room is to be enclosed by watertight bulkheads extending to the freeboard deck.

3.5 Chain Lockers *(2012)*

For vessels with freeboard length, L_f, (as defined in 3-1-1/3.3) greater than 24 meters (79 feet), chain lockers and chain pipes are to be made watertight up to the weather deck. The arrangements are to be such that accidental flooding of the chain locker cannot result in damage to auxiliaries or equipment necessary for the proper operation of the vessel nor in successive flooding into other spaces. Bulkheads between separate chain lockers not forming a part of subdivision bulkhead (* see 3-2-7/Figure 1A below), or bulkheads which form a common boundary of chain lockers (see 3-2-7/Figure 1B below), need not be watertight.

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

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

For closure of chain pipes, see 3-2-12/23.7.

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

FIGURE 1A *(2007)*

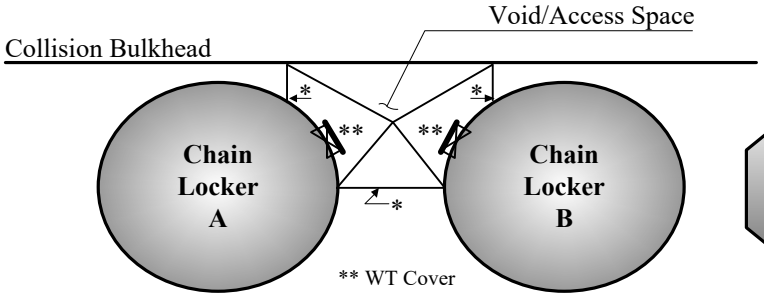
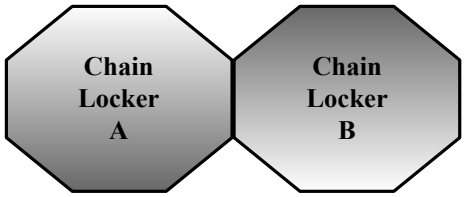


FIGURE 1B *(2007)*



3.7 Hold Bulkheads *(1 July 1998)*

In addition to the above required bulkheads, for vessels of applicable type and size, the number and arrangement of hold bulkheads are to satisfy the subdivision and damage requirements in 3-3-1/3.3. Review procedures for this requirement are indicated in 3-3-1/5.

5 Construction of Watertight Bulkheads

5.1 Plating *(1998)*

Watertight bulkhead plating thickness is to be 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 = $(3.075\sqrt{\alpha} - 2.077)/(\alpha + 0.272)$ $(1 \le \alpha \le 2)$

= 1.0 $(\alpha > 2)$

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

q = $235/Y$ N/mm^2 ($24/Y$ kgf/mm^2, $34{,}000/Y$ psi)

Y = specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, psi), as defined in 2-1-1/13, for the higher strength material or 72% of the specified minimum tensile strength, whichever is less

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

- For passenger vessels, h is to be taken as not less than the distance to the margin line.
- For cargo vessels, h is to be not less than the distance to the bulkhead deck at center unless a deck lower than the uppermost continuous deck is designated as the freeboard deck, as allowed in 3-1-1/13.1, in which case, h is to be not less than the distance to the designated freeboard deck at center.

c = 254 (460) for collision bulkhead

= 290 (525) for other watertight bulkheads

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 3-2-7/5.3.

5.3 Stiffeners *(2016)*

The section modulus, SM of each bulkhead stiffener, in association with the plating to which it is attached, is to be 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 = 0.30 for a stiffener with effective brackets at both ends of its span. An effective bracket for the application of this value of c is to have scantlings not less than shown in 3-1-2/Table 5 and is to extend onto the stiffener for a distance at least one-eighth of the length, ℓ, of the stiffener.

= 0.43 for a stiffener with an effective bracket at one end and a clip connection or horizontal girder at the other end. An effective bracket for the application of this value of c is to have scantlings not less than shown in 3-1-2/Table 5 and is to extend onto the stiffener for a distance at least one-eighth of the length, ℓ, of the stiffener.

= 0.56 for a stiffener with clip connections at both ends or a clip connection at one end and a horizontal girder at the other end.

= 0.60 for a stiffener between horizontal girders or for a stiffener with no end attachments.

h = distance from the middle of ℓ to the deepest equilibrium waterline in the one compartment damaged condition, in m (ft)

- For passenger vessels, h is to be taken as not less than the distance to the margin line.
- For cargo vessels, h is to be taken as not less than the distance to the bulkhead deck at center unless a deck lower than the uppermost continuous deck is designated as the freeboard deck, as allowed in 3-1-1/13.1, in which case, h is to be not less than the distance to the designated freeboard deck at center.
- For all vessels, where this distance is less than 6.10 m (20 ft), h is to be taken as 0.8 times the distance plus 1.22 m (4 ft).

s = spacing of stiffeners, in m (ft)

ℓ = distance, in m (ft), 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 vessels under 46 meters (150 ft) 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.

The section modulus of stiffeners on collision bulkheads is to be increased by 25% over the section modulus of stiffeners on ordinary watertight bulkheads.

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:

$$SM_{hs} = Q(SM) \quad \text{cm}^3 \ (\text{in}^3)$$

where

SM = stiffener section modulus as defined in the above

Q = as defined in 3-2-1/7.5

5.5 Girders and Webs *(1998)*

Each horizontal girder or vertical web supporting bulkhead stiffeners is to have a section modulus, SM, not less than that 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 = 1.0

h = vertical distance, in m (ft), to the deepest equilibrium waterline in the one compartment damaged condition from the middle of s in the case of a horizontal girder or from the middle of ℓ in the case of a vertical web.

- For passenger vessels, h is to be taken as not less than the distance to the margin line.
- For cargo vessels, h is to be not less than the distance to the bulkhead deck at center unless a deck lower than the uppermost continuous deck is designated as the freeboard deck, as allowed in 3-1-1/13.1, in which case, h is to be not less than the distance to the designated freeboard deck at center.
- For all vessels, where this distance is less than 6.10 m (20 ft), h is to be taken as 0.8 times the distance plus 1.22 m (4 ft).

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

ℓ = unsupported span of girder or web, in m (ft). Where brackets are fitted in accordance with 3-1-2/5.5, the length, ℓ, may be measured as permitted therein.

The required section modulus of girders or webs on collision bulkheads are to be increased by 25% over the required section modulus of girders or webs on ordinary bulkheads. The depth of a girder or web is not to be less than twice the depth of the cutout unless effective compensation is provided for stiffener cutouts. Tripping brackets are to be fitted at intervals of about 3 m (10 ft), and stiffeners are to be fitted as may be required.

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

5.7 Corrugated Bulkheads

5.7.1 Plating

The plating of corrugated bulkheads is to be of the thickness required by 3-2-7/5.1 with the following modification. The spacing to be used is the greater of dimensions *a* or *c*, as indicated in 3-2-7/Figure 2. The angle ϕ is to be 45 degrees or more.

5.7.2 Stiffeners

The section modulus, *SM*, for a corrugated bulkhead is to be not 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

ℓ = distance between supporting members, in m (ft)

s = $a + b$, where a and b are as defined in 3-2-7/Figure 2, in m (ft)

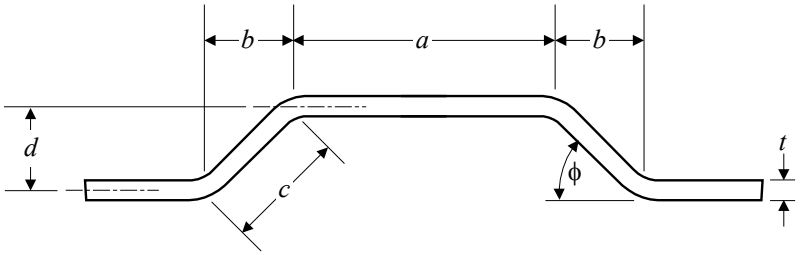
c = 0.56

h = as defined in 3-2-7/5.3

The developed section modulus, *SM,* may be obtained from the following equation, where *a*, *t*, and *d* are as indicated in 3-2-7/Figure 2, in cm (in.).

$$SM = td^2/6 + (adt/2) \quad \text{cm}^3 \ (\text{in}^3)$$

FIGURE 2
Corrugated Bulkhead



5.7.3 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 corrugation 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 the bulkhead plating or penetration welds of equal strength (3-2-7/Figure 3). See also 3-2-16/3.

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.

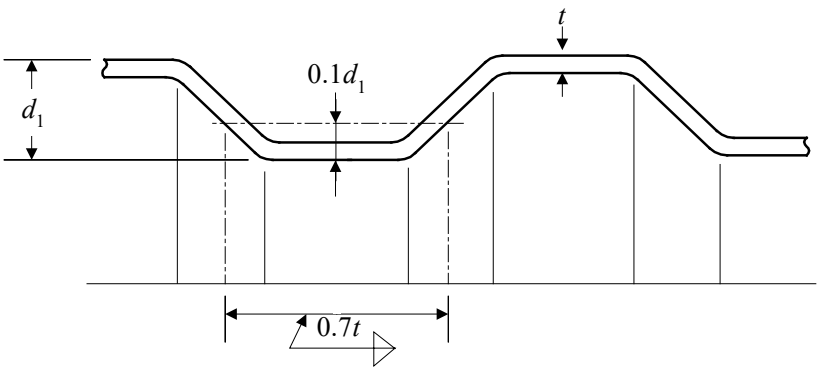
ii) The corrugation flanges are to be in line with the supporting floors. Scallops and cut-outs in the supporting members aligned with corrugation flanges and webs are to be closed by insert collar plates. Alternatives to closing the scallops and cut-outs may be accepted provided that adequate strength 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 3-2-18.

FIGURE 3
Corrugated Bulkhead End Connections



7 Watertight Doors

7.1 Vessels Requiring Subdivision and Damage Stability

7.1.1 Doors Used While at Sea *(2002)*

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

7.1.2 Access Doors Normally Closed at Sea

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

7.1.3 Doors or Ramps Dividing Large Cargo Spaces

Watertight doors or ramps of satisfactory construction may be fitted to internally 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 they be closed by the shipboard personnel before the voyage commences and kept closed during navigation and that the time of opening such doors or ramps in port and of closing them before the vessel leaves port is to be entered in the log book.

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

7.1.4 Other Openings Closed at Sea

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

7.3 Other Vessels

Watertight doors may be installed in all watertight bulkheads, except collision bulkheads.

7.5 Construction

Watertight doors are to be of ample strength for the water pressure to which they may be subjected. 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 and are to be tested at the maker's works.

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 Testing *(2014)*

Watertight doors are to be tested for operation at the manufacturer's plant. Watertightness of doors which become immersed by an equilibrium or intermediate waterplane at any stage of assumed flooding is to be confirmed by prototype hydrostatic testing 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:

i) The bulkhead deck or freeboard deck, as applicable, or

ii) The most unfavorable damage waterplane, if that be greater

Tests are to be carried out in the presence of the Surveyor and a test certificate is to be issued.

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 after installation onboard.

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 8 Deep Tanks

1 General Arrangement

The arrangement of all deep tanks, their intended service, and the heights of the overflow pipes are to be clearly indicated on the drawings submitted for approval. Tanks forward of the collision bulkhead are not to be arranged for the carriage of oil or other flammable or combustible substances.

3 Construction

Boundary bulkheads and tight divisions of all deep tanks are to be constructed in accordance with the requirements of this section where they exceed those of Section 3-2-7. Where the specific gravity of the liquid exceeds 1.05, the design head, h, in this section is to be increased by the ratio of the specific gravity of 1.05.

5 Construction of Deep-tank Bulkheads

5.1 Plating *(2017)*

The minimum thickness of deep-tank boundary bulkheads and tight divisions is to be obtained from the following equation:

$t = (sk\sqrt{qh}\ /254) + 2.5$ mm but not less than 6.5 mm or $s/150 + 2.5$ mm, whichever is greater

$t = (sk\sqrt{qh}\ /460) + 0.10$ in. but not less than 0.25 in. or $s/150 + 0.10$ in., whichever is greater

where

t = thickness, in mm (in.)

s = stiffener spacing, in mm (in.)

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

= 1.0 $(\alpha > 2)$

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

q = $235/Y$ N/mm^2 ($24/Y$ kgf/mm^2, $34{,}000/Y$ psi)

Y = as defined in 3-2-7/5.1

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

- A point located at two-thirds of the distance to the bulkhead or freeboard deck, or
- A point located at two-thirds the distance from the top of the tank to the top of the overflow, or
- The load line, or
- A point located above the top of the tank, not less than the greater of the following:
- $0.01L + 0.15$ 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, as obtained below:

$$h_1 = \rho h_t + h_a \text{ m (ft)}$$

$$h_0 = (2/3)(\rho h_s + 9.95P_s) \text{ m} \qquad (P_s \text{ in bar})$$

$$= (2/3)(\rho h_s + 9.75P_s) \text{ m} \qquad (P_s \text{ in kgf/cm}^2)$$

$$= (2/3)(\rho h_s + 2.25P_s) \text{ ft} \qquad (P_s \text{ in lbf/in}^2)$$

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 3-2-8/5 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)

5.3 Stiffeners

The section modulus, SM, of each deep-tank stiffener, in association with the plating to which it is attached, is not to be less than that obtained from the following equation:

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

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

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 than shown in 3-1-2/Table 2 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 an effective bracket attachment at one end and a clip connection or horizontal girder at the other end. An effective bracket for the application of this value of c is to have scantlings not less than shown in 3-1-2/Table 2 and is to extend onto the stiffener for a distance at least one-eighth of the length, ℓ, of the stiffener.

= 0.90 for stiffeners having clip connections at both ends or having such attachments at one end and horizontal girders at the other end.

= 1.00 for stiffeners having horizontal girders at both ends.

ℓ = the distance, in m (ft), 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.

s = stiffener spacing, in m (ft)

h = the 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 middle of ℓ to the bulkhead or freeboard deck, or

- A point located at two-thirds of the distance from the top of the tank to the top of the overflow, or
- The load line, or
- A point located above the top of the tank, not less than the greater of the following:
- $0.01L + 0.15$ m (0.5 ft), where L is the length of a vessel as defined in 3-1-1/3, or 0.46 m (1.5 ft)

5.5 Corrugated Bulkheads

Where corrugated bulkheads are used as deep-tank boundaries, the scantlings may be developed from 3-2-7/5.7. The plating thickness, t, and value of SM are to be as required by 3-2-8/5.1 and 3-2-8/5.3, respectively, with $c = 0.90$.

5.7 Girders and Webs *(2018)*

Horizontal girders or vertical webs supporting bulkhead stiffeners in deep tanks are to have a section modulus as required by this paragraph. Girders or webs supporting frames or beams in deep tanks are to have section modulus as required by Sections 3-2-5 and 3-2-6, respectively, or as required by this paragraph, whichever is the greater. The section modulus, SM, of each girder or web is not to be less than that 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 = 1.5

h = vertical distance, in m (ft), from the middle of s in the case of a girder or from the middle of ℓ in the case of a web to the same heights to which h for the stiffeners is measured (see 3-2-8/5.3)

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

ℓ = unsupported length of girder or web, in m (ft). Where brackets are fitted in accordance with 3-1-2/5.5, the length, ℓ, may be measured as permitted therein.

The depth of a girder or web is not to be less than 2.5 times the depth of the cutout unless effective compensation is provided for stiffener cutouts. The thickness is to be not less than 1 mm per 100 millimeters (0.01 inch per inch) of depth plus 3 mm (0.12 in.) but need not exceed 11.5 mm (0.46 in.). Tripping brackets are to be fitted at intervals of about 3 m (10 ft) and stiffeners are to be fitted as may be required.

5.11 Anti-rolling Tank Bulkheads *(2019)*

Where anti-rolling tanks are provided, the required scantlings may be calculated from the above Paragraphs 3-2-8/5.1 through 3-2-8/5.7 based on h measured to the point located above tank bottom as follows:

$$h = B(0.259 + 0.966h_z/B) \text{ m (ft)}$$

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 3-2-8/5.1 and 3-2-8/5.3 is to be applied.

7 Tank Top Plating

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. Beams, girders and pillars are to be as required by Section 3-2-6.

9 Higher-strength Materials

9.1 General

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

9.3 Plating

Deep-tank plating of higher-strength material is to be of not less thickness than that obtained by 3-2-8/5.1.

9.5 Stiffeners

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

$$SM_{hts} = 7.8chs\ell^2Q \text{ cm}^3$$

$$SM_{hts} = 0.0041chs\ell^2Q \text{ in}^3$$

c, h, s and ℓ are as defined in 3-2-8/5.3 and Q is as defined in 3-2-1/7.5.

11 Drainage and Air Escape *(2011)*

Limber and air holes are to be cut, as required, in non-tight parts of the tanks to permit the free flow of liquids to the suction pipes and the escape of air to the vents. Vent pipes are to be arranged to prevent over pressuring of tanks. (See 4-4-3/9.1) Arrangements are to be made for draining the tops of the tanks.

13 Testing

Requirements for testing are contained in Section 3-7-1.

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 9 Superstructures and Deckhouses

1 Superstructure Scantlings

1.1 Side and Top Plating

The thickness of superstructure side plating is to be not less than that obtained from the requirements of 3-2-2/5. The thickness is also not to be less than that required by 3-2-9/3.5 for exposed aft-end bulkheads. Superstructure top plating is to be in accordance with Section 3-2-3.

1.3 Framing and Internal Bulkheads

Superstructure side frames are to be in accordance with 3-2-5/5.3. Bulkheads, partial bulkheads or web frames are to be fitted in the superstructure over the main hull bulkheads and elsewhere, as may be required to give effective transverse rigidity.

1.5 Breaks in Continuity

Breaks in the continuity of superstructures are to be specially strengthened (See 3-2-2/13). The arrangements in this area are to be clearly shown on the plans submitted for approval. Openings and changes in the scantlings of the decks and shell are to be kept well clear of the breaks.

1.7 Structural Support

Main bulkheads in the hull are to be arranged to provide support under the ends of the superstructures.

3 Exposed Bulkheads of Superstructures and Deckhouses

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.

Special consideration may be given to the bulkhead scantlings of deckhouses which do not protect openings in the freeboard deck, superstructure deck or in the top of a lowest tier deckhouse or which do not protect machinery casings, provided they do not contain accommodation or do not protect equipment essential to the operation or safety of the vessel.

Superstructures or deckhouses located within the midship $0.4L$ that have lengths greater than $0.1L$ are to have effective longitudinal scantlings to give a hull-girder section modulus through the superstructure or deckhouse meeting the requirements for the main hull-girder. The superstructure scantlings are to be in accordance with 3-2-9/1 and the house top and side plating of long deckhouses are to be not less than $0.009s + 0.8$ mm ($0.009s + 0.032$ in.) where s is the spacing of the deck beams in mm (in.).

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

In general, the first or lowest tier is that located on the freeboard deck. Where the depth to the uppermost continuous weather deck is such that the freeboard to this deck exceeds tabular freeboard by at least one standard superstructure height, deckhouses and superstructures on this weather deck may be considered second tier. Watertight bulkheads are to extend to this weather deck. This consideration of excess freeboard may be followed in a similar manner to determine third tier deckhouses or superstructures.

3.3 Stiffeners

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:

$$SM = 3.5s\ell^2h \quad \text{cm}^3$$

$$SM = 0.00185s\ell^2h \quad \text{in}^3$$

where

s = stiffener spacing, in m (ft)

ℓ = tween deck height or unsupported length, in m (ft)

h = $a[(bf) - y]c$, design head in m (ft). For unprotected front bulkheads on the lowest tier, h is to be taken as not less than 9.9 m (32.5 ft), and for sides and ends of first tier, h is to be taken as not less than 3.3 m (10.8 ft). For all other bulkheads the minimum value of h is to be not less than 1.25 + L/200 m (4.1 + L/200 ft).

a = coefficient given in 3-2-9/Table 1.

b = $1.0 + \left[\dfrac{(x/L) - 0.45}{C_b + 0.2}\right]^2$ where $(x/L) \le 0.45$

b = $1.0 + 1.5\left[\dfrac{(x/L) - 0.45}{C_b + 0.2}\right]^2$ where $(x/L) > 0.45$

C_b = block coefficient at summer load waterline, based on the vessel's length, L, as defined in 3-1-1/3, not to be taken less than 0.60 nor greater than 0.80. For aft end bulkheads forward of amidships, C_b need not be taken as less than 0.80.

x = distance, in m (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, as defined in 3-1-1/3, in m (ft)

f = $(L/10)(e^{-L/300}) - [1 - (L/150)^2]$ for L, in m, see also 3-2-9/Table 2

$(L/10)(e^{-L/984}) - [3.28 - L/272)^2]$ for L, in ft, see also 3-2-9/Table 2

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 position being considered, in m (ft)

B_1 = actual breadth of vessel at the freeboard deck at the position being considered, in m (ft)

Where windows are fitted in bulkheads, the spacing, s, is to be the spacing of the mullion stiffeners. The mullion stiffeners are to extend continuously from deck to deck.

TABLE 1
Values of a

Bulkhead Location	*Metric Units*	*US Units*
Unprotected front Lowest tier	2.0 + L/120	2.0 + L/393.6
Unprotected front Second tier	1.0 + L/120	1.0 + L/393.6
Unprotected front Third tiers	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*
24	1.24
40	2.57
60	4.07
80	5.41
90	6.00

US Units	
L, ft	*f*
79	4.09
130	8.34
200	13.6
250	17.0
295	19.8

3.5 Plating

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

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

$$t = s\sqrt{h}/50 \quad \text{in.}$$

where

s and h are as defined in 3-2-9/3.3 above. When determining h, y is to be measured to the middle of the panel.

In no case is the thickness for bulkheads, other than the lowest tier, to be less than 5.0 mm (0.20 in.).

In addition, the thicknesses are to be not less than the following:

For the lowest tier and for deckhouses on the forecastle deck:

For front bulkheads:

$$t = (s/0.60)(6 + 0.02L) \quad \text{mm}$$

$$t = (s/1.97)(0.24 + 0.00024L) \quad \text{in.}$$

For side and end bulkheads:

$$t = (s/0.60)(5 + 0.02L) \quad \text{mm}$$

$$t = (s/1.97)(0.20 + 0.00024L) \quad \text{in.}$$

Where L is as defined in 3-2-9/3.3 and s is as defined in 3-2-9/3.3, but is not to be taken less than 0.60 m (1.97 ft).

3.7 End Attachments *(2016)*

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 are to be formed by end brackets, by welding the webs all around to the deck plating or by lapping the stiffener onto the deck beam to prevent stress concentration.

The ends of all transverse webs in way of girders or transverses are to be welded.

Where only the webs are welded, the flange or face bar is to be sniped not more than 30°.

The webs of all the bulkhead stiffeners may be sniped, having due regard to their scantlings and the depth of the web.

3.9 Raised-quarter-deck Bulkheads

Raised-quarter-deck bulkheads are to have plating of not less thickness than required for unprotected 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.

5 Enclosed Superstructures

5.1 Closing Appliances *(2017)*

All openings in the bulkheads of enclosed superstructures are to be provided with efficient means of closing, so that in any sea conditions, water will not penetrate the vessel. Opening and closing appliances are to be framed and stiffened so that the whole structure, when closed, is equivalent to the unpierced bulkhead.

Doors for access openings into enclosed superstructures are to be of steel or other equivalent material, permanently and strongly attached to the bulkhead. Scantlings for door panels and stiffeners are to be obtained from 3-2-9/3.3 and 3-2-9/3.5 based on the design head of the bulkhead where the door is located. Minimum thickness requirements in 3-2-9/3.3 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, permanently attached to the bulkhead or to the doors themselves, and the doors are to be so arranged that they can be operated from both sides of the bulkhead. Doors located above Position 2 (refer to 3-2-12/5.1) 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.

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

Portlights in the end bulkheads of enclosed superstructures are to be of substantial construction and provided with efficient inside deadlights. Also see 3-2-14/7 and 3-2-14/9.

The location and means of the closing appliances for windows are to be in accordance with 3-2-14/9.

5.3 Sills of Access Openings

Except as otherwise provided in these Rules, the height of the sills of access openings in bulkheads at the ends of enclosed superstructures is to be at least 380 mm (15 in.) above the deck. See 3-2-12/Table 1 for required sill heights.

5.5 Means of Access

Superstructures are not to be regarded as enclosed unless access is provided for the crew to reach machinery and other working spaces inside these superstructures by alternate means which are available at all times when bulkhead openings are closed.

7 Open Superstructures

Superstructures with openings which do not fully comply with 3-2-9/5 are to be considered as open superstructures. See also 3-2-14/5.7.

9 Deckhouses *(2017)*

Deckhouses are to comply with 3-2-9/3. Bulkheads are to be arranged as necessary in the main hull to support deckhouses.

The closing appliances for the openings in deckhouse bulkheads are to comply with 3-2-9/5.1.

Doors for access openings into deckhouses are to be of steel or other equivalent material, permanently and strongly attached to the bulkhead. Scantlings for door panels and stiffeners are to be obtained from 3-2-9/3.3 and 3-2-9/3.5 based on the design head of the bulkhead where the door is located. Minimum thickness requirements in 3-2-11/3.3 for exposed bulkheads are to be applied to panels of doors located on exposed bulkheads of superstructure and deckhouses at and below position two 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, permanently attached to the bulkhead or to the doors themselves, and the doors are to be arranged so that they can be operated from both sides of the bulkhead. Doors located above Position 2 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.

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

10 Aluminum Deckhouses *(2002)*

10.1 Scantling Correction

Where deckhouses are constructed of aluminum alloys, the required plate thickness and stiffener section modulus, *SM,* are first to be determined as required for steel deckhouses, and are then to be increased by the material factor, Q_0, 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:

Deck plating:

$$t_{al} = \frac{0.9(Q + \sqrt{Q})}{2} t_s$$

Bulkhead plating:

$$t_{al} = 0.9 Q_0 t_s$$

Deck and bulkhead stiffeners:

$$SM_{al} = 0.9 Q_0 SM_s$$

where

t_{al} = minimum thickness of aluminum plate

t_s = required plate thickness for steel obtained from 3-2-3/3 for decks and 3-2-9/3.5 for side and end bulkheads

SM_{al} = minimum section modulus of aluminum stiffeners

SM_s = minimum section modulus of steel stiffeners, as determined from 3-2-6/1 and 3-2-6/3 for deck stiffeners and 3.2.9/3.3 for bulkhead stiffeners

Q = material factor, as determined from 3-2-9/10.3 below

Q_0 = material factor, as determined from 3-2-9/10.3 below

10.3 Material Factors

The material factor, Q, is obtained from the following equation:

$Q = 0.9 + (120/Y_{al})$ SI Units

$Q = 0.9 + (12/Y_{al})$ MKS Units

$Q = 0.9 + (17000/Y_{al})$ U.S. Units

but is not to be taken as less than Q_0 below.

The material factor, Q_0, is obtained from the following equation:

$Q_0 = 635/(\sigma_y + \sigma_u)$ SI Units

$Q_0 = 65/(\sigma_y + \sigma_u)$ MKS Units

$Q_0 = 92000/(\sigma_y + \sigma_u)$ U.S. Units

Y_{al} = minimum yield strength of the welded aluminum alloy under consideration at 2% offset in a 254 mm (10 in.) gauge length, in N/mm^2 (kgf/mm^2, psi), in accordance with the requirements of the table below

σ_u = minimum ultimate strength of the welded aluminum alloy under consideration, in N/mm^2 (kgf/mm^2, psi), 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, psi), in accordance with the table below

Minimum Mechanical Properties for Butt-Welded Aluminum Alloys *(2011)*

Alloy	*Ultimate Tensile Strength (σ_u) N/mm^2 (kgf/mm^2, psi)*	*Yield Strength (σ_y) [3] N/mm^2 (kgf/mm^2, psi)*
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 *(2011)* For other tempers, refer to 2-5-A1/Table 2 of the ABS *Rules for Materials and Welding (Part 2) – Aluminum and Fiber Reinforced Plastics (FRP).*

2 Values when welded with 4043, 5183, 5356 or 5556 filler wire.

3 Yield strength is not required for weld procedure qualification. Values shown apply to the yield strength values of 3-2-9/10.3.

For other alloys, refer to Table 4 of Section 3 of the Aluminum Association's Aluminum Construction Manual.

10.5 Attachments

Stiffeners on bulkheads are to be attached to the deck plating at their upper and lower ends by welding all around, for which cladding metal is to be inserted between stiffeners and steel deck plate. Suitable means are to be taken to avoid direct contact of faying surfaces of aluminum to steel.

11 Helicopter Decks

11.1 General

Helicopter landing facilities, where provided, are to meet the following structural and safety requirements. The attention of owners, builders and designers is directed to various international and governmental regulations and guides regarding the operational and other design requirements for helicopters landing on ships. See also Section 1-1-5 of the ABS *Rules for Conditions of Classification (Part 1)* and 4-5-1/7 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 to be considered 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 3-2-9/Table 3. Plastic design considerations may be applied for deck plating and stiffeners.

11.3.1 Overall Distributed Loading

A minimum distributed loading of 2010 N/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 the 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 loadings 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 loadings on helicopter decks and their supporting structures.

11.3.7 Bolted Connections *(2018)*

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.

11.5 Safety Net

The unprotected perimeter of the helicopter landing deck is to be provided with safety netting or equivalent.

11.7 Aluminum Decks *(2018)*

For requirements on aluminum helicopter decks, refer to 3-2-11/11.5 of the ABS *Rules for Building and Classing Offshore Support Vessels.*

11.9 Means of Escape and Access *(2018)*

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 3-2-11/11.5 of the ABS *Rules for Building and Classing Offshore Support Vessels* 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

iii) 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/Table 1 of the *Steel Vessel Rules*.

iv) 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.

TABLE 3
Allowable Factors of Safety Based on *Y* for Helicopter Decks

Y = specified minimum yield point or yield strength of the material

	Plating	*Beams*	*Girders, Stanchions 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 that obtained from the following:

Beam Spacing	*t*
460 mm	4.0 mm
610 mm	5.0 mm
760 mm	6.0 mm

Beam Spacing	*t*
18 in.	0.16 in.
24 in.	0.20 in.
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.

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 10 Keels, Stems, Stern Frames, Shaft Struts, and Propeller Nozzles

1 Keels

1.1 Bar Keels

Bar keels are to have thicknesses and depths not less than that obtained from the following equations:

$t = 0.625L + 12.5$ mm $\qquad$ $t = 0.0075L + 0.50$ in.

$h = 1.46L + 100$ mm $\qquad$ $h = 0.0175L + 4$ in.

where

t = thickness, in mm (in.)

h = depth, in mm (in.)

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

Thicknesses and widths other than given above are acceptable, provided the section moduli and moments of inertia about the transverse horizontal axis are not less than given above, nor is h/t more than 4.5.

1.3 Plate Keels

The thickness of the plate keel throughout the length of the vessel is to be not less than the bottom shell required in 3-2-2/3.3.

3 Stems

3.1 Bar Stems

Bar stems are to have thicknesses and widths not less than that obtained from the following equations:

$t = 0.625L + 6.35$ mm $\qquad$ $t = 0.0075L + 0.25$ in.

$w = 1.25L + 90$ mm $\qquad$ $w = 0.015L + 3.5$ in.

where

t = thickness, in mm (in.)

w = width, in mm (in.)

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

This thickness and width is to be maintained between the keel and design load waterline. Above the design load waterline, they may be gradually reduced until the area at the head is 70% of that obtained from the 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 above, nor w/t more than 5.5. The thickness of the bar stem, in general, should also not be less than twice the shell thickness.

3.3 Cast or Forged Stems

Cast or forged stems of special shape are to be proportioned to provide strengths at least equivalent to those of bar stems, as obtained in 3-2-10/3.1, and all joints and connections are to be at least as effective as would be required on equivalent bar stems.

3.5 Plate Stems

Where plate stems are used, they are not to be less in thickness than the bottom shell plating required in 3-2-2/1 and 3-2-2/3, where s is the frame spacing, or 610 mm (24 in.), if greater.

5 Sternposts

5.1 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 $\qquad t = 0.0088L + 0.39$ in.

$b = 1.283L + 87.4$ mm $\qquad b = 0.0154L + 3.44$ in.

where

t = thickness, in mm (in.)

b = width, in mm (in.)

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

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.

5.3 Cast, Forged, or Fabricated Sternposts

Cast, forged or fabricated sternposts of special shape are to be so proportioned as to provide strengths at least equivalent to those of bar posts, as obtained from 3-2-10/5.1, and all joints and connections are to be at least as effective as would be required on equivalent bar posts.

7 Stern Frames

Except as modified in 3-2-10/9, the scantlings of stern frames of single screw vessels are to be in accordance with the following, as applicable.

7.1 Below the Boss

7.1.1 Fabricated Stern Frame

The thickness, t, width, w, and length, ℓ, are not to be less than given by the following equations:

$t = 0.225\sqrt{L}$ cm $\qquad t = 0.049\sqrt{L}$ in.

$w = 5\sqrt{L}$ cm $\qquad w = 1.09\sqrt{L}$ in.

$\ell = 4\sqrt{L}$ cm $\qquad \ell = 0.87\sqrt{L}$ in.

Widths and lengths other than given above are acceptable, provided the section modulus, SM, about the longitudinal axis is not less than:

$SM = 1.60L^{1.5}$ cm^3 $\qquad SM = 0.0164L^{1.5}$ in^3

where

t = thickness of side plating, in cm (in.) (See 3-2-10/Figure 1)

w = width of stern frame, in cm (in.) (See 3-2-10/Figure 1)

ℓ = length of stern frame, in cm (in.) (See 3-2-10/Figure 1)

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

7.1.2 Cast Stern Frame

The thicknesses, t_1, t_2, width, w, and length, ℓ, are not to be less than given by the following equations:

$t_1 = 0.3\sqrt{L}$ cm $\qquad$ $t_1 = 0.065\sqrt{L}$ in.

but not less than 2.5 cm (1.0 in.)

$t_2 = 1.25t_1$

$w = 5\sqrt{L}$ cm $\qquad$ $w = 1.09\sqrt{L}$ in.

$\ell = 4\sqrt{L}$ cm $\qquad$ $\ell = 0.87\sqrt{L}$ in.

Widths and lengths other than given above are acceptable, provided the section modulus, SM, about the longitudinal axis is not less than:

$SM = 1.60L^{1.5}K_g$ cm^3 $\qquad$ $SM = 0.0164L^{1.5}K_g$ in^3

where

t_1 = thickness of casting at end. (See 3-2-10/Figure 1)

t_2 = thickness of casting at mid-length. (See 3-2-10/Figure 1)

K_g = material factor defined in 3-2-11/1.3

w, ℓ, L are as defined in 3-2-10/7.1.1.

The thickness in way of butt welding to shell plating may be tapered below t_1. The length of taper is to be at least three times the offset.

The castings are to be cored out to avoid large masses of thick material likely to contain defects and to maintain a relatively uniform section throughout. Suitable radii are to be provided in way of changes in section.

7.3 Above the Boss

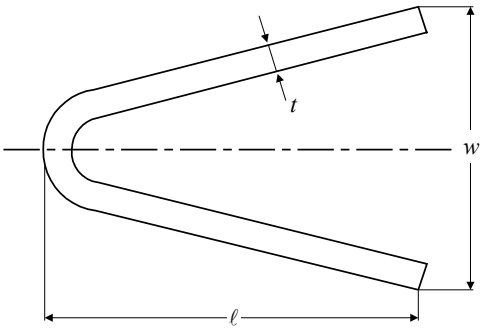
Above the propeller boss, the scantlings are to be in accordance with 3-2-10/7.1, except that in the upper part of the propeller aperture where the hull form is full and centerline supports are provided, the thickness may be reduced to 80% of the requirements in 3-2-10/7.1, subject to the same minimum for cast steel stern frames.

7.5 Secondary Members

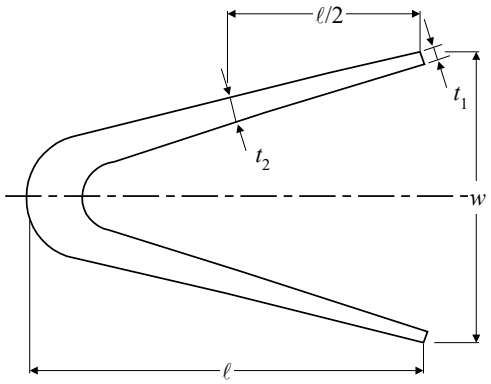
Where round bars are used at the after edge of stern frames, their scantlings and connection details are to be such as to facilitate welding.

Ribs or horizontal brackets of thickness not less than $0.8t$ or $0.8t_1$ are to be provided at suitable intervals, extended forward and attached to the adjacent floor. Where t or t_1 is reduced in accordance with 3-2-10/7.3, a proportionate reduction in the thickness of ribs or horizontal brackets may be made.

FIGURE 1
Stern Frame



a. Fabricated



b. Cast

9 Stern Frames with Shoepieces

The scantlings below the boss of stern frames with shoepieces are to be gradually increased to provide strength and stiffness in proportion to those of the shoepieces.

11 Shoepieces

11.1 General

The shoepiece 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.

11.3 Design Stress

The equivalent stress, σ_e, in the shoepiece 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:

$$\sigma_e = n\sqrt{\sigma_b^2 + 3\tau^2}$$

where

n = 1000 (1000, 2240)

K_g = K, as defined in 3-2-11/1.3 for castings and forgings

= 1.0 for ordinary strength hull steel plate

σ_b = bending stress = $0.5C_R\ell/Z_v$

C_R = rudder force, as defined in 3-2-11/3.

ℓ = horizontal distance between centerline of rudder stock and the particular section of the stern frame shoe, in m (in.) (see 3-2-10/Figure 2)

Z_v = section modulus of shoepiece 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 = sectional area at the section of the shoepiece under consideration, in mm^2 (in^2)

11.5 Minimum Scantlings

In addition, shoepiece width is to be approximately twice the depth, and vertical and horizontal section modulus and sectional area are in no case less than required by the following equations.

$Z_z = k_z C_R \ell K_g$ cm^3 (in^3)

$Z_y = 0.5Z_z$ cm^3 (in^3)

$A_s' = k_a C_R K_g$ mm^2 (in^2)

where

Z_z = minimum required section modulus of shoepiece about the vertical axis at the particular section under consideration

Z_y = minimum required section modulus of shoepiece about the transverse horizontal axis at the particular section under consideration

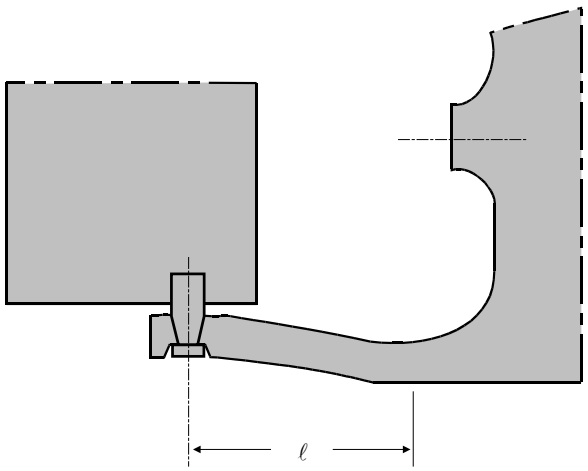
A_s' = minimum required sectional area of shoepiece at the section under consideration

k_z = 6.25 (61.3, 0.0967)

k_a = 10.4 (102, 0.161)

C_R, ℓ and K_g are as defined in 3-2-10/11.3.

FIGURE 2
Shoepiece



13 Rudder Horns

Vessels that have rudder horns are to meet the requirements in 3-2-13/5 of the *Steel Vessel Rules*.

15 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, and the thickness of the pintle housing is not to be less than 25% of the pintle diameter.

17 Shaft Struts

17.1 General

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.

17.3 V Strut

17.3.1 Inertia

The moment of inertia, $I_{x\text{-}x}$, of each strut arm is not to be less than that obtained from the following equation:

$$I_{x\text{-}x} = 0.0044D^4 \quad \text{mm}^4 \ (\text{in}^4)$$

where

D = required diameter of ABS Grade 2 tail shaft, in mm (in.) (see Section 4-3-1)

17.3.2 Section Modulus

The section modulus, $SM_{x\text{-}x}$, of each strut arm is not to be less than that obtained from the following equation:

$$SM_{x\text{-}x} = 0.024D^3 \quad \text{mm}^3 \ (\text{in}^3)$$

where

D = required diameter of ABS Grade 2 tail shaft, in mm (in.)

Where the included angle is less than 45 degrees, the foregoing scantlings are to be specially considered.

17.5 I Strut

17.5.1 Inertia

The moment of inertia, $I_{x\text{-}x}$, of the strut arm is not to be less than that obtained from the following equation:

$$I_{x\text{-}x} = 0.018D^4 \quad \text{mm}^4 \ (\text{in}^4)$$

where

D = required diameter of ABS Grade 2 tail shaft, in mm (in.)

17.5.2 Section Modulus

The section modulus, $SM_{x\text{-}x}$, of the strut is not to be less than that obtained from the following equation:

$$SM_{x\text{-}x} = 0.068D^3 \quad \text{mm}^3 \ (\text{in}^3)$$

where

D = required diameter of ABS Grade 2 tail shaft, in mm (in.)

17.7 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.

19 Propeller Nozzles *(2009)*

19.1 Application

The requirements in this section are applicable for fixed 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 submitted for review.

19.3 Design Pressure

The design pressure of the nozzle is to be obtained from the following:

$$p_d = 10^{-6} \cdot c \cdot \varepsilon \cdot \left(\frac{N}{A_p} \right) \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

where

c = coefficient as indicated in 3-2-10/Table 1

ε = coefficient as indicated in 3-2-10/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 *(2009)*

Propeller Zone (see 3-2-10/Figure 3)	c		
	p_d *in N/mm^2*	p_d *in kgf/mm^2*	p_d *in psi*
2	10.0	1.02	11.62×10^3
1 & 3	5.0	0.51	5.81×10^3
4	3.5	0.36	4.067×10^3

TABLE 2
Coefficient ε *(2009)*

	p_d *in N/mm^2*	p_d *in kgf/mm^2*	p_d *in psi*
ε	$21 - 2 \times 10^{-2} \left(\frac{N}{A_p} \right)$	$21 - 2 \times 10^{-2} \left(\frac{N}{A_p} \right)$	$21 - 16 \times 10^{-2} \left(\frac{N}{A_p} \right)$

19.5 Nozzle Cylinder

19.5.1 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 3-2-10/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 3-2-10/19.3

t_c = corrosion allowance determined by 3-2-10/Table 4

K_n = nozzle material factor as defined in 3-2-11/1.3

TABLE 3
Coefficient c_n *(2009)*

	p_d *in N/mm^2*	p_d *in kgf/mm^2*	p_d *in psi*
c_n	1.58×10^{-1}	4.95×10^{-1}	1.32×10^{-2}

TABLE 4
Corrosion Allowance t_c *(2009)*

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 (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.	

19.5.2 Internal Diaphragm Thickness

Thickness of nozzle internal ring web is not to be less than the required nozzle shell plating for Zone 3.

19.7 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, in m (ft)

b = nozzle length, in m (ft)

V_d = design speed in ahead condition, in knots, as defined in 3-2-11/3.1

Q = reduction factor conditional on material type

= 1.0 for ordinary strength steel

= 0.78 for H32 strength steel

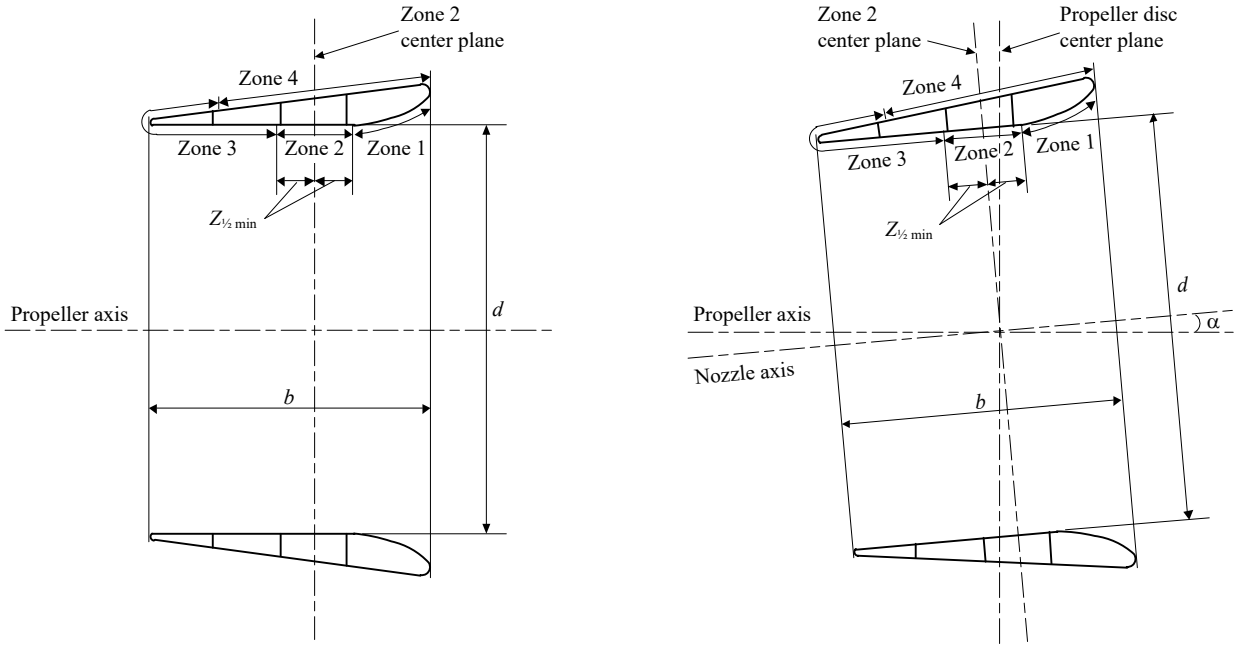
= 0.72 for H36 strength steel

= 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 taken equal to 0.7 (0.0012) for fixed nozzles

FIGURE 3
Propeller Nozzle Section View *(2014)*



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

$z_{1/2\ min}$ = 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 3-2-10/Figure 3(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 3-2-10/Figure 3(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

19.9 Welding Requirement

The inner and outer nozzle shell plating is to be welded to the internal stiffening ring webs with double continuous welds as far as practicable. Plug/slot welding is prohibited for the inner shell, but may be accepted for the outer shell plating, provided that the nozzle ring web spacing is not greater than 350 mm (13.8 in.).

21 Propulsion Improvement Devices (PID) as Hull Appendages *(2017)*

21.1 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.

21.3 Plans and Documentation *(2019)*

The following plans and details are to be submitted for approval, while the calculation is 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.

21.5 Design and Arrangement

The following requirements are to be complied with for the propulsion improvement devices as outlined in 3-2-10/21.1. 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.

21.7 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 Section 2-4-1 of the ABS *Rules for Materials and Welding (Part 2)* and Section 3-2-16, 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.

23 Inspection of Castings

The location of radiographic or other subsurface inspections of large stern-frame and rudder-horn castings is to be indicated on the approved plans. 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 11 Rudders and Steering Equipment *(2009)*

1 General

1.1 Application *(1 July 2016)*

Requirements specified in this section are applicable to:

i) Ordinary profile rudders described in 3-2-11/Table 1A;

ii) High-lift rudders described in 3-2-11/Table 1B;

iii) Other steering equipment other than rudders identified in Section 3-2-11.

Rudders not covered in 3-2-11/Table 1A or 3-2-11/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 *Steel Vessel Rules*.

1.3 Materials for Rudder, Rudder Stock and Steering Equipment *(1 July 2015)*

Rudder stocks, pintles, coupling bolts, keys and other steering equipment components described in this Section are to be made from material in accordance with the requirements of Chapter 1 of the ABS *Rules for Materials and Welding (Part 2)*, 3-1-2/Table 2, 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 $Y \le 235$ 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 4-3-3/1.9 is to be indicated on the submitted rudder or steering gear plan. See 4-3-3/1.5 and 3-2-11/5.7.

Note that this expected torque is not the design torque for rudder scantlings.

1.7 Rudder Stops

Strong and effective structural rudder stops are to be fitted. Where adequate positive mechanical stops are provided within the steering gear in accordance with 4-3-3/5.1, structural stops will not be required.

3 Rudder Design Force

Rudder force, C_R, upon which rudder scantlings are to be based, is to be obtained from equation described either in 3-2-11/3.1 or 3-2-11/3.3 as applicable. Where for the 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 *(2014)*

Where the rudder profile can be defined by a single quadrilateral, the rudder force is to be obtained from the following equation:

$$C_R = n\, k_R k_c k_\ell A V_R^2 \qquad \text{kN (tf, Ltf)}$$

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 3-2-11/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 as illustrated in 3-2-11/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 3-2-11/Table 1A and 1B. For profile types differing from those in 3-2-11/Table 1A and 1B, k_c is subject to special consideration.

k_ℓ = coefficient as specified in 3-2-11/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 the 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 3-2-11/Figure 1B. 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 3-2-11/3.1 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:

$$C_{R1} = C_R A_1/A \qquad \text{kN (tf, Ltf)}$$

$$C_{R2} = C_R A_2/A \qquad \text{kN (tf, Ltf)}$$

where

C_R and A are as defined in 3-2-11/3.1.

A_1 and A_2 are as described in 3-2-11/Figure 1B.

3.5 Rudders Blades with Twisted Leading-Edge *(2014)*

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
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:

$$C_{R1} = nk_R k_c k_\ell A_1 V_R^2 \quad \text{kN (tf, Ltf)} \qquad \text{for twisted upper rudder blade;}$$

$$C_{R2} = nk_R k_c k_\ell A_2 V_R^2 \quad \text{kN (tf, Ltf)} \qquad \text{for twisted lower rudder blade;}$$

$$C_R = C_{R1} + C_{R2} \quad \text{kN (tf, Ltf)} \qquad \text{overall design force;}$$

ii) For Categories 2, 3, and 4, rudder design force indicated in 3-2-11/3.1 is applicable, that is:

$$C_R = nk_R k_c k_\ell A V_R^2 \quad \text{kN (tf, Ltf)}$$

where

n, k_R, k_c, k_ℓ, A, and V_R are as defined in 3-2-11/3.1, (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 3-2-11/Table 1A for twisted rudders of Categories 1 & 2;

b) k_c is taken from 3-2-11/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 *(2014)*

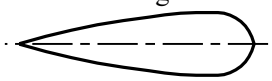
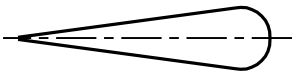
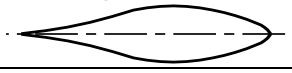
	Profile Type	k_c	
		Ahead Condition	*Astern Condition*
1	Single plate	1.0	1.0
2	NACA-OO GÖttingen 	1.1	0.80
3	Flat side 	1.1	0.90
4	Mixed (e.g., HSVA) 	1.21	0.90
5	Hollow	1.35	0.90
6	Twisted rudder of Cat. 1 & 2	1.21 (if not provided)	0.90 (if not provided)

TABLE 1B
Coefficient k_c for High-Lift/Performance Rudders *(1 July 2016)*

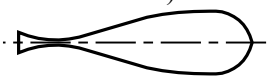
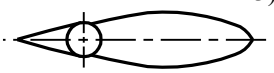
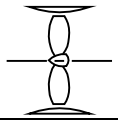
	Profile Type	k_c	
		Ahead Condition	*Astern Condition*
1	Fish tail (e.g., Schilling high-lift rudder) 	1.4	0.8
2	Flap rudder (or Twisted rudder of Cat. 3) 	1.7	1.3 (if not provided)
3	Rudder with steering nozzle 	1.9	1.5

FIGURE 1A
Rudder Blade without Cutouts *(2009)*

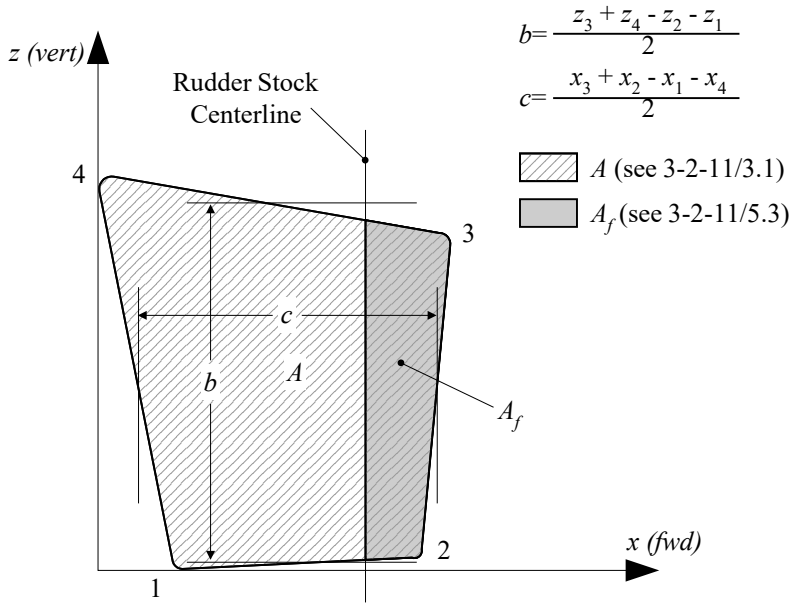
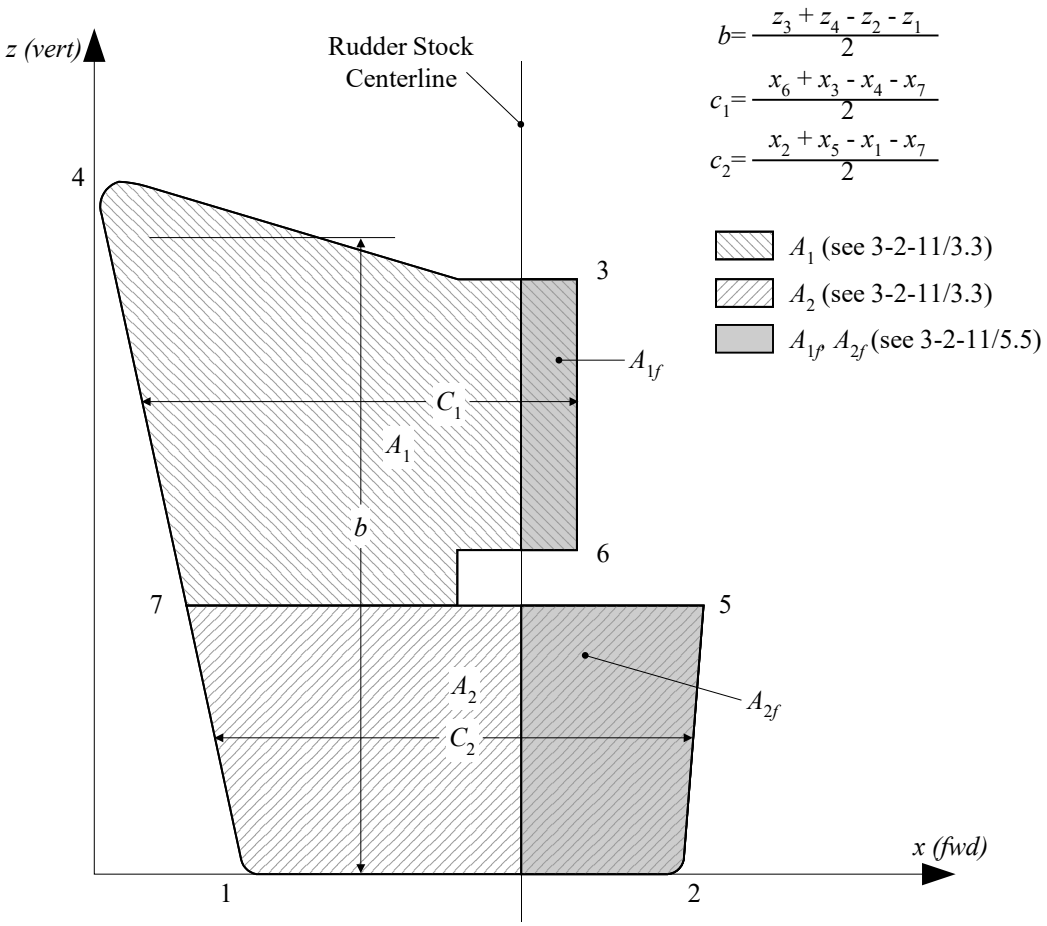


FIGURE 1B
Rudder Blade with Cutouts *(2009)*



5 Rudder Design Torque

5.1 General

The rudder design torque, Q_R, for rudder scantling calculations is to be in accordance with 3-2-11/5.3 or 3-2-11/5.5 as applicable.

5.3 Rudder Blades without Cutouts *(2014)*

Rudder torque, Q_R, is to be determined from the following equation for both ahead and astern conditions.

$$Q_R = C_R r \quad \text{kN-m (tf-m, Ltf-ft)}$$

where

C_R = rudder force, as calculated in 3-2-11/3

r = $c(\alpha - k)$ but not less than $0.1c$ for ahead condition

c = mean breadth of rudder area, as shown in 3-2-11/Figure 1A, in m (ft)

α = coefficient as indicated in 3-2-11/Table 3

k = A_f/A

A_f = area of rudder blade situated forward of the centerline of the rudder stock, in m^2 (ft^2), as shown in 3-2-11/Figure 1A

A = whole rudder area as described in 3-2-11/3.1

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 *(2012)*

Rudder/Propeller Layout	k_ℓ
Rudders outside propeller jet	0.8
Rudders behind a fixed propeller nozzle	1.15
Steering nozzles and azimuthing thrusters	1.15
All others	1.0

TABLE 3
Coefficient α *(2014)*

Rudder Position or High-lift	α		
	Ahead Condition	*Astern Condition*	
Located behind a fixed structure, such as a rudder horn	0.25	0.55	
Located where no fixed structure forward of it	0.33	0.75 (hollow profile)	0.66 (non-hollow)
High-Lift Rudders (see 3-2-11/Table 1B)	Special consideration (0.40 if unknown)	Special consideration	

5.5 Rudders Blades with Cutouts

This paragraph refers to rudder blades with cutouts (semi-spade rudders) as defined in 3-2-11/3.3. 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:

$$Q_R = C_{R1} r_1 + C_{R2} r_2 \qquad \text{kN-m (tf-m, Ltf-ft)}$$

but not to be taken less than $Q_{R\min}$ in the ahead condition

where

$Q_{R\min}$ = $0.1 C_R (A_1 c_1 + A_2 c_2)/A$

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 3-2-11/Figure 1B

α = coefficient as indicated in 3-2-11/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 3-2-11/Figure 1B

C_R, C_{R1}, C_{R2}, A_1, A_2 are as defined in 3-2-11/3.3.

5.7 Rudders with Twisted Leading Edge *(2014)*

In general, rudder torque, Q_R, indicated in 3-2-11/5.3 is applicable for rudders with twisted leading edge, where C_R is obtained from 3-2-11/3.5.

5.9 Trial Conditions

The 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 3-2-11/1.5) or the rated torque of steering gear (see 4-3-3/1.5).

7 Rudder Stocks

7.1 Upper Rudder Stocks *(2012)*

The upper rudder 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 that obtained from the following equation:

$$S = N_u \sqrt[3]{Q_R K_s} \qquad \text{mm (in.)}$$

where

N_u = 42.0 (89.9, 2.39)

Q_R = total rudder torque, as defined in 3-2-11/5, in kN-m (tf-m, Ltf-ft)

K_s = material factor for upper rudder stock, as defined in 3-2-11/1.3

7.3 Lower Rudder Stocks *(2018)*

In determining lower rudder stock scantlings, values of rudder design force and torque calculated in 3-2-11/3 and 3-2-11/5 are to be used. Bending moments, shear forces, as well as the reaction forces are to be determined from 3-2-11/7.5 and 3-2-11/13.5, 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-A2.

The lower rudder stock diameter is not to be less than that obtained from the following equation:

$$S_\ell = S\sqrt[6]{1 + (4/3)(M/Q_R)^2} \qquad \text{mm (in)}$$

where

S = upper stock required diameter from 3-2-11/7.1, 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 3-2-11/5, 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 $118/K$ N/mm^2 ($12.0/K$ kgf/mm^2, $17100/K$ lbs/in^2).

$$\sigma_c = \sqrt{\sigma_b^{\,2} + 3\tau^2} \qquad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, lbs/in}^2\text{)}$$

where

K = material factor as defined in 3-2-11/1.3.

σ_b = $10.2 \times 10^6 M/S_\ell^3$ for SI and MKS units

= $270 \times 10^3 M/S_\ell^3$ for US units

τ = $5.1 \times 10^6 Q_R/S_\ell^3$ for SI and MKS units

= $135 \times 10^3 Q_R/S_\ell^3$ for US units

7.4 Rudder Trunk and Rudder Stock Sealing *(1 July 2019)*

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 and/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/Table 1. Rudder trunks comprising of materials other than steel are to be specially considered.

iv) *Scantlings.* Where the rudder stock is arranged in a trunk in such a way that the trunk is stressed by forces due to rudder action, 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 3-2-11/1.3 for castings
= 1.0 for ordinary strength hull steel plate
= Q as defined in 3-2-1/7.5 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 3-2-11/Figure 2) is to be as large as practicable and to comply with the following:

r = 60 mm when $\sigma \geq 40/k$ N/mm^2
60 mm when $\sigma \geq 4.09/k$ kgf/mm^2
2.4 in. when $\sigma \geq 5800/k$ psi

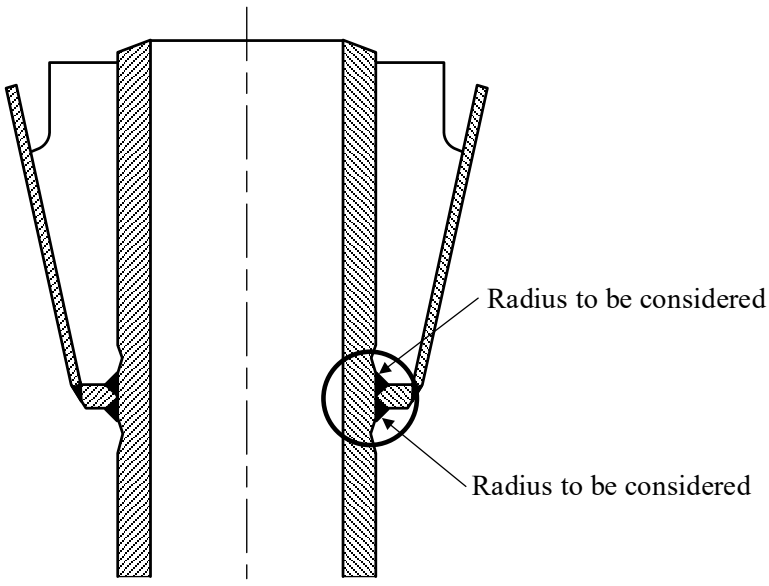
r = $0.1S_\ell$, without being less than 30 mm when $\sigma < 40/k$ N/mm^2
= $0.1S_\ell$, without being less than 30 mm when $\sigma < 4.09/k$ kgf/mm^2
= $0.1S_\ell$, without being less than 1.2 in. when $\sigma < 2900/k$ psi

where

S_ℓ = rudder stock diameter axis defined in 3-2-11/7.3
σ = bending stress in the rudder trunk in N/mm^2 (kgf/mm^2, psi)
k = material factor as defined in 3-2-11/7.4iv)

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 *(1 July 2016)*



7.5 Bending Moments

The bending moment on the rudder and rudder stock may be determined in accordance with Appendix 3-2-A2 or in accordance with the following equations.

7.5.1 Spade Rudders

$$M_n = C_R \ell_n \quad \text{kN-m (Ltf-ft)}$$

$$M_s = C_R \frac{A_1}{A} \ell_c \quad \text{kN-m (Ltf-ft)}$$

where

M_n = bending moment at neck bearing

M_s = bending moment at section under consideration

ℓ_n = distance from center of neck bearing to the centroid of rudder area, m (ft)

ℓ_c = distance from section under consideration to the centroid of rudder area, A_1, m^2 (ft^2)

A_1 = area below section under consideration, m^2 (ft^2)

C_R and A are as defined in 3-2-11/3.

7.5.2 Balanced Rudders with Shoepiece Support

The bending moment at the neck bearing may be taken as indicated below. Bending moments at other locations are to be determined by direct calculation and are to be submitted. See Appendix 3-2-A2 for guidance in calculating bending moments.

$$M_n = NC_R\ell_b \quad \text{kN-m (Ltf-ft)}$$

where

M_n = bending moment at neck bearing

ℓ_b = distance between center of neck bearing and center of shoepiece pintle bearing, m (ft)

$$N = \left[\frac{0.5 + \frac{\alpha_1}{8}}{1 + \alpha_1 \left(1 + \frac{\ell_u}{\ell_b} \frac{I_b}{I_u} \right)} \right]$$

$$\alpha_1 = \frac{\ell_b^3}{\ell_s^3} \frac{I_d}{I_b}$$

I_d = mean moment of inertia of shoepiece about the vertical axis, cm^4 (in^4)

ℓ_s = distance between center of shoepiece pintle bearing and the effective support point of the shoepiece in the hull, m (ft)

I_b = mean moment of inertia of the rudder, cm^4 (in^4), considering a width of rudder plating twice the athwartship dimension of the rudder and excluding welded or bolted cover plates for access to pintles, inc.

ℓ_u = distance between center of the neck bearing and the center of the rudder carrier bearing, m (ft)

I_u = mean moment of inertia of rudder stock, between neck bearing and rudder carrier bearing, cm^4, (in^4)

C_R is as defined in 3-2-11/3.

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.

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 3-2-11/9.3 (horizontal couplings) or 3-2-11/9.5 (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 that obtained by the following equation:

$$d_b = 0.62\sqrt{d_s^3 K_b /(nrK_s)} \qquad \text{mm (in.)}$$

where

d_s = required rudder stock diameter, S (3-2-11/7.1) or S_ℓ (3-2-11/7.3) as applicable, in way of the coupling

n = total number of bolts in the horizontal coupling

r = mean distance, in mm (in.), of the bolt axes from the center of the bolt system

K_b = material factor for bolts, as defined in 3-2-11/1.3

K_s = material factor for stock, as defined in 3-2-11/1.3

9.3.2 Coupling Flange

Coupling flange thickness is not to be less than the greater of the following equations:

$$t_f = d_{bt}\sqrt{K_f /(K_b)} \qquad \text{mm (in.)}$$

$$t_f = 0.9d_{bt} \qquad \text{mm (in.)}$$

where

d_{bt} = calculated bolt diameter as per 3-2-11/9.3.1 based on a number of bolts not exceeding 8

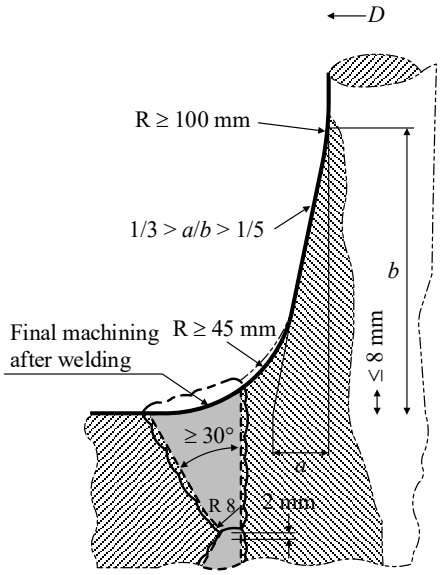
K_f = material factor for flange, as defined in 3-2-11/1.3

K_b = material factor of bolts, as defined in 3-2-11/1.3

9.3.3 Joint between Rudder Stock and Coupling Flange *(1 July 2016)*

The welded joint between the rudder stock and the flange is to be made in accordance with 3-2-11/Figure 3 or equivalent.

FIGURE 3
Welded Joint Between Rudder Stock and Coupling Flange *(1 July 2016)*



9.5 Vertical Couplings

9.5.1 Coupling Bolts *(1 July 2016)*

There are to be at least eight coupling bolts in vertical couplings and the diameter, d_b, of each bolt is not to be less than that obtained from the following equation:

$$d_b = 0.81 d_s \sqrt{K_b /(nK_s)} \qquad \text{mm (in.)}$$

where

n = total number of bolts in the vertical coupling, which is not to be less than 8

d_s, K_b, K_s are as defined in 3-2-11/9.3.

In addition, the first moment of area, m, of the bolts about the center of the coupling is not to be less than that given by the following equation:

$$m = 0.00043 d_s^3 \qquad \text{mm}^3 \text{ (in}^3\text{)}$$

where

d_s = diameter, in mm (in.), as defined in 3-2-11/9.3

9.5.2 Coupling Flange

Coupling flange thickness is not to be less than d_b, as defined in 3-2-11/9.5.1.

9.5.3 Joint between Rudder Stock and Coupling Flange *(1 July 2016)*

The welded joint between the rudder stock and the flange is to be made in accordance with 3-2-11/Figure 3 or equivalent.

11 Tapered Stock Couplings

11.1 Coupling Taper *(1 July 2016)*

Tapered stock couplings are to comply with the following general requirements in addition to type-specific requirements given in 3-2-11/11.3 or 3-2-11/11.5 as applicable:

i) Tapered stocks, as shown in 3-2-11/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) Taper length (ℓ) in the casting is generally not to be less than 1.5 times the stock diameter (d_o) as shown in 3-2-11/Figure 4.

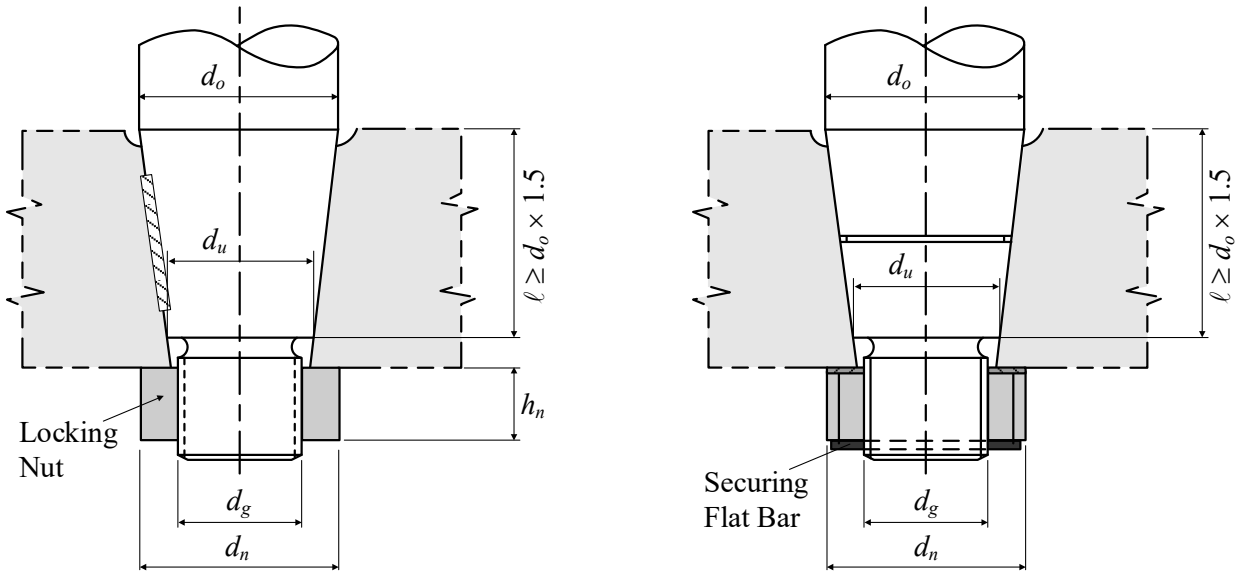
iv) The taper on diameter (c) is to be 1/12 to 1/8 for keyed taper couplings and 1/20 to 1/12 for couplings with hydraulic mounting/dismounting arrangements, as shown in the following table.

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 against sea water ingress.

Type of Coupling Assembly	$c = \frac{d_o - d_u}{\ell}$
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 *(2018)*



a) Keyed Fitting

b) Keyless Fitting

11.3 Keyed Fitting *(1 July 2019)*

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:

$$a_s = \frac{17.55 Q_F}{d_k \sigma_{F1}} \text{ cm}^2 \qquad a_s = \frac{21.06 Q_F}{d_k \sigma_{F1}} \text{ in}^2$$

where

Q_F = design yield moment of rudder stock, in N-m (kgf-m, lbf-ft)

$$= 0.02664 \frac{d_t^3}{k} \text{ N-m}$$

$$= 0.002717 \frac{d_t^3}{k} \text{ kgf-m}$$

$$= 321.9838 \frac{d_t^3}{k} \text{ lbf-ft}$$

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 $1.145 d_t$.

d_t = stock diameter, in mm (in.), according to 3-2-11/7.1

k = material factor for stock as given in 3-2-11/1.3

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:

$$a_k = \frac{5 Q_F}{d_k \sigma_{F2}} \text{ cm}^2 \qquad a_k = \frac{6 Q_F}{d_k \sigma_{F2}} \text{ in}^2$$

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 90% 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 3-2-11/11.5v) and 3-2-11/11.5vi) for a torsional moment $Q'_F = 0.5 Q_F$. Notwithstanding the requirements in 3-2-11/11.5iii) and 3-2-11/11.5v), 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.

* *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 2019)*

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:

$$p_{req1} = \frac{2Q_F}{d_m^2 \ell \pi \mu_o} 10^3 \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{)} \qquad p_{req1} = \frac{24Q_F}{d_m^2 \ell \pi \mu_o} \quad \text{psi}$$

$$p_{req2} = \frac{6M_b}{d_m \ell^2} 10^3 \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{)} \qquad p_{req2} = \frac{72M_b}{d_m \ell^2} \quad \text{psi}$$

where

Q_F = design yield moment of rudder stock, as defined in 3-2-11/11.3iii)

d_m = mean cone diameter, in mm (in.)

ℓ = cone 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:

$$p_{perm} = \frac{0.95 Y_G \left(1 - \alpha^2\right)}{\sqrt{3 + \alpha^4}} - p_b \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

where

p_b = $\frac{3.5M_b}{d_m \ell^2} 10^3$ N/mm^2 (kgf/mm^2, $\frac{42M_b}{d_m \ell^2}$ 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 to be not less than $1.5d_m$, in mm (in.)

The outer diameter of the gudgeon in mm (in.) shall not be less than $1.25d_0$, with d_0 defined in 3-2-11/Figure 4.

vi) *Push-up Length.* The push-up length $\Delta\ell$, in mm (in.), $\Delta\ell$ is to comply with the following formula:

$$\Delta\ell_1 \le \Delta\ell \le \Delta\ell_2$$

where

$$\Delta\ell_1 = \frac{p_{req} d_m}{E\left(\frac{1-\alpha^2}{2}\right)c} + \frac{0.8R_{tm}}{c} \text{ mm (in.)}$$

$$\Delta\ell_2 = \frac{p_{perm} d_m}{E\left(\frac{1-a^2}{2}\right)c} + \frac{0.8R_{tm}}{c} \text{ mm (in.)}$$

R_{tm} = mean roughness, in mm (in.) taken equal to 0.01

c = taper on diameter according to 3-2-11/11.1iv)

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 3-2-11/11.5v).

Note: In case of hydraulic pressure connections the required push-up force P_e for the cone may be determined by the following formula:

$$P_e = p_{req} d_m \pi \ell \left(\frac{c}{2} + 0.02\right) \text{ N (kgf, lbf)}$$

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.

vii) *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 3-2-11/11.5v) and 3-2-11/11.5vi), respectively.

viii) The locking nut is to be fitted in accordance with 3-2-11/11.7.

11.7 Locking Nut

Dimensions of the securing nut, as shown in 3-2-11/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. Calculations proving the effectiveness of the securing device are to be submitted.

13 Pintles

13.1 General *(1 July 2016)*

Pintles are to have a conical attachment to the gudgeons with a taper on diameter of:

1/12 to 1/8 for keyed and other manually assembled pintles with locking nut.

1/20 to 1/12 for pintle mounted with oil injection and hydraulic nut.

13.3 Diameter *(1 July 2016)*

The diameter of the pintles is not to be less than that obtained from the following equation.

$$d_p = k_1 \sqrt{BK_p} \quad \text{mm (in.)}$$

where

k_1 = 11.1 (34.7, 1.38)

B = bearing force, in kN (tf, Ltf), from 3-2-11/13.5 but not to be taken less than B_{min} as specified in 3-2-11/Table 4

K_p = material factor for the pintle, as defined in 3-2-11/1.3

TABLE 4
Minimum Bearing Force B_{min} *(2009)*

Pintle Type		B_{min}
Conventional two pintle rudder		0.5 C_R
3-2-A2/Figure 3	lower pintle	0.5 C_R
3-2-A2/Figure 3	main pintle	$C_R \ell_a / \ell_p$*
3-2-13/Figure 3 of the *Steel Vessel Rules*	main pintle	$C_R \ell_a / \ell_p$*
	upper pintle	0.25 C_R

* $B_{min} = C_R$ where $\ell_a / \ell_p \geq 1$

ℓ_a, ℓ_p as described in 3-2-13/Figure 3 of the *Steel Vessel Rules*

For rudders on horns with two pintles, as shown in 3-2-11/Figure 1B, calculations are to include pintle bearing forces with the vessel running ahead at the maximum continuous rated shaft rpm and at the lightest operating draft.

Threads and nuts are to be in accordance with 3-2-11/11.7.

The pintle and pintle boss are to comply with the following requirements:

i) The depth of the pintle boss is not to be less than d_p.

ii) 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.

iii) The bearing pressure is to be in accordance with 3-2-11/15.1.

iv) The thickness of the pintle housing is not to be less than 25% of the pintle diameter.

13.4 Push-up Pressure and Push-up Length *(1 July 2019)*

The required push-up pressure for pintles, in N/mm^2 (kgf/mm^2, psi), is to be determined by the following formula:

$$p_{req} = \frac{0.4 B_1 d_o}{d_m^2 \ell} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

where

B_1 = supporting force in the pintle, in N (kgf, lbf)

d_0 = 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 3-2-11/11.5vi), using required push-up pressure and properties for the pintle.

13.5 Shear and Bearing Forces

The shear and bearing forces may be determined in accordance with Appendix 3-2-A2 or by the equations given below.

13.5.1 Spade Rudder

Bearing force at rudder carrier: $P_u = \dfrac{M_n}{\ell_u}$ kN (tf Ltf)

Bearing force at neck bearing: $P_n = C_R + P_u$ kN (tf Ltf)

Shear force at neck bearing: $F_n = C_R$ kN (tf Ltf)

where C_R is as defined in 3-2-11/3 and ℓ_u is as defined in 3-2-11/7.5.2.

13.5.2 Balanced Rudder with Shoepiece Support

Bearing force at rudder carrier: $P_u = \dfrac{M_n}{\ell_u}$ kN (tf Ltf)

Bearing force at neck bearing: $P_n = P_u\left(1 + \dfrac{\ell_u}{\ell_b}\right) + \dfrac{C_R}{\ell_b}\left(\dfrac{\ell_R}{2} + \ell_p\right)$ kN (tf Ltf)

where

ℓ_b = distance between the center of neck bearing support and the center of shoepiece support, as shown in 3-2-A2/Figure 2

= $\ell_p + \ell_r + \ell_\ell$

ℓ_p = distance between bottom of rudder blade and center of support of neck bearing

ℓ_ℓ = distance between top of rudder blade and center of support of neck bearing

Bearing force at shoepiece: $P_p = C_R + P_u - P_n$ kN (tf, Ltf) but not less than $0.5C_R$

Shear force at neck bearing: $F_n = P_n - P_u$ kN (tf, Ltf)

where C_R is as defined in 3-2-11/3.

15 Supporting and Anti-Lifting Arrangements

15.1 Bearings *(2012)*

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 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.)

$A_{b\min}$ = $k_1 \frac{P}{q_a}$ mm^2 (in^2)

k_1 = 1000 (2240)

P = bearing reaction force, in kN (tf, Ltf), as determined from 3-2-11/Table 5

p_a = allowable surface pressure, as indicated in 3-2-11/Table 6 depending on bearing material, in N/mm^2 (kgf/mm^2, 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 3-2-11/Table 6.

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 *(1 July 2016)*

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 3-2-11/15.1.5i).

- The bearing length L_p of the pintle is to be in accordance with 3-2-11/13.1.

15.3 Rudder Carrier *(1 July 2016)*

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 *(2009)*

Bearing Type	*P, Bearing Reaction Force kN (tf, Ltf)*
Pintle bearings	$P = B$ as defined in 3-2-11/13
Other bearings	*Calculation of P* is to be submitted. Guidelines for calculation can be found in Appendix 3-2-A2

TABLE 6
Allowable Bearing Surface Pressure *(1 July 2016)*

	p_a		
Bearing Material	*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 between 60 and 70 Shore D(1)	5.5(2)	0.56(2)	800(2)
steel(3) and bronze and hot-pressed bronze-graphite materials	7.0	0.71	1000

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/mm² (1.02 kgf/mm², 1450 psi).

3 Stainless and wear-resistant steel in an approved combination with stock liner.

17 Double Plate Rudder

17.1 Strength *(1 July 2017)*

The section modulus and web area of the rudder mainpiece are to be such that the stresses indicated in the following Subparagraphs are not exceeded.

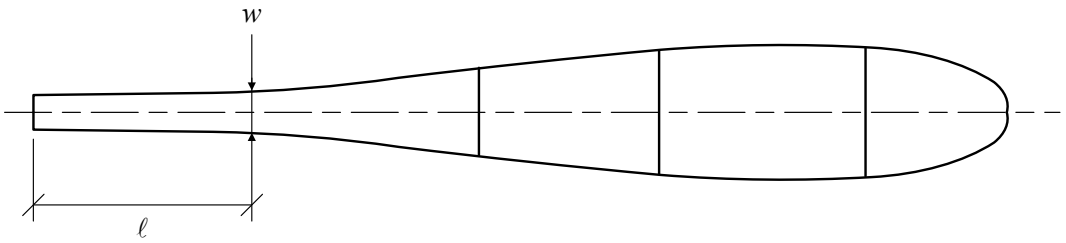
In calculating the section modulus of the rudder, the effective width of side plating is to be taken as not greater than twice the athwartship dimension of the rudder. Bolted cover plates on access openings to pintles are not to be considered effective in determining the section modulus of the rudder. 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. Generous radii are to be provided at abrupt changes in section where there are stress concentrations, including in way of openings and cover plates. When inspection windows are located in the panel below the rudder hub, the stress is to be as permitted in way of cutouts.

Moments, shear forces and reaction forces are to be as given in 3-2-11/7.5 and 3-2-11/13.5.

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 of the rudder blade is also to be submitted for review. See 3-2-11/Figure 5.

FIGURE 5 *(1 July 2017)*



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 a rounded end with a finite thickness or diameter (see 3-2-11/Figure 6), the vortex shedding frequency calculated using the equation given below is to be higher than 35 Hz.

$$f_s = \frac{S_t U}{\beta_D D + \beta_T T}$$

where

f_s = vortex shedding frequency, in Hz

U = flow velocity, in m/s (ft/s), which is taken as vessel's design speed with vessel running ahead at the maximum continuous rated shaft rpm and at the summer load waterline

S_t = nominal Strouhal number

= 0.18

β_D = 0.27

C = minimal chord length of rudder cross section profile, in m (ft)

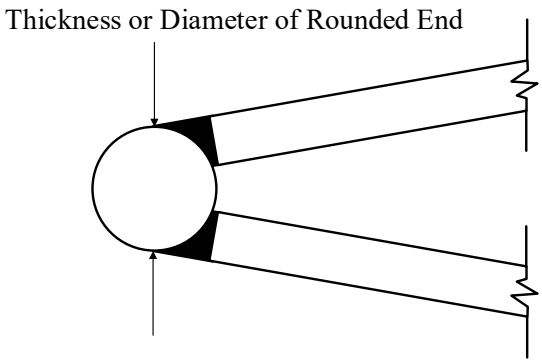
D = nominal boundary layer thickness at trailing edge

= $0.01C$

β_T = 0.77

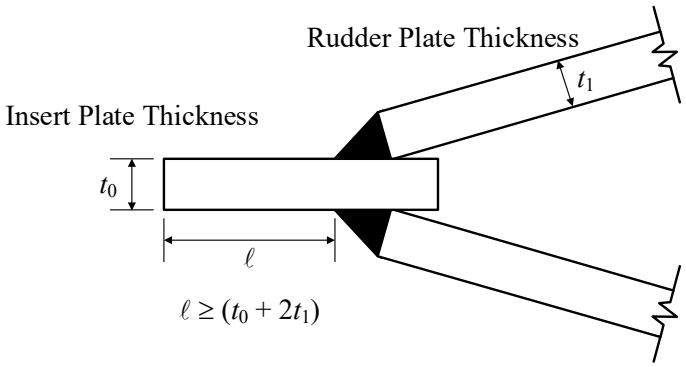
T = thickness or diameter of rounded end, in m (ft)

FIGURE 6 *(1 July 2017)*



ii) For a rudder trailing edge with a flat insert plate (see 3-2-11/Figure 7), the insert plate thickness, t_0, is to be no larger than $1.5V_d$ in mm, where V_d is the design speed in ahead condition, in knots, as defined in 3-2-11/3.1. The extension beyond the weld to rudder plate, ℓ, is to satisfy the following 3-2-11/Figure 7 and with consideration of possible local vibratory bending of the insert plate.

FIGURE 7 *(1 July 2017)*



Alternatively, a vibration analysis is to be carried out to confirm that the natural frequency of the rudder is to be at least ±20% away from the vortex shedding frequency preferably determined using either a detailed numerical analysis method such as CFD or testing for ballast and full draft at 85% and 100% V_d as defined in 3-2-11/3.1.

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 3-2-11/17.1.2 applies are as follows:

Bending stress $\sigma_b = K_\sigma/Q$ N/mm^2 (kgf/mm^2, psi)

Shear stress $\tau = K_\tau/Q$ N/mm^2 (kgf/mm^2, psi)

Equivalent stress $\sigma_e = \sqrt{\sigma_b^{\,2} + 3\tau^2} = K_e/Q$ N/mm^2 (kgf/mm^2, 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 3-2-1/7.5 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 3-2-11/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)

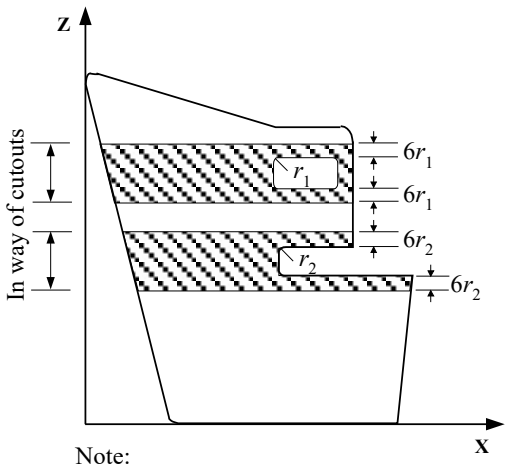
Equivalent stress $\sigma_e = \sqrt{\sigma_b^{\,2} + 3\tau^2} = K_e$ N/mm^2 (kgf/mm^2, psi)

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 3-2-11/17.1.2 apply equally to high tensile and ordinary steels.

FIGURE 8 *(2009)*



Note:
r_1 = corner radius of rudder plate in way of portable bolted inspection hole
r_2 = corner radius of rudder plate

The mainpiece of the rudder is to be formed by the rudder side plating (but not more than the effective width indicated above) and vertical diaphragms extending the length of the rudder or the extension of the rudder stock or a combination of both.

17.3 Side, Top and Bottom Plating *(1 July 2016)*

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

$$t = 0.0055s\beta\sqrt{k_1 d + (k_2 C_R / A)} \times \sqrt{Q} + k_3$$

where

Q = 1.0 for ordinary strength hull steel
= as defined in 3-2-1/7.5 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 load line draft of the vessel, in m (ft)

C_R = rudder force according to 3-2-11/3, 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 thickness of the rudder side or bottom plating is to be at least 2 mm (0.08 in.) greater than that required by 3-2-8/5 for deep tank plating in association with a head, h, measured to the summer load line.

The rudder side plating in way of the solid part is to be of increased thickness per 3-2-11/17.7.

17.5 Diaphragm Plates *(2018)*

Vertical and horizontal diaphragms are to be fitted within the rudder, effectively attached to each other and to the side plating. Vertical diaphragms are to be spaced approximately 1.5 times the spacing of horizontal diaphragms.

The thickness of diaphragm plates is not to be less than 70% of the required rudder side plate thickness or 8 mm (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 3-2-11/17.1.

The diaphragm plating in way of the solid part is to be of increased thickness for vertical and horizontal diaphragm plates per 3-2-11/17.7.

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:

$$w_s = c_s S_\ell^3 \left(\frac{H_E - H_X}{H_E} \right)^2 \frac{Q}{K_s} 10^{-4} \quad \text{cm}^3 \qquad w_s = c_s S_\ell^3 \left(\frac{H_E - H_X}{H_E} \right)^2 \frac{Q}{K_s} 10^{-1} \quad \text{in}^3$$

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 3-2-11/Figure 9, in m (ft)

Q = material factor for the rudder blade plating as given in 3-2-11/17.1

K_s = material factor for the rudder stock as given in 3-2-11/1.3

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:

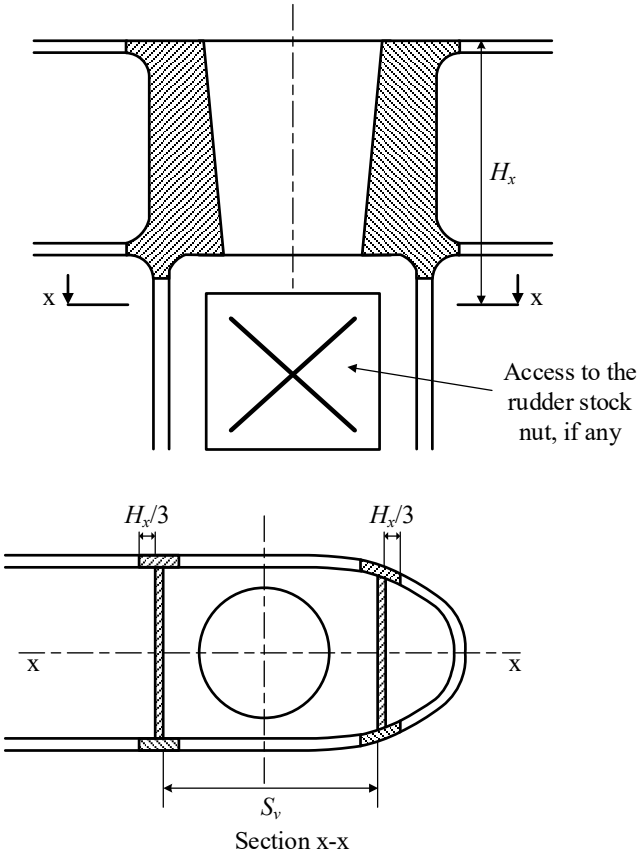
$$b = s_v + 2H_X/3 \quad \text{m (ft)}$$

where

s_v = spacing between the two vertical diaphragm, in m (ft) (see 3-2-11/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 *(1 July 2016)*



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:

$$t_H = 1.2t \quad \text{mm (in.)}$$

$$t_H = 0.045 d_S^2 / s_H \quad \text{mm (in.)}$$

where

t = defined in 3-2-11/17.3

d_S = diameter, in mm (in.), to be taken equal to:

= S_ℓ as per 3-2-11/7.3, for the solid part housing the rudder stock

= d_p as per 3-2-11/13.1, 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 3-2-11/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 *(1 July 2016)*

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	1.2*t*	1.6*t*	1.2*t*	1.4*t*
Semi-spade and spade rudders	1.4*t*	2.0*t*	1.3*t*	1.6*t*

t = thickness of the rudder plating, in mm (in.), as defined in 3-2-11/17.3

17.9 Welding and Design Details *(1 July 2016)*

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 2*t*, 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 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 semi-spade 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 *(1 July 2016)*

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 3-2-11/7.3. 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 that obtained from the following equation:

$$t_b = 0.0015sV_R + 2.5 \quad \text{mm}$$

$$t_b = 0.0015sV_R + 0.1 \quad \text{in.}$$

where

s = spacing of stiffening arms, in mm (in.), not to exceed 1000 mm (39 in.)

V_R = speed, as defined in 3-2-11/3

19.5 Arms

The thickness of the arms is not to be less than the blade thickness obtained in 3-2-11/19.3. The section modulus of each set of arms about the axis of the rudder stock is not to be less than that obtained from the following equation:

$$SM = 0.0005sC_1^2V_R^2Q \quad \text{cm}^3$$

$$SM = 0.0000719sC_1^2V_R^2Q \quad \text{in}^3$$

where

C_1 = horizontal distance from the aft edge of the rudder to the centerline of the rudder stock, in m (ft)

s and V_R are as defined in 3-2-11/19.3.

Q is as defined in 3-2-11/17.3.

21 Steering Nozzles *(2012)*

21.1 Application Scope

Requirements in this Subsection are applicable to conventional steering nozzles, as illustrated in 3-2-11/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 of the *Steel Vessel Rules*, 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 *(2015)*

The design force, C_R, for steering nozzles is to be obtained from the following equation:

$$C_R = nk_Rk_ck_\ell A_tV_R^2 = C_{R1} + C_{R2} \quad \text{kN (tf, Ltf)}$$

$$C_{R1} = nk_Rk_ck_\ell A_{eq} V_R^2 \quad \text{kN (tf, Ltf)}$$

$$C_{R2} = nk_Rk_ck_\ell (A_{po} + A_{mf})V_R^2 \quad \text{kN (tf, Ltf)}$$

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 3-2-11/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 $1.35d_mb$

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)

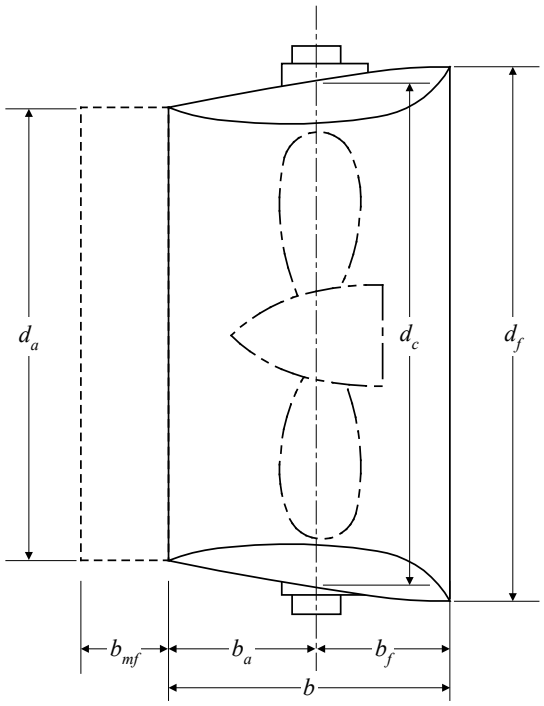
k_c = 1.9 for ahead condition

= 1.5 for astern condition

k_ℓ = 1.15, as specified in 3-2-11/Table 2

n, V_R are as defined in 3-2-11/3.1.

FIGURE 10
Nozzle Geometry *(2012)*



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:

$$Q_R = C_R r \quad \text{kN-m (tf-m, Ltf-ft)}$$

where

r = $(\alpha - k)\ell$, but not less than 0.1 ℓ 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 3-2-11/Table 3.

A, C_R are as defined in 3-2-11/21.3.

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:

$$S = N_u \sqrt[3]{Q_R K_s} \quad \text{mm (in.)}$$

where

N_u = 42.0 (823.9, 2.39)

Q_R = as defined in 3-2-11/21.5

K_s = material factor for nozzle stock, as defined in 3-2-11/1.3

21.7.2 Lower Stock

In determining lower stock diameters, values of nozzle design force and torque calculated in 3-2-11/21.3 and 3-2-11/21.5 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-A2.

The lower nozzle stock diameter is not to be less than obtained from the following equation:

$$S_\ell = S \sqrt[6]{1 + 4/3\left(M/Q_R\right)^2} \quad \text{mm (in.)}$$

where

S = required upper stock diameter from 3-2-11/21.7.1, 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 3-2-11/21.5, 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 *(2015)*

The design pressure of the nozzle is to be obtained from the following:

$$p = p_d + p_s \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

where

$$p_s = c_s\, c_m \frac{C_{R1}}{2A_{eq}} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

c_s = 0.001 (0.0001, 0.145)

c_m = as indicated in 3-2-11/Table 8

C_{R1}, A_{eq} as defined in 3-2-11/21.3

p_d as defined in 3-2-10/19.3

TABLE 8
Coefficient c_m *(2015)*

Propeller Zone (see 3-2-10/Figure 3)	c_m		
	p_s *in N/mm²*	p_s *in kgf/mm²*	p_s *in psi*
2	0.35	3.6×10^{-2}	4.067×10^{2}
1 & 3	0.5	5.1×10^{-2}	5.81×10^{2}
4	1.0	1.02×10^{-1}	11.62×10^{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:

$$t = t_o + t_c \quad \text{mm (in.), but not to be taken less than 7.5 mm (0.3 in.)}$$

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 3-2-10/Table 3

S_p = spacing of ring webs, in mm (in.)

p = design pressure, in N/mm^2 (kgf/mm^2, psi), as defined in 3-2-11/21.9

t_c = corrosion allowance determined by 3-2-10/Table 4

K_n = nozzle material factor as defined in 3-2-11/1.3

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 3-2-10/Figure 3.

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 3-2-11/17 are to be satisfied as applicable;

ii) For single-plate movable flap, requirements in 3-2-11/19 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 3-2-10/19.7, 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 3-2-10/19.9.

23 Azimuthal Thruster *(2012)*

23.1 Application Scope *(2017)*

23.1.1 Extent of Coverage

Requirements in this Subsection are applicable to Azimuthal Thrusters (also referred as integrated nozzle propellers), as illustrated in 3-2-11/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 of the *Steel Vessel Rules*, 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 *(2017)*

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 *(2017)*

The design force, C_R, for azimuthal thrusters is the maximum load for crash stop condition (3-2-11/23.1) or as obtained from the following equation, whichever is greater:

$$C_R = nk_R k_c k_\ell A V_R^2 = C_{R1} + C_{R2} \quad \text{kN (tf, Ltf)}$$

$$C_{R1} = nk_R k_c k_\ell A_{eq} V_R^2 \quad \text{kN (tf, Ltf)}$$

$$C_{R2} = nk_R k_c k_\ell A_{tb} V_R^2 \quad \text{kN (tf, Ltf)}$$

where

C_{R1} = Design force associated with the turning movement of the thruster nozzle

C_{R2} = Design force associated with the turning movement of other component of the thruster

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 3-2-11/Figure 11(a), in m (ft)

b = nozzle length as shown in 3-2-11/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 $1.35d_m b$, 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 3-2-11/Figure 11(a), in m (ft)

k_c = 1.9 for ahead condition

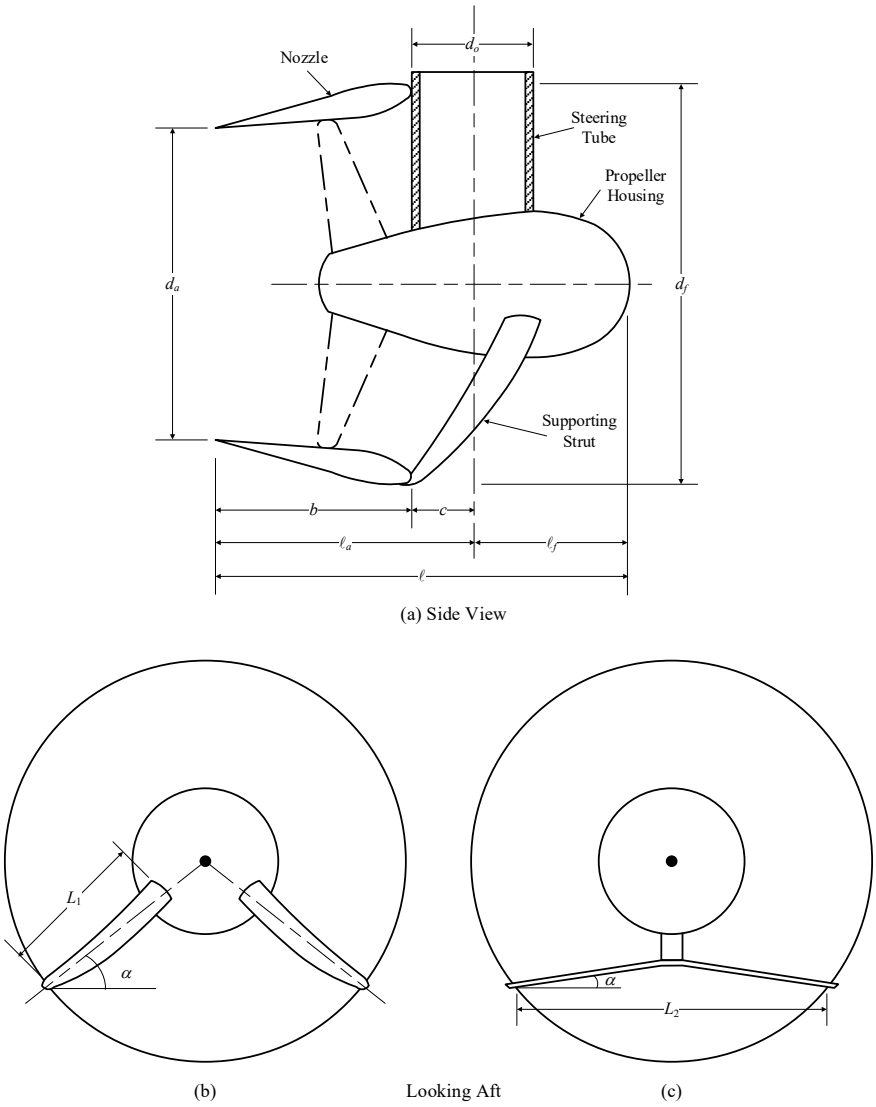
= 1.5 for astern condition.

k_ℓ = 1.15, as specified in 3-2-11/Table 2

n, V_R are as defined in 3-2-11/3.1.

**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 *(2017)*



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:

$$Q_R = C_R r \text{ kN-m (tf-m, Ltf-ft)}$$

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 $0.5\ A_{tb}$, in m^2 (ft^2)

α is as defined in 3-2-11/Table 3.

C_R and A are as defined in 3-2-11/23.7.

23.11 Design Pressure *(2015)*

The design pressure of the nozzle is to be obtained from the following:

$$p = p_d + p_s \text{ N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

where

$$p_s = c_s\, c_m \frac{C_{R1}}{2A_{eq}} \text{ N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

p_d, c_s, and c_m are as defined in 3-2-11/21.9.

C_{R1}, A_{eq} are as defined in 3-2-11/23.7.

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:

$$t = t_o + t_c \text{ mm (in.), but not to be taken less than 7.5 mm (0.3 in.)}$$

where

t_o = $c_n\, S_p \cdot \sqrt{pK_n}$ mm (in.)

c_n = coefficient as indicated in 3-2-10/Table 3

S_p = nozzle ring web spacing, in mm (in.)

p = design pressure as defined in 3-2-11/23.11

t_c = corrosion allowance determined by 3-2-10/Table 4

K_n = material factor of the nozzle, as defined in 3-2-11/1.3

23.13.2 Internal Diaphragm

Thickness of nozzle internal ring webs and diaphragms are not to be less than that required by 3-2-10/19.5.2.

23.15 Steering Tube

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 3-2-11/7.

where

Q_R is replaced by the design torque as defined in 3-2-11/23.9

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

23.17 Section Modulus

Azimuthal thruster nozzle is to have a section modulus at least equal to that specified in 3-2-10/19.7, where n is replaced by 1.1 (0.00187).

23.19 Thruster Nozzle Top Connections *(2017)*

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 3-2-11/23.25.2.

23.19.2 Bolted Connection

The following are to be complied with:

i) Flange couplings are to be supported by an ample bodies 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 be comply with 3-2-11/9.3.2 or 3-2-11/9.5.2, as applicable.

iii) The coupling bolts are to be of fitted bolts and meet the scantling requirements specified in 3-2-11/9.3.1 or 3-2-11/9.5.1, as applicable.

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 *(2017)*

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 3-2-11/1.3iii)].

23.21.2 Plate Thickness

The minimum plate thickness of the strut is not to be less than obtained from the following:

$$t = \sqrt{\frac{3F_{eqv}L_{eqv}}{2b_{avg}\sigma_F}} \quad \text{mm (in.), but not to be taken less than 7.5 mm (0.3 in.)}$$

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 3-2-11/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 3-2-11/Figure 11(c)]

A_{eqv} = equivalent area of nozzle supporting strut, in m^2 (ft^2)

= $L_1\, b_{avg}$, as illustrated in 3-2-11/Figure 11(b)

= $L_2\, b_{avg}$, as illustrated in 3-2-11/Figure 11(c)

L_{eqv} = equivalent length of nozzle supporting strut, in m (ft)

= L_1, as illustrated in 3-2-11/Figure 11(b)

= L_2, as illustrated in 3-2-11/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 3-2-11/23.11.

23.23 Direct Analysis *(2017)*

Direct calculations may be accepted in lieu of applying prescriptive formulas presented in 3-2-11/23.7 to 3-2-11/23.21, 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:

$$s_{rel} = 0.1 s_{cl} \quad \text{mm (in.)}$$

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 *(2017)*

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 3-2-16 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 of Hull Welds* where applicable and any additional requirements specified by the manufacturer.

23.25.1 Nozzle Welding

i) Integrated nozzle welding details are to comply with 3-2-10/19.9

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.

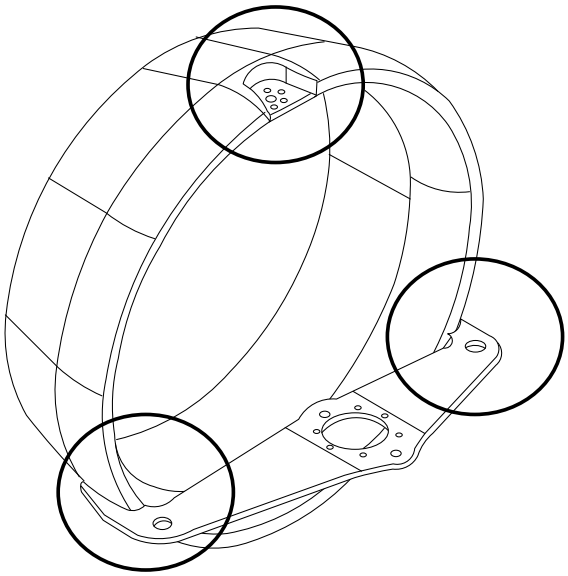
23.25.2 Connection Welding

Where the connections between nozzle and the hull/steering tube, strut and nozzle/propeller housing are welded (see figure below and 3-2-11/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 3-2-16, as applicable.

iii) Volumetric or surface examination is to be performed on the welds of brackets and the shell penetration.



PART
3

CHAPTER 2 Hull Structures and Arrangements

APPENDIX 2 Guidelines for Calculating Bending Moment and Shear Force in Rudders and Rudder Stocks

1 Application

Bending moments, shear forces and reaction forces of rudders, stocks and bearings may be calculated according to this Appendix for the types of rudders indicated. Moments and forces on rudders of different types or shapes than those shown are to be calculated using alternative methods and will be specially considered.

3 Spade Rudders *(2014)*

3.1 Rudder

3.1.1 Shear Force

For regular spade rudders as shown in 3-2-A2/Figure 1(a), the shear force, *V(z)*, at a horizontal section of the rudder above baseline is given by the following equation:

$$V(z) = \frac{zC_R}{A}\left[c_\ell + \frac{z}{2\ell_R}(c_u - c_\ell)\right] \quad \text{kN (tf, Ltf)}$$

where

z = distance from the rudder baseline to the horizontal section under consideration, in m (ft)

C_R = rudder force, as defined in 3-2-11/3, in kN (tf, Ltf)

A = total projected area of rudder blade in m^2 (ft^2), as defined in 3-2-11/3

c_ℓ, c_u and ℓ_R are dimensions as indicated in 3-2-A2/Figure 1(a), in m (ft).

For spade rudders with embedded rudder trunks let deep in the rudder blade, as shown in 3-2-A2/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:

$$V(z')_1 = \frac{z'C_{R1}}{A_1}\left[c_u - \frac{z'}{2\ell_\ell}(c_u - c_b)\right] \quad \text{kN (tf, Ltf), over area } A_1$$

$$V(z)_2 = \frac{zC_{R2}}{A_2}\left[c_b + \frac{z}{2\ell_b}(c_b - c_l)\right] \quad \text{kN (tf, Ltf), over area } A_2$$

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-A2/3.1.1.

c_ℓ, c_b, c_u, ℓ_u, and ℓ_b are dimensions as illustrated in 3-2-A2/Figure 1(b).

3.1.2 Bending Moment

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 equations:

$$M(z) = \frac{z^2 C_R}{2A}\left[c_\ell + \frac{z}{3\ell_R}(c_u - c_\ell)\right] \quad \text{kN-m, (tf-m, Ltf-ft)}$$

For spade rudders with embedded rudder trunk, the bending moment at a horizontal section within area A_1 is obtained from the following:

$$M(z')_1 = \frac{(z')^2 C_{R1}}{2A_1}\left[c_u - \frac{z'}{3\ell_\ell}(c_u - c_b)\right] \quad \text{kN-m, (tf-m, Ltf-ft)}$$

With the maximum bending moment M_1 over area A_1 equals to:

$$M_1 = C_{R1}\ell_\ell\left[1 - \frac{2c_b + c_u}{3(c_b + c_u)}\right] \quad \text{kN-m, (tf-m, Ltf-ft)}$$

For spade rudders with embedded rudder trunk, the bending moment at a horizontal section within area A_2 is obtained from the following:

$$M(z)_2 = \frac{z^2 C_{R2}}{2A_2}\left[c_\ell + \frac{z}{3\ell_b}(c_u - c_\ell)\right] \quad \text{kN-m, (tf-m, Ltf-ft)}$$

With the maximum bending moment M_2 over area A_2 equals to:

$$M_2 = C_{R2}\ell_b \frac{2c_\ell + c_b}{3(c_\ell + c_b)} \quad \text{kN-m, (tf-m, Ltf-ft)}$$

where z, z', C_{R1}, C_{R2}, A_1, A_2, c_ℓ, c_u and ℓ_R are as defined in 3-2-A2/3.1.1.

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:

$$V_\ell = C_R \qquad \text{kN (tf, Ltf)}$$

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-A2/3.1.1.

3.3.2 Bending Moment at Neck Bearing *(2017)*

For regular spade rudder, the bending moment in the rudder stock at the neck bearing, M_n, is given by the following equation:

$$M_n = C_R\left[\ell_\ell + \frac{\ell_R(2c_\ell + c_u)}{3(c_\ell + c_u)}\right] \quad \text{kN-m (tf-m, Ltf-ft)}$$

where

C_R = rudder force as defined in 3-2-11/3

c_ℓ, c_u, ℓ_ℓ and ℓ_R are dimensions as indicated in 3-2-A2/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:

$$M_n = M_2 - M_1 \quad \text{kN-m (tf-m, Ltf-ft)}$$

where $M_1$and M_2 are as defined in 3-2-A2/3.1.2.

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:

$$M_t = C_R\left[\ell_\ell + \frac{\ell_R(2c_\ell + c_u)}{3(c_\ell + c_u)}\right] \times \left[\frac{(\ell_u + \ell_R + \ell_\ell - z_t)}{\ell_u}\right] \quad \text{kN-m (tf-m, Ltf-ft)}$$

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:

$$M_t = M_R\left[\frac{(\ell_R + \ell_u - z_t)}{\ell_u}\right] \quad \text{kN-m (tf-m, Ltf-ft)}$$

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-A2/3.1.1

M_R = is the greater of M_1 and M_2, as defined in 3-2-A2/3.1.2

c_ℓ, c_u, ℓ_ℓ, ℓ_u and ℓ_R are dimensions as indicated in 3-2-A2/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

$$= -\frac{M_n}{\ell_u} \quad \text{kN (tf, Ltf)}$$

P_n = reaction force at the neck bearing

$$= C_R + \frac{M_n}{\ell_u} \quad \text{kN (tf, Ltf)}$$

For spade rudder with embedded rudder trunk, the reaction forces at the bearings are given by the following equations:

$$P_u = -\frac{M_n}{\ell_u + \ell_\ell} \quad \text{kN (tf, Ltf)}$$

$$P_n = C_R + P_u \quad \text{kN (tf, Ltf)}$$

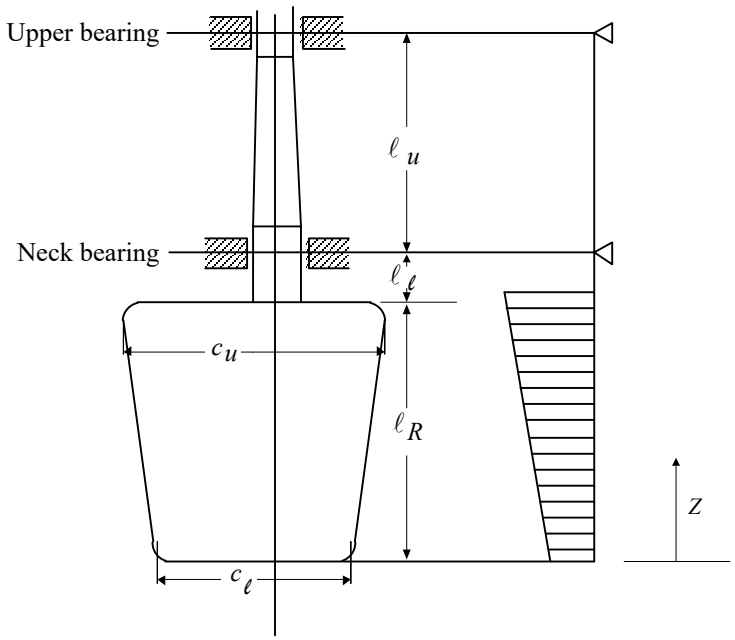
where

M_n = bending moment at the neck bearing, as defined in 3-2-A2/3.3.2

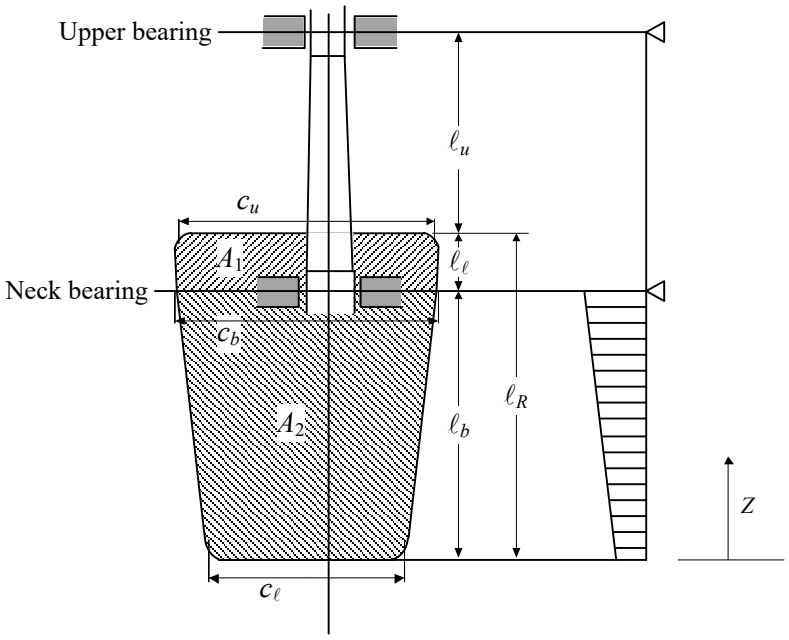
C_R = rudder force, as defined in 3-2-11/3

ℓ_u is as indicated in 3-2-A2/Figure 1, in m (ft).

FIGURE 1
Spade Rudder *(2014)*



(a) Regular Spade Rudder



(b) Spade Rudder with Embedded Rudder Trunk

5 Rudders Supported by Shoepiece

5.1 Shear Force, Bending Moment and Reaction Forces

Shear force, bending moment and reaction forces may be calculated according to the model given in 3-2-A2/Figure 2.

w_R = rudder load per unit length

$$= \frac{C_R}{\ell_R} \text{ kN/m (tf/m, Ltf/ft)}$$

where

C_R = rudder force, as defined in 3-2-11/3

k_s = spring constant reflecting support of the shoepiece

$$= \frac{n_s I_s}{\ell_s^3} \text{ kN/m (tf/m, Ltf/ft)}$$

n_s = 6.18 (0.630, 279)

I_s = moment of inertia of shoepiece about the vertical axis, in cm^4 (in^4)

I_u = moment of inertia of the rudder stock above the neck bearing, in cm^4 (in^4)

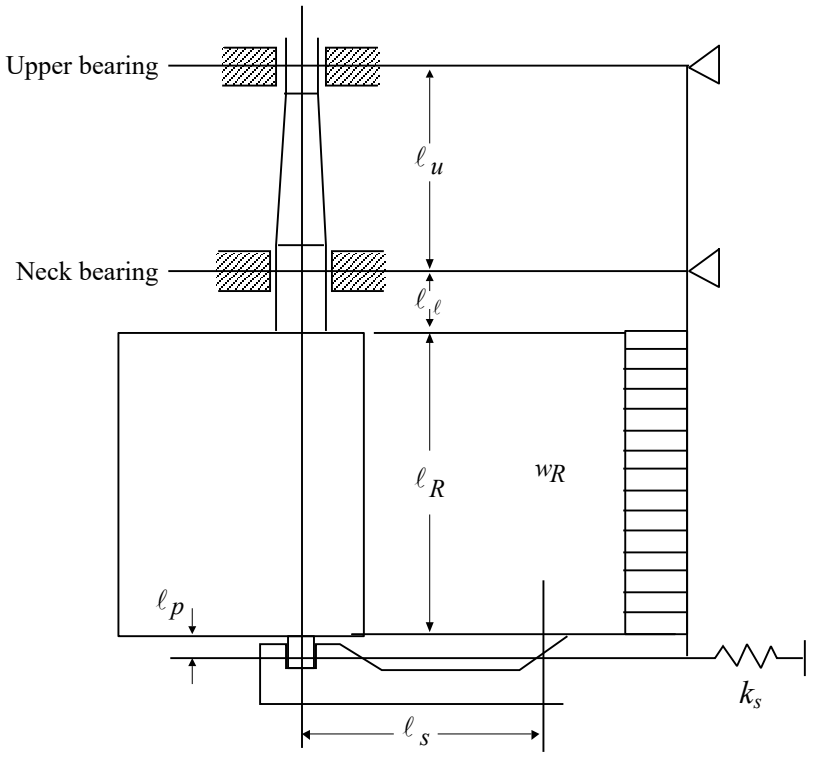
I_ℓ = moment of inertia of the rudder stock below the neck bearing, in cm^4 (in^4)

I_R = moment of inertia of the rudder about the longitudinal axis, in cm^4 (in^4)

I_p = moment of inertia of the pintle, in cm^4 (in^4)

ℓ_ℓ, ℓ_s, ℓ_R and ℓ_u are dimensions as indicated in 3-2-A2/Figure 2, in m (ft).

FIGURE 2
Rudder Supported by Shoepiece



7 Rudders Supported by a Horn with One Pintle *(2009)*

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-A2/Figure 3.

w_{R1} = rudder load per unit length above pintle

= $\dfrac{C_{R1}}{\ell_{R1}}$ kN/m (tf/m, Ltf/ft)

w_{R2} = rudder load per unit length below pintle

= $\dfrac{C_{R2}}{\ell_{R2}}$ kN/m (tf/m, Ltf/ft)

where

C_{R1} = rudder force, as defined in 3-2-11/3.3

C_{R2} = rudder force, as defined in 3-2-11/3.3

k_h = spring constant reflecting support of the horn

= $\dfrac{1}{\dfrac{\ell_h^3}{n_b I_h} + \dfrac{\Sigma\left(\dfrac{s_i}{t_i}\right) e^2 \ell_h}{n_t a^2}}$ 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)

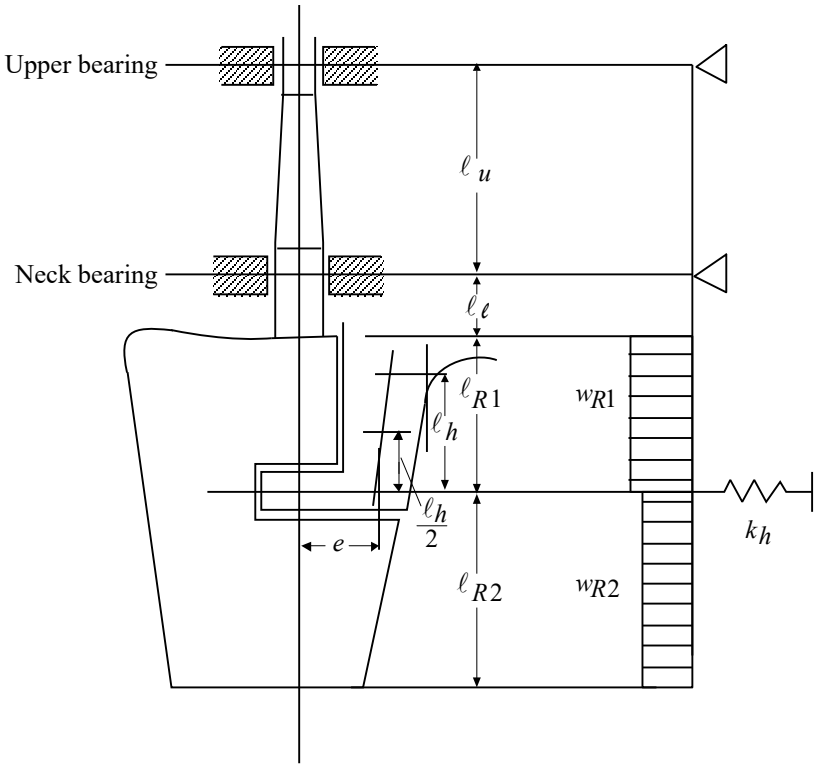
s_i = the girth length of each segment of the horn of thickness t_i, in cm (in.)

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_{R1} and ℓ_{R2} are dimensions as indicated in 3-2-A2/Figure 3, in m (ft).

FIGURE 3
Rudder Supported by a Horn with One Pintle *(2009)*



9 Rudders Supported by a Horn Arranged with Two Pintles (Supports) *(1 July 2016)*

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-A2/Figure 4.

w_{R1} = rudder load per unit length above lower rudder support/pintle

$$= \frac{C_{R1}}{\ell_{R1}} \text{ kN/m (tf/m, Ltf/ft)}$$

w_{R2} = rudder load per unit length below lower rudder support/pintle

$$= \frac{C_{R2}}{\ell_{R2}} \text{ kN/m (tf/m, Ltf/ft)}$$

where

C_{R1} = rudder force, as defined in 3-2-11/3.3

C_{R2} = rudder force, as defined in 3-2-11/3.3

ℓ_{R1} and ℓ_{R2} are dimensions as indicated in 3-2-A2/Figure 4, in m (ft).

In 3-2-A2/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:

$$y_1 = -K_{12}\,B_2 - K_{22}\,B_1 \quad \text{m (ft)}$$

- At the upper rudder horn bearing:

$$y_2 = -K_{11}\,B_2 - K_{12}\,B_1 \quad \text{m (ft)}$$

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:

$$K_{11} = m\left[1.3\frac{\lambda^3}{3EJ_{1h}} + \frac{e^2\lambda}{GJ_{th}}\right] \quad \text{m/kN (m/tf, ft/Ltf)}$$

$$K_{22} = m\left[1.3\left[\frac{\lambda^3}{3EJ_{1h}} + \frac{\lambda^2(d-\lambda)}{2EJ_{1h}}\right] + \frac{e^2\lambda}{GJ_{th}}\right] \quad \text{m/kN (m/tf, ft/Ltf)}$$

$$K_{12} = m\left[1.3\left[\frac{\lambda^3}{3EJ_{1h}} + \frac{\lambda^2(d-\lambda)}{EJ_{1h}} + \frac{\lambda(d-\lambda)^2}{EJ_{1h}} + \frac{(d-\lambda)^3}{3EJ_{2h}}\right] + \frac{e^2 d}{GJ_{th}}\right] \quad \text{m/kN (m/tf, ft/Ltf)}$$

m = 1.00 (9.8067, 32.691)

d = height of the rudder horn, in m (ft), defined in 3-2-A2/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-A2/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-A2/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-A2/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-A2/Figure 4).

J_{th} = torsional stiffness factor of the rudder horn, in m^4 (ft^4)

$$= \frac{4F_T^2}{\sum_i \frac{u_i}{t_i}} \quad \text{for any thin wall closed section, in m}^4\ (\text{ft}^4)$$

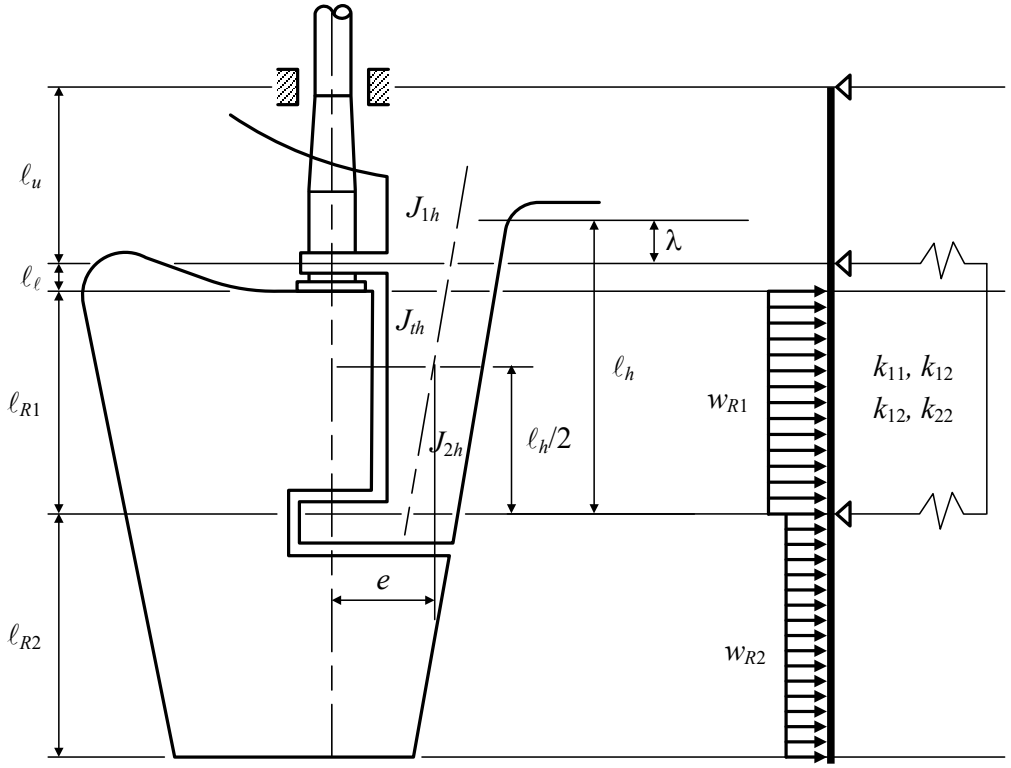
Note that the J_{th} value is taken as an average value, valid over the rudder horn height.

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) *(1 July 2016)*



PART
3

CHAPTER **2 Hull Structures and Arrangements**

SECTION **12 Protection of Deck Openings**

1 General

All openings in decks are to be framed to provide efficient support and attachment for the ends of the deck beams. The proposed arrangement and details for all hatchways are to be submitted for approval.

3 Additional Requirements for Bulk Carriers, Ore Carriers and Combination Carriers *(2004)*

On all bulk carriers, ore carriers and combination carriers, in addition to all relevant requirements in this Section, all cargo hold hatch covers, hatch coamings and closing arrangements for cargo hold hatches in position 1, as defined in 3-2-12/5.1, are to meet the requirements in 5C-4-2/13.3 of the *Steel Vessel Rules*.

5 Positions and Design Pressures *(1 January 2005)*

5.1 Positions of Deck Openings *(1 January 2005)*

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.

5.3 Vertical Weather Design Pressures *(1 July 2018)*

The design pressures are not to be taken as less than the following. Values at intermediate lengths are to be determined by interpolation.

5.3.1 Cargo Hatch Covers in Position 1

$$p = R\{15.8 + (L_f/N)[1 - (5/3)(x/L_f)] - 3.6x/L_f\} \quad \text{kN/m}^2 \text{ (tf/m}^2\text{, Ltf/ft}^2\text{)}$$

In no case is p to be less than:

$$p = 1.2897(0.15L_f + 11.6) \quad \text{kN/m}^2$$
$$= 0.1316(0.15L_f + 11.6) \quad \text{tf/m}^2$$
$$= 0.0121(0.0457L_f + 11.6) \quad \text{Ltf/ft}^2$$

For a position 1 hatchway located at least one superstructure standard height higher than the freeboard deck:

$$p = 1.2897\ (0.15L_f + 11.6) \quad \text{kN/m}^2$$
$$= 0.1316(0.15L_f + 11.6) \quad \text{tf/m}^2$$
$$= 0.0121(0.0457L_f + 11.6) \quad \text{Ltf/ft}^2$$

where

L_f = freeboard length, in m (ft), as defined in 3-1-1/3.3

L_{f1} = freeboard length, in m (ft), as defined in 3-1-1/3.3, but is not to be taken as less than 24 m (80 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)

5.3.2 Cargo Hatch Covers in Position 2

Where a position 2 hatchway is located at least one superstructure standard height higher than the freeboard deck, the 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 3-2-12/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 3-2-12/Figure 2.

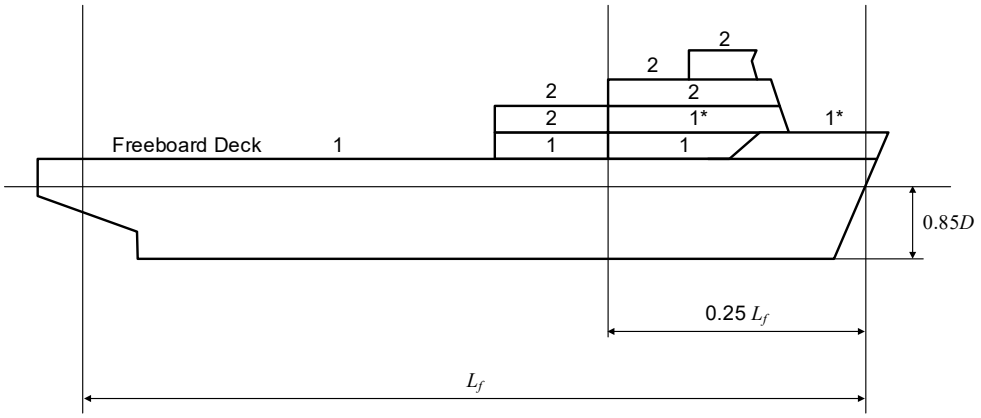
$h_N = (1.05 + 0.01L_f)$ m

where $1.8 \text{ m} \le h_N \le 2.3$ m

$h_N = 3.281\ (1.05 + 0.0031L_f)$ ft

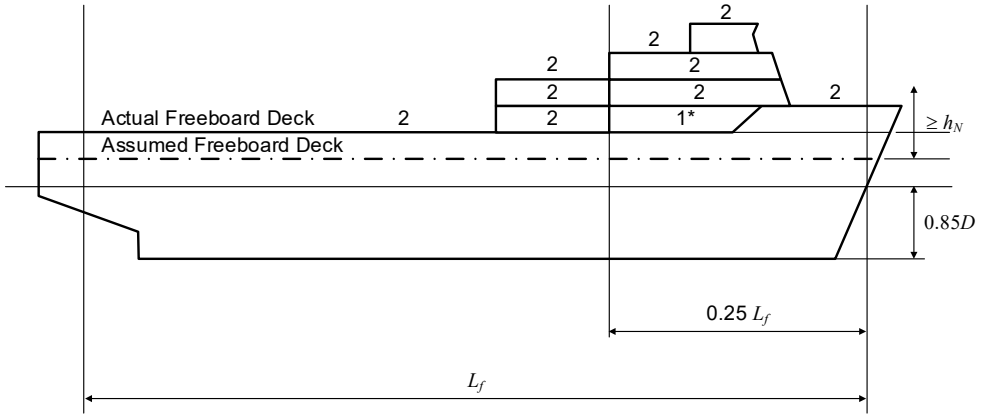
where $5.91 \text{ ft} \le h_N \le 7.55$ ft

FIGURE 1
Positions 1 and 2 *(1 July 2018)*



* reduced load upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck

FIGURE 2
Positions 1 and 2 for an Increased Freeboard *(1 July 2018)*



* reduced load upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck

5.5 Horizontal Weather 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:

$$p_H = a_H c_H R(b_H c_L f - z) \quad \text{kN/m}^2 \text{ (tf/m}^2\text{, Ltf/ft}^2\text{)}$$

where

f = $0.04L + 4.1$ for L in meters

= $0.0122L + 4.1$ for L in feet

c_L = $\sqrt{0.011L}$ for L in meters

= $\sqrt{0.00336L}$ for L in feet

b_H = $1.0 + \left(\dfrac{\frac{x'}{L} - 0.45}{C_b + 0.2}\right)^2$ for $\dfrac{x'}{L} < 0.45$

= $1.0 + 1.5\left(\dfrac{\frac{x'}{L} - 0.45}{C_b + 0.2}\right)^2$ for $\dfrac{x'}{L} \geq 0.45$

a_H = $20 + \dfrac{e_H L_1}{12}$ for unprotected front coamings and hatch cover skirt plates

= $10 + \dfrac{e_H L_1}{12}$ 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

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 3-2-12/5.3.1

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 3-2-12/Table 1.

TABLE 1
Minimum Design Load $p_{H\min}$ *(1 July 2018)*

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)	$R\left(25 + \frac{e_H L}{10}\right)$	$R\left(12.5 + \frac{e_H L}{20}\right)$

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 3-2-12/11.23.2(c).

7 Hatchway Coamings, Companionway Sills and Access Sills

7.1 Coaming and Sill Heights

The heights above deck of coamings of hatchways secured weathertight by tarpaulins and battening devices, and sills of companionways and access openings, are to be not less than given in 3-2-12/Table 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.

TABLE 2
Coaming and Sill Heights

L equal to or over 24 meters (79 feet) in length

	Position 1	*Position 2*
Hatch Coamings	600 mm (23.5 in.)	450 mm (17.5 in.)
Companionway Sills	600 mm (23.5 in.)	380 mm (15 in.)
Access Sills	380 mm (15 in.)	380 mm (15 in.)

L under 24 meters (79 feet) in length

	Position 1	*Position 2*
Hatch Coamings and Companionways	450 mm (17.5 in.)	300 mm (12 in.)
Access Sills	380 mm (15 in.)	300 mm (12 in.)

Notes:

1 Coaming and 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 coaming/sill height should be as indicated above, unless otherwise specifically requested by Flag Administration.

7.3 Coaming Plates *(1 July 2018)*

Where 3-2-12/11 is not applicable, coaming plates 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)

7.5 Coaming Stiffeners *(2016)*

Except as noted below, coaming stiffening is to comply with the following:

i) Horizontal stiffeners are to be fitted on coamings 450 mm (17.5 in.) or greater in height.*

ii) The breadth of the stiffeners is not to be less than that obtained from the following equation:*

$$b = 1.67L + 50 \quad \text{mm}$$

$$b = 0.02L + 2 \quad \text{in.}$$

where

b = breadth, in mm (in.)

L = length of vessel, in m (ft), as defined in 3-1-1/3, but need not exceed 76 m (250 ft)

iii) Efficient brackets or stays are to be fitted from the stiffeners to the deck at intervals of not more than 3 m (10 ft).*

iv) Where exposed coamings are 760 mm (30 in.) or more in height, the arrangement of the stiffeners and brackets or stays is to provide equivalent support.*

v) Where end coamings are protected, the arrangement of the stiffeners and brackets or stays may be modified.

vi) Where chocks are provided on the coaming to limit the horizontal movement of hatch covers, the strength of the coaming and deck structure is to be adequate to withstand the load on these chocks. Similar consideration is to be given to pads supporting the weight from hatch covers.

* *Note:* Small hatches as specified in 3-2-12/14 need not comply with these requirements. (See the strength requirements for small hatches in 3-2-12/14.3)

7.7 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, they are, in general, to be longitudinally stiffened. The coaming thickness is to be not less than required by 3-2-3/3, and the longitudinal stiffeners not less than required by 3-2-6/1.3 for strength deck longitudinal beams where s is the stiffener spacing, ℓ is the distance between coaming brackets, and h is as given in 3-2-6/1.3.2. Special consideration will be given to the coaming scantlings where adequate buckling strength is shown to be otherwise provided.

9 Hatchways Closed by Portable Covers and Secured Weathertight by Tarpaulins and Battening Devices

9.1 Pontoon Covers

9.1.1 Scantlings *(1 January 2005)*

Where steel pontoon covers are used, the maximum allowable stress and deflection under the design pressures in 3-2-12/5.3, 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, in mm (in.)

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-A3 may be used to determine required scantlings.

9.1.2 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.

9.1.3 Wedges

Wedges are to be of tough wood with 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.

9.1.4 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.).

9.1.5 Tarpaulins

At least two thoroughly waterproofed tarpaulins 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.

9.1.6 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.

9.3 Wooden Hatch Covers

9.3.1 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.

9.3.2 Portable Beams *(1 January 2005)*

Where portable beams for supporting wooden hatch boards are made of steel, the maximum allowable stress and deflection under the design loads in 3-2-12/5.3 are as follows:

Maximum allowable stress	$0.68Y$
Maximum allowable deflection	0.0044 times the span

Where Y is as defined in 3-2-12/9.1.1.

Where the cross section of portable beams is not constant along the span, Appendix 3-2-A3 may be used to determine required beam scantlings.

9.3.3 Closing/Securing Arrangements

Closing arrangements are to be in accordance with 3-2-12/9.1.2 through 3-2-12/9.1.6.

9.3.4 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.

9.5 Steel Hatch Covers

9.5.1 Scantlings *(1 January 2005)*

Where steel hatch covers are fitted, the maximum allowable stress and deflection under the design loads in 3-2-12/5.3 and the minimum top plate thickness 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 and s are as defined in 3-2-12/9.1.1.

Covers are to be assumed to be simply supported.

Where the cross section of hatch over stiffeners is not constant along the span, Appendix 3-2-A3 may be used to determine required scantlings.

9.5.2 Closing Arrangements

Closing arrangements are to be in accordance with 3-2-12/9.1.2 through 3-2-12/9.1.6.

9.7 Bearing Surface

The width of each bearing surface for hatchway covers is to be at least 65 mm (2.5 in.)

9.9 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.

11 Hatchways Closed by Covers of Steel Fitted with Gaskets and Clamping Devices *(1 July 2018)*

These requirements apply to all ships except 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 in 5C-3-4/19 of the *Steel Vessel Rules*.

11.1 Strength of Covers

11.1.1 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 3-2-12/5.5 and 3-2-12/11.9 to 3-2-12/11.13, the equivalent stress σ_e related to the net thickness shall not exceed 0.9Y when the stresses are assessed by means of FEM.

For grillage analysis, the equivalent stress may be taken as follows:

$$\sigma_e = \sqrt{\sigma^2 + 3\tau^2} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

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:

$$\sigma_e = \sqrt{\sigma_x{}^2 - \sigma_x \cdot \sigma_y + \sigma_y{}^2 + 3\tau^2} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

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) of the *Steel Vessel Rules*.

11.1.2 Deflection

The maximum vertical deflection of primary supporting members due to the vertical design load according to 3-2-12/5.3 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.

11.1.3 Material

Hatch covers and coamings are to be made of material in accordance with 3-1-2/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.

11.1.4 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.

11.1.5 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 3-2-12/11.1 through 3-2-12/11.17 and 3-2.12/11.21.

The required gross thicknesses are obtained by adding corrosion additions, t_S, given in 3-2-12/Table 9.

Strength calculations using beam theory, grillage analysis or FEM are to be performed with net scantlings.

11.3 Local Net Plate Thickness

The minimum local net plate thickness t of the hatch cover top plating is:

$$t = 15.8F_p s\sqrt{\frac{p}{0.95Y}} \quad \text{mm}$$

$$t = 23.64F_p s\sqrt{\frac{p}{0.95Y}} \quad \text{in.}$$

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)

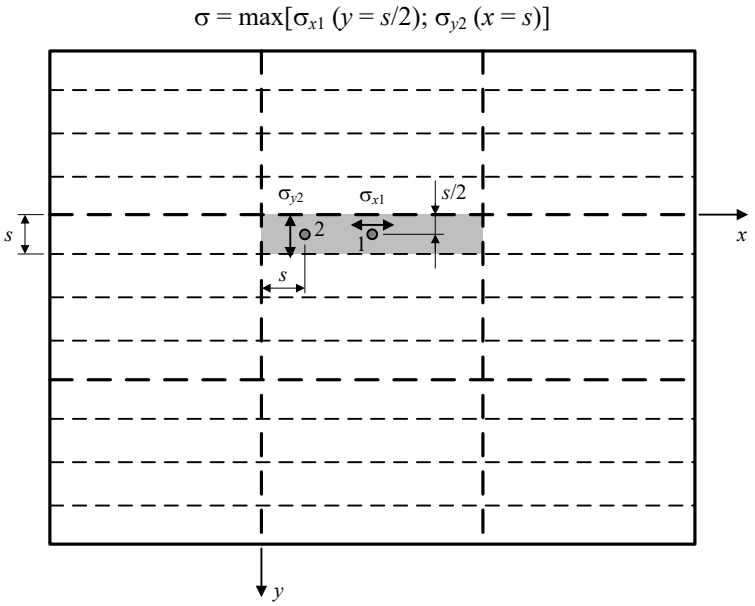
p = pressure p_V and p_L, as defined in 3-2-12/5.3 and 3-2-12/11.9.1, in kN/m^2 (tf/m^2, Ltf/ft^2)

σ = maximum normal stress of hatch cover top plating, determined according to 3-2-12/Figure 3, N/mm^2 (kgf/mm^2, psi)

Y is as defined in 3-2-12/11.1

For flange plates under compression sufficient buckling strength according to 3-2-12/11.17 is to be demonstrated.

FIGURE 3
Determination of Normal Stress of the Hatch Cover Plating *(1 July 2018)*



11.3.1 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 3-2-3/7.

Where the hatch cover is subject to other load as well, the hatch cover is to coupling with the applicable requirement in 3-2-12/11.

11.3.2 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 3-2-12/11.1.1. 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:

$$t = 6.5s \quad \text{mm}$$

$$= 0.078s \quad \text{in.}$$

where s is as defined in 3-2-12/11.3

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.

11.5 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:

$$Z = \frac{104}{Y} s_s \ell_s^2 p \quad \text{cm}^3, \text{ for design load according to 3-2-12/5.3}$$

$$= \frac{2793}{Y} s_s \ell_s^2 p \quad \text{in}^3$$

$$Z = \frac{93}{Y} s_s \ell_s^2 p \quad \text{cm}^3, \text{ for design loads according to 3-2-12/11.9.1}$$

$$= \frac{2498}{Y} s_s \ell_s^2 p \quad \text{in}^3$$

$$A_s = \frac{10.8 s_s \ell_s p}{Y} \quad \text{cm}^2, \text{ for design load according to 3-2-12/5.3}$$

$$= \frac{2418 s_s \ell_s p}{Y} \quad \text{in}^2$$

$$A_s = \frac{9.6 s_s \ell_s p}{Y} \quad \text{cm}^2, \text{ for design load according to 3-2-12/11.9.1}$$

$$= \frac{2149 s_s \ell_s p}{Y} \quad \text{in}^2$$

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 3-2-12/11.1

p is as defined in 3-2-12/11.3

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 3-2-12/11.1

Stiffeners parallel to primary supporting members and arranged within the effective breadth according to 3-2-12/11.15.1 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 3-2-12/11.1.1. 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 3-2-12/11.17.3 is to be verified.

For hatch covers subject to wheel loading or point loads stiffener scantlings are to be determined using the permissible stresses according to 3-2-12/11.1.1.

11.7 Net Scantlings of Primary Supporting Members

11.7.1 Primary Supporting Members

Scantlings of primary supporting members are obtained from calculations according to 3-2-12/11.15 under consideration of permissible stresses according to 3-2-12/11.1.1.

For all components of primary supporting members sufficient safety against buckling must be verified according to 3-2-12/11.17. For biaxial compressed flange plates this is to be verified within the effective widths according to 3-2-12/11.17.3(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 3-2-12/11.3

11.7.2 Edge Girders (Skirt Plates)

Scantlings of edge girders are obtained from the calculations according to 3-2-12/11.15 under consideration of permissible stresses according to 3-2-12/11.1.1.

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 3-2-12/5.5.

Y is as defined in 3-2-12/11.1.

s is as defined in 3-2-12/11.3.

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:

$$I = uq\,s_{SD}^4 \quad \text{cm}^4 \ (\text{in}^4)$$

where

u = 6 (58.842, $7.693 \cdot 10^{-3}$)

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)

11.9 Cargo Loads

11.9.1 Distributed Loads

The load on hatch covers due to distributed 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:

$$p_L = p_C(1 + a_a) \quad \text{kN/m}^2 \ (\text{tf/m}^2, \text{Ltf/ft}^2)$$

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 = $0.11\dfrac{v_0}{\sqrt{e_H L}}$

$$m_D = m_0 - 5(m_0 - 1)\frac{x'}{L} \quad \text{for } 0 \le \frac{x'}{L} \le 0.2$$

$$= 1.0 \quad \text{for } 0.2 < \frac{x'}{L} \le 0.7$$

$$= 1 + \frac{m_0 + 1}{0.3}\left[\frac{x'}{L} - 0.7\right] \quad \text{for } 0.7 < \frac{x'}{L} \le 1.0$$

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.

11.9.2 Point Loads

The load 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:

$$P_P = P_S(1 + a_a) \quad \text{kN (tf, Ltf)}$$

where

P_S = single force, in kN (tf, Ltf)

a_a is as defined in 3-2-12/11.9.1.

11.11 Container Loads

11.11.1 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:

$$P = \frac{M}{4} \cdot (1 + a_a) \quad \text{kN (tf, Ltf)}$$

where

M = maximum designed weight of container stack in kN (tf, Ltf)

a_a is as defined in 3-2-12/11.9.1.

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 3-2-12/Figure 4:

$$A_z = \frac{M}{2} \cdot (1 + a_a) \cdot \left(0.45 - 0.42\frac{h_m}{f_P}\right) \quad \text{kN (tf, Ltf)}$$

$$B_z = \frac{M}{2} \cdot (1 + a_a) \cdot \left(0.45 + 0.42\frac{h_m}{f_P}\right) \quad \text{kN (tf, Ltf)}$$

$$B_y = 0.24465M \quad \text{kN (tf, Ltf)}$$

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 3-2-12/11.9.1.

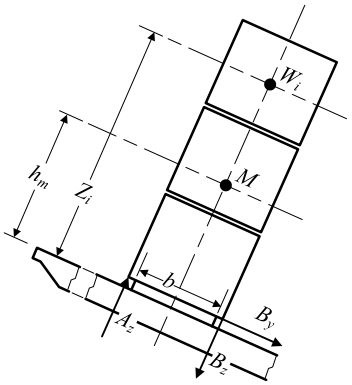
When strength of the hatch cover structure is assessed by grillage analysis according to 3-2-12/11.15, h_m and z_i need to be taken above the hatch cover supports. Force B_y does not need to be considered in this case.

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 *(1 July 2018)*



11.11.2 Load Cases with Partial Loading

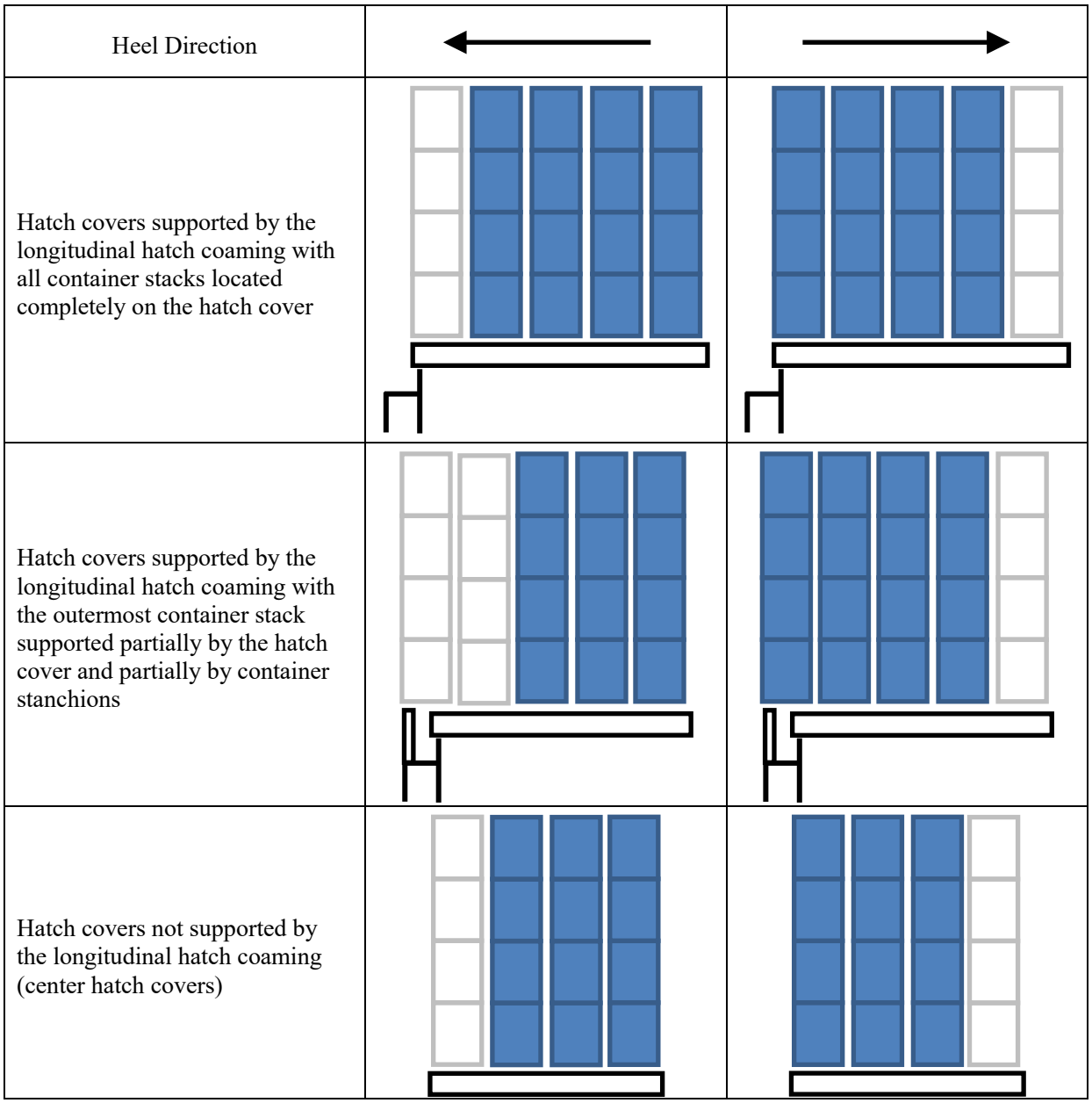
The load cases contained in 3-2-12/11.11.1 are also to be considered for partial non homogeneous loading which may occur in practice (e.g., where specified container stack places are empty). For each hatch cover, the heel directions, as shown in 3-2-12/Figure 5, are to be considered.

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 3-2-12/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 *(1 July 2018)*



11.13 Loads due to Elastic Deformations of the Vessel's Hull

Hatch covers, which in addition to the loads according to 3-2-12/5.3 to 3-2-12/5.5 and 3-2-12/11.9 to 3-2-12/11.11 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 3-2-12/11.1.1.

11.15 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 3-2-12/11.15.2.

11.15.1 Effective Cross-sectional Properties for Calculation by 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 3-2-12/Figure 7.

The effective breadth of plating e_m of primary supporting members is to be determined according to 3-2-12/Table 3, 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 3-2-12/11.17.3(b).

TABLE 3
Effective Breadth e_m of Plating of Primary Supporting Members *(1 July 2018)*

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:

$\ell = \ell_0$ for simply supported primary supporting members

$\ell = 0.6\ \ell_0$ for primary supporting members with both ends constraint,

where ℓ_0 is the unsupported length of the primary supporting member

e width of plating supported, measured from center to center of the adjacent unsupported fields

11.15.2 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.

11.17 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.)

α_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.)

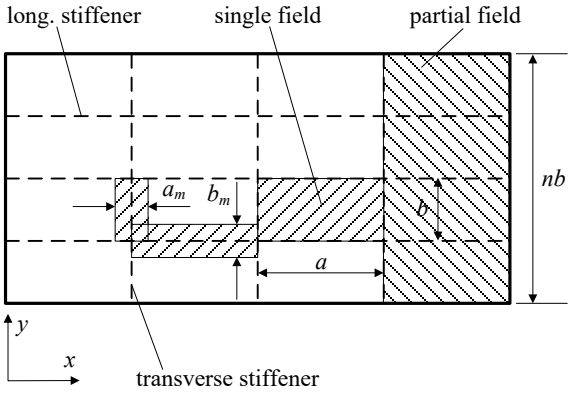
σ_{mx} = membrane stress in x-direction, in N/mm^2 (kgf/mm^2, psi)

σ_{my} = membrane 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)

Compressive and shear stresses are to be taken positive; tension stresses are to be taken negative.

FIGURE 6
General Arrangement of Panel *(1 July 2018)*



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:

$$\sigma_{mx} = (\sigma_x^* - 0.3\,\sigma_y^*)/0.91$$

$$\sigma_{my} = (\sigma_y^* - 0.3\,\sigma_x^*)/0.91$$

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 3-2-12/Table 4.

TABLE 4
Correction Factor F_1 *(1 July 2018)*

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 3-2-12/5.3

= 1.10 for hatch covers when subjected to loads according to 3-2-12/5.5 and 3-2-12/11.9 to 3-2-12/11.13

λ = reference degree of slenderness, taken equal to:

= $\sqrt{\frac{Y}{K\sigma_r}}$

K = buckling factor according to 3-2-12/Table 6

E = *2.06 x 10^5 N/mm^2 (21,000 kgf/mm^3, 30 x 10^6 psi)*

Y is as defined in 3-2-12/11.1.1.

11.17.1 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:

$$\left(\frac{|\sigma_{mx}|SF}{\kappa_x Y}\right)^{e1} + \left(\frac{|\sigma_{my}|SF}{\kappa_y Y}\right)^{e2} - B\left(\frac{\sigma_{mx}\sigma_{my}SF^2}{Y^2}\right) + \left(\frac{|\tau|SF\sqrt{3}}{\kappa_\tau Y}\right)^{e3} \le 1.0$$

The first two terms and the last term of the above condition shall not exceed 1.0.

The reduction factors κ_x, κ_y and κ_τ are given in 3-2-12/Table 5.

Where $\sigma_{mx} \le 0$ (tension stress), $\kappa_x = 1.0$.

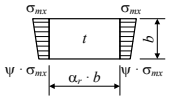
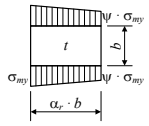
Where $\sigma_{my} \le 0$ (tension stress), $\kappa_y = 1.0$.

The exponents e_1, e_2, and e_3 as well as the factor B are to be taken as given in 3-2-12/Table 5.

TABLE 5
Coefficients e_1, e_2, e_3 and Factor B *(1 July 2018)*

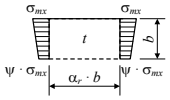
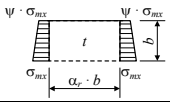
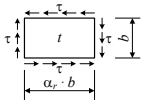
Exponents e_1 - e_3 and Factor B	*Plate Panel*
e_1	$1 + \kappa_x^4$
e_2	$1 + \kappa_y^4$
e_3	$1 + \kappa_x\ \kappa_y\ \kappa_\tau^2$
B σ_{mx} and σ_{my} positive (compression stress)	$(\kappa_x \kappa_y)^5$
B σ_{mx} or σ_{my} negative (tension stress)	1

TABLE 6
Buckling and Reduction Factors for Plane Elementary Plate Panels *(1 July 2018)*

Buckling Load Case	*Edge Stress Ratio* ψ	*Aspect Ratio* $\alpha_r = a/b$	*Buckling Factor K*	*Reduction Factor* κ
1 	$1 \ge \psi \ge 0$	$\alpha_r \ge 1$	$K = \dfrac{8.4}{\psi + 1.1}$	$\kappa_x = 1$ for $\lambda \le \lambda_c$ $\kappa_x = c\left(\dfrac{1}{\lambda} - \dfrac{0.22}{\lambda^2}\right)$ for $\lambda > \lambda_c$ $c = (1.25 - 0.12\psi) \le 1.25$ $\lambda_c = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0.88}{c}}\right)$
	$0 \ge \psi \ge -1$		$K = 7.63 - \psi(6.26 - 10\psi)$	
	$\psi \le -1$		$K = 5.975(1 - \psi)^2$	
2 	$1 \ge \psi \ge 0$	$\alpha_r \ge 1$	$K = F_1\left(1 + \dfrac{1}{\alpha_r^2}\right)^2 \cdot \dfrac{2.1}{(\psi + 1.1)}$	$\kappa_y = c\left(\dfrac{1}{\lambda} - \dfrac{R + F^2(H - R)}{\lambda^2}\right)$ $c = (1.25 - 0.12\psi) \le 1.25$ $R = \lambda\left(1 - \dfrac{\lambda}{c}\right)$ for $\lambda < \lambda_c$ $R = 0.22$ for $\lambda \ge \lambda_c$ $\lambda_c = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0.88}{c}}\right)$ $F = \left(1 - \dfrac{\frac{K}{0.91} - 1}{\lambda_p^{\,2}}\right) \cdot c_1 \ge 0$ $\lambda_p^2 = \lambda^2 - 0.5$ for $1 \le \lambda_p^2 \le 3$ $c_1 = \left(1 - \dfrac{F_1}{\alpha_r}\right) \ge 0$ $H = \lambda - \dfrac{2\lambda}{c\left(T + \sqrt{T^2 - 4}\right)} \ge R$ $T = \lambda + \dfrac{14}{15\lambda} + \dfrac{1}{3}$
	$0 \ge \psi \ge -1$	$1 \le \alpha_r \le 1.5$	$K = F_1\left[\left(1 + \dfrac{1}{\alpha_r^2}\right)^2 \cdot \dfrac{2.1(1 + \psi)}{1.1} - \dfrac{\psi}{\alpha_r^2}(13.9 - 10\psi)\right]$	
		$\alpha_r > 1.5$	$K = F_1\left[\left(1 + \dfrac{1}{\alpha_r^2}\right)^2 \cdot \dfrac{2.1(1 + \psi)}{1.1} - \dfrac{\psi}{\alpha_r^2}\left(5.87 - 1.87\alpha_r^2 + \dfrac{8.6}{\alpha_r^2} - 10\psi\right)\right]$	
	$\psi \le -1$	$1 \le \alpha_r \le \dfrac{3(1 - \psi)}{4}$	$K = 5.975F_1\left(\dfrac{1 - \psi}{\alpha_r}\right)^2$	
		$\alpha_r > \dfrac{3(1 - \psi)}{4}$	$K = F_1\left[3.9675\left(\dfrac{1 - \psi}{\alpha_r}\right)^2 + 0.5375\left(\dfrac{1 - \psi}{\alpha_r}\right)^4 + 1.87\right]$	

Explanations for boundary conditions ----- plate edge free
——— plate edge simply supported

TABLE 6 (continued)
Buckling and Reduction Factors for Plane Elementary Plate Panels *(1 July 2018)*

Buckling Load Case	*Edge Stress Ratio* ψ	*Aspect Ratio* $\alpha_r = a/b$	*Buckling Factor K*	*Reduction Factor* κ
3 	$1 \geq \psi \geq 0$	$\alpha_r > 0$	$K = \dfrac{4\left(0.425 + \dfrac{1}{\alpha_r^2}\right)}{3\psi + 1}$	$\kappa_x = 1$ for $\lambda \leq 0.7$ $\kappa_x = \dfrac{1}{\lambda^2 + 0.51}$ for $\lambda > 0.7$
	$0 \geq \psi \geq -1$		$K = 4\left(0.425 + \dfrac{1}{\alpha_r^2}\right)(1 + \psi) - 5\psi(1 - 3.42\psi)$	
4 	$1 \geq \psi \geq -1$	$\alpha_r > 0$	$K = \left(0.425 + \dfrac{1}{\alpha_r^2}\right)\dfrac{3 - \psi}{2}$	
5 	-----	-----	$K = K_\tau \cdot \sqrt{3}$	$\kappa_\tau = 1$ for $\lambda \leq 0.84$ $\kappa_\tau = \dfrac{0.84}{\lambda}$ for $\lambda > 0.84$
		$\alpha_r \geq 1$	$K_\tau = \left[5.34 + \dfrac{4}{\alpha_r^2}\right]$	
		$0 < \alpha_r < 1$	$K_\tau = \left[4 + \dfrac{5.34}{\alpha_r^2}\right]$	
Explanations for boundary conditions		- - - - - plate edge free ——— plate edge simply supported		

11.17.2 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 3-2-12/11.17.1.

11.17.3 Strength of Partial and Total Fields of Hatch Covers

11.17.3(a) Longitudinal and Transverse Secondary Stiffeners. It is to be demonstrated that the continuous longitudinal and transverse stiffeners of partial and total plate fields comply with the conditions set out in 3-2-12/11.17.3(c) through 3-2-12/11.17.3(d).

For u-type stiffeners, the proof of torsional buckling strength according to 3-2-12/11.17.3(d) can be omitted.

Single-side welding is not permitted to use for secondary stiffeners except for u-stiffeners.

11.17.3(b) Effective Width of Hatch Cover Top and Bottom Plating. For demonstration of buckling strength according to 3-2-12/11.17.3(c) through 3-2-12/11.17.3(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 3-2-12/11.17.

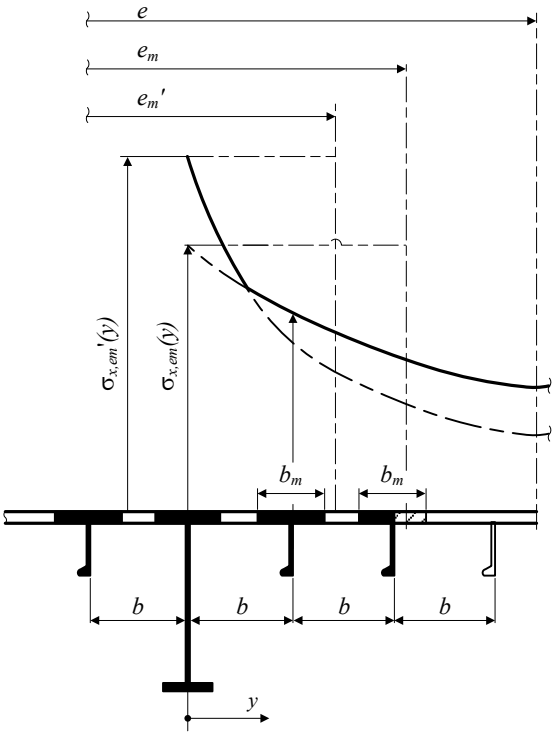
κ_x, κ_y are as defined in 3-2-12/11.17.1.

See also 3-2-12/Figure 6.

The effective width of plating is not to be taken greater than the value obtained from 3-2-12/11.15.1.

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 *(1 July 2018)*



i) Stiffening Parallel to Web of Primary Supporting Member

$$b < e_m$$

$$e'_m = nb_m$$

$$n = \left(\frac{e_m}{b}\right)$$

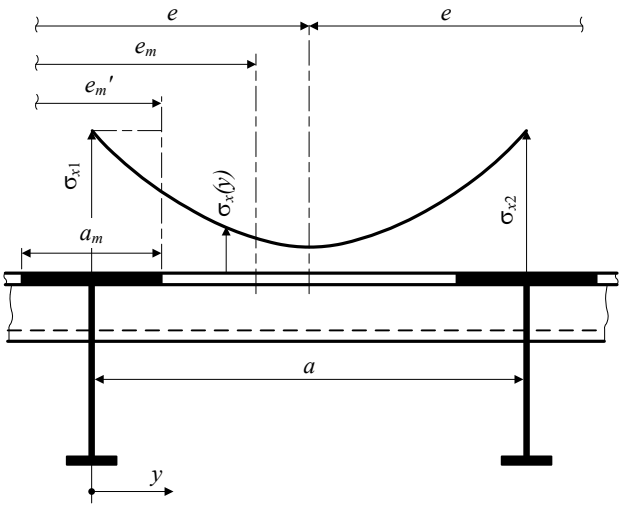
where

b_m = effective width of plating for transverse stiffeners, in mm (in.)

e and e_m are as defined in 3-2-12/11.15.

b and n are as defined in 3-2-12/11.17.

FIGURE 8
Stiffening Perpendicular to Web of Primary Supporting Member *(1 July 2018)*



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 3-2-12/11.15.

a and n are as defined in 3-2-12/11.17.

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:

$$\sigma_{mx}(y) = \sigma_{x1}\left\{1 - \frac{y}{e}\left[3 + c_1 - 4c_2 - 2\frac{y}{e}(1 + c_1 - 2c_2)\right]\right\}$$

where

$$c_1 = \frac{\sigma_{x2}}{\sigma_{x1}} \qquad 0 \leq c_1 \leq 1$$

$$c_2 = \frac{1.5}{e} \cdot \left(e''_{m1} + e''_{m2}\right) - 0.5$$

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 3-2-13/11.15.

Shear stress distribution in the flange plates may be assumed linearly.

11.17.3(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 transverse stiffeners, in N/mm^2 (kgf/mm^2, psi)

σ_b = bending stress in the stiffener

= $\dfrac{M_0 + M_1}{Z_{st} \cdot 10^3}$, in N/mm^2 (kgf/mm^2)

= $998\left(\dfrac{M_0 + M_1}{Z_{st} \cdot 10^3}\right)$, in psi

M_0 = bending moment due to the deformation w of stiffener, taken equal to:

= $F_{Ki}\dfrac{p_z w}{c_f - p_z}$ 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:

= $\dfrac{p_\ell b a^2}{24 \cdot 10^3}$ for longitudinal stiffeners, in N-mm (kgf/mm)

= $\dfrac{15593 p_\ell b a^2}{24 \cdot 10^3}$ for longitudinal stiffeners, in lbf-in

= $\dfrac{p_\ell a (nb)^2}{c_s 8 \cdot 10^3}$ for transverse stiffeners, in N-mm (kgf/mm)

= $\dfrac{15593 p_\ell a (nb)^2}{c_s 8 \cdot 10^3}$ for transverse stiffeners, in lbf-in

n is as defined in 3-2-12/11.17, 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} = $\frac{\pi^2}{a^2} EI_x \cdot 10^4$ for longitudinal stiffeners, in N (kgf)

= $\frac{\pi^2}{a^2} EI_x$ for longitudinal stiffeners, in lbf

F_{Kiy} = $\frac{\pi^2}{(nb)^2} EI_y \cdot 10^4$ for transverse stiffeners, in N (kgf)

F_{Kiy} = $\frac{\pi^2}{(nb)^2} EI_y$ 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 3-2-12/11.17.3(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

= $I_y \geq \frac{at^3}{12 \cdot 10^4}$ 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:

$$\frac{a}{b} \geq 2.0 \quad : \quad m_1 = 1.47 \quad m_2 = 0.49$$

$$\frac{a}{b} < 2.0 \quad : \quad m_1 = 1.96 \quad m_2 = 0.37$$

for transverse stiffeners:

$$\frac{a}{nb} \geq 0.5 \quad : \quad m_1 = 0.37 \quad m_2 = \frac{1.96}{n^2}$$

$$\frac{a}{nb} < 0.5 \quad : \quad m_1 = 0.49 \quad m_2 = \frac{1.47}{n^2}$$

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:

= $\frac{p_\ell b a^4}{384 \cdot 10^7 \cdot EI_x}$ for longitudinal stiffeners, in mm

= $\frac{1550 p_\ell b a^4}{384 \cdot 10^2 \cdot EI_x}$ for longitudinal stiffeners, in inches

= $\frac{5 a p_\ell (nb)^4}{384 \cdot 10^7 \cdot EI_y c_s^2}$ for transverse stiffeners, in mm

= $\frac{775 a p_\ell (nb)^4}{3840 \cdot EI_y c_s^2}$ for transverse stiffeners, in inches

c_f = elastic support provided by the stiffener

i) *For longitudinal stiffeners:*

$$c_{fx} = F_{Kix}\frac{\pi^2}{a^2}(1 + c_{px}), \text{ in N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

$$c_{px} = \frac{1}{1+\dfrac{0.91\left(\dfrac{12\cdot 10^4 I_x}{t^3 b}-1\right)}{c_{xa}}}, \text{ in N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

$$c_{px} = \frac{1}{1+\dfrac{0.91\left(\dfrac{12\cdot I_x}{t^3 b}-1\right)}{c_{xa}}}, \text{ in psi}$$

$$c_{xa} = \left[\frac{a}{2b}+\frac{2b}{a}\right]^2 \quad \text{for } a \geq 2b$$

$$= \left[1+\left(\frac{a}{2b}\right)^2\right]^2 \quad \text{for } a < 2b$$

ii) *For transverse stiffeners:*

$$c_{fy} = c_S F_{Kiy}\frac{\pi^2}{(nb)^2}(1 + c_{py}), \text{ in N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

$$c_{py} = \frac{1}{1+\dfrac{0.91\left(\dfrac{12\cdot 10^4 I_y}{t^3 a}-1\right)}{c_{ya}}}, \text{ in N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

$$c_{py} = \frac{1}{1+\dfrac{0.91\left(\dfrac{12 I_y}{t^3 a}-1\right)}{c_{ya}}}, \text{ in psi}$$

$$c_{ya} = \left[\frac{nb}{2a}+\frac{2a}{nb}\right]^2 \quad \text{for } nb \geq 2a$$

$$= \left[1+\left(\frac{nb}{2a}\right)^2\right]^2 \quad \text{for } nb < 2a$$

c_s = factor accounting for the boundary conditions of the transverse stiffener

= 1.0 for simply supported stiffeners

= 2.0 for partially constraint stiffeners

Z_{st} = net section modulus of stiffener (long. or transverse) including effective width of plating according to 3-2-12/11.17.3(b), in cm^3 (in^3)

E = *2.06 x 10^5 N/mm^2 (21,000 kgf/mm^3, 30 x 10^6 psi)*

Ψ, σ_{mx}, σ_{my}, τ, SF, t, a, and b are as defined in 3-2-12/11.17,

Y is as defined in 3-2-12/11.1.1,

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).

11.17.3(d) Torsional Buckling of Secondary Stiffeners.

i) Longitudinal Secondary Stiffeners. The longitudinal ordinary stiffeners are to comply with the following criteria:

$$\frac{\sigma_{mx} SF}{\kappa_T Y} \le 1.0$$

where

κ_T = coefficient taken equal to:

= 1.0 for $\lambda_T \le 0.2$

$$= \frac{1}{\Phi + \sqrt{\Phi^2 - \lambda_T^2}} \quad \text{for } \lambda_T > 0.2$$

Φ = $0.5[1 + 0.21(\lambda_T - 0.2) + \lambda_T^2]$

λ_T = reference degree of slenderness taken equal to:

$$= \sqrt{\frac{Y}{\sigma_{KiT}}}$$

$$\sigma_{KiT} = \frac{E}{I_P}\left(\frac{\pi^2 I_\omega 10^2}{a^2}\varepsilon + 0.385 I_T\right), \text{ in N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

$$= \frac{E}{100 I_P}\left(\frac{\pi^2 I_\omega 10^2}{a^2}\varepsilon + 0.385 I_T\right), \text{ in psi}$$

For I_p, I_T, I_ω see 3-2-12/Figure 9 and 3-2-12/Table 7.

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.)

E = *2.06 x 10^5 N/mm^2 (21,000 kgf/mm^2, 30 x 10^6 psi)*

SF, σ_{mx}, *a*, and *b* are as defined in 3-2-12/11.17.

Y is as defined in 3-2-12/11.1.1.

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 3-2-12/11.17.3(d)i).

FIGURE 9
Dimensions of Stiffeners *(1 July 2018)*

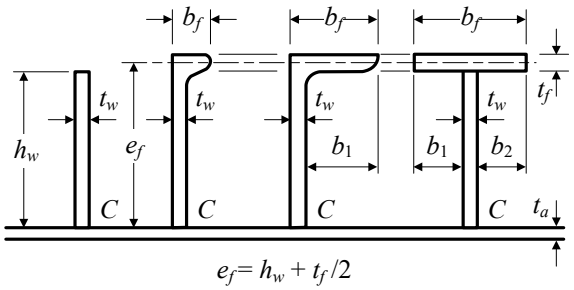


TABLE 7
Moments of Inertia *(1 July 2018)*

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	$\frac{1}{i_m}\left(\frac{A_w \cdot h_w^2}{3} + A_f \cdot e_f^2\right)$	$\frac{h_w \cdot t_w^3}{3 \cdot i_m}\left(1 - 0.63\frac{t_w}{h_w}\right)$ + $\frac{b_f \cdot t_f^3}{3 \cdot i_m}\left(1 - 0.63\frac{t_f}{b_f}\right)$	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			

11.19 Details of Hatch Covers

11.19.1 Container Foundations on Hatch Covers

The substructures of container foundations are to be designed for cargo and container loads according to 3-2-12/4.3 through 3-2-12/5.5 and 3-2-12/11.9 through 3-2-12/11.11 applying the permissible stresses according to 3-2-12/11.1.1.

11.19.2 Weathertightness

11.19.2(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.

11.19.2(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 3-2-12/11.19.2(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:

  $$H(x) \geq d + f_b + h \quad \text{m (ft)}$$

  where

  f_b = minimum required freeboard for the vessel, in m (ft)

h = 4.6 m (15.09 ft) for $\frac{x}{L_f} \le 0.75$

= 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.
- Bilge alarms are to be provided in each hold fitted with non-weathertight covers.
- 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.

11.19.2(c) Drainage Arrangements. Cross-joints of multi-panel covers are to be provided with efficient drainage arrangements.

11.21 Hatch Coaming Strength Criteria

11.21.1 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 $(0.236 + \frac{1.2L_1}{10000}$ in.)

where

L_1 = L, need not be taken greater than 300 m (958 ft)

s is as defined in 3-2-12/11.3.

p_H is as defined in 3-2-12/5.5.

Y is as defined in 3-2-12/11.1.1.

Longitudinal strength aspects are to be observed.

11.21.2 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:

$$Z = \frac{83}{Y} s\ell_s^2 p_H \quad \text{cm}^3$$

$$= \frac{2230}{Y} s\ell_s^2 p_H \quad \text{in}^3$$

$$A_s = \frac{10 s\ell_s p_H}{Y} \quad \text{cm}^2$$

$$= \frac{2240 s\ell_s p_H}{Y} \quad \text{in}^2$$

where

ℓ_s = secondary stiffener span to be taken as the spacing of coaming stays, in m (ft)

s is as defined in 3-2-12/11.3.

p_H is as defined in 3-2-12/5.5.

Y is as defined in 3-2-12/11.1.1.

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:

$$t = 19.6\sqrt{\frac{p_H s(\ell - 0.5\, s)}{Y}} \quad \text{mm}$$

$$= 29.32\sqrt{\frac{p_H s(\ell - 0.5\, s)}{Y}} \quad \text{in.}$$

where

s is as defined in 3-2-12/11.3.

p_H is as defined in 3-2-12/5.5.

Y is as defined in 3-2-12/11.1.1.

11.21.3 Coaming Stays

Coaming stays are to be designed for the loads transmitted through them and permissible stresses according to 3-2-12/11.1.1.

11.21.3(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 3-2-12/Figure 10 a and b) shall not be less than:

$$Z = \frac{526}{Y} e_s h_s^2 p_H \quad \text{cm}^3$$

$$= \frac{14138}{Y} e_s h_s^2 p_H \quad \text{in}^3$$

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 3-2-12/5.5.

Y is as defined in 3-2-12/11.1.1.

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.

11.21.3(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 3-2-12/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 3-2-12/11.25, in mm (in.)

e_s and h_s are as defined in 3-2-12/11.21.3(a).

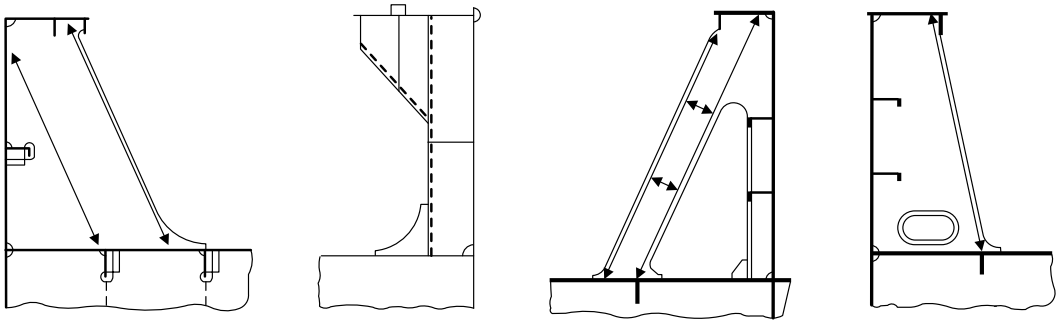
p_H is as defined in 3-2-12/5.5.

Y is as defined in 3-2-12/11.1.1.

For other designs of coaming stays, such as those shown in 3-2-12/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 3-2-12/11.1.1.

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 *(1 July 2018)*



a b c d

11.21.3(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.

11.21.4 Further Requirements for Hatch Coamings

11.21.4(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 3-2-12/7.9).

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.

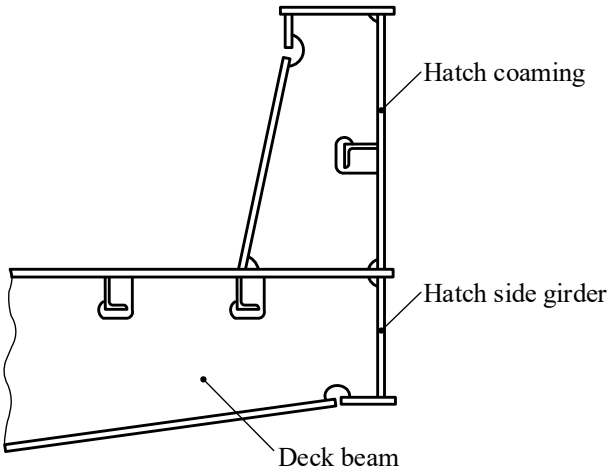
11.21.4(b) Local Details. Local details are to be adequate for the purpose of transferring the loads on the hatch covers to the hatch coamings and, through them, to the deck structures below. Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.

Structures under deck are to be checked against the load transmitted by the stays.

11.21.4(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.

11.21.4(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. 3-2-12/Figure 11 gives an example.

FIGURE 11
Example for Arrangement of Coaming Plates *(1 July 2018)*



11.21.4(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.

11.23 Closing Arrangements

11.23.1 Securing Devices

11.23.1(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 3-2-12/11.7.2. 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.

11.23.1(b) Rod Cleats. Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

11.23.1(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.

11.23.1(d) Cross-sectional Area of the Securing Devices. The gross cross-sectional area of the securing devices is not to be less than:

$$A = qs_{SD}k_\ell \quad \text{cm}^2\ (\text{in}^2)$$

where

s_{SD} = spacing between securing devices as defined in 3-2-12/11.7.2, 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 3-2-12/11.1.1, 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/mm² (23.963 kgf/mm^2, 34084 psi)

q is as defined in 3-2-12/11.7.2.

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 3-2-12/11.23.1(e). As load the packing line pressure q multiplied by the spacing between securing devices s_{SD} is to be applied.

11.23.1(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 3-2.12/11.11, see 3-2-12/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:

$$\sigma_V = \frac{42}{k_\ell} \text{ N/mm}^2$$

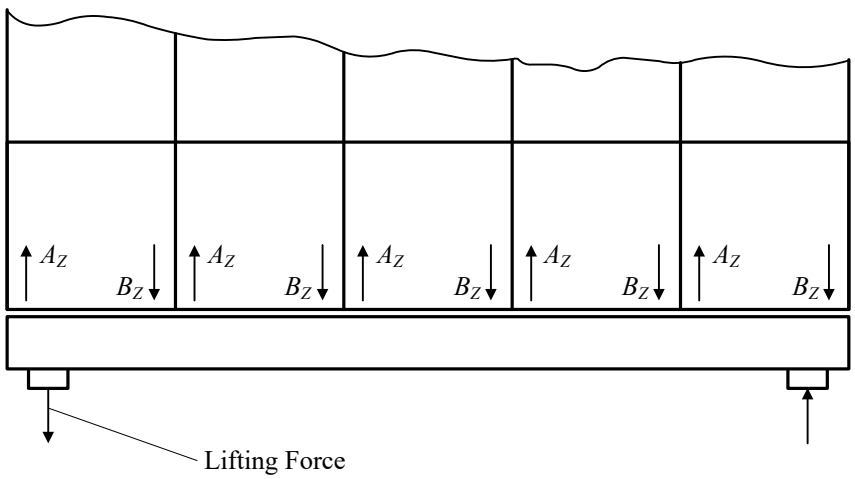
$$= \frac{42.08}{k_\ell} \text{ kgf/mm}^2$$

$$= \frac{50.41}{k_\ell} \text{ psi}$$

where k_ℓ is as defined in 3-2-12/11.23.1(d).

The partial load cases given in 3-2-12/Figure 5 may not cover all unsymmetrical loadings, critical for hatch cover lifting.

FIGURE 12
Lifting Forces at a Hatch Cover *(1 July 2018)*



11.23.2 Hatch Cover Supports, Stoppers and Supporting Structures

11.23.2(a) Horizontal Mass Forces. For the design of hatch cover supports the horizontal mass force is to be calculated:

$$F_h = m_h a_h \text{ N}$$

$$= 0.102 m_h a_h \text{ kgf}$$

$$= 0.031 m_h a_h \text{ lbf}$$

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 3-5-1/13.3.2.

The accelerations in longitudinal direction and in transverse direction do not need to be considered as acting simultaneously.

11.23.2(b) Hatch Cover Supports. For the transmission of the support forces resulting from the load cases specified in 3-2-12/5.3 through 3-2-12/5.5 and 3-2-12/11.9, and of the horizontal mass forces specified in 3-2-12/11.23.2(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:

$$p_{n\max} = d_h p_n \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

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 3-2-12/11.11.1

p_n = see 3-2-12/Table 8

For metallic supporting surfaces not subjected to relative displacements the nominal surface pressure applies:

$$p_{n\max} = 3p_n \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

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.

Drawings of the supports must be submitted. In the drawings of supports the permitted maximum pressure given by the material manufacturer must be specified.

TABLE 8
Permissible Nominal Surface Pressure p_n *(1 July 2018)*

Support Material	*p_n N/mm² (kgf/mm², 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)	–

Where large relative displacements of the supporting surfaces are to be expected, the use of material having low wear and frictional properties is recommended.

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:

$$P_{sh} = \alpha \cdot \frac{P_{sV}}{\sqrt{d_h}}$$

where

P_{sV} = vertical supporting force

α is as defined in 3-5-1/13.3.2.

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 3-2-12/11.1.1 are not exceeded.

For substructures and adjacent structures of supports subjected to horizontal forces P_{sh}, fatigue strength is to be considered in the design.

11.23.2(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 3-2-12/5.5 and 3-2-12/11.23.2(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 3-2-12/11.1.1. In addition, the provisions in 3-2-12/11.23.2(b) are to be observed.

11.25 Corrosion Addition and Steel Renewal

11.25.1 Corrosion Addition for Hatch Covers and Hatch Coamings

The scantling requirements of the above sections imply the following general corrosion additions t_S:

TABLE 9
Corrosion Additions t_S for Hatch Covers and Hatch Coamings *(1 July 2018)*

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 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)

11.25.2 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 3-2-12/Table 9.

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.).

13 Hatchways Closed by Portable Covers in Lower Decks or within Fully Enclosed Superstructures

13.1 General

The following scantlings are intended for conventional type covers. Those for covers of special types are to be specially considered.

13.3 Portable Beams and Wood Covers

Portable beams supporting lower deck hatch covers on which cargo is stowed are to have a section modulus, *SM*, of not 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 = 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 7.05 (715, 45).

s = spacing of the portable beams, in m (ft)

ℓ = length of the portable beam, in m (ft)

The depth of the portable beam is not to be less than 4% of its unsupported span.

Wood covers are not to be less than 63.5 mm (2.5 in.) thick where the spacing of the portable beams does not exceed 1.52 m (5 ft). Where the height to which the cargo may be loaded on top of the cover exceeds 2.59 m (8.5 ft), or where the spacing of the portable beams exceeds 1.52 m (5 ft), the thickness of the wood covers is to be suitably increased.

13.5 Steel Covers

The thickness of the plating for steel covers is not to be less than required for platform decks in enclosed cargo spaces, as obtained from 3-2-3/1. A stiffening bar is to be fitted around the edges, as required, to provide the necessary rigidity to permit the covers being handled without deformation. The effective depth of the framework is normally to be not less than 4% of its unsupported length. The stiffeners in association with the plating to which they are attached are to have section modulus, *SM*, as determined by the following equation:

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

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

where

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 7.05 (715, 45).

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

ℓ = length of the stiffener, in m (ft)

13.7 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 that obtained from 3-2-3/3, for platform deck plating, except that the thickness of plate panels adjacent to the edges of the covers is to be at least 15% greater than obtained from 3-2-3/7.

14 Small Hatches on the Exposed Fore Deck *(2004)*

14.1 Application

This subsection is applicable to vessels with length, L, (as defined in 3-1-1/3.1) between 80 meters (263 feet) and 90 meters (295 feet).

The requirements of this subsection apply to all small hatches [opening normally 2.5 m^2 (27 ft^2) or less] 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 3-2-12/14.5i), 3-2-12/14.5ii), the third paragraph of 3-2-12/14.7 and 3-2-12/14.9.

14.3 Strength

For small rectangular steel hatch covers, the plate thickness, stiffener arrangement and scantlings are to be in accordance with 3-2-12/Table 10 and 3-2-12/Figure 13. Stiffeners, where fitted, are to be aligned with the metal-to-metal contact points required in 3-2-12/14.7 (see also 3-2-12/Figure 13). Primary stiffeners are to be continuous. All stiffeners are to be welded to the inner edge stiffener (see 3-2-12/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.

14.5 Primary Securing Devices

The primary securing devices are to be such that their hatch covers can be secured in place and made weather-tight 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.

14.7 Requirements for Primary Securing

The hatch cover is to be fitted with a gasket of elastic material. This is to be designed to allow a metal-to-metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged. The metal-to-metal contacts are to be arranged close to each securing device, in accordance with 3-2-12/Figure 13, and of sufficient capacity to withstand the bearing force.

The primary securing method is to be designed and manufactured such that the designed compression pressure is achieved by one person without the need of any tools.

For a primary securing method using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed by means of curving the forks upward and a raised surface on the free end or a similar method to minimize the risk of butterfly nuts being dislodged while in use. The plate thickness of unstiffened steel forks is not to be less than 16 mm ($^5/_8$ in.). An example arrangement is shown in 3-2-12/Figure 14.

For small hatch covers located on the exposed deck forward of the fore-most cargo hatch, the hinges are to be fitted such that the predominant direction of green sea will cause the cover to close, which means that the hinges are normally to be located on the fore edge.

On small hatches located between the main hatches, for example, between Nos. 1 and 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable, for protection from green water in beam sea and bow quartering conditions.

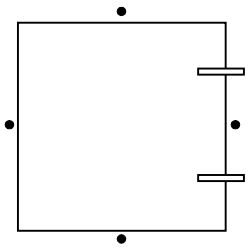
14.9 Secondary Devices

Small hatches on the fore deck are to be fitted with an independent secondary securing device, e.g., by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

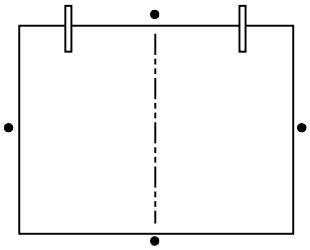
TABLE 10
Scantlings for Small Steel Hatch Covers on the Fore Deck

Nominal Size (mm × mm)	*Cover Plate Thickness (mm)*	*Primary Stiffeners*	*Secondary Stiffeners*
		Flat Bar (mm × mm); number	
630 × 630	8	---	---
630 × 830	8	100 × 8; 1	---
830 × 630	8	100 × 8; 1	---
830 × 830	8	100 × 10; 1	---
1030 × 1030	8	120 × 12; 1	80 × 8; 2
1330 × 1330	8	150 × 12; 2	100 × 10; 2

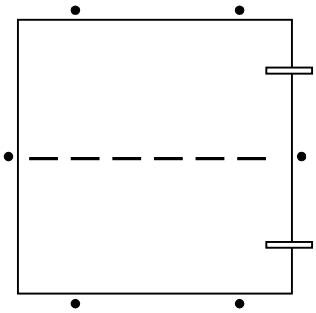
FIGURE 13
Arrangement of Stiffeners



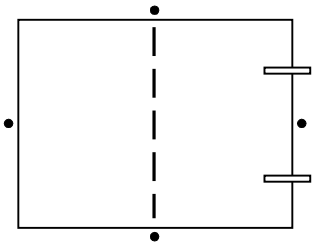
Nominal size 630 × 630



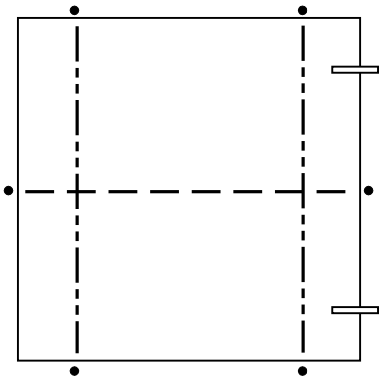
Nominal size 630 × 830



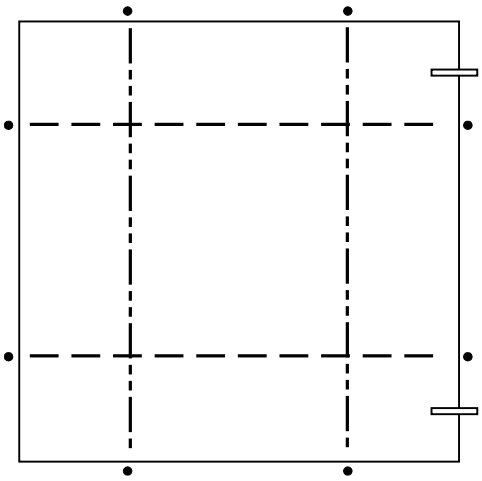
Nominal size 830 × 830



Nominal size 830 × 630



Nominal size 1030 × 1030



Nominal size 1330 × 1330

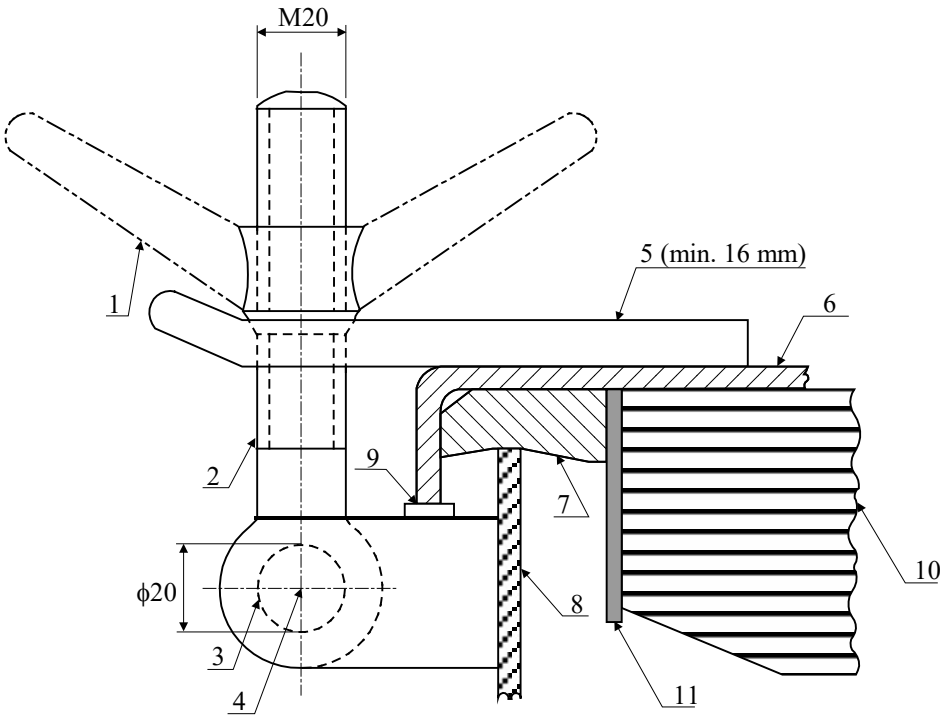
Hinge

Securing device/metal to metal contact

Primary stiffener

Secondary stiffener

FIGURE 14
Example of Primary Securing Method



(Note: Dimensions in millimeters)

1: butterfly nut
2: bolt
3: pin
4: center of pin
5: fork (clamp) plate
6: hatch cover
7: gasket
8: hatch coaming
9: bearing pad welded on the bracket of a toggle bolt for metal to metal contact
10: stiffener
11: inner edge stiffener

15 Hatchways within Open Superstructures

Hatchways within open superstructures are to be considered as exposed.

17 Hatchways within Deckhouses

Hatchways within deckhouses are to have coamings and closing arrangements as required in relation to the protection afforded by the deckhouse from the standpoint of its construction and the means provided for the closing of all openings into the house.

19 Container Loading *(1 July 2016)*

Where it is intended to carry containers on steel hatch covers, the exact locations of the container pads and the maximum total static load on the pads are to be indicated on the plans. Where the pads are not in line with the supporting structures, headers are to be provided to transmit the loads to these members. Each member intended to support containers is to be designed for container loads in 3-2-15/9.11 of the *Steel Vessel Rules*, applying the permissible stresses in 3-2-15/9.1.1 of the *Steel Vessel Rules*.

21 Machinery Casings

21.1 Arrangement

Machinery-space openings in Position 1 or 2 are to be framed and efficiently enclosed by steel casings of ample strength, and, wherever practicable, those in freeboard decks are to be within superstructures or deckhouses. Openings in exposed casings are to be fitted with doors complying with the requirements of 3-2-9/5.1. The sills are to be in accordance with 3-2-12/7.1 for companionways. Other openings in such casings are to be fitted with equivalent covers, permanently attached. Stiffeners are to be spaced at not more than 760 mm (30 in.)

21.3 Exposed Casings on Freeboard or Raised Quarter Decks

Exposed casings on freeboard or raised quarter decks are to have plating not less in thickness than that obtained from 3-2-9/3 or the following equation, whichever is greater:

$$t = 0.0164L + 6 \quad \text{mm}$$

$$t = 0.0002L + 0.24 \quad \text{in.}$$

where

t = thickness, in mm (in.)

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

Stiffeners are to be at least as effective as those required for watertight bulkheads where ℓ is the tween deck height and h is $\ell/2$.

21.5 Exposed Casings on Superstructure Decks

Exposed casings on superstructure decks are to have plating not less in thickness than that obtained from the following equation:

$$t = 0.033L + 3.5 \quad \text{mm}$$

$$t = 0.0004L + 0.14 \quad \text{in.}$$

where

t = thickness, in mm (in.)

L = length of vessel, in m (ft), as defined in 3-1-1/3, but is not to be taken as less than 30.5 m (100 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)

21.7 Casings within Open Superstructures

Casings within open superstructures are to be of similar scantlings to those obtained from 3-2-12/21.5 for exposed casings on superstructure decks.

21.9 Casings within Enclosed Superstructures, Deckhouses, or below Freeboard Decks

Casings within enclosed superstructures or in decks below freeboard deck where cargo is carried are to have plating not less in thickness than that obtained from the following equation:

$t = 0.022L + 3.8$ mm

$t = 0.00027L + 0.15$ in.

where

t = thickness, in mm (in.)

L = length of vessel, in m (ft), as defined in 3-1-1/3, but is not to be taken as less than 30.5 m (100 ft).

Stiffeners are to be fitted in line with the beams and are to have section modulus, *SM,* as required for exposed casings by 3-2-12/21.5, but the coefficient in the formula may be 0.14 instead of 0.25 and h is the tween-deck height.

23 Miscellaneous Openings in Freeboard and Superstructure Decks

23.1 Manholes and Scuttles

Manholes and flush scuttles in Position 1 or 2 within superstructures other than enclosed superstructures are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

23.3 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 an efficient deckhouse or companionway. Doorways in such deckhouses or companionways are to be fitted with doors complying with the requirements given in 3-2-9/5.1.

23.5 Escape Openings *(1 July 2012)*

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.

23.7 Chain Pipe Opening *(1 July 2012)*

Chain pipes through which anchor cables are led are to be provided with permanently attached closing appliances to minimize the ingress of water. A canvas cover with appropriate lashing arrangement will be acceptable* for this purpose. A cement and wire mesh arrangement is not permitted.

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

* *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

APPENDIX 3 Portable Beams and Hatch Cover Stiffeners of Variable Cross Section

1 Application

For portable beams and hatch cover stiffeners with free ends and varying cross section along their span, the section modulus, *SM,* and inertia, *I,* at the midspan required by 3-2-12/9.3.2, 3-2-12/9.5.1 and 3-2-12/11.1.1 may be obtained from the following equations:

$$SM = \frac{C_1 K_1 ps\,\ell^2}{\sigma_a} \quad \text{cm}^3\ (\text{in}^3)$$

$$I = C_2 K_2 ps\ell^3\ \text{cm}^4\ (\text{in}^4)$$

where

C_1 = 125 (125, 1.5)

C_2 = 2.87 (28.2, 2.85×10^{-5}) for 3-2-12/9.1.1 and 3-2-12/9.3.2

= 2.26 (22.1, 2.24×10^{-5}) for 3-2-12/9.5.1 and 3-2-12/11.1

K_1 = $1 + \frac{3.2\alpha - \gamma - 0.8}{7\gamma + 0.4}$, but not less than 1.0

α = length ratio

= ℓ_1/ℓ

γ = *SM* ratio

= SM_1/SM

ℓ_1, ℓ, SM_1 and *SM* are as indicated in 3-2-A3/Figure 1

σ_a = allowable stress given in 3-2-12/9.1.1, 3-2-12/9.3.2, 3-2-12/9.5.1, and 3-2-12/11.1, 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-A3/Figure 1

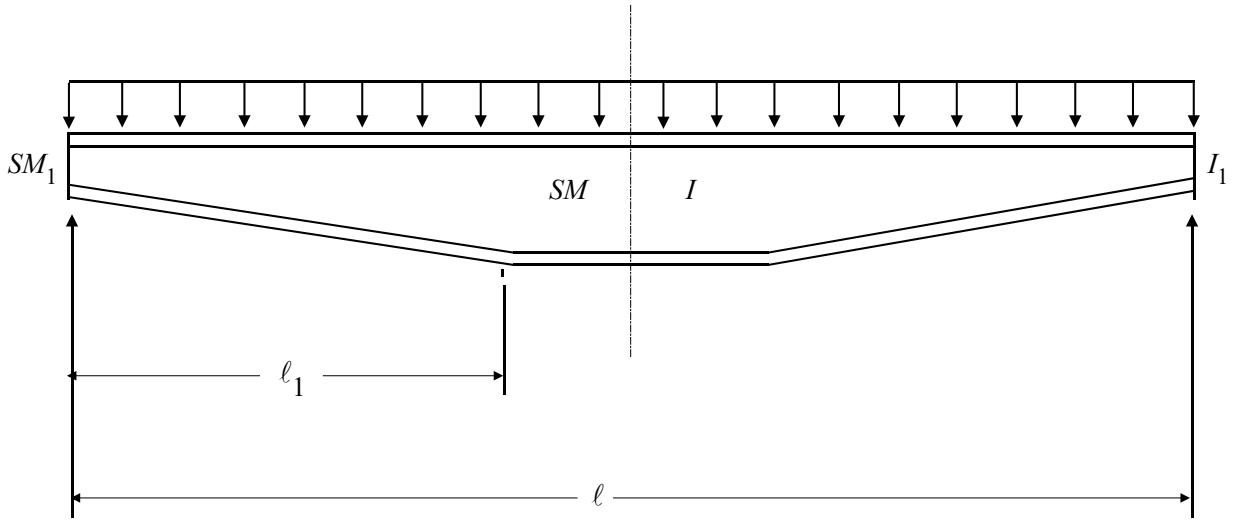
= I_1/I

p = design load given in 3-2-12/5.3, 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**

SECTION 13 **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 strongly constructed and capable of being made thoroughly watertight. Where frames are cut in way of such ports, web frames are to be fitted on the sides of the openings, and suitable arrangements are to be provided for the support of the beams over the openings. Thick shell plates or doublers are to be fitted, as required, to compensate for the openings. The corners of the openings are to be well rounded. Waterway angles and scuppers are to be provided on the decks in way of ports in cargo spaces below the freeboard deck or in cargo spaces within enclosed superstructures to prevent the spread of any leakage water over the decks.

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 edges of cargo, gangway or fueling-port openings are not to be below a line parallel to the freeboard deck at side having as its lowest point at least 230 mm above the or 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 4-4-2/23.3).

3 Bow Doors, Inner Doors, Side Shell Doors and Stern Doors *(1998)*

3.1 General *(2005)*

Where bow doors of the visor or side-opening type are fitted leading to complete or long forward enclosed superstructure 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 the collision bulkhead and stern doors leading into enclosed spaces are to meet the requirements of this Section.

3.3 Arrangement

As far as practicable, bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door.

3.3.1 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.

3.3.2 Inner Doors

An inner door is to be fitted in the extension of the collision bulkhead required by 3-2-7/3.1.1. A vehicle ramp made watertight and conforming to 3-2-7/3.1.1 in the closed position may be accepted for this purpose.

3.3.3 Side Shell and Stern Doors *(1998)*

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 that locks a securing device in the closed position.

7 Securing and Supporting Devices

7.1 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.

7.1.1 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.

7.1.2 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 3-2-13/19.5.1, is not to be less than M_{yo}, as given by the following equation:

$$M_{yo} = Wc + 0.1\sqrt{a^2 + b^2}\sqrt{F_x^2 + F_z^2}$$

Where W, a, b, c, F_x and F_z are as defined in 3-2-13/19. 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 do not act in the forward direction when the door is loaded in accordance with 3-2-13/19.5.4.

7.3 Side Shell and Stern Doors *(1998)*

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 3-2-13/7.1.1.

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

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 *(1998)*

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 3-2-13/9.5.1.

9.5 Indication/Monitoring *(1998)*

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).

9.5.1 Indicators *(2005)*

The indicator system is to be designed on the fail safe principle and in accordance with the following. See 3-2-13/9.5.1(e).

9.5.1(a) Location and Type (1998). 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.

9.5.1(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.

9.5.1(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.

9.5.1(d) Protection of Sensors. Sensors are to be protected from water, ice formation and mechanical damage.

9.5.1(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.

9.5.2 Water Leakage Protection *(2005)*

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 3-2-13/9.5.1(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 3-2-13/9.5.1(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 3-2-13/9.5.1(e).

9.5.3 Door Surveillance *(2005)*

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 Watertightness

11.1 Bow Doors

Bow doors are to be so fitted as to ensure tightness consistent with operational conditions and to give effective protection to the inner doors.

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 *(1998)*

Side shell doors and stern doors are to be so fitted as to ensure water tightness.

11.7 Testing at Watertight Door Manufacturer *(2014)*

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 unpierced bulkhead when closed.

13.3 Primary Structure *(2005)*

Scantlings of primary members are to be designed so that the allowable stresses indicated in 3-2-13/25.1 are not exceeded when the structure is subjected to the design loads indicated in 3-2-13/19.1. 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 by 3-2-5/1.1 and 3-2-5/5.3. In addition, stiffener webs are to have a net sectional area not less than that obtained from the following equation:

$$A = VQ/10 \text{ cm}^2 \quad (A = VQ \text{ cm}^2, A = VQ/6.5 \text{ in}^2)$$

where

V = shear force, in kN (tf, Ltf), in the stiffener calculated using the uniformly distributed external pressure, P_{eb}, given in 3-2-13/19.1

Q = as defined in 3-2-1/7.5

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 *(2005)*

Scantlings of securing and supporting devices are to be designed so that the allowable stresses indicated in 3-2-13/25.1 are not exceeded when the structure is subjected to the design loads indicated in 3-2-13/19.3. 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 3-2-13/25.5.

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 load compression of 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 3-2-13/25.3.

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 3-2-13/25.1 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 3-2-13/19.5.3 without stresses exceeding the allowable stresses in 3-2-13/25.1.

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 3-2-13/25.1. The opening moment, M_o, to be balanced by this force is as given in 3-2-13/19.5.2.

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 of 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 that required for vehicle decks in Sections 3-2-6 and 3-2-3.

15.3 Primary Structure

Scantlings of primary members are to be designed so that the allowable stresses indicated in 3-2-13/25.1 are not exceeded when the structure is subjected to the design loads indicated in 3-2-13/21.1.

15.5 Securing and Supporting Devices

Scantlings of securing and supporting devices are to be designed so that the allowable stresses indicated in 3-2-13/19 are not exceeded when the structure is subjected to the design loads indicated in 3-2-13/17.5. 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 3-2-13/25.5.

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 3-2-13/25.3.

17 Side Shell Door and Stern Door Scantlings *(1998)*

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 that required for vehicle decks in Sections 3-2-6 and 3-2-3.

17.3 Primary Structure *(2005)*

Scantlings of primary members are to be designed so that the allowable stresses indicated in 3-2-13/25.1 are not exceeded when the structure is subjected to the design loads indicated in 3-2-13/23. Normally, simple beam theory may be applied to determine the bending stresses. Members are to be 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 that required by Section 3-2-5 for frames in the same location. In addition, the net sectional area of stiffener webs is to be in accordance with 3-2-13/13.5, using the external pressure, p_e, given in 3-2-13/23.

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 3-2-13/25.1 are not exceeded when the structure is subjected to the design loads indicated in 3-2-13/23. 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 3-2-13/25.5.

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 3-2-13/25.3.

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 3-2-13/25.1 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} for vessels engaged in restricted service will be specially considered.

$$P_{eb} = nc(0.22 + 0.15 \tan \beta)(0.4V_d \sin \alpha + 0.6\sqrt{kL}\,)^2 \quad \text{kN/m}^2 \text{ (tf/m}^2\text{, Ltf ft}^2\text{)}$$

where

n = 2.75 (0.280, 0.0256)

c = $0.0125L$ for $L < 80$ m

= $0.00385L$ for $L < 260$ ft

= 1.0 for $L \geq 80$ m (260 ft)

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

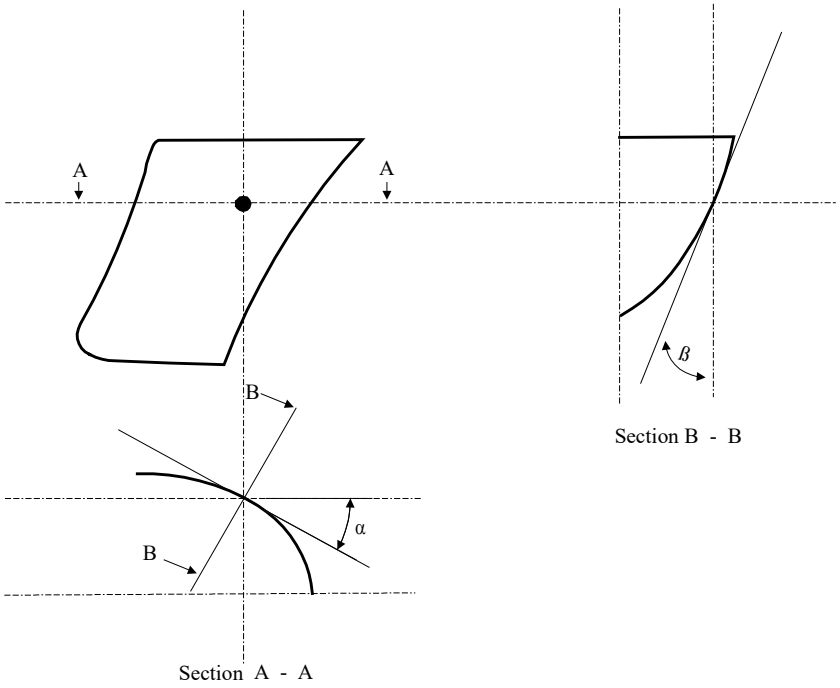
β = flare angle at the point to be considered, defined as the angle between a vertical line and the tangent to the side shell plating measured in a vertical plane normal to the horizon tangent to the shell plating. See 3-2-13/Figure 1.

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 3-2-13/Figure 1.

k = 1.0 (1.09, 0.305)

V_d = vessel design speed, as defined in 3-2-11/3

FIGURE 1
Entry and Flare Angles



19.3 External Forces *(2005)*

The design external forces considered in determining scantlings of securing and supporting devices of bow doors are not to be taken less than those given by the following equations:

$$F_x = P_{em} A_x$$

$$F_y = P_{em} A_y$$

$$F_z = P_{em} A_z$$

where

F_x = design external force in the longitudinal direction, in kN (tf, Ltf)

F_y = design external force in the horizontal direction, in kN (tf, Ltf)

F_z = design external force in the vertical direction, in kN (tf, Ltf)

A_x = area, in m^2 (ft^2), of the transverse vertical 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 vertical projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark or between the bottom of the door and the top of the door, whichever is the lesser. Where the flare angle of the bulwark is at least 15º less than the flare of the adjacent shell plating, the bulwark may be excluded and the distance may be measured from the bottom of the door to the upper deck or to the top of the door, whichever is the lesser.

A_z = area, in m^2 (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 15º less than the flare of the adjacent shell plating, the bulwark may be excluded and the distance may be measured from the bottom of the door to the upper deck or to the top of the door, whichever is the lesser.

P_{em} = bow door pressure, P_b, determined using α_m and β_m in place of α and β.

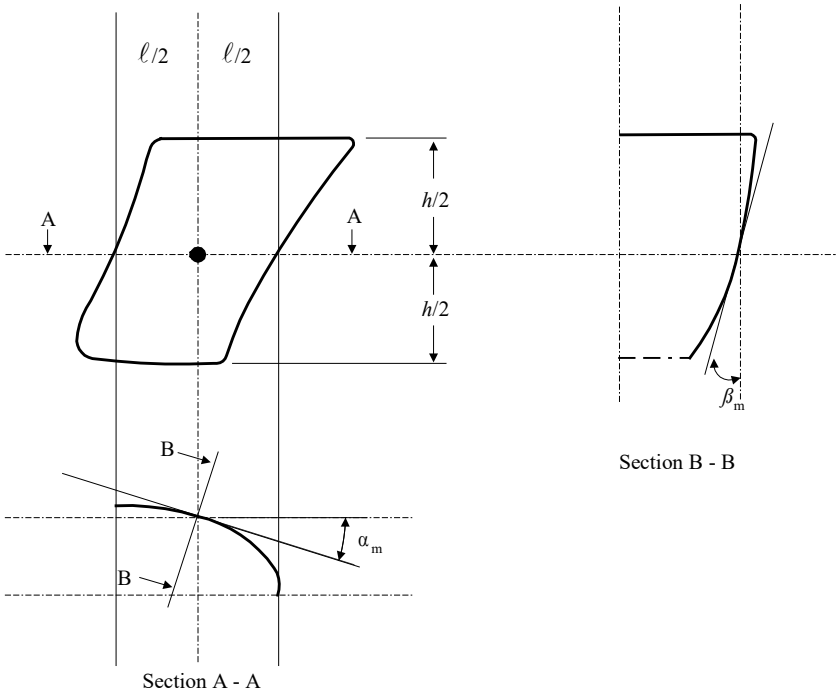
β_m = flare angle measured at a point on the bow door $\ell/2$ aft of the stem line on a plane $h/2$ above the bottom of the door, as shown in 3-2-13/Figure 2.

α_m = entry angle measured at the same point as β_m. See 3-2-13/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 = 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:

$$M_y = F_x a + Wc - F_z b \quad \text{kN-m (tf-m, Ltf-ft)}$$

where F_x and F_z are defined in 3-2-13/19.3

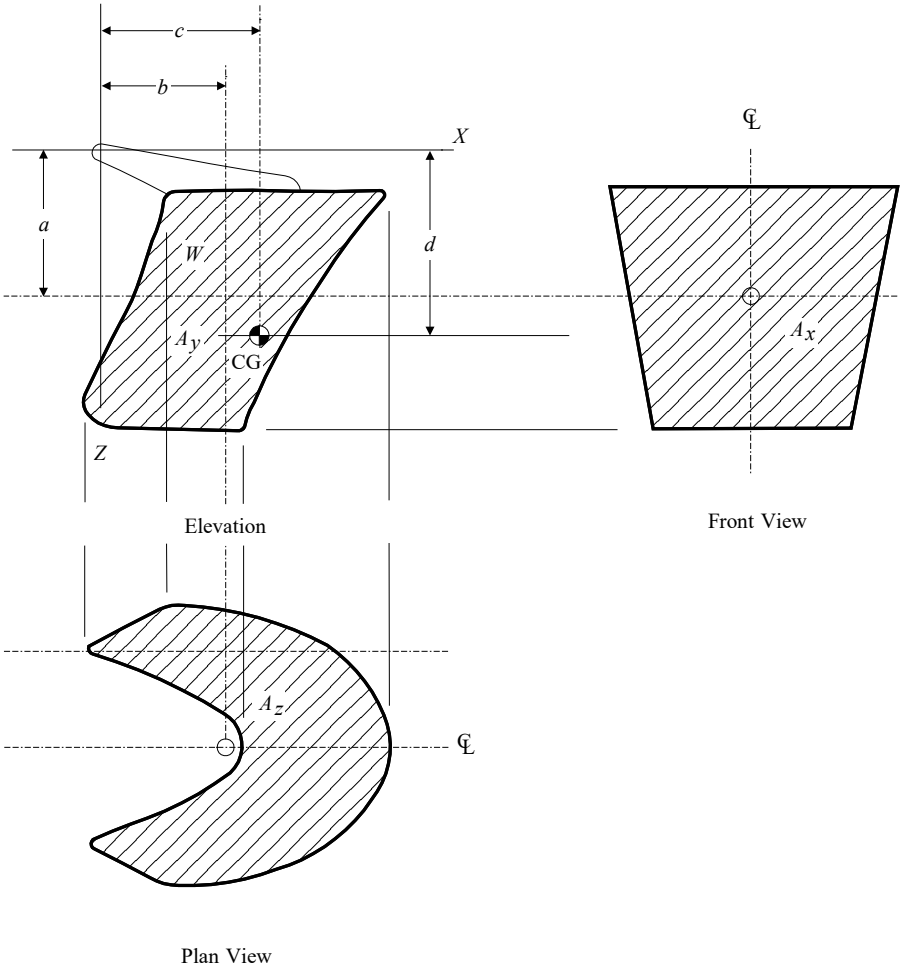
W = weight of the visor door, in kN (tf, Ltf)

a = vertical distance, in m (ft), from the visor pivot to the centroid of the transverse vertical projected area of the visor door. See 3-2-13/Figure 3.

b = horizontal distance, in m (ft), from visor pivot to the centroid of the horizontal projected area of the visor door. See 3-2-13/Figure 3.

c = horizontal distance, in m (ft), from the visor pivot to the center of gravity of the visor. See 3-2-13/Figure 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:

$$M_o = Wd + 5A_xa \text{ kN-m } (M_o = Wd + 0.5A_xa \text{ tf-m}, M_o = Wd + 0.047A_xa \text{ Ltf-ft})$$

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 3-2-13/19.3 and W is as defined in 3-2-13/19.5.1.

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 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 $0.7F_x$, $0.7F_z$ 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:

$P_{ei} = 0.45L$ kN/m^2 ($0.046L$ tf/m^2, $0042L$ Ltf/ft^2)

$P_h = 10h$ kN/m^2 ($1.0h$ tf/m^2, $0.029h$ Ltf/ft^2)

where

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

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 *(1998)*

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: $F_e = Ap_e$

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: $F_e = Ap_e + F_p$

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: $F_e = Ap_e$

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, 0233)

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)

k_3 = 1.0 (1.0, 0.305)

c = $0.0125L$ for $L < 80$ m (260 ft)

= 1.0 for $L \geq 80$ m (260 ft)

L = length of vessel, as defined in 3-1-1/3, in m (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: τ = $80/Q$ N/mm^2 ($8.2/Q$ kgf/mm^2, $11600/Q$ psi)

Bending Stress: σ = $120/Q$ N/mm^2 ($12.2/Q$ kgf/mm^2, $17400/Q$ psi)

Equivalent Stress ($\sqrt{\sigma^2 + 3\tau^2}$): σ_e = $150/Q$ N/mm^2 ($15.3/Q$ kgf/mm^2, $21770/Q$ psi)

where Q is defined in 3-2-1/7.5.

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 *(1998)*

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 *(1998)*

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 **14 Bulwarks, Rails, Freeing Ports, Portlights, Windows, Ventilators, Tank Vents, and Overflows**

1 Bulwarks and Guard Rails

1.1 Height *(2017)*

The height of bulwarks and guard rails on exposed freeboard and superstructure decks, at the boundary of first tier deckhouses and at the ends of superstructures is to be at least 1 m (39.5 in.). Where this height would interfere with the normal service or operation of a vessel, a lesser height may be approved if adequate protection is provided. Where approval of a lesser height is requested, justifying information is to be submitted.

1.3 Strength of Bulwarks

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. 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.

1.5 Guard Rails *(1998)*

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 *(2017)*

At least every third stanchion is to be supported by a bracket or stay. Where the arrangements would interfere with the safe traffic of persons on board, the following alternative arrangements of stanchions may be acceptable:

i) At least every third stanchion is to be of increased breadth, $kb_s = 2.9b_s$ at the attachment of stanchion to the deck, or,

ii) At least every second stanchion is to be of increased breadth, $kb_s = 2.4b_s$ at the attachment of stanchion to the deck, or,

iii) Every stanchion is to be of increased breadth, $kb_s = 1.9b_s$ at the attachment of stanchion to the deck.

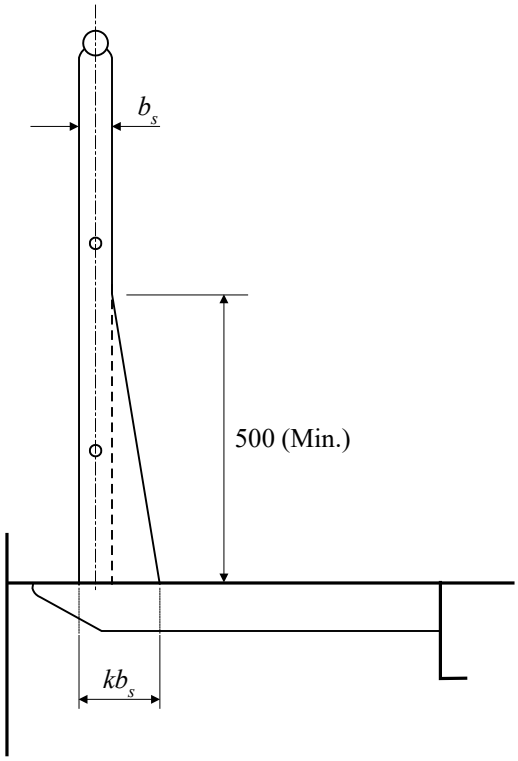
where, b_s is the breadth of normal stanchion according to the recognized design standard. (see 3-2-14/Figure 1)

In any arrangement of *i), ii)* or *iii)* above, the following details are to be complied with:

iv) Flat steel stanchion required by *i), ii)* or *iii)* above is to be aligned with member below deck unless the deck plating thickness exceeds 20 mm (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 supporting member of the stanchion is to be of 100 × 12 mm (4.0 × 0.5 in.) flat bar welded to deck by double continuous fillet

FIGURE 1
Guardrail Stanchion *(2007)*



1.5.3

The opening below the lowest course is not to exceed 230 mm (9 in.). The distance between the remaining courses is not to be more than 380 mm (15 in.).

1.5.4

For vessels with rounded gunwales, stanchions are to be placed on the flat of the deck.

3 Access and Crew Protection *(1 July 1998)*

3.1 General

Satisfactory means in the form of guard rails, lifelines, gangways or underdeck passages, etc., are to be provided for the protection of the crew in getting to and from their quarters, the machinery space and all other parts used in the necessary work of the vessel.

3.3 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 *(2014)*

Type of vessel	*Locations of access in Vessel*	*Assigned Summer Freeboard*	*Acceptable arrangements according to type of freeboard assigned*			
			Type A	*Type B–100*	*Type B–60*	*Type B & B+*
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 navigation 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)
		> 3000 mm (> 118 in.)	a b e	a b e	a b c(1) c(2) e f(1) f(2)	d(1) d(2) d(3) e f(1) f(2) f(4)
	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.	≤ 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 navigation equipment, or both, and bow, or	≤ $(A_f + H_s)$**	e f(1) f(5)			
	2.1.3. In the case of a flush deck vessel, between crew accommodation and the forward end of vessel.	> $(A_f + H_s)$**	e f(1) f(2)			

* 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.

I. Construction Keys (a) through (f)

(a) A well-lighted and ventilated underdeck 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.

(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 3-2-14/3.1 and 3-2-14/1.5, 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 3-2-14/1.5. On Type B ships, 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.

TABLE 1 (continued)
Acceptable Arrangement for Access *(2014)*

(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) *(2014)* 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 3-2-14/3.1 and 3-2-14/1.5.1 & 3-2-14/1.5.3, 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 Type B ships certified for the carriage of liquids in bulk, the hatch coamings may be accepted as forming one side of the walkway, provided a combined height of hatch coaming and hatch cover in the closed condition is not less than 1 m (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 center line of vessel; or fitted on hatchways at or near the center line 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 center line as practicable.

III. Notes:

1. In all cases where wire ropes are fitted, adequate devices are to be provided to enable maintaining their tautness.
2. A means of passage over obstructions, if any, such as pipes or other fittings of a permanent nature is to be provided.
3. Generally, the width of the gangway or walkway should not exceed 1.5 m (5 ft).

5 Freeing Ports

5.1 Basic Area

Where bulwarks on freeboard decks form wells, ample provision is to be made for rapidly freeing the decks of water and for draining them. The minimum freeing-port area on each side of the vessel for each well 20 m (66 ft) or less in length is to be obtained from the following equation:

$A = 0.7 + 0.035\ell$ m^2 $\qquad$ $A = 7.6 + 0.115\ell$ ft^2

Where the bulwark length exceeds 20 m (66 ft):

$A = 0.07\ell$ m^2 $\qquad$ $A = 0.23\ell$ ft^2

where

A = freeing-port area, in m^2 (ft^2)

ℓ = bulwark length in m (ft), but need not exceed $0.7L$

If a bulwark is more than 1.2 m (3.9 ft) in height, the freeing-port area is to be increased by 0.004 m^2 per meter (0.04 ft^2 per foot) of length of well for each 0.1 m (1 ft) difference in height. If a bulwark is less than 0.9 m (3 ft) in height, the freeing port area may be decreased by the same ratio. In vessels with no sheer, the calculated area is to be increased by 50%. Where sheer is less than standard, the percentage is to be obtained by interpolation.

5.3 Trunks, Deckhouses, and Hatchway Coamings

Where a vessel is fitted with a trunk on the freeboard deck, and open rails are not fitted in way of the trunk for at least one-half its length, or where continuous or substantially continuous hatchway side coamings are fitted or long deckhouse exist between detached superstructures, the minimum area of freeing-port openings is to be obtained from the following table.

Breadth of trunk, deckhouse or hatchway in relation to breadth of vessel	*Area of freeing ports in relation to total area of bulwarks*
40% or less	20%
75% or more	10%

The area of freeing ports at intermediate breadths is to be obtained by linear interpolation.

5.5 Superstructure Decks

Where bulwarks on superstructure decks form wells, the bulwarks are to comply with 3-2-14/5.1, except that the minimum freeing-port area on each side of the vessel for each well is to be one-half of the area obtained in 3-2-14/5.1 and 3-2-14/5.3.

5.7 Open Superstructures

In vessels having superstructures that are open at either end or both ends, adequate provisions for freeing the spaces within such superstructures are to be provided. The arrangements will be subject to special approval.

5.9 Details of Freeing Ports

The lower edges of the freeing ports are to be as near the deck as practicable. Two-thirds of the required freeing-port area is to be provided in the half of the well nearest the lowest point of the sheer curve. Freeing-port openings are to be protected by rails or bars in such a manner that the maximum clear vertical or horizontal space is 230 mm (9 in.). Where shutters are fitted, ample clearance is to be provided to prevent them from jamming. Hinges are to have pins and bearings of corrosion-resistant material and, in general, the hinges are to be located at the top of the shutter. If the shutters are equipped with securing appliances, the appliances are to be of approved construction.

7 Portlights

7.1 Application *(1 July 1998)*

This subsection applies to passenger vessels and cargo vessels with the keel laid or in similar stage of construction on or after 1 July 1998. 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.

7.3 Location *(1 July 1998)*

The lower edges of the portlight sills are not to be below a line drawn parallel to the bulkhead/ freeboard deck at side having as its lowest point either 2.5% of the breadth of the vessel or 500 mm (19.5 in.) above the designed load waterline, whichever is the greater distance.

In addition, portlights are not to be fitted in spaces which are used exclusively for the carriage of cargo.

7.5 Construction *(1 July 1998)*

7.5.1 General

Portlights to spaces below the bulkhead/freeboard deck or to spaces within enclosed superstructures and deckhouses protecting openings leading to below the bulkhead/freeboard deck are to be fitted with efficient hinged, inside deadlights arranged so that they can be effectively closed and secured watertight. The portlights, together with their glasses and deadlights, are to comply with a recognized standard. They are to have strong frames (other than cast iron) and opening-type portlights are to have noncorrosive hinge pins.

7.5.2 Non-opening Type

Where vessels are subject to damaged stability requirements of 3-3-1/3.3, 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 3-2-14/7.5.2 to be of opening type, are to be of such construction as will prevent unauthorized opening where:

i) The sills of which are below the bulkhead/freeboard deck, as permitted in 3-2-14/7.3, or

ii) 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

9.1 Location *(2019)*

Windows are defined as being rectangular openings, or round or oval openings, with an area exceeding 0.16 m^2.

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.

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 (e.g., ISO 3903 and ISO 5779).

9.3 Deadlights and Storm Covers *(2019)*

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:

i) 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.

ii) 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.

iii) 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.

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.

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.

9.5 Construction

Window frames are to be metal or other approval material and effectively secured to the adjacent structure. 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. Special consideration is to be given to angled house fronts.

Deadlights and storm covers are to be of a strength equivalent to the adjacent bulkhead. Non-metallic deadlights and storm covers are not acceptable.

The thickness of the window glazing is not to be less than that obtained from 3-2-14/9.5.1, 3-2-14/9.5.2 or 3-2-14/9.5.3 below, whichever is greatest.

9.5.1

$$t = s\left(\sqrt{\frac{pk}{1000\sigma_a}}\right) \text{ mm} \qquad t = s\left(\sqrt{\frac{pk}{\sigma_a}}\right) \text{ in.}$$

9.5.2

$$t = s\left(\sqrt[3]{\frac{pk_1}{20E}}\right) \text{ mm} \qquad t = s\left(\sqrt[3]{\frac{pk_1}{0.02E}}\right) \text{ in.}$$

9.5.3 Minimum Tempered Monolithic Glass Thicknesses:

t = 9.5 mm (0.37 in.) for front windows

t = 6.5 mm (0.25 in.) for side and end windows

where

t = required window thickness, in mm (in.)

s = lesser dimension of window, in mm (in.)

h = pressure head, in m (ft), given in 3-2-9/3.3

p = $9.8h$ kN/m^2 ($0.44h$ psi)

k = factor given in 3-2-14/Table 2

k_1 = factor given in 3-2-14/Table 2

σ_a = $0.30\sigma_f$

σ_f = material flexural strength; see 3-2-14/Table 3

E = material flexural modulus; see 3-2-14/Table 3

TABLE 2

ℓ/s	k	k_1
>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 Testing

All windows and portlights are to be hose-tested after installation.

11 Ventilators, Tank Vents, and Overflows *(2004)*

11.1 General *(2004)*

Ventilators are to comply with the requirements of 3-2-14/11.3. Tank vents and overflows are to comply with the requirements in 3-2-14/11.5. In addition, for those located on the fore deck of vessels with length, L, (as defined in 3-1-1/3.1) between 80 meters (263 feet) and 90 meters (295 feet), the requirements given in 3-2-14/11.7 are to be complied with.

11.3 Ventilators *(2004)*

11.3.1 Coaming Construction *(1 July 2016)*

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.

$$t = 0.01d + 5.5 \quad \text{mm}$$

$$t = 0.01d + 0.22 \quad \text{in.}$$

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.

11.3.2 Coaming Height

Ventilators in Position 1 are to have coamings at least 900 mm (35.5 in.) high. Ventilators in Position 2 are to have coamings at least 760 mm (30 in.) high. For definitions of Position 1 and Position 2, see 3-2-12/5. Coaming heights may be reduced on vessels which have freeboard in excess of the minimum geometric freeboard and/or a superstructure deck with the height of the deck in excess of the standard height of a superstructure.

11.3.3 Means for Closing Ventilators

Except as provided below, ventilator openings are to be provided with efficient, permanently attached closing appliances. In vessels measuring 24 m (79 ft) or more in length (as defined in the International Convention on Load Lines, 1966), 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.

These coaming height requirements may be modified in vessels measuring less than 24 m (79 ft) in length.

11.5 Tank Vents and Overflows *(2004)*

Tank vents and overflows are to be in accordance with the requirements of 4-4-3/9 and 4-4-3/11 of these Rules and, where applicable, the requirements given below in 3-2-14/11.7.

11.7 Ventilators, Tank Vents and Overflows on the Fore Deck *(2004)*

11.7.1 Application

The requirements of this paragraph apply to all ventilators, tank vents and overflows located on the exposed fore deck within the forward 0.25L on vessels with length, L, (as defined in 3-1-1/3.1) between 80 meters (263 feet) and 90 meters (295 feet) and where the height of the exposed deck in way of the item is less than 0.1L or 22 meters (72 ft) above the summer load waterline, whichever is the lesser.

11.7.2 Applied Loading to the Air Pipes and Ventilators

11.7.2(a) Pressure (1 July 2014). 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:

$$p = f \rho V^2 C_d C_s C_p \quad \text{kN/m}^2 \text{ (tf/m}^2\text{, Ltf/ft}^2\text{)}$$

where:

f = 0.5 (0.05, 0.0156)

ρ = density of sea water, 1.025 t/m^3 (1.025 t/m^3, 0.0286 Lt/ft^3)

V = velocity of water over the fore deck

= 13.5 m/sec (44.3 ft/sec) for $d \le 0.5d_1$

= $13.5\sqrt{2\left(1-\frac{d}{d_1}\right)}$ 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 (72.2 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 pipes or ventilator heads of cylindrical form with its axis in the vertical direction

C_s = slamming coefficient, 3.2

C_p = protection coefficient:

= 0.7 for pipes and ventilator heads located immediately behind a breakwater or forecastle

= 1.0 elsewhere including immediately behind a bulwark

11.7.2(b) Force. Forces acting in the horizontal direction on the pipe and its closing device may be calculated from the above pressure using the largest projected area of each component.

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 critical positions; at penetration pieces, at weld or flange connections, at toes of supporting brackets. Bending stresses in the net section are not to exceed $0.8Y$, where Y is the specified minimum yield stress or 0.2% proof stress of the steel at room temperature. Irrespective of corrosion protection, a corrosion addition to the net section of 2.0 mm (0.08 in.) is then to be applied.

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 3-2-14/Table 4. Where brackets are required, three or more 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 3-2-14/Table 4, but need not extend over the joint flange for the head. Bracket toes at the deck are to be suitably supported.

iii) For other configurations, loads according to 3-2-14/11.7.2 are to be applied and means of support determined in order to comply with the requirements above. Brackets, where fitted, are to be of suitable thickness and length according to their height.

iv) Final (gross) pipe thickness is not to be taken less than as indicated in 4-4-3/9.3.

v) The minimum internal diameter of the air pipe or overflow is not to be less than 65 mm.

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 3-2-14/Table 5. Brackets, where required, are to be as specified in 3-2-14/11.7.3(b)ii).

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 3-2-14/11.3 nor in 3-2-14/Table 4.

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 3-2-14/11.7.2.

11.7.3(e) Rotary Heads. Rotating type mushroom ventilator heads are not to be used for application in this location.

TABLE 4
760 mm (30 in.) High Tank Vents and Overflows Thickness and Bracket Standards *(2004)*

Nominal Pipe Size		*Minimum Fitted Gross Thickness*		*Maximum Projected Area of Head*		*Height (1) of Brackets*	
A	*B*						
mm	*in.*	*mm*	*in.*	*cm^2*	*in^2*	*mm*	*in.*
65	$2^1/_2$	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 (2)	11.8 (2)
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 3-2-14/11.7.3(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.

Note: For other air pipe heights, the relevant requirements of 3-2-14/11.7.3 are to be applied.

TABLE 5
900 mm (35.4 in.) High Ventilator
Thickness and Bracket Standards *(2004)*

Nominal Pipe Size		*Minimum Fitted Gross Thickness*		*Maximum Projected Area of Head*		*Height (1) of Brackets*	
A	*B*						
mm	*in.*	*mm*	*in.*	cm^2	in^2	*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	-	-

Note: For other ventilator heights, the relevant requirements of 3-2-14/11.7.3 are to be applied.

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 15 Ceiling, Sparring, and Protection of Steel

1 Ceiling

In cargo holds of vessels with single bottoms, close ceiling is to be fitted on the floors and up to the upper turns of the bilges. The ceiling on the floors is to be laid in portable sections or other convenient arrangements are to be made for removal for cleaning, painting or inspection. The ceiling may be omitted where the bottom is filled with cement to the tops of the floors.

In cargo holds of vessels with double bottoms, close ceiling is to be fitted from the outboard edges of the double bottoms up to the upper turns of the bilges. Under all cargo hatches, either ceiling is to be fitted or the thickness of the inner bottom is to be increased by 2 mm (0.08 in.). Ceiling fitted at the bilges is to be removable for cleaning, painting or inspection. Ceiling fitted on the inner bottom plating either is to be laid on battens for drainage or is to be bedded in a suitable composition.

The thickness of wood ceiling is not to be less than 25 mm (1 in.) in vessels 9 m (30 ft) in length, not less than 50 mm (2 in.) in vessels between 20 m (65 ft) and 61 m (200 ft) in length, not less than 57 mm (2.25 in.) in vessels 61 to 76 m (200 to 250 ft) in length, nor less than 63 mm (2.5 in.) in vessels over 76 m (250 ft) in length. Between 9 m (30 ft) and 20 m (65 ft) in length, the thicknesses may be determined by interpolation.

3 Sparring

In spaces intended to carry general cargo, sparring, where fitted, is to be arranged between the bilge ceiling and the beam brackets. In vessels over 20 m (65 ft) in length, sparring is not to provide less protection to the framing than would be obtained from wood battens 40 mm (1.625 in.) thick, 140 mm (5.5 in.) wide, and spaced 380 mm (15 in.) center to center. In vessels 9 m (30 ft) in length, the thickness of wood battens may be reduced to 20 mm (0.8 in.). Between 9 m (30 ft) and 20 m (65 ft) in length, the thicknesses may be proportioned. Sparring is to be portable and fitted in cleats or in portable frames. If sparring is not fitted, the notation **NS** will be entered in the *Record*, indicating no sparring.

5 Protection of Steel Work

5.1 All Spaces *(1 July 2018)*

Unless otherwise approved, all steel surfaces are to be suitably coated with paint and/or cathodic protection as applicable. For more details, refer to the ABS *Guidance Notes on Cathodic Protection of Ships* and the ABS *Guidance Notes on the Application and Inspection of Marine Coating Systems.*

5.3 Salt Water Ballast Space

Tanks or holds for salt water ballast are to have a corrosion-resistant hard type coating such as epoxy or zinc on all structural surfaces. Where a long retention of salt water is expected due to the type of vessel or unit, special consideration for the use of inhibitors or sacrificial anodes may be given.

5.5 Oil Spaces

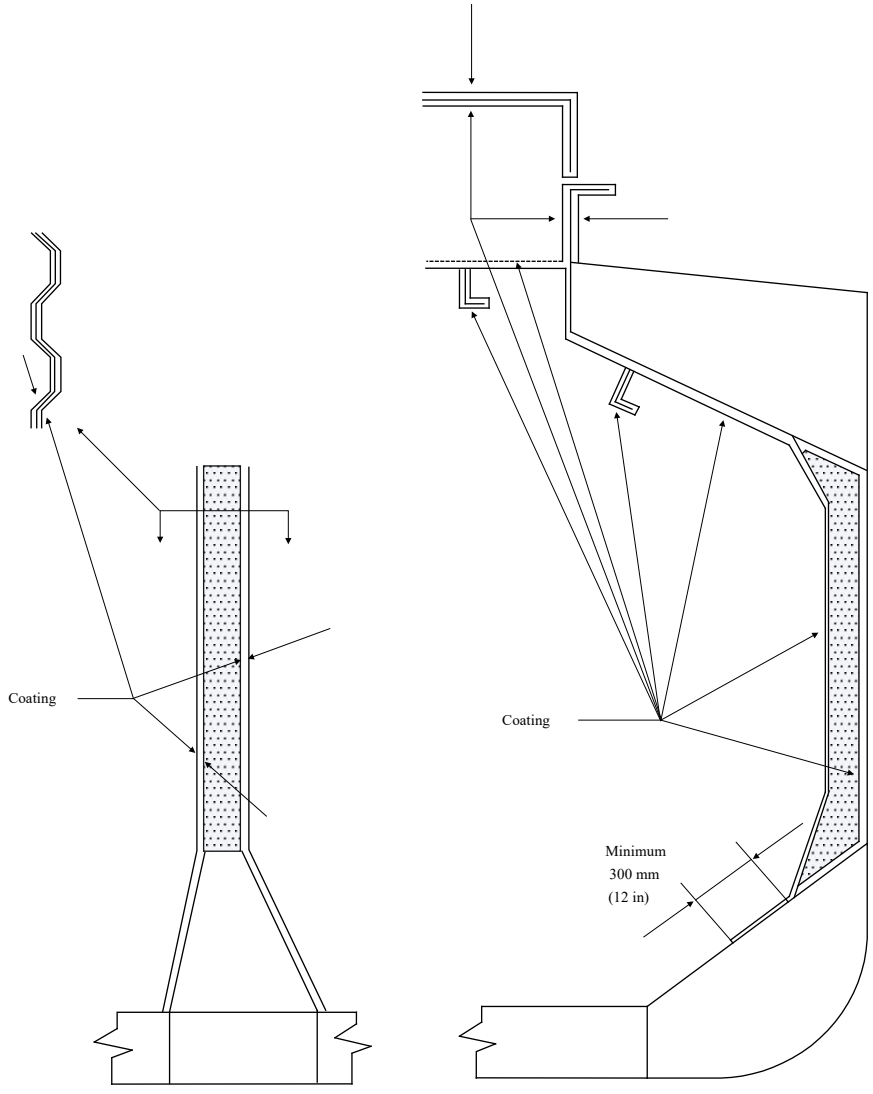
Tanks intended for oil or the holds of combination carriers intended for the carriage of dry bulk cargoes and oil cargoes need not be coated unless required by 3-2-15/5.7.

5.7 Cargo Holds on Bulk Carriers (including Combination Carriers) *(1998)*

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 3-2-15/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 *(1998)*



a) TRANSVERSE BULKHEAD

b) HOLD, HATCH COAMINGS AND HATCH COVER

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 16 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.

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 ($^1/_{16}$ 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 ($^1/_{16}$ 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 precaution 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 *(1 July 2015)*

For all welds in ballast tanks in all types of vessels and/or double side skin spaces of bulk carriers required to be in compliance with the IMO PSPC and/or IMO PSPC-COT Regulations, continuous welding is to be adopted.

1.3 Tee Connections

1.3.1 Size of Fillet Welds

Frames, beams, bulkheads stiffeners, floors and intercostals, etc. are to have at least the disposition and sizes of intermittent or continuous fillet welds, as required by 3-2-16/Table 1. Where it is desirable to substitute continuous welding for intermittent welding, as given in 3-2-16/Table 1, a reduction from the required size of fillet may be allowed if equivalent strength is provided.

1.3.2 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.

1.3.3 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 the depth of the longitudinal. For deck longitudinals only, a matched pair of welds is required at the transverses.

1.3.4 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.

1.5 Tee Type End Connections

Tee type end connections, where fillet welds are used, are to have continuous welds on each side. In general, the sizes of the welds, w, are not to be less than $^3/_4$ times the thickness of the member being attached, but in special cases where heavy members are attached to relatively light plating, the sizes may be modified. In certain cases, only the webs of girders, beams and stiffeners need be attached. In such cases, it is recommended that the unattached face plates or flanges be cut back.

1.7 Tee Joints at Boundary Connections

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 3-2-16/Table 1 for stiffeners to deep tank bulkheads, except in way of tanks where equivalent continuous welds are to be used.

1.9 Ends of Unbracketed Stiffeners

Unbracketed stiffeners of shell, watertight and oiltight bulkheads and house fronts are to have double continuous welds for one-tenth of their length at each end.

Unbracketed stiffeners of nontight structural bulkheads, deckhouse sides and after ends are to have a pair of matched intermittent welds at each end.

1.11 Reduced Weld Size

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 3-2-16/1.11.1 or 3-2-16/1.11.2, provided the requirements of 3-2-16/1.3 are satisfied.

1.11.1 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.

1.11.2 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 ($^1/_{16}$ in.) may be permitted, provided that the penetration at the root is at least 1.5 mm ($^1/_{16}$ in.) into the members being attached.

1.13 Lapped Joints

Lapped joints are generally to have overlaps of not less width than twice the thinner plate thickness plus 25 mm (1 in.).

1.13.1 Overlapped End Connections

Overlapped end connections of longitudinal strength members within the midship 0.4L are to have continuous fillet welds on both edges, each equal in size w to the thickness of the thinner of the two plates joined. All other overlapped end connections are to have continuous welds on each edge of sizes w such that the sum of the two is not less than 1.5 times the thickness of the thinner plate.

1.13.2 Overlapped Seams *(2018)*

Overlapped seams are to have welds on both edges of the sizes required by 3-2-16/1.7 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).

1.13.3 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.).

1.15 Plug Welds or Slot Welds

Plug welds or slot welds may be specially approved for particular applications. Where used in the body of doublers and similar locations, such welds may be spaced about 305 mm (12 in.) between centers in both directions.

3 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) critical (e.g., oil/water boundary) joints.

The designer is to give consideration to minimizing the possibility of lamellar tearing in such joints. Ultrasonic inspection of the plate in way of the connection may be required prior to and after fabrication to assure the absence of possible laminations and lamellar tearing.

5 Alternatives

The foregoing are considered minimum requirements for electric-arc welding in hull construction, but alternate methods, arrangements and details will be considered for approval. Fillet weld sizes may be determined from structural analyses based on sound engineering principles, provided they meet the overall strength standards of the Rules.

TABLE 1
Weld Sizes and Spacing – Millimeters

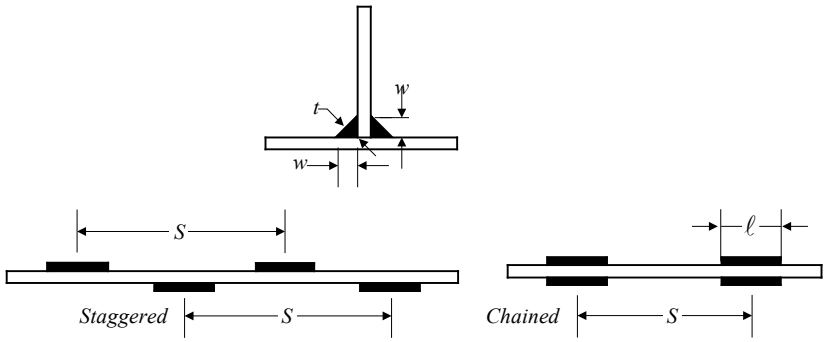
For weld requirements for thicknesses intermediate to those shown in the table, use the nearest thickness shown in the table.

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 3-2-16/Table 1 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.

For double continuous welding as an alternative to intermittent welding, see 3-2-16/1.3.1.



	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 3-2-16/1.7							
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
Solid floors to center vertical keel plate in engine room, under boiler bearers, wide-spaced floors with longitudinal frames	In accordance with 3-2-16/1.7							
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 3-2-16/1.7							
To inner bottom in engine room	In accordance with 3-2-16/1.7							
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 3-2-16/1.7							
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 3-2-16/1.7							

TABLE 1 (continued)
Weld Sizes and Spacing – Millimeters

	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*							
Center Girder								
Nontight to inner-bottom or center strake in way of engine and to shell or bar keel	In accordance with 3-2-16/1.7							
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 3-2-16/1.7							
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 3-2-16/1.7							
Frames								
To shell in aft peaks of vessels having high power and fine form	—	—	150	125	150	150	150	125
To shell for 0.125*L* 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
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 3-2-16/1.7							
Stiffeners to deep tank 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

TABLE 1 (continued)
Weld Sizes and Spacing – Millimeters

	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*							
Decks (continued)								
Peripheries of strength decks, exposed decks, and all watertight or oiltight decks, tunnels and flats	In accordance with 3-2-16/1.7							
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 3-2-16/1.7				
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 3-2-16/1.7							
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.
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 1
Weld Sizes and Spacing – Inches

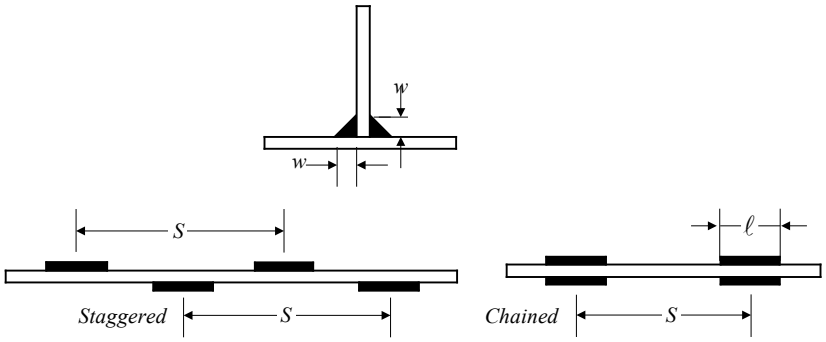
For weld requirements for thicknesses intermediate to those shown in the table, use the nearest thickness shown in the table.

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 3-2-16/Table 1 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.

For double continuous welding as an alternative to intermittent welding, see 3-2-16/1.3.1.



	Leg 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 3-2-16/1.7							
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-spread floors with longitudinal frames	In accordance with 3-2-16/1.7							
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 3-2-16/1.7							
To inner bottom in engine room	In accordance with 3-2-16/1.7							
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 3-2-16/1.7							
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 3-2-16/1.7							

TABLE 1 (continued)
Weld Sizes and Spacing – Inches

	Leg 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.*							
Center Girder								
Nontight to inner-bottom or center strake in way of engine and to shell or bar keel	In accordance with 3-2-16/1.7							
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 3-2-16/1.7							
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 3-2-16/1.7							
Frames								
To shell in aft peaks of vessels having high power and fine form	—	—	6	5	6	6	6	5
To shell for 0.125*L* 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								
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 10 sq. in. or less	*10	*10	12	11	12	11	10	10
Webs to face plate area of face plate exceeds 10 sq. in.	—	—	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 3-2-16/1.7							
Stiffeners to deep tank 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

TABLE 1 (continued)
Weld Sizes and Spacing – Inches

	Leg 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.*							
Decks (continued)								
Peripheries of strength decks, exposed decks, and all watertight or oiltight decks, tunnels and flats	In accordance with 3-2-16/1.7							
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 3-2-16/1.7				
Transverses or deep beams to decks in tanks	—	8	9	8	9	8	7	6
Transverses or deep beams to decks 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 3-2-16/1.7							
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.
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.

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 17 Machinery Space and Tunnel *(1 July 2018)*

1 General

1.1 Arrangement

In view of the effect upon the structure of the necessary openings in the machinery space, the difficulty of securing adequate support for the decks, of maintaining the stiffness of sides and bottom and of distributing the weight of the machinery, special attention is directed to the need for arranging, in the early stages of design, for the provision of plated through beams and such casing and pillar supports as are required to secure structural efficiency. Careful attention to these features in design and construction is to be regarded as of the utmost importance.

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 4-3-1/21).

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 and reduction gears 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

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 3-2-4/5.1 of the *Steel Vessel Rules*). Boilers are to be installed such, as to ensure accessibility and proper ventilation being at least 460 mm (18 in.) clear of tank tops, bunker walls, etc. 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

The plating of flat sides of shaft or other watertight tunnels is to be of the thickness as obtained from 3-2-7/5.1 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. Neither 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:

$$SM = 4.42\, hs\ell^2 \quad \text{cm}^3$$

$$SM = 0.0023\, hs\ell^2 \quad \text{in}^3$$

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:

$$t = 0.1345\, dh + 9 \quad \text{mm}$$

$$t = 0.000492\, dh + 0.36 \quad \text{in.}$$

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 scantling draft 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 18 Guidance on Finite Element Analysis *(2019)*

1 General

The intent of this Section is to provide guidance on the use of finite element methods (FEM) for evaluating linear response of hull structural components, equipment foundations and reinforcement structure to applied loads.

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 components.

1.1 Submittal Items

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 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 analysis, including their versions and dates.

ii) Detailed descriptions of structural modeling principles and any deviations in the model from the structural drawings.

iii) Plots of the structural models.

- *a)* Geometry
- *b)* Plate thickness

iii) Material properties and beam properties, if applicable.

iv) Details of boundary conditions applied

v) All loading conditions analyzed

vi) Data for load application*

vii) Summaries and plots of calculated deflections and reactions. Validate the load direction and global balance in the model.

viii) Summaries and plots of calculated stresses

ix) Details of buckling assessments, if necessary

x) Comparison table for design/drawing scantlings and FEA model scantlings

xi) Reference of software used in analysis, including its version and date

* *Note:* Details on how loads (static, dynamic, impact, etc.) are determined for structural evaluation.

3 Structural Modeling

3.1 Finite Element Types

The choice of finite element type 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 elements and three or four membrane/plate elements are considered sufficient for representation of a structure and requirements in this appendix assumes the use of such element types in the models. Higher order elements may also be applied. Details of basic element types are given in 3-2-18/Table 1.

TABLE 1
Finite Element Type

Element Type	*Description*
Rod (or truss) element	Line element with axial stiffness only and constant cross-sectional area along 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

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

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.

3.5 Modeling Guidance

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 included in the model, as appropriate.

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.

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 not to exceed the spacing between the frames. The mesh should be progressively and smoothly refined to capture structural details where important or found necessary.

i) 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 representing sniped or tapered flanges is to be considered proportionally using an average area over the length of the element

ii) The aspect ratio of plate elements is, in general, not to exceed three. The use of triangular plate elements is to be kept to a minimum.

iii) Shell elements are to be used for plate elements subjected to lateral loading.

iv) Gross scantlings are to be used in modeling the structure.

5 Boundary Conditions

Boundary conditions applied are to reflect, as closely as possible, the actual support conditions of the structure. The extent of the model 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

Loads applied on a model are to be as required by either 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 following approximation could be utilized:

$$a_V = 0.102*[(x - L/c)]g$$

$$a_L = a_T = 0.5g$$

$$c = 70\ (229.7)$$

where

a_V = vertical acceleration, in m/s^2 (ft/s^2)

a_L = longitudinal acceleration in m/s^2 (ft/s^2)

a_T = transverse acceleration in m/s^2 (ft/s^2)

L = length as per 3-1-1/3.1, in m (ft)

g = acceleration of gravity = 9.8 m/s^2 (32.2 ft/s^2)

The value of "x" is dependent on the location of the area to be assessed and is to be taken as that given in the table below. The value of "x" at intermediate locations is to be determined by interpolation. L is to be measured from AP to forward.

AP & aft of AP	*0.1L*	*0.2L*	*0.3L ~ 0.6L*	*0.7L*	*0.8L*	*0.9L*	*FP & forward*
$x = 18$	17	16	15	16	17	18	19

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

Unless otherwise specified in these Rules or other 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 3-2-18/Table 2 for the specific mesh size.

TABLE 2
Stress Limits for Plate Element Models

Mesh Size	*Stress Limit*	
	Static + Dynamic	*Static*
1 × stiffener spacing (*SS*)	0.90 S_mF_y	0.63 S_mF_y
$^1/_2 \times SS$	0.95 S_mF_y	0.67 S_mF_y
$^1/_3 \times SS$	1.00 S_mF_y	0.70 S_mF_y
$^1/_4 \times SS$ (1)	1.06 S_mF_y	0.74 S_mF_y
$^1/_5 \times SS \sim {}^1/_{10} \times SS$ (1)	1.12 S_mF_y	0.78 S_mF_y

Notes:

1 Stress limits greater than 1.00 S_mF_y are to be restricted to small areas in way of structural discontinuities.

2 S_m = 1.00 for mild steel
= 0.95 for HT32
= 0.908 for HT36
=0.875 for HT40

3 For intermediate mesh size, the stress limit may be obtained by linear interpolation.

4 For longitudinally effective structure that is modeled without the hull girder loads, the allowable stresses are to be decreased by 10%.

5 This guidance note has generally 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.

9.3 Buckling Strength

Buckling strength is to be adequate for the critical locations and high stresses 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 5C of the *Marine Vessel Rules*, as applicable for specific vessel type. For vessels that do not have specific requirements in Part 5C of the *Marine Vessel Rules*, reference is made to Appendix 2 of the ABS *Guide for 'SafeHull-Dynamic Loading Approach' for Vessels*.

PART
3

CHAPTER 3 Subdivision and Stability

CONTENTS

SECTION 1 General Requirements 259

1 General 259

3 Criteria 259

3.1 Intact Stability 259

3.3 Subdivision and Damage Stability 259

5 Review Procedures 260

5.1 Administration Review 260

5.3 ABS Review 260

7 Damage Control Information 260

7.1 General 260

7.3 Damage Control Plan 260

7.5 Damage Control Booklet 261

9 Onboard Computers for Stability Calculations 261

APPENDIX 1 Intact Stability of Tankers During Liquid Transfer Operations 262

1 General 262

1.1 Note 262

1.3 Operations to be Addressed 262

APPENDIX 2 Computer Software for Onboard Stability Calculations 265

1 General 265

1.1 Scope 265

1.3 Design 265

3 Calculation Systems 265

5 Types of Stability Software 265

7 Functional Requirements 266

7.1 Calculation Program 266

7.3 Direct Damage Stability Calculations 266

7.5 Warning 266

7.7 Data Printout 266

7.9 Date and Time 266

7.11 Information of Program 267

7.13 Units 267

7.15 Computer Model 267

7.17 Further Requirements for Type 4 Stability Software 267

9 Acceptable Tolerances 269
9.1 Calculation Program of the Approved Stability Information....270
9.3 Independent Program for Assessment of Stability....270
11 Approval Procedure 271
11.1 Conditions of Approval of the Onboard Software for Stability Calculations....271
11.3 General Approval (optional)....271
11.5 Specific Approval....272
13 Operation Manual 273
15 Installation Testing....273
17 Periodical Testing 273
19 Other Requirements....274

TABLE 1 Acceptable Tolerances 270

PART
3

CHAPTER 3 Subdivision and Stability

SECTION 1 General Requirements

1 General

Vessels of the following categories are to have subdivision and stability in accordance with the criteria as shown.

3 Criteria

3.1 Intact Stability

All vessels which have a length of 24 m (79 ft) or over, as defined in the International Convention on Load Lines, are to have intact stability guidance as required by Regulation 10 of the International Convention on Load Lines. The following criteria may be used for classification purposes:

- Cargo vessels of 24 m (79 ft) in length and over with or without deck cargo: IMO Code on Intact Stability

In case the above criteria are not applicable to a particular vessel, the intact stability will be reviewed by ABS in accordance with other recognized criteria appropriate to the vessel's type, size and intended service.

Tankers for which the request for class for new construction is received on or after 1 July 1997 are to meet the requirements in Appendix 3-3-A1, "Intact Stability of Tankers During Liquid Transfer Operations."

3.3 Subdivision and Damage Stability

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, 1974, as amended as follows:

• Passenger vessel	Regulation II-1/4 through 8-1 (Section 5C-7-3 of the ABS *Rules for Building and Classing Steel Vessels*)
• Gas Carrier	IGC Code (Section 5C-8-2 of the ABS *Rules for Building and Classing Steel Vessels*)
• Chemical carrier	IBC Code (Section 5C-9-2 of the ABS *Rules for Building and Classing Steel Vessels*)
• Offshore support vessel	Section 3-3-1 of the ABS *Rules for Building and Classing Offshore Support Vessels*
• *(1 July 1998)* Cargo vessel of 80 m (262 ft)or more in subdivision length	Regulation II-1/4 through 7-3

5 Review Procedures

5.1 Administration Review

When the vessel is issued an International Load Line Certificate, Passenger Ship Safety Certificate, Cargo Ship Safety Construction Certificate, International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk or International Certificate of Fitness for Carriage of Dangerous Chemicals in Bulk by the flag Administration or its agent other than ABS, such Certificate will be accepted as evidence that the vessel has subdivision and stability in accordance with the criteria in the respective Convention.

Where the Administration undertakes the review of subdivision and stability and ABS is issuing the above Certificate, the acceptance of subdivision and stability by the Administration will be required before the certificate is issued.

5.3 ABS Review *(1 July 2016)*

In all other cases, the information and calculations for subdivision and stability are to be submitted to ABS for review. Where the intact stability criteria are not applicable to a particular vessel, the review will be in accordance with other recognized criteria acceptable to ABS.

For all vessels to be assigned the **Towing Service** notation or those designed for towing, the sea trial conditions including the anticipated drafts of the vessel, levels in each tank, weights and locations of any additional equipment onboard during the trials, and the maximum number of persons onboard the vessel during the sea trials are to be submitted to ABS for review, prior to the sea trials.

7 Damage Control Information *(2015)*

7.1 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.

7.3 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.

7.5 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.

9 Onboard Computers for Stability Calculations *(1 July 2007)*

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 should cover all stability requirements applicable to the vessel and is to be approved by ABS for compliance with the requirements of Appendix 3-3-A2, "Onboard Computers for Stability Calculations".

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 for tankers (i.e., vessels designed to carry liquid in bulk) were developed from the IMO draft MSC Circular containing recommendations for existing oil tankers and the anticipated amendments to MARPOL for new 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 vulnerable existing tankers and for new tankers now rather than be deferred until the proposed amendments to MARPOL enter into force. The solution should not be limited only to tankers subject to MARPOL.

1.3 Operations to be Addressed

Liquid transfer operations include cargo loading and unloading, lightering, ballasting and deballasting, ballast water exchange and tank cleaning operations.

3

Every tanker is to comply with the intact stability criteria specified in subparagraphs 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.

3.1

In port, the initial metacentric height, GM_0, is not to be less than 0.15 m. Positive intact stability is to extend from the initial equilibrium position at which GM_0 is calculated over a range of at least 20 degrees to port and to starboard.

3.3

At sea, the intact stability criteria contained in paragraphs 2.2.1 to 2.2.4 of Part A, Chapter 2 of the IMO Code on Intact Stability, are applicable, or the criteria contained in the national requirements of the flag Administration are applicable 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.

7

The intact stability criteria specified in 3-3-A1/3 is preferably 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 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. The use of such systems is encouraged;

9.11

Provide for corrective actions to be taken by the officer-in-charge in case of unexpected technical 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 Computer Software for Onboard Stability Calculations *(2018)*

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.

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 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 as well as 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 only applicable 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 reapproved.

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 *(2018)*

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 *(2018)*

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, downflooding angle and the corresponding downflooding opening 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

If direct damage stability calculations are performed, the relevant damage cases according to the applicable rules are to be pre-defined for automatic check of a given loading condition.

7.5 Warning *(2018)*

A clear warning is to be given on screen and in hard copy printout if 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 *(2018)*

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 *(2018)*

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 accommodation	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). *

* 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-A2/9.1 or 3-3-A2/9.3. 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.
- 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-A2/9.1 or 3-3-A2/9.3, 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-A2/Table 1.

TABLE 1
Acceptable Tolerances *(2018)*

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
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 (both solid and corrected for free surfaces)	±1% or 5 cm, whichever is greater
GZ values	±1% or 5 cm, whichever is greater
Downflooding angle	±2°
Equilibrium angles	±1°
Distance from WL to unprotected and weathertight openings, or other relevant point, if applicable	±5% or 5 cm, whichever is greater
Areas under righting arm curve	±5% or 0.0012 mrad

TABLE 1 (continued)
Acceptable Tolerances *(2018)*

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 When applying a tolerance in 3-3-A2/Table 1 that contains two values, the allowable tolerance is the greater of the two values.

3 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 3-3-A2/Table 1 provided a software examination is carried out in sufficient detail to clearly document that such differences are technically justifiable.

4 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 *(2018)*

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-A2/11.5),
- 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-A2/7.

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-A2/15). 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 pre-calculated 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 *(2018)*

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 light weight check.
- 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 *(2018)*

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-A2/15.

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

SECTION 1 Structural Fire Protection 276

1 General 276
- 1.1 SOLAS Application 276
- 1.3 Regulation 276
- 1.5 Definitions 276
- 1.7 Materials Containing Asbestos 276

3 Passenger Vessels 276

5 Cargo Vessels 276
- 5.1 All Vessels 276
- 5.3 Tankers 276
- 5.5 Vessels Carrying Chemicals or Liquefied Gases in Bulk 277

7 Review Procedures 277
- 7.1 Administration Review 277
- 7.3 ABS Review 277

9 Fiber Reinforced Plastic (FRP) Gratings 277

APPENDIX 1 Fiber Reinforced Plastic (FRP) Gratings 278

1 General 278

3 FRP Grating Material Systems 278

5 Fire Test Requirements 278
- 5.1 Structural Fire Integrity 278
- 5.3 Flame Spread 279
- 5.5 Smoke Generation 279

7 Structural Fire Integrity Test Procedures 279

9 Structural Fire Integrity Matrix 279

11 Other Authorized Uses 280

TABLE 1 Structural Fire Integrity Matrix 279

PART
3

CHAPTER 4 Fire Safety Measures

SECTION 1 Structural Fire Protection

1 General

1.1 SOLAS Application

For classification purposes, the fire and 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 section does not relax the requirements in other sections of the Rules.

Gross tonnage is to be taken as defined in 3-1-1/17.

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 *(1 July 2011)*

Installation of materials which contain asbestos is prohibited.

3 Passenger Vessels

For passenger vessels, the requirements of Section 5C-7-4 of the ABS *Rules for Building and Classing Steel Vessels* are applicable.

5 Cargo Vessels

5.1 All Vessels

For all cargo vessels as defined in Regulation II-2/3.7, 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.

5.3 Tankers

For tankers as defined in Regulation 3.48, Chapter II-2 of 1974 SOLAS, as amended, the following requirements are additional to 3-4-1/5.1.

5.3.1 Low Flash Point Cargoes

For tankers intended for the carriage of cargoes having 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.

5.3.2 High Flash Point Cargoes

For tankers intended for the carriage of cargoes having flash point above 60°C (140°F), the requirements in 3-4-1/5.1 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.

5.5 Vessels Carrying Chemicals or Liquefied Gases in Bulk

Vessels intending to carry chemicals or liquefied gases in bulk are to comply with the applicable requirements of Part 5C, Chapters 8 and 9 of the *Steel Vessel Rules*, as applicable, and the governing Administrative Regulations.

7 Review Procedures

7.1 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.

7.3 ABS Review

In all other cases, the required information and plans are to be submitted to ABS for review.

9 Fiber Reinforced Plastic (FRP) Gratings *(2015)*

Where approved by the Administration, the use of Fiber Reinforced Plastic (FRP) gratings is to be in accordance with Appendix 3-4-A1.

PART
3

CHAPTER 4 Fire Safety Measures

APPENDIX 1 Fiber Reinforced Plastic (FRP) Gratings *(2015)*

1 General

1.1 *(2018)*

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/Table 1.

FRP gratings are to meet the performance requirements of and are to be tested in accordance with ASTM F3059-15, *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 *(2018)*

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/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 four 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 *(2018)*

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 *(2018)*

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)

TABLE 1 (continued)
Structural Fire Integrity Matrix *(2018)*

Location	*Service*	*Fire Integrity*
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 foam firefighting systems on tank vessels	L2
	Walkways or areas which may be used for escape, or access for firefighting systems and AFFF hose reels, emergency operation, or rescue on MODUs and production platforms including safe access to tanker bows	L2
	Walkways or areas which may be used for escape, or access for firefighting, emergency operation or rescue other than 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 4-1-1/13.1.

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 *(2018)* 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 *(2018)*

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-A1/5.5. Applications 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

SECTION 1 Anchoring, Mooring and Towing Equipment 283

1 General 283

3 Calculation of EN 283

3.1 Basic Equation 283

3.3 Vessels of Unrestricted Service Having EN of 205 and Above 284

3.5 Vessels Having EN Less Than 205 or Vessels Intended for Towing Service 284

5 Equipment with the Symbol Ⓔ 285

7 Equipment without the Symbol Ⓔ 285

7.1 General 285

7.3 Vessels intended for Limited Service 285

7.5 Vessels Intended for Towing Service 286

9 Materials and Tests 286

11 Anchor Types 286

13 Windlass or Winch Support Structure 286

13.1 General 286

13.3 Support Structure 287

13.5 Trial 289

14 Hawse Pipes 290

15 Securing of the Inboard Ends of Chain Cables 290

16 Securing of Stowed Anchors 290

17 Mooring and Towing Equipment 290

17.1 All Vessels 290

17.3 Mooring Lines 290

17.5 Tow line 293

17.7 Mooring and Tow Line Construction 293

17.9 Mooring Winches 293

17.11 Mooring and Towing Arrangement 294

19 Bollard, Fairlead and Chocks 295

19.1 General 295

19.3 Shipboard Fittings 295

19.5 Safe Working Load (SWL) and Towing Load (TOW) 296

19.7 Towing and Mooring Arrangements Plan 297

TABLE 1 Equipment for Self-propelled Ocean-going Vessels 298

TABLE 2 Mooring Lines for Self-propelled Ocean-going Vessels with $EN \leq 2000$ 302

TABLE 3 Tow Lines for Self-propelled Ocean-going Vessels 303

FIGURE 1 Effective Heights of Deckhouses 285
FIGURE 2 Direction of Forces and Weight.....289
FIGURE 3 Sign Convention.....289

PART
3

CHAPTER 5 Equipment

SECTION 1 Anchoring, Mooring and Towing Equipment

1 General *(1 July 2018)*

All self-propelled vessels are to have anchors and chains. The 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 is to be capable of heaving in either cable. Suitable arrangements are to be provided for securing the anchors and stowing the cables. 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 by efficient means (see 3-5-1/15).

Equipment Number calculations for unconventional vessels with unique topside arrangements or operational profiles may be specially considered. Such consideration may include accounting for additional wind areas of widely separated deckhouses or superstructures in the equipment number calculations or equipment sizing based on direct calculations. However, in no case may direct calculations be used to reduce the equipment size to be less than that required by 3-5-1/3.

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. 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 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 3-2-6/1.6.

3 Calculation of EN

3.1 Basic Equation *(1 July 2018)*

The basic Equipment Number (EN) is to be obtained from the following equation for use in determining required equipment.

$$EN = k\Delta^{2/3} + mBh + nA$$

where

k = 1.0 (1.0, 1.012)

m = 2 (2, 0.186)

n = 0.1 (0.1, 0.00929)

Δ = molded displacement, in metric tons (long tons), to the summer load waterline

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

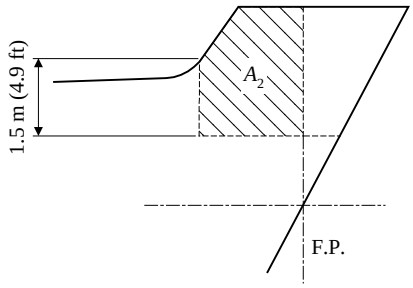
h = effective height, in m (ft), from the Summer Load waterline to the top of the uppermost house; for the lowest tier, h is to be measured at centerline from the upper deck or from a notional deck line where there is local discontinuity in the upper deck, as shown in 3-5-1/Figure 1

= $a + h_1 + h_2 + h_3 + \ldots$, as shown in 3-5-1/Figure 1. In the calculation of h, sheer and trim may be neglected

a = freeboard, in m (ft), from the summer load waterline amidships.

$h_1, h_2, h_3 \ldots$ = height, in m (ft), on the center line of each tier of houses having a breadth greater than $B/4$

A = side-projected area, in m^2 (ft^2), of the hull, superstructure and houses above the summer load waterline which are within the Rule length. Superstructures or deck houses having a breadth at any point no greater than $0.25B$ may be excluded. Screens and bulwarks more than 1.5 m (4.9 ft) in height are to be regarded as parts of houses when calculating h and A, except as specified in 3-5-1/17.3 for mooring lines. The height of the hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining h and A. With regard to determining A, when a bulwark is more than 1.5 m (4.9 ft) high, the area shown below as A_2 should be included in A.



3.3 Vessels of Unrestricted Service Having EN of 205 and Above

For vessels of unrestricted service having an EN of 205 or above in accordance with 3-5-1/3.1, the calculated EN is to be used in association with 3-5-1/Table 1. For vessels intended for towing service, see 3-5-1/3.5.

3.5 Vessels Having EN Less Than 205 or Vessels Intended for Towing Service

For vessels of unrestricted service having EN less than 205 calculated in accordance with 3-5-1/3.1 or for vessels intended for towing service, the EN for use with 3-5-1/Table 1 may be calculated in accordance with the following equation.

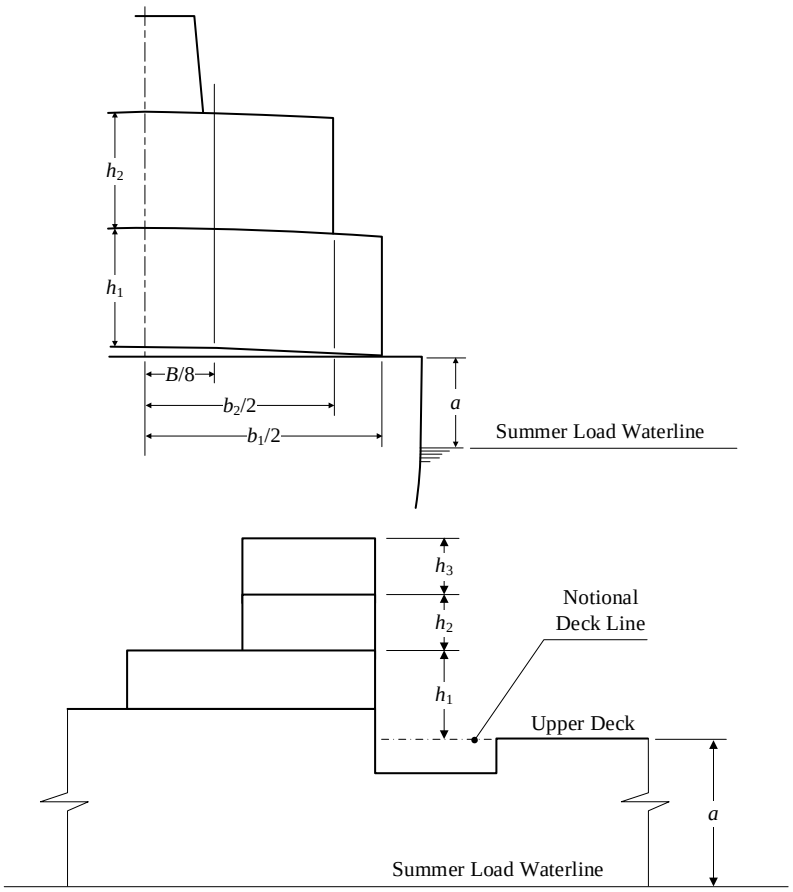
Equipment Number = $k\Delta^{2/3} + m\,(Ba + \sum bh) + nA$

Where k, m, n, Δ, B, a and A are as defined in 3-5-1/3.1 above and;

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/Figure 1.

FIGURE 1
Effective Heights of Deckhouses *(1 July 2018)*



5 Equipment with the Symbol Ⓔ

The equipment weight and size for all vessels with the symbol Ⓔ is to be in accordance with 3-5-1/Table 1 in association with EN calculated by 3-5-1/3.

7 Equipment without the Symbol Ⓔ

7.1 General

Where the symbol Ⓔ is not desired for vessels with EN calculated as permitted by 3-5-1/3.5, the equipment is to be in accordance with 3-5-1/Table 1, in association with the EN so calculated, but the following modifications may be accepted. See also 3-5-1/9.

7.3 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 3-5-1/3.5, are to have one anchor of the tabular weight and one-half the tabulated length of anchor chain in 3-5-1/Table 1. Alternatively, two anchors of one-half the tabular weight with the total length of anchor chain listed in 3-5-1/Table 1 may be fitted, provided both anchors are positioned and ready for use and the windlass is capable of heaving in either anchor.

7.5 Vessels Intended for Towing Service *(2001)*

Vessels intended for towing service are to have at least one anchor of one-half the tabular weight listed in 3-5-1/Table 1.

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.

9 Materials and Tests

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 are to be in accordance with a national or other recognized standard.

Where the symbol Ⓔ is not desired in accordance with 3-5-1/7.1, 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.

11 Anchor Types

Anchors are, in general, to be of the stockless type. The weight of the head of a stockless anchor, including pins and fittings, is not to be less than three-fifths of the total weight of the anchor. Where specifically requested by the Owners, ABS is prepared to give consideration to the use of special types of anchors, and where these are of proven superior holding ability, consideration may also be given to some reduction in the weight, up to a maximum of 25%, from the weight specified in 3-5-1/Table 1. In such cases, an appropriate notation will be made in the *Record*.

13 Windlass or Winch Support Structure

13.1 General *(2014)*

The windlass is to be of good and substantial make, suitable for the size of intended anchor cable. The winch is to be well bolted down to a substantial bed, and deck beams below the windlass are to be of extra strength and additionally supported. Where wire ropes are used in lieu of chain cables, winches capable of controlling the wire rope at all times are to be fitted.

Construction and installation of all windlasses and 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 manufacturer or builder is to submit, in accordance with 4-1-1/7, the following, as applicable:

13.1.1 Plans

i) Arrangement and details of the windlass or 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.

13.1.2 Calculations

Detailed stress calculations for the applicable system components listed in 3-5-1/13.1.1 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 Appendix 4-3-1A1 of the *Steel Vessel Rules*, for the gears and shafts, or to other recognized standard or code of practice.

13.3 Support Structure *(2004)*

The windlass is to be bolted down to a substantial foundation which is to meet the following load cases and associated criteria.

13.3.1 Operating Loads

13.3.1(a) Load on Windlass Support Structure (2006). The following load is to be applied in the direction of the chain.

With cable stopper not attached to windlass:	45% of B.S.
With cable stopper attached to windlass:	80% of B.S.
Without cable stopper:	80% of B.S.

B.S. = minimum breaking strength of the chain, as indicated in 2-2-2/Tables 2 and 3 of the ABS *Rules for Materials and Welding (Part 2)*.

13.3.1(b) Load on Cable Stopper and Support Structure (2006). A load of 80% of B.S. is to be applied in the direction of the chain.

13.3.1(c) Allowable Stress (2006). The stresses in the structures supporting the windlass and cable stopper are not to exceed the yield point.

13.3.2 Sea Loads *(2014)*

For vessels with length, L (as defined in 3-1-1/3.1), between 80 meters (263 feet) and 90 meters (295 feet), 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.

13.3.2(a) Pressures. The following pressures and associated areas are to be applied (see 3-5-1/Figure 2):

- 200 kN/m^2 (20.4 tf/m^2, 4178 lbf/ft^2) normal to the shaft axis and away from the forward perpendicular, over the projected area in this direction,
- 150 kN/m^2 (15.3 tf/m^2, 3133 lbf/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

  H = overall height of windlass.

13.3.2(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/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:

$$R_{xi} = P_x \, hx_i \, A_i / I_x$$

$$R_{yi} = P_y \, hy_i \, A_i / I_y$$

and

$$R_i = R_{xi} + R_{yi} - R_{si}$$

where

P_x = force, kN (tf, lbf), acting normal to the shaft axis

P_y = force, kN (tf, lbf), 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:

$$F_{xi} = (P_x - \alpha g M)/N$$

$$F_{yi} = (P_y - \alpha g M)/N$$

and

$$F_i = (F_{xi}^2 + F_{yi}^2)^{0.5}$$

where

α = coefficient of friction (0.5)

M = mass of windlass, in tonnes (Ltons)

g = gravity: 9.81 m/sec^2 (32.2 ft/sec^2)

N = number of groups of bolt.

The axial tensile/compressive and lateral forces from the above equations are also to be considered in the design of the supporting structure.

13.3.2(c) Stresses in Bolts. Tensile axial stresses in the individual bolts in each group of bolt *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.

13.3.2(d) Allowable Stress (1 July 2018)

i) *Bolts.* The safety factor against bolt proof strength is to be not less than 2.0.

ii) *Supporting Structures.* The allowable stresses in the above deck framing and the hull structure supporting the windlass and chain stopper are as follows:

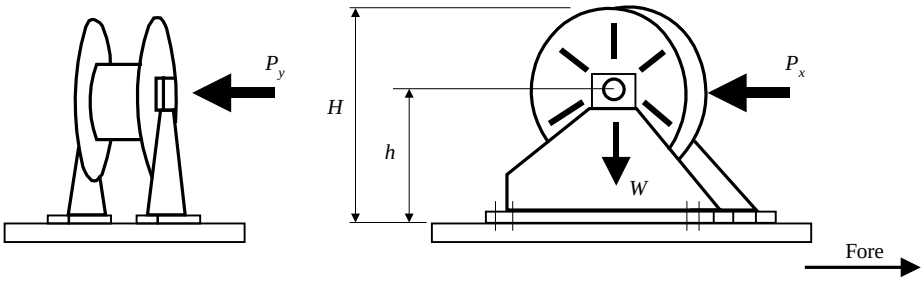
- Normal stress: 100% of the specified minimum yield stress of the material
- Shear stress: 60% of the specified minimum yield stress of the material

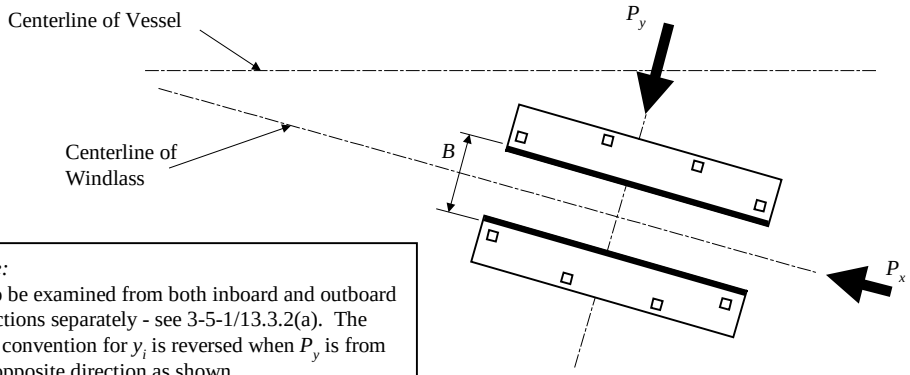
iii) The net minimum scantlings of the supporting hull structure are to comply with the requirements given in 3-5-1/13.3.2(d)ii). The required gross scantlings are determined according to 3-2-6/1.6.4.

13.5 Trial

See 3-7-2/1.

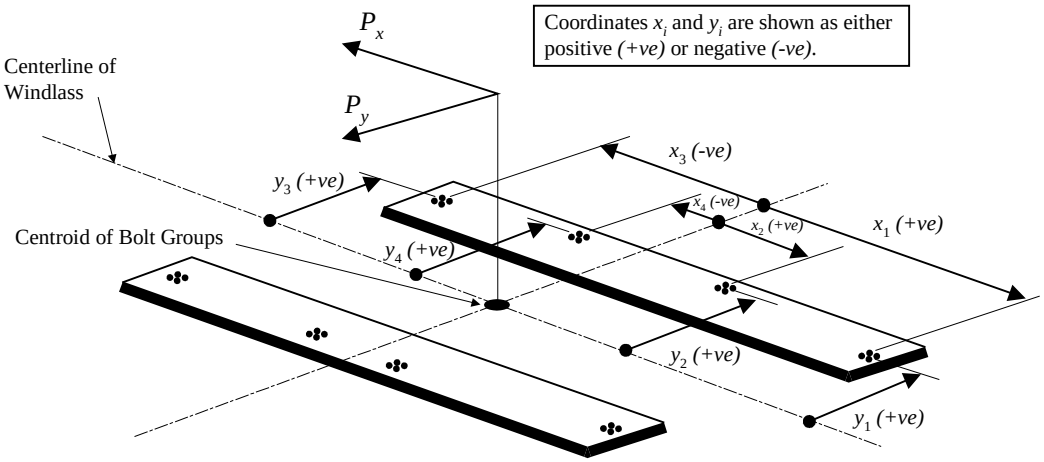
FIGURE 2
Direction of Forces and Weight *(2004)*





Note:
P_y to be examined from both inboard and outboard directions separately - see 3-5-1/13.3.2(a). The sign convention for y_i is reversed when P_y is from the opposite direction as shown.

FIGURE 3
Sign Convention *(2004)*



Coordinates x_i and y_i are shown as either positive *(+ve)* or negative *(-ve)*.

14 Hawse Pipes

Hawse pipes are to be of ample size and strength. They are to have full rounded flanges and the least possible lead, in order to minimize the nip on the cables. 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 3-2-16 for the plating thickness and type of joint selected. 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). Hawse pipes for stockless anchors are to provide ample clearances. 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. 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.

15 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.

16 Securing of Stowed Anchors *(1 July 2018)*

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, anchor lashings (e.g., a “devil’s claw”) are to be 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.

17 Mooring and Towing Equipment *(1 July 2018)*

17.1 All Vessels

Hawsers and towlines and requirements for associated equipment and arrangements as described in in 3-5-1/17.9 and 3-5-1/17.11 are not required as a condition of classification. The hawsers and towlines listed in 3-5-1/Table 2 and 3-5-1/Table 3 are intended as a minimum guide.

17.3 Mooring Lines

The mooring lines for vessels with Equipment Number EN of less than or equal to 2000 are given in 3-5-1/17.3.1. For other vessels, the mooring lines are given in 3-5-1/17.3.2.

The Equipment Number EN is to be calculated in compliance with 3-5-1/3. Deck cargo as given by the loading manual is to be included for the determination of side-projected area *A*.

17.3.1 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/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/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

17.3.2 Mooring Lines for Vessels with EN > 2000

The minimum strength and number of mooring lines for vessels with an Equipment Number EN > 2000 are given in 3-5-1/17.3.2(a) and 3-5-1/17.3.2(b), respectively, and is intended as a guide. The length of mooring lines is given by 3-5-1/17.3.3.

The strength 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 should be calculated similar to the side-projected area A according to 3-5-1/3 but considering the following conditions:

- For oil tankers, chemical tankers, bulk carriers, and ore carriers the lightest ballast draft is to be considered for the calculation of the side-projected area A_1. For other vessels the lightest draft of usual loading conditions is to be considered if the ratio of the freeboard in the lightest draft and the full load condition is equal to or above two. Usual loading conditions are loading conditions as given by the trim and stability booklet that are expected to regularly occur during operation and, in particular, that exclude light weight conditions, propeller inspection conditions, etc.
- 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 cargo as given by the loading manual is to be included for the determination of side-projected area A_1. Deck cargo may not need to be considered if a usual light draft condition without cargo on deck generates a larger side-projected area A_1 than the full load condition with cargo on deck. The larger of both side-projected areas is to be chosen as side-projected area A_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):

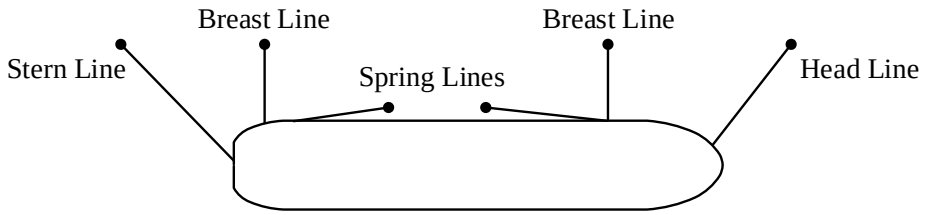
v_w	=	$25.0 - 0.002\,(A_1 - 2000)$ m/s	for passenger vessels, ferries, and car carriers with 2000 m^2 < A_1 ≤ 4000 m^2
	=	21.0 m/s	for passenger vessels, ferries, and car carriers with A_1 > 4000 m^2
	=	25.0 m/s	for other vessels
	=	$82.0 - 0.00061\,(A_1 - 21528)$ ft/s	for passenger vessels, ferries, and car carriers with 21528 ft^2 < A_1 ≤ 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.

Note: 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.



17.3.2(a) Minimum Breaking Strength. The minimum breaking strength, in kN (kgf, lbf), of the mooring lines should be taken as:

$$MBL = 0.1 \cdot A_1 + 350 \quad kN$$

$$MBL = 10.20 \cdot A_1 + 35690 \quad kgf$$

$$MBL = 2.089 \cdot A_1 + 78680 \quad lbf$$

The minimum breaking strength 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 3-5-1/17.3.2. For these vessels, the acceptable wind speed v_w*, in m/s, can be estimated as follows:

$$MBL^* \geq \left(\frac{21}{v_w}\right)^2 \cdot MBL \qquad \text{for } v_w \text{ in m/s}$$

$$MBL^* \geq \left(\frac{68.9}{v_w}\right)^2 \cdot MBL \qquad \text{for } v_w \text{ in ft/s}$$

where

v_w = wind speed as per 3-5-1/17.3.2

MBL* = breaking strength of the mooring lines intended to be supplied

MBL = breaking strength according to the above formula

However, the minimum breaking strength should not be taken less than corresponding to an acceptable wind speed of 21 m/s (68.9ft/s):

If lines are intended to be supplied for an acceptable wind speed v_w* higher than v_w as per 3-5-1/17.3.2, the minimum breaking strength should be taken as:

$$MBL^* = \left(\frac{v_w^*}{v_w}\right)^2 \cdot MBL$$

17.3.2(b) Number of Mooring Lines. The total number of head, stern, and breast lines (see Note in 3-5-1/17.3.2) should be taken as:

$$n = 8.3 \cdot 10^{-4} \cdot A_1 + 6 \qquad \text{for } A_1 \text{ in m}^2$$

$$n = 7.71 \cdot 10^{-5} \cdot A_1 + 6 \qquad \text{for } A_1 \text{ in ft}^2$$

For oil tankers, chemical tankers, bulk carriers, and ore carriers the total number of head, stern, and breast lines should 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 should 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 strength of the lines. The adjusted strength, MBL*, should be taken as:

$MBL^* = 1.2 \cdot MBL \cdot n/n^* \leq MBL$ for increased number of lines

$MBL^* = MBL \cdot n/n^*$ for reduced number of lines

where

n^* = increased or decreased total number of head, stern and breast lines

n = number of lines for the considered vessel type as calculated by the above formulas without rounding.

Similarly, the strength 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 (see Note in 3-5-1/17.3.2) is not to be taken as less than:

Two lines, where $EN < 5000$

Four lines, where $EN \geq 5000$

The strength 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 strength of the lines, the number of spring lines is to be likewise increased, but rounded up to the nearest even number.

17.3.3 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/Table 2. For vessels with $EN > 2000$ the length of mooring lines may be taken as 200 m (109 fathoms).

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.

17.5 Tow line

The tow lines are given in 3-5-1/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/Table 3, the Equipment Number (EN) is to be taken according to 3-5-1/3.

17.7 Mooring and Tow Line Construction

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 3-5-1/17.3 and 3-5-1/17.5, no fiber rope is to be less than 20 mm (0.79 in) in diameter. For polyamide ropes, the minimum breaking strength 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.

17.9 Mooring Winches

17.9.1

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 minimum breaking strength 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.

17.9.2

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 minimum breaking strength. For automatic winches, these figures apply when the winch is set to the maximum power with automatic control.

17.9.3

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.

17.11 Mooring and Towing Arrangement

17.11.1 Mooring Arrangement

Mooring lines in the same service (e.g., breast lines, see Note in 3-5-1/17.11.2) 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.

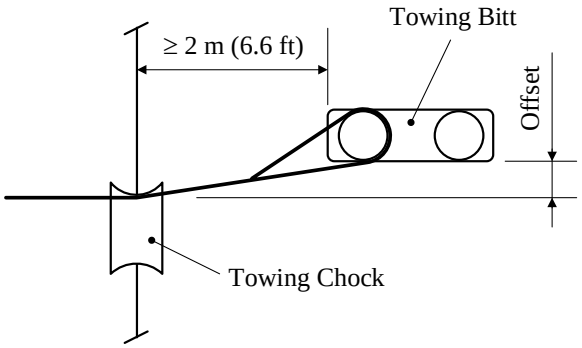
17.11.2 Towing Arrangement

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 in 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 all vessels, it is recommended to provide towing arrangements fore and aft of sufficient strength for 'other towing' service as defined in 3-2-6/1.6.2(b).

19 Bollard, Fairlead and Chocks *(1 July 2018)*

19.1 General

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 of this section. The requirements for the supporting structures of these deck fittings are specified in 3-2-6/1.6.

19.3 Shipboard Fittings

The size of shipboard fittings is to be in accordance with recognized standards (e.g., ISO 13795 Ships and marine technology – Ship's mooring and towing fittings – Welded steel bollards for sea-going vessels) or comply with the requirements given in 3-5-1/19.3.1 and 3-5-1/19.3.2. For shipboard fittings not in accordance with recognized standard the corrosion addition, t_c, and the wear allowance, t_w, given in 3-2-6/1.6.4, respectively, are to be considered. 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 3-2-6/1.6.

19.3.1 Mooring Operations

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 that according to 3-5-1/Table 2 [see Notes in 3-2-6/1.6.2(a)].

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 3-2-6/1.6.2 and 3-2-6/1.6.3. 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 3-2-6/1.6.4(b). A wear down allowance is to be included as defined in 3-2-6/1.6.4(c). 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.

19.3.2 Towing Operations

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 minimum breaking strength of the tow line according to 3-5-1/Table 3 (see Notes in 3-2-6/1.6.2(b) for other towing services),

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 3-2-6/1.6.2 and 3-2-6/1.6.3. 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 3-2-6/1.6.4(b). A wear down allowance is to be included as defined in 3-2-6/1.6.4(c). Consideration may be given to accepting load tests as alternative to strength assessment by calculations.

19.5 Safe Working Load (SWL) and Towing Load (TOW)

The requirements on SWL apply for a single post basis (no more than one turn of one cable).

19.5.1 Mooring Operations

i) The Safe Working Load (SWL) is the load limit for mooring purpose.

ii) Unless a greater SWL is requested by the applicant according to 3-2-6/1.6.2(c), the SWL is not to exceed the minimum breaking strength of the mooring line according to 3-5-1/Table 2, see Notes in 3-2-6/1.6.2(a).

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 3-5-1/19.5.2 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 3-5-1/19.7 is to define the method of use of mooring lines.

19.5.2 Towing Operations

i) The Safe Towing Load (TOW) is the load limit for towing purpose.

ii) TOW used for normal towing operations is not to exceed 80% of the design load per 3-2-6/1.6.2(b) for normal towing operations.

iii) TOW used for other towing operations is not to exceed 80% of the design load according to 3-2-6/1.6.2(b) for other towing service.

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) For fittings intended to be used for both towing and mooring, the requirements in 3-2-6/1.6 and 3-5-1/19 applicable to mooring are to be applied relative to mooring operations.

vi) 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 3-5-1/19.5.1 is to be marked in addition to TOW.

vii) 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.

viii) The towing and mooring arrangements plan mentioned in 3-5-1/19.7 is to define the method of use of towing lines.

19.5.3 Marking and Plan

19.5.3(a) Marking. The SWL of each shipboard fitting is to be marked (by weld bead or equivalent) on the fittings used for towing/mooring.

19.5.3(b) Plan. The towing and mooring arrangements plan mentioned in 3-5-1/19.7 is to define the method of use of mooring lines and/or towing lines.

19.7 Towing and Mooring Arrangements Plan

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.

Information provided on the plan is to include in respect of each shipboard fitting:

- Location on the vessel;
- Fitting type;
- SWL and TOW;
- Purpose (mooring/harbor towing/other towing); and
- Manner of applying towing or mooring line load including limiting fleet angles.

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 minimum breaking strength of each mooring line (MBL);
- The acceptable environmental conditions as given in 3-5-1/17.3.2 for the recommended minimum breaking strength of mooring lines for vessels with Equipment Number EN > 2000:
  - 30 second mean wind speed from any direction (v_W or v_W* according to 3-5-1/17.3.2)
  - Maximum current speed acting on bow or stern (±10°)

TABLE 1
Equipment for Self-propelled Ocean-going Vessels *(1 July 2018)*

SI, MKS Units

The weight per anchor of bower anchors given in 3-5-1/Table 1 is for anchors of equal weight. The weight of individual anchors may vary 7% plus or minus from the tabular weight, provided that the combined weight of all anchors is not less than that required for anchors of equal weight. The total length of chain required to be carried onboard, as given in 3-5-1/Table 1, is to be reasonably divided between the two bower anchors.

		Stockless Bower Anchors		*Chain Cable Stud Link Bower Chain***			
					Diameter		
Equipment Numeral	*Equipment Number**	*Number*	*Mass per Anchor, kg*	*Length, m*	*Normal-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	—
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
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

TABLE 1 (continued)

SI, MKS Units							
		Stockless Bower Anchors		*Chain Cable Stud Link Bower Chain***			
					Diameter		
Equipment Numeral	*Equipment Number**	*Number*	*Mass per Anchor, kg*	*Length, m*	*Normal-Strength Steel (Grade 1), mm*	*High-Strength Steel (Grade 2), mm*	*Extra High-Strength Steel (Grade 3), mm*
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	600	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
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

* For intermediate values of equipment number, use equipment complement in sizes and weights given for the lower equipment number in the table.

** 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.

All surfaces being in contact with the wire need to be rounded with a radius of not less than 10 times the wire rope diameter (including stem).

TABLE 1
Equipment for Self-propelled Ocean-going Vessels *(1 July 2018)*

US Units

The weight per anchor of bower anchors given in 3-5-1/Table 1 is for anchors of equal weight. The weight of individual anchors may vary 7% plus or minus from the tabular weight, provided that the combined weight of all anchors is not less than that required for anchors of equal weight. The total length of chain required to be carried onboard, as given in 3-5-1/Table 1, is to be reasonably divided between the two bower anchors.

		Stockless Bower Anchors		*Chain Cable Stud Link Bower Chain***			
					Diameter		
Equipment Numeral	*Equipment Number**	*Number*	*Mass per Anchor, pounds*	*Length, fathoms*	*Normal-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
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

TABLE 1 (continued)

US Units

		Stockless Bower Anchors		*Chain Cable Stud Link Bower Chain***			
					Diameter		
Equipment Numeral	*Equipment Number**	*Number*	*Mass per Anchor, pounds*	*Length, fathoms*	*Normal-Strength Steel (Grade 1), inches*	*High-Strength Steel (Grade 2), inches*	*Extra High-Strength Steel (Grade 3), inches*
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
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

* For intermediate values of equipment number, use equipment complement in sizes and weights given for the lower equipment number in the table.

** 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.

All surfaces being in contact with the wire need to be rounded with a radius of not less than 10 times the wire rope diameter (including stem).

TABLE 2
Mooring Lines for Self-propelled Ocean-going Vessels with *EN* ≤ 2000 *(1 July 2018)*

Equipment Number		*Mooring Lines*					
Exceeding	*Not Exceeding*	*Number*	*Minimum Length of Each Line* *		*Minimum Breaking Strength*		
			(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
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

* 3-5-1/17.3.3 is to be observed.

TABLE 3
Tow Lines for Self-propelled Ocean-going Vessels *(1 July 2018)*

Equipment Number		*Tow Line*				
Exceeding	*Not Exceeding*	*Minimum Length*		*Minimum Breaking Strength*		
		(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
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	80100	176500
1390	1480	200	109	836	85200	187800
1480	1570	220	120	888	90600	199700
1570	1670	220	120	941	96000	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

PART
3

CHAPTER 6 Navigation

CONTENTS

SECTION 1 Visibility 305

1 Navigation Bridge Visibility 305

1.1 Field of Vision 305

1.3 Windows and Their Arrangements 308

1.5 Unconventional Design 309

1.7 Articulated Tug-Barge Units 309

FIGURE 1 305

FIGURE 2 306

FIGURE 3 307

FIGURE 4 307

FIGURE 5 307

FIGURE 6 308

PART
3

CHAPTER 6 Navigation

SECTION 1 Visibility *(1 July 1998)*

1 Navigation Bridge Visibility

(2011) 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 with regard to the visibility from the navigation bridge, unless they are navigating solely the Great Lakes of North America and their connecting and tributary waters as far east as the lower exit of the St. Lambert Lock at Montreal in the Province of Quebec, Canada. Special consideration will be given to vessels that operate only on domestic or on short, limited, international voyages.

1.1 Field of Vision

1.1.1 Conning Position

1.1.1(a) *(1 July 2006)* 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/Figure 1.

FIGURE 1 *(1 July 2006)*

1. A conning position is a place on the bridge with a commanding view and which is used by navigators when commanding, maneuvering and controlling a vessel.
2. Attention is drawn to flag Administrations requiring lengths of less than $2L_{OA}$.

1.1.1(b) No blind sector caused by cargo, cargo gear or other obstructions outside of the wheelhouse forward of the beam which obstructs the view of the sea surface as seen from the conning position is to exceed 10°. The total arc of blind sectors is not to exceed 20°. The clear sectors between blind sectors are to be at least 5°. However, in the view described in 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/Figure 3.

1.1.2 Bridge Wing

1.1.2(a) From each bridge wing, the horizontal field of vision is to extend over an arc of at least 225°, that is, from at least 45° on the opposite bow to right ahead and then from right ahead to right astern through 180° on the same side of the vessel. See 3-6-1/Figure 4.

1.1.2(b) (1 July 2011) The vessel's side is to be visible from the bridge wing.

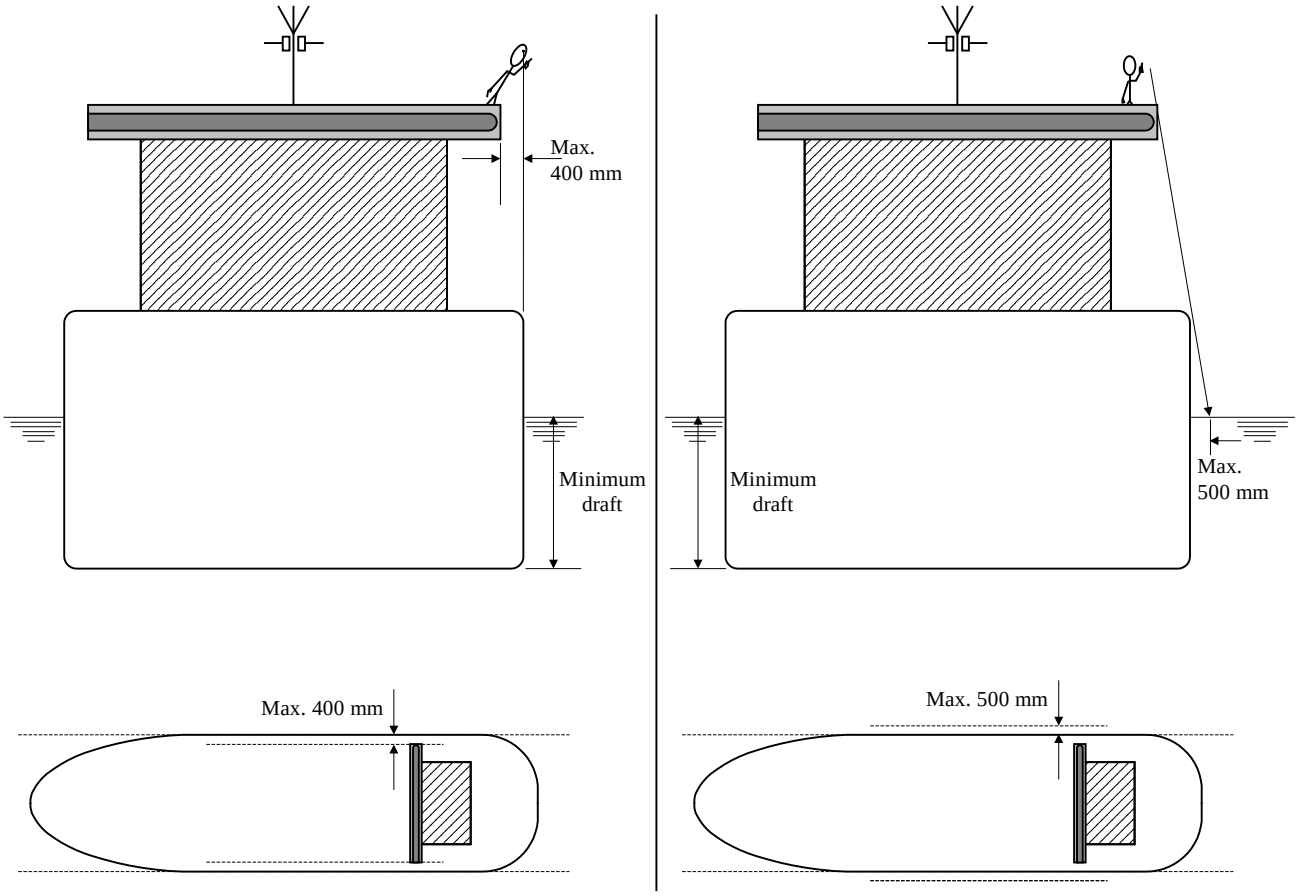
i) The requirements of 3-6-1/1.1.2(b) are accomplished when:

- 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/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.

FIGURE 2 *(1 July 2011)*



1.1.3 Main Steering Position

From the main steering position, the horizontal field of vision is to extend over an arc from right ahead to at least 60° on each side of the vessel. See 3-6-1/Figure 5.

FIGURE 3

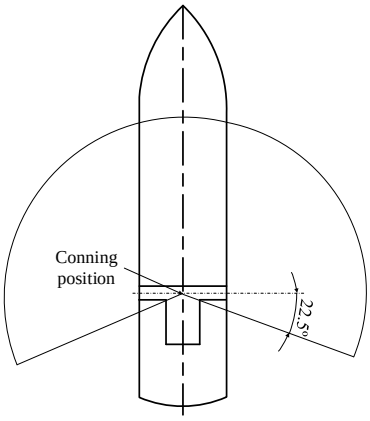


FIGURE 4

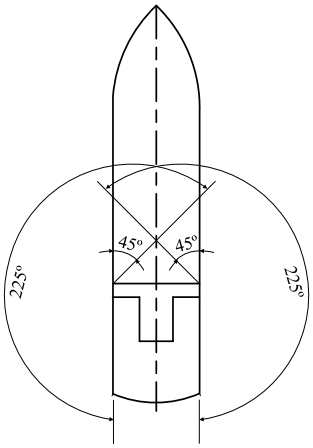
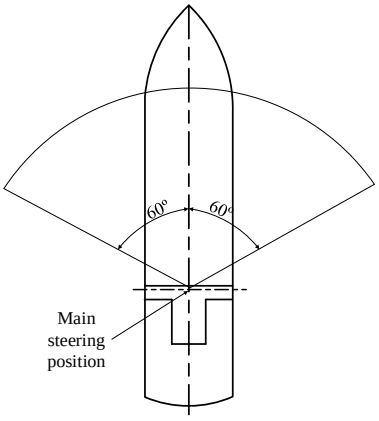


FIGURE 5 *(2017)*



1.1.4 Remote Camera System *(1 July 2014)*

For vessels of 55 m (180 ft) in length, and above, 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 4-7-2/Table 1 and 4-7-4/Table 1;

vi) 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.

1.3 Windows and Their Arrangements

Windows and their arrangements are to meet the following requirements:

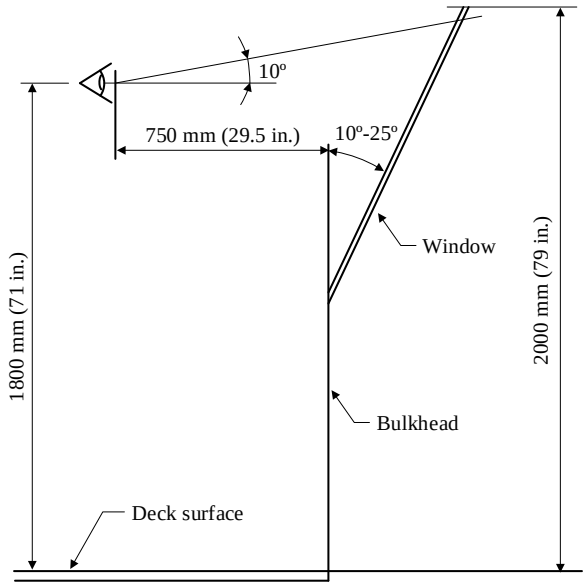
1.3.1 Framing

Framing between navigation bridge windows is to be kept to a minimum to meet the structural strength and stiffness requirements, and is not to be installed immediately in front of any workstations;

1.3.2 Inclination Angle

The bridge front windows are to be inclined from a vertical plane top out, at an angle of not less than 10° and not more than 25°, see 3-6-1/Figure 6;

FIGURE 6



1.3.3 Glass

Polarized and tinted windows are not to be fitted, and

1.3.4 Clear View

At all times, regardless of the weather conditions, at least two of the navigation bridge front windows are to provide a clear view, and in addition, depending on the bridge configuration, an additional number of windows are to provide a clear view. To this end, the following, or equivalent, is to be provided:

1.3.4(a) Sun Screens. Sunscreens with minimum color distortion. These sunscreens are to be readily removable and not permanently installed.

1.3.4(b) Wipers and Fresh Water Wash Systems. Heavy-duty wipers, preferably provided with an interval function, and fresh water wash systems. These wipers are to be capable of operating independently of each other.

1.3.4(c) De-icing and De-misting Systems. De-icing and de-misting systems to be provided.

1.3.4(d) Fixed Catwalk. A fixed catwalk with guardrails, fitted forward of the bridge windows, to enable manual cleaning of windows in the event of failure of the above systems.

1.3.5 Lower Edge

The height of the lower edge of the navigation bridge front windows above the bridge deck is to be kept as low as possible. In no case is the lower edge to present an obstruction to the forward view as described in this Section.

1.3.6 Upper Edge

The upper edge of the navigation bridge front windows is to allow a forward view of the horizon for a person with a height of eye of 1800 mm (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/Figure 6.

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 to achieve a level of visibility that is as near as practical to those prescribed in this Section.

1.7 Articulated Tug-Barge Units *(2017)*

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.

PART
3

CHAPTER 7 Testing, Trials and Surveys During Construction – Hull

CONTENTS

SECTION 1 Tank, Bulkhead and Rudder Tightness Testing.....311

1 General 311

3 Testing Requirements for Ships Built in Compliance with SOLAS 1974 as Amended.....311

3.1 Application 311

3.3 Test Types and Definitions 312

3.5 Test Procedures 313

5 Testing Requirements for Ships Not Built in Compliance with SOLAS 1974 as Amended.....319

TABLE 1 Testing Requirements for Tanks and Boundaries 316

TABLE 2 Additional Testing Requirements for Vessels or Tanks of Special Service 318

TABLE 3 Application of Leak Testing, Coating and Provision of Safe Access for Type of Welded Joints.....318

SECTION 2 Trials 320

1 Anchor Windlass Trials 320

3 Bilge System Trials 320

5 Steering Trials.....320

SECTION 3 Surveys.....321

1 Construction Welding and Fabrication.....321

3 Hull Castings and Forgings.....321

5 Piping 321

PART
3

CHAPTER 7 Testing, Trials and Surveys During Construction – Hull

SECTION 1 Tank, Bulkhead and Rudder Tightness Testing *(2018)*

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 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

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 of the *Steel Vessel Rules* will apply.

Testing of structures not listed in 3-7-1/Table 1 and 3-7-1/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 Note 3 of 3-7-1/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/Table 1. For the timing of 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/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/Table 1 or 3-7-1/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 approved 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/Table 1 and 3-7-1/Table 2.

ii) The tank boundaries are to be tested at least from 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 watertightness 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)ii) 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 watertightness 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/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/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/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/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/Table 1 or 3-7-1/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 penetration 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 using 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/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/Table 3.

3.5.7 Hydrostatic or Hydropneumatic Tightness Testing

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 *(2018)*

	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 water head - to 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]	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
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 of the *Steel Vessel Rules* for additional test at the manufacturer.

TABLE 1 (continued)
Testing Requirements for Tanks and Boundaries *(2018)*

	Tank or Boundary to be Tested	*Test Type*	*Test Head or Pressure*	*Remarks*
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	Weathertight hatch covers and closing appliances	Leak (3, 7)	See 3-7-1/3.5.4(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	
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	

Notes:

1 *(2018)* 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 *(2018) 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 *(2016)* 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 *(2018)* 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 *(2018)* 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 *(2018)* 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 of the *Steel Vessel Rules* 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	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	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 *(2018)* See 3-7-1/3.5.2(b).

2 *(1 July 2013)* 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 *(2016)*

Type of Welded Joints		*Leak Testing*	*Coating (1)*		*Safe Access (2)*	
			Before Leak Testing	*After Leak Testing & Before Structural Test*	*Leak Testing*	*Structural Test*
Butt	Automatic	Not required	Allowed(3)	N/A	Not required	Not required
	Manual or Semi-automatic(4)	Required	Not allowed	Allowed	Required	Not required
Fillet	Boundary including penetrations	Required	Not allowed	Allowed	Required	Not required

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 *(2016)* 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 Requirements 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 3-7-1/3.5.2(b) "Testing Schedule for New Construction or Major Structural Conversion" and alternative test requirements for 3-7-1/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/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) Watertightness 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 3-7-1/5.3 shall apply in lieu of 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 *(1 July 2012)*

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 hawsepipe 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. Also, it is to be demonstrated that the windlass is capable of lifting each anchor with 82.5 m (45 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 4-3-3/15.3 for the 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 welding and fabrication, refer to Chapter 4 of the ABS *Rules for Materials and Welding (Part 2)* and the ABS *Guide for Nondestructive Inspection of Hull Welds*.

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 Piping

For surveys in connection with the manufacture and testing of piping, refer to Part 4, Chapter 4.