RULES FOR BUILDING AND CLASSING

OFFSHORE SUPPORT VESSELS
2018

PART 3
HULL CONSTRUCTION AND EQUIPMENT

(Updated August 2018 – see next page)

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

© 2017-2018 American Bureau of Shipping. All rights reserved.
1701 City Plaza Drive
Spring, TX 77389 USA

Updates

August 2018 consolidation includes:

- July 2018 version plus Corrigenda/Editorials

July 2018 consolidation includes:

- January 2018 version plus Notice No. 1 and Corrigenda/Editorials

Rule Change Notice *(2018)*

The effective date of each technical change since 1993 is shown in parentheses at the end of the subsection/paragraph titles within the text of each Part. Unless a particular date and month are shown, the years in parentheses refer to the following effective dates:

(2000) and after	1 January 2000 (and subsequent years)	*(1996)*	9 May 1996
(1999)	12 May 1999	*(1995)*	15 May 1995
(1998)	13 May 1998	*(1994)*	9 May 1994
(1997)	19 May 1997	*(1993)*	11 May 1993

Listing by Effective Dates of Changes from the 2017 Rules

Notice No. 1 (effective on 1 July 2017) to the 2017 Rules, which is incorporated in the 2018 Rules, is summarized below.

EFFECTIVE DATE 1 July 2017 – shown as *(1 July 2017)*
(based on the contract date for new construction between builder and Owner)

Part/Para. No.	*Title/Subject*	*Status/Remarks*
3-2-14/17.1	Strength	To reflect current practice for cover plates and address vortex shedding for spade rudders with embedded trunks. (Incorporates Notice No. 1)
3-2-14/Figure 5 (New)	<No Title>	To reflect current practice for cover plates and address vortex shedding for spade rudders with embedded trunks. (Incorporates Notice No. 1)
3-2-14/Figure 6 (New)	<No Title>	To reflect current practice for cover plates and address vortex shedding for spade rudders with embedded trunks. (Incorporates Notice No. 1)
3-2-14/Figure 7 (New)	<No Title>	To reflect current practice for cover plates and address vortex shedding for spade rudders with embedded trunks. (Incorporates Notice No. 1)
3-2-14/17.1.2	In way of Cutouts	To reflect current practice for cover plates and address vortex shedding for spade rudders with embedded trunks. (Incorporates Notice No. 1)

EFFECTIVE DATE 1 January 2018 – shown as *(2018)*
(based on the contract date for new construction between builder and Owner)

Part/Para. No.	*Title/Subject*	*Status/Remarks*
3-1-1/3.1	Scantling Length (L)	To align the requirements with ICLL 1966/Reg. 3 & IACS UR S2.
3-1-1/3.3	Freeboard Length (L_f)	To align the requirements with ICLL 1966/Reg. 3 & IACS UR S2.
3-1-1/15.1	Freeboard Deck	To align the requirements with ICLL 1966/Reg. 3 & IACS UR S2.
3-1-1/17	Deadweight (*DWT*) and Lightship Weight	To incorporate interpretation made in IACS UI SC273 and MPC128.
3-1-2/Table 2	Material Class or Grade of Structural Members	To identify the minimum steel grades for deck plating other than strength deck (Line No. C4) at corners of cargo hatch openings adjacent to the engine room and/or deck house.
3-1-2/11	Drydocking	To specify that the docking arrangement is only required for vessels over 90 m (295 ft) in length.
3-2-4/9.5	Inner Bottom Plating for Vessels Intended to Use Grabs	To align the requirements with IACS UI SC208 Corr.2 and SVR 5C-3-4/7.3.2 (a) & (b).
3-2-4/9.6 (New)	Optional Supplementary Requirement for Vessels Intended to Use Grabs	To align the requirements with IACS UI SC208 Corr.2 and SVR 5C-3-4/7.3.2 (a) & (b).
3-2-11/11.3.7 (New)	Bolted Connections	To specify requirements for bolted connections on helidecks.

Part/Para. No.	*Title/Subject*	*Status/Remarks*
3-2-11/11.9.2	Means of Escape and Access	To clarify the requirements for aluminum helideck escape stairs and intermediate platforms.
3-2-13/1.1	Plate Stems	To consider the material factor in the net thickness of the plate stem, in line with CSR-H.
3-2-14/7.3	Lower Rudder Stocks	To make the stress units consistent with the allowable stress.
3-2-14/Figure 4	Tapered Couplings	To be consistent with the requirements of 3-2-14/11.7.
3-2-14/17.5	Diaphragm Plates	To allow larger openings on diaphragm plates when the effects of openings are considered in the strength assessment.
3-2-15/3.3.1	Cargo Hatch Covers in Position 1	To align the requirements with IACS UR S21, S21A, and 3-2-15/3.3.1 of the *Steel Vessel Rules* for less than 100 m.
3-2-17/9.7	Window Glazing	To clarify that the international standard ISO21005 or equivalent national standards are acceptable.
3-2-17/9.9	Testing	To specify that ISO 614 should be used to meet our rule requirements of OSV 3-2-17/9.9 only for thermally toughened glass.
3-3-A1/3.5	Alternative Criteria for Offshore Support Vessels	To specify the exact applicable vessel's length in line with MSC 267(85)-IS Code.
3-3-A3 (Title)	Computer Software for Onboard Stability Calculations	To align the Rules with IACS UR L5, Revision 3.
3-3-A3/5	Types of Stability Software	To align the Rules with IACS UR L5, Revision 3.
3-3-A3/7.1	Calculation Program	To align the Rules with IACS UR L5, Revision 3.
3-3-A3/7.5	Warning	To align the Rules with IACS UR L5, Revision 3.
3-3-A3/7.15 (New)	Computer Model	To align the Rules with IACS UR L5, Revision 3.
3-3-A3/7.17 (New)	Further Requirements for Type 4 Stability Software	To align the Rules with IACS UR L5, Revision 3.
3-3-A3/Table 1	Acceptable Tolerances	To align the Rules with IACS UR L5, Revision 3.
3-3-A3/11.1	Conditions of Approval of the Onboard Software for Stability Calculations	To align the Rules with IACS UR L5, Revision 3.
3-3-A3/11.5	Specific Approval	To align the Rules with IACS UR L5, Revision 3.
3-3-A3/13	Operation Manual	To align the Rules with IACS UR L5, Revision 3.
3-3-A3/15	Installation Testing	To align the Rules with IACS UR L5, Revision 3.
3-3-A3/17	Periodical Testing	To align the Rules with IACS UR L5, Revision 3.
3-3-A3/19	Other Requirements	To align the Rules with IACS UR L5, Revision 3.
3-4-A1/1.1	<No Title>	To align the requirements with ASTM F3059-15, in line with IACS, IMO, and USCG policy.
3-4-A1/5	Fire Test Requirements	To align the requirements with ASTM F3059-15, in line with IACS, IMO, and USCG policy.
3-4-A1/7	Structural Fire Integrity Test Procedures	To align the requirements with ASTM F3059-15, in line with IACS, IMO, and USCG policy.
3-4-A1/Table 1	Structural Fire Integrity Matrix	To align the requirements with ASTM F3059-15, in line with IACS, IMO, and USCG policy.
3-6-1/Figure 3	<No Title>	To align with the wording "Conning Position" as indicated in 3-6-1/1.1.1(c).
3-6-1/Figure 5	<No Title>	To shift the location of the main steering position.
3-7-1	Tank, Bulkhead and Rudder Tightness Testing	To reflect the comments from Administrations, Industry Organizations and IMO considered during review of the proposed Testing Guidelines associated with SOLAS Chapter II-1, Regulation 11, reflected in IACS UR S14 (Rev.6, Sept 2016).

Listing by Effective Dates of Changes from the 2018 Rules

Notice No. 1 (effective on 1 July 2018) to the 2018 Rules, is summarized below.

EFFECTIVE DATE 1 July 2018 – shown as *(1 July 201\8)*
(based on the contract date for new construction between builder and Owner)

Part/Para. No.	*Title/Subject*	*Status/Remarks*
3-2-1/5.3	Hull Girder Section Modulus	To align the Rules with IACS UR S4. (Incorporates Notice No. 1)
3-2-7/4	Deck Fittings Support Structures	To update the requirements for minimum recommended number and strength of mooring lines, in line with IACS Rec 10 and UR A2. (Incorporates Notice No. 1)
3-2-7/Figure 2 (New)	Sample Arrangement	To update the requirements for minimum recommended number and strength of mooring lines, in line with IACS Rec 10 and UR A2. (Incorporates Notice No. 1)
3-2-7/Figure 3 (New)	Attachment Point of Mooring Line	To update the requirements for minimum recommended number and strength of mooring lines, in line with IACS Rec 10 and UR A2. (Incorporates Notice No. 1)
3-2-7/Figure 4 (New)	Attachment Point of Towing Line	To update the requirements for minimum recommended number and strength of mooring lines, in line with IACS Rec 10 and UR A2. (Incorporates Notice No. 1)
3-2-15/3.3	Vertical Weather Design Pressures	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/Figure 1 (New)	Positions 1 and 2	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/Figure 2 (New)	Positions 1 and 2 for an Increased Freeboard	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/3.5 (New)	Horizontal Weather Design Pressures	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/Table 1 (New)	Minimum Design Load $p_{H\min}$	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/753	Coaming Plates	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/7	Hatchways Closed by Covers of Steel and Fitted with Gaskets and Clamping Devices	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/Figure 3 (New)	Determination of Normal Stress of the Hatch Cover Plating	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/Figure 4 (New)	Forces due to Container Loads	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/Figure 5 (New)	Partial Loading of a Container Hatch Cover	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/Table 2 (New)	Effective Breadth e_m of Plating of Primary Supporting Members	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/Figure 6 (New)	General Arrangement of Panel	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/Table 3 (New)	Correction Factor F_1	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/Table 4 (New)	Coefficients e_1, e_2, e_3 and Factor B	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/Table 5 (New)	Buckling and Reduction Factors for Plane Elementary Plate Panels	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/Figure 7 (New)	Stiffening Parallel to Web of Primary Supporting Member	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)

Part/Para. No.	*Title/Subject*	*Status/Remarks*
3-2-15/Figure 8 (New)	Stiffening Perpendicular to Web of Primary Supporting Member	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/Figure 9 (New)	Dimensions of Stiffeners	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/Table 6 (New)	Moments of Inertia	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/Figure 10 (New)	Examples for Typical Coaming Stay Configurations	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/Figure 11 (New)	Example for Arrangement of Coaming Plates	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/Figure 12 (New)	Lifting Forces at a Hatch Cover	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/Table 7 (New)	Permissible Nominal Surface Pressure p_n	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/Table 8 (New)	Corrosion Additions t_S for Hatch Covers and Hatch Coamings	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-15/8 (New)	Hatchways Closed by Covers of Aluminum and Fitted with Gaskets and Clamping Devices	To align requirements with IACS UR S21A and the ABS *Steel Vessel Rules*. (Incorporates Notice No. 1)
3-2-18/5.1	All Spaces	To specify that cathodic protection is also an efficient corrosion protection system for immersive parts of steel surfaces, and to provide references to relevant ABS guidance. (Incorporates Notice No. 1)
3-5-1/1	General	To address incidents such as anchor losses and incidents during mooring and towing, in line with IACS Rec 10, UR A1, and UR A2. (Incorporates Notice No. 1)
3-5-1/3	Equipment Mass and Size	To address incidents such as anchor losses and incidents during mooring and towing, in line with IACS Rec 10, UR A1, and UR A2. (Incorporates Notice No. 1)
3-5-1/Figure 1	Effective Heights of Deck Houses	To address incidents such as anchor losses and incidents during mooring and towing, in line with IACS Rec 10, UR A1, and UR A2. (Incorporates Notice No. 1)
3-5-1/9	Mooring and Towing Equipment	To address incidents such as anchor losses and incidents during mooring and towing, in line with IACS Rec 10, UR A1, and UR A2. (Incorporates Notice No. 1)
3-5-1/11.1.1(c)	Allowable Stress	To address incidents such as anchor losses and incidents during mooring and towing, in line with IACS Rec 10, UR A1, and UR A2. (Incorporates Notice No. 1)
3-5-1/11.1.1(d) (New)	<No Title>	To address incidents such as anchor losses and incidents during mooring and towing, in line with IACS Rec 10, UR A1, and UR A2. (Incorporates Notice No. 1)
3-5-1/11.1.2(d)	Allowable Stress	To address incidents such as anchor losses and incidents during mooring and towing, in line with IACS Rec 10, UR A1, and UR A2. (Incorporates Notice No. 1)
3-5-1/13 (New)	Securing of the Inboard Ends of Chain Cables	To address incidents such as anchor losses and incidents during mooring and towing, in line with IACS Rec 10, UR A1, and UR A2. (Incorporates Notice No. 1)
3-5-1/14 (New)	Securing of Stowed Anchors	To address incidents such as anchor losses and incidents during mooring and towing, in line with IACS Rec 10, UR A1, and UR A2. (Incorporates Notice No. 1)
3-5-1/15	Bollard, Fairlead and Chocks	To address incidents such as anchor losses and incidents during mooring and towing, in line with IACS Rec 10, UR A1, and UR A2. (Incorporates Notice No. 1)
3-5-1/Table 1	Equipment for Self-propelled Ocean-going Vessels	To address incidents such as anchor losses and incidents during mooring and towing, in line with IACS Rec 10, UR A1, and UR A2. (Incorporates Notice No. 1)

Part/Para. No.	*Title/Subject*	*Status/Remarks*
3-5-1/Table 2 (Deleted)	Towline and Hawsers for Self-propelled Ocean-going Vessels	To address incidents such as anchor losses and incidents during mooring and towing, in line with IACS Rec 10, UR A1, and UR A2. (Incorporates Notice No. 1)
3-5-1/Table 2 (New)	Mooring Lines for Self-propelled Ocean-going Vessels with $EN \geq 2000$	To address incidents such as anchor losses and incidents during mooring and towing, in line with IACS Rec 10, UR A1, and UR A2. (Incorporates Notice No. 1)
3-5-1/Table 3 (New)	Tow Lines for Self-propelled Ocean-going Vessels	To address incidents such as anchor losses and incidents during mooring and towing, in line with IACS Rec 10, UR A1, and UR A2. (Incorporates Notice No. 1)

PART
3

Hull Construction and Equipment

CONTENTS

CHAPTER 1 General 1

Section 1 Definitions 3
Section 2 General Requirements 7

CHAPTER 2 Hull Structures and Arrangements 18

Section 1 Longitudinal Strength 38
Section 2 Shell Plating 60
Section 3 Decks 71
Section 4 Bottom Structures 80
Section 5 Frames 94
Section 6 Web Frames and Side Stringers 102
Section 7 Beams and Longitudinals 107
Section 8 Pillars, Deck Girders, and Transverses 117
Section 9 Watertight Bulkheads and Doors 122
Section 10 Deep Tanks 140
Section 11 Superstructures, Deckhouses and Helicopter Decks 145
Section 12 Machinery Space and Tunnel 159
Section 13 Stems, Stern Frames, Rudder Horns, and Propeller Nozzles 162
Section 14 Rudders and Steering Equipment 176
Section 15 Protection of Deck Openings 229
Section 16 Protection of Shell Openings 277
Section 17 Bulwarks, Rails, Freeing Ports, Portlights, Windows, Ventilators, Tank Vents and Overflows 282
Section 18 Ceiling, Sparring and Protection of Steel 297
Section 19 Weld Design 298
Section 20 Guidance on Finite Element Analysis 305

Appendix 1 Calculation of Shear Stresses for Vessels Having Plane Plate Longitudinal Bulkheads 50
Appendix 2 Loading Manuals 52
Appendix 3 Buckling Strength of Longitudinal Strength Members for Vessels Over 61 m (200 ft) in Length 54
Appendix 4 Guidelines for Calculating Bending Moment and Shear Force in Rudders and Rudder Stocks 219
Appendix 5 Hatch Cover Stiffeners of Variable Cross Section 275
Appendix 6 Ice Operations 309

CHAPTER 3 Subdivision and Stability 319
Section 1 General Requirements 321

Appendix 1 Intact Stability Requirements for Offshore Support Vessels 323
Appendix 2 Damage Stability Requirements for Offshore Supply Vessels 329
Appendix 3 Onboard Computers for Stability Calculations 332

CHAPTER 4 Fire Safety Measures 342
Section 1 Fire Protection, Detection, and Extinction 343

Appendix 1 Fiber Reinforced Plastic (FRP) Gratings 345

CHAPTER 5 Equipment 348
Section 1 Anchoring, Mooring and Towing Equipment 349

CHAPTER 6 Navigation 370
Section 1 Visibility 371

CHAPTER 7 Testing, Trials and Surveys During Construction – Hull 377
Section 1 Tank, Bulkhead and Rudder Tightness Testing 378
Section 2 Trials 387
Section 3 Surveys 388

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) 4
7 Depth 4
7.1 Molded Depth (D) 4
7.3 Scantling Depth (D_s) 4
9 Draft 4
9.1 Molded Draft (d) 4
9.3 Scantling Draft (d_s) 4
11 Maximum Service Speed (V) 4
13 Molded Displacement and Block Coefficient 4
13.1 Molded Displacement (Δ) 4
13.3 Block Coefficient (C_b) 4
15 Decks 5
15.1 Freeboard Deck 5
15.3 Bulkhead Deck 5
15.5 Strength Deck 5
15.7 Superstructure Deck 5
17 Deadweight (DWT) and Lightship Weight 5
19 Primary Support Members 5
21 Local Support members 5
23 Units 6

FIGURE 1 3

SECTION 2 General Requirements 7

1 Material and Fabrication 7
1.1 Material 7
1.3 Application 8
3 Application of Steel Materials 100 mm (4.0 in.) and Under in Thickness 8
3.1 Selection of Material Grade 8
3.3 Note for Users 8
3.5 Structures Exposed to Low Air Temperatures 11
3.7 Design Temperature t_D 13

5 Scantlings....14
5.1 General....14
5.3 Rounding of Calculated Thickness....14
5.5 Dynamic Loading Approach....15
7 Proportions....15
9 Workmanship....15
11 Drydocking....15
13 Structural Sections....15
13.1 General....15
13.3 Primary Support Members....15
13.5 Local Support Members....15
15 Structural Design Details....16
15.1 General....16
15.3 Termination of Structural Members....16
15.5 Fabrication....17

TABLE 1 Material Grades....8
TABLE 2 Material Class or Grade of Structural Members for Vessels ≥ 90 m (295 ft) in Length....9
TABLE 3 Material Class or Grade of Structural Members for Vessels 61 m (200 ft) ≤ L < 90 m (295 ft) in Length....11
TABLE 4 Application of Material Classes and Grades – Structures Exposed at Low Temperatures....12
TABLE 5 Material Grade Requirements for Classes I, II and III at Low Temperatures....13

FIGURE 1 Commonly Used Definitions of Temperatures....14

PART
3

CHAPTER 1 General

SECTION 1 Definitions

1 Application

The following definitions of symbols and terms are to be understood (in the absence of other specifications) where they appear in these Rules. These Rules are applicable for vessels having a speed length ratio $V/\sqrt{L}$ < 2.36 (1.3) where L is in meters (feet) as defined in 3-1-1/3.1 and V is in knots as defined in 3-1-1/11. Where this proportion equals or exceeds the prescribed limit value, the ABS *Rules for Building and Classing High Speed Craft* applies.

3 Length

3.1 Scantling Length (L) *(2018)*

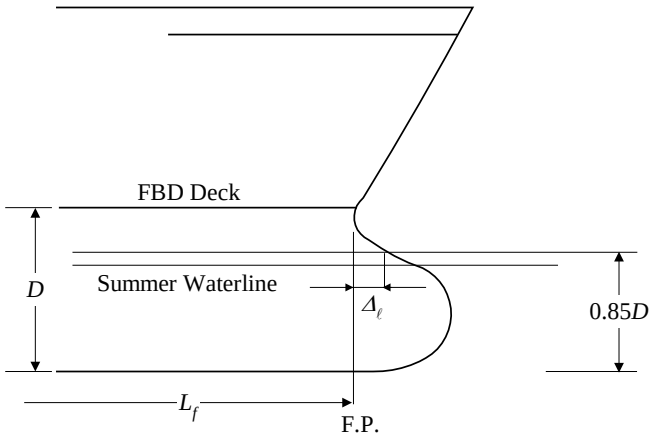
L is the distance in meters (feet) on the summer load line from the fore side of the stem to the centerline of the rudder stock. For use with these Rules, L is not to be less than 96% and need not be greater than 97% of the extreme length on the summer load line. The forward end of L is to coincide with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

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 aftermost point of the stem is above the waterline, the forward end of the length, L_f, is to be taken at the aftermost point of the stem above that waterline. See 3-1-1/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 the distance in meters (feet) from the molded base line to the strength deck as defined in 3-1-1/15.5 and in 3-2-2/3.1 through 3-2-2/3.7, as applicable.

9 Draft

9.1 Molded Draft (*d*)

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

9.3 Scantling Draft (d_s)

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

The draft, d_s, for use in scantling requirements is the molded draft to the deepest load line to which the vessel is designed to operate in service. However, in no case is the vessel to be issued a load line certificate to operate at sea with a draft greater than that corresponding to the freeboard assigned, if that be less.

For the purpose of these Rules, scantling draft d_s should not be taken less than $0.67D_s$. The declared scantling draft is to be indicated on the Midship Section and Shell Expansion drawings.

11 Maximum Service Speed (*V*)

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

13 Molded Displacement and Block Coefficient

13.1 Molded Displacement (Δ)

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

13.3 Block Coefficient (C_b)

C_b is the block coefficient at the summer load line 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 3-1-1/13.1.

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

d = molded draft, as defined in 3-1-1/9.1

B_{wl} = the greatest molded breadth at the summer load line, in m (ft)

15 Decks

15.1 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 sides of the ship are fitted with permanent means of watertight closing. Where a vessel is designed for a special draft, considerably less than that corresponding to the least freeboard obtainable under the *International Load Line Regulations*, the freeboard deck, for the purpose of these Rules, may be taken as the actual lowest deck from which the draft can be obtained under those regulations.

15.3 Bulkhead Deck

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

15.5 Strength Deck

The strength deck is the deck that forms the top of the effective hull girder at any part of its length. See 3-2-1/11.1.

15.7 Superstructure Deck

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

17 Deadweight (*DWT*) and Lightship Weight *(2018)*

For the purpose of these Rules, deadweight, *DWT*, is the difference in metric tons (long tons) between the displacement of the vessel at its summer load line in water having a specific gravity of 1.025 and the lightship weight.

For the purpose of these Rules, lightship weight is the displacement of the vessel in metric tons (long tons) with no cargo, fuel, lubricating oil, ballast water, fresh water nor feed water in tanks, no consumable stores, and no passengers or crew nor their effects. The weight of mediums on board for the fixed fire-fighting systems (e.g., freshwater, CO_2, dry chemical powder, foam concentrate, etc.) are to be included in the lightweight and lightship condition.

19 Primary Support Members

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

21 Local Support members

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

23 Units

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

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

SI units (MKS units, US customary units)

PART
3

CHAPTER 1 General

SECTION 2 General Requirements

1 Material and Fabrication

1.1 Material

1.1.1 Steel

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

1.1.2 Aluminum Alloys

The use of aluminum alloys complying with the requirements in Chapter 5 of the ABS *Rules for Materials and Welding (Part 2) – Aluminum and Fiber Reinforced Plastics (FRP)* is to be considered upon submission of a specification of the proposed alloys and their proposed method of fabrication.

1.1.3 Design Consideration

Adequate buckling strength is to be provided in the structure. Buckling can be critical in areas of high compressive stress such as where high strength steels or where aluminum alloys are used. The scantlings of vessels with L < 61 m (200 ft) generally are not required to comply with any buckling criteria, however; there may be situations where buckling criteria should be considered by the designer (i.e., critical loading conditions, Item 1.3 of 3-2-A2/Table 1).

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.

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

1.1.4 Guidance for Repair

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

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

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

1.3 Application

The requirements of these Rules apply to offshore service vessels of all welded steel construction. However, aluminum alloys for deckhouses, helicopter landing platforms, masts, ladders and hatch covers are acceptable when approved in accordance with the requirements of Chapter 5 of the ABS *Rules for Materials and Welding (Part 2) – Aluminum and Fiber Reinforced Plastics (FRP)*. Connections between steel and aluminum structures are to be made by interfacing bimetallic inserts. Aluminum structures and components are to be fully and efficiently precluded from having direct contact with steel by approved non-wicking, non- water absorbing insulating materials, to avoid electrolytic corrosion.

3 Application of Steel Materials 100 mm (4.0 in.) and Under in Thickness *(2014)*

3.1 Selection of Material Grade *(2014)*

Steel materials for particular locations are not to be of lower grades than those required by 3-1-2/Table 1 for the material class given in 3-1-2/Table 2 and 3-1-2/Table 3.

3.3 Note for Users

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

Precautions against corrosion fatigue may also be necessary.

TABLE 1
Material Grades *(2017)*

Plate Thickness t mm (in.)	*Material Class*		
	I	II	III
$t \le 15$ ($t \le 0.60$)	A [2], AH	A, AH	A, AH
$15 < t \le 20$ ($0.60 < t \le 0.79$)	A, AH	A, AH	B, AH
$20 < t \le 25$ ($0.79 < t \le 0.98$)	A, AH	B, AH	D, DH
$25 < t \le 30$ ($0.98 < t \le 1.18$)	A, AH	D, DH	D [1], DH
$30 < t \le 35$ ($1.18 < t \le 1.38$)	B, AH	D, DH	E, EH
$35 < t \le 40$ ($1.38 < t \le 1.57$)	B, AH	D, DH	E, EH
$40 < t \le 100$ ($1.57 < t \le 4.0$)	D, DH	E, EH	E, EH

Notes

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

2 *(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 rolled sections.

TABLE 2
Material Class or Grade of Structural Members for Vessels ≥ 90 m (295 ft) in Length *(2018)*

Line No.	*Structural Members*	*Within 0.4L Amidships*	*Outside 0.4L amidships*
		Material Class[8] or Grade	*Material Class or Grade*
A	**Secondary**		
A1	Longitudinal bulkhead strakes, other than those belonging to the Primary category	I	A[10]/AH
A2	Deck plating exposed to weather, other than that belonging to the Primary or Special category		
A3	Side plating [12]		
B	**Primary**		
B1	Bottom plating, including keel plate	II	A[10]/AH
B2	Strength deck plating, excluding that belonging to the Special category [13]		
B3	Continuous longitudinal members above strength deck, excluding hatch coamings [13]		
B4	Uppermost strake in longitudinal bulkhead		
B5	Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank		
C	**Special**		
C1	Sheer strake at strength deck [1, 9, 13]	III	II (I outside 0.6*L* amidships)
C2	Stringer plate in strength deck [1, 9, 13]		
C3	Deck strake at longitudinal bulkhead [2, 9, 13]		
C4	Strength deck plating at outboard corners of cargo hatch openings in container carriers and other ships with similar hatch opening configurations [3, 13]		
C5	Strength deck plating at corners of cargo hatch openings in bulk carriers, ore carriers, combination carriers and other ships with similar hatch opening configurations [4, 13]		
C6	Bilge strake [5, 6, 9]		
C7	Longitudinal hatch coamings of length greater than 0.15*L* [7]		
C8	End brackets and deck house transition of longitudinal cargo hatch coamings [7]		
D	**Other Categories**		
D1	*(1 July 2015)* Plating materials for stern frames supporting rudder and propeller boss, rudders, rudder horns, steering equipment [15], propeller nozzles, and shaft brackets	-	II[11]
D2	Strength members not referred to in A to C and D1 [17]	A[10]/AH	A[10]/AH
D3	Face plates and webs of primary members and hatch covers	II [14]	II [14]
D4	*(2017)* Equipment foundations, Non-hull structure, Appurtenant structures	[16]	[16]

Notes:

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

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

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

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

5 May be of class II in ships with a double bottom over the full breadth and with length less than 150 m (492 ft).

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

7 Not to be less than grade D/DH.

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

TABLE 2 (continued)
Material Class or Grade of Structural Members
for Vessels ≥ 90 m (295 ft) in Length *(2018)*

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

10 *(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 plates and up to and including 19 mm (0.75 in.) for sections.

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

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

13 *(1 July 2015)* Not to be less than grade B/AH for members contributing to the longitudinal strength within 0.4*L* amidships in ships with length exceeding 150 m (492 feet) and single strength deck.

14 May be Class I for rolled sections

15 *(1 July 2015)* Steering equipment components other than rudders, as described in Section 3-2-14.

16 *(2017)* ASTM A36 steel otherwise tested and certified to the satisfaction of ABS may be used in lieu of Grade A for a thickness up to and including 12.5 mm (0.5 in.) for plates and up to and including 19 mm (0.75 in.) for sections.

17 *(2018)* Deck plating below the strength deck at corners of cargo hatch openings immediately forward and aft of the engine room and/or deck house in container carriers and other ships with similar hatch opening configurations, is not to be less than Class I.

TABLE 3
Material Class or Grade of Structural Members for Vessels 61 m (200 ft) ≤ *L* < 90 m (295 ft) in Length *(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 of the ABS *Rules for Materials and Welding (Part 2)*.

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

4 *(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 plates 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 3-2-14.

3.5 Structures Exposed to Low Air Temperatures *(2017)*

For ships intended to operate in areas with low air temperatures [below and including –20°C (–4°F)], the materials in exposed structures are to be selected based on the design temperature t_D, to be taken as defined in 3-1-2/3.7.

Materials in the various strength members above the lowest ballast water line (BWL) exposed to air are not to be of lower grades than those corresponding to Classes I, II and III, as given in 3-1-2/Table 4, 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 4) and structures below the lowest ballast water line, see 3-1-2/3.1.

TABLE 4
Application of Material Classes and Grades – Structures Exposed at Low Temperatures *(2017)*

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)		
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.).

The material grade requirements for hull members of each class depending on thickness and design temperature are defined in 3-1-2/Table 5. For design temperatures t_D < –55°C (–67°F), materials are to be specially considered.

TABLE 5
Material Grade Requirements for Classes I, II and III at Low Temperatures *(2015)*

Class I

Thickness, in mm (in.)	*–20 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
$10 < t \le 15$ ($0.39 < t \le 0.60$)	B, AH	D, DH	D, DH	D, DH
$15 < t \le 20$ ($0.60 < t \le 0.79$)	B, AH	D, DH	D, DH	E, EH
$20 < t \le 25$ ($0.79 < t \le 0.98$)	D, DH	D, DH	D, DH	E, EH
$25 < t \le 30$ ($0.98 < t \le 1.18$)	D, DH	D, DH	E, EH	E, EH
$30 < t \le 35$ ($1.18 < t \le 1.38$)	D, DH	D, DH	E, EH	E, EH
$35 < t \le 45$ ($1.38 < t \le 1.80$)	D, DH	E, EH	E, EH	-, FH
$45 < t \le 50$ ($1.80 < t \le 1.97$)	E, EH	E, EH	-, FH	-, FH

Class II

Thickness, in mm (in.)	*–20 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
$10 < t \le 20$ ($0.39 < t \le 0.79$)	D, DH	D, DH	E, EH	E, EH
$20 < t \le 30$ ($0.79 < t \le 1.18$)	D, DH	E, EH	E, EH	-, FH
$30 < t \le 40$ ($1.18 < t \le 1.57$)	E, EH	E, EH	-, FH	-, FH
$40 < t \le 45$ ($1.57 < t \le 1.80$)	E, EH	-, FH	-, FH	-, -
$45 < t \le 50$ ($1.80 < t \le 1.97$)	E, EH	-, FH	-, FH	-, -

Class III

Thickness, in mm (in.)	*–20 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)*
$t \le 10$ ($t \le 0.39$)	D, DH	D, DH	E, EH	E, EH
$10 < t \le 20$ ($0.39 < t \le 0.79$)	D, DH	E, EH	E, EH	-, FH
$20 < t \le 25$ ($0.79 < t \le 0.98$)	E, EH	E, EH	E, FH	-, FH
$25 < t \le 30$ ($0.98 < t \le 1.18$)	E, EH	E, EH	-, FH	-, FH
$30 < t \le 35$ ($1.18 < t \le 1.38$)	E, EH	-, FH	-, FH	-, -
$35 < t \le 40$ ($1.38 < t \le 1.57$)	E, EH	-, FH	-, FH	-, -
$40 < t \le 50$ ($1.57 < t \le 1.97$)	-, 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 3-1-2/3.1.

3.7 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

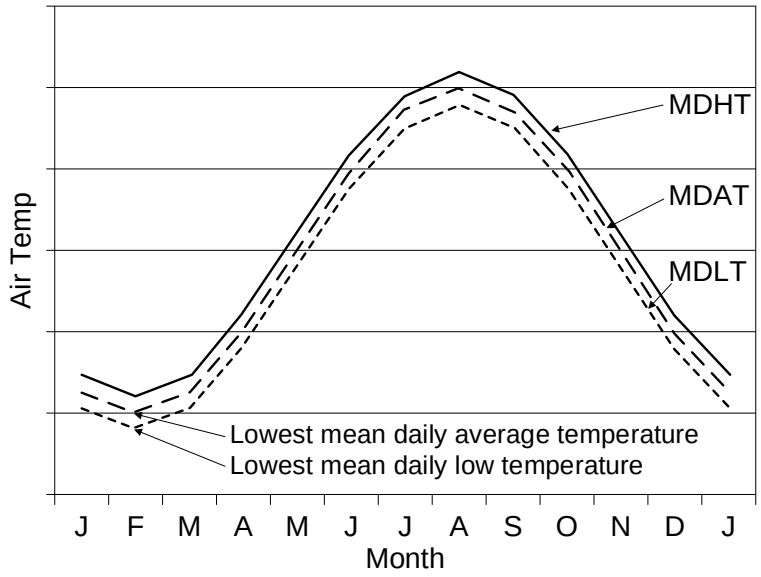
For seasonally restricted service the lowest value within the period of operation applies.

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

5 Scantlings

5.1 General

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

5.3 Rounding of Calculated Thickness

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

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

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

5.5 Dynamic Loading Approach

The notation **SH-DLA** will be assigned to vessels which have been reviewed based upon an acceptable dynamic load and structural analysis procedure, taking into consideration the dynamic load components acting on the vessel.

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

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

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

7 Proportions

In general, these Rules are valid for all vessels having characteristics as described in 3-2-1/1.

9 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 ABS *Rules for Materials and Welding (Part 2)*. See also 3-7-3/1.

11 Drydocking *(2018)*

Consideration is to be given to drydocking the vessel within twelve months after delivery. For vessels over 90 m (295 ft) in length, information indicating docking arrangements is to be submitted for information and furnished onboard the vessel for guidance.

13 Structural Sections

13.1 General

The scantling requirements of these Rules are applicable to rolled section angle bars, channels, bulb plates, flat bars etc. and built-up sections.

13.3 Primary Support Members

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

13.5 Local Support Members

13.5.1 Section Modulus

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

13.5.2 Web Thickness

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

Members with flange $50C_1C_2$

Members without flange $15C_1C_2$

where

C_1 = 0.95 (horizontal web within a tank)
= 1.0 (all other cases)

C_2 = 1.0 (ordinary strength steel)
= 0.92 (HT32)
= 0.90 (HT36)
= 0.88 (HT40)

15 Structural Design Details

15.1 General

The designer is to give consideration to the following:

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

ii) The proportions of built-up members for compliance with established standards for structural stability. See 3-1-2/13.5.2 and Appendix 3-2-A4.

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

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

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

A booklet of standard construction details based on the above considerations is to be submitted for review and comment.

15.3 Termination of Structural Members

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

Where load-bearing members are not required to be attached at their ends, special attention is to be given to the end taper, by using a sniped end of not more than 30°. The local plating in way of the sniped end is to have adequate thickness to transmit the bending strength and shear strength of the snipe ended member to the supporting member.

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

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

Bracket toes and sniped end members are to be kept within 25 mm (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 an end attachment, the longitudinal is to extend into the adjacent transversely framed structure, or stop at a local transverse member fitted at about one transverse frame space (see 3-2-5/1.5) beyond the last floor or web that supports the longitudinal.

The end attachments of non-load bearing members may, in general, be snipe ended. The sniped end is to be not more than 30° and is to be kept generally within 25 mm (1.0 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.).

15.5 Fabrication

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

PART
3

CHAPTER 2 Hull Structures and Arrangements

CONTENTS

SECTION 1 Longitudinal Strength 38

1 Application 38

3 Longitudinal Hull Girder Strength 38

3.1 Minimum Section Modulus for Vessels Under 61 m (200 ft) in Length 38

3.3 Longitudinal Strength for Vessels 61 m (200 ft) in Length and Over 38

3.5 Wave Loads 39

3.7 Bending Strength 42

3.9 Shearing Strength 43

5 Longitudinal Strength with Higher-Strength Materials 45

5.1 Hull Girder Moment of Inertia 45

5.3 Hull Girder Section Modulus 46

5.5 Hull Girder Shearing Force 46

7 Loading Guidance 46

7.1 Loading Manual 46

7.3 Allowable Stresses 46

9 Section Modulus Calculation 46

9.1 Items Included in the Calculation 46

9.3 Effective Areas Included in the Calculation 47

9.5 Section Modulus to the Deck or Bottom 47

9.7 Section Modulus to the Top of Cargo Rails and/or Longitudinal Side Walkways 47

11 Strength Decks 48

11.1 Definition 48

11.3 Tapering of Deck Sectional Areas 48

13 Effective Lower Decks 48

15 Longitudinal Deck Structures Inboard of Lines of Openings 48

15.1 Effectiveness 48

17 Buckling Strength for Vessels Over 61 m (200 ft) in Length 49

FIGURE 1 Sign Convention 40

FIGURE 2 Distribution Factor M 40

FIGURE 3 Distribution Factor F_1 41

FIGURE 4 Distribution Factor F_2 41

FIGURE 5 Shear Force Distribution 45

SECTION 2 Shell Plating 60

1 Application 60

3 Shell Plating Amidships 60

3.1 Vessels with No Partial Superstructures above Uppermost Continuous Deck 60

3.3 Superstructures Fitted Above Uppermost Continuous Deck (Side Plating Extended) 61

3.5 Superstructures Fitted Above Uppermost Continuous Deck (Side Plating Not Extended) 61

3.7 In Way of Comparatively Short Superstructures 61

3.9 Side Shell Plating 61

3.11 Side Fenders 61

3.13 Sheer Strake 62

3.15 Bottom Shell Plating Amidships 63

3.17 Flat Keel Plate for Vessels above 90 meters (295 feet) in Length 65

5 Shell Plating at Ends 65

5.1 Minimum Shell Plating Thickness 65

5.3 Immersed Bow Plating 65

5.5 Bottom Forward 66

5.7 Forecastle Side Plating 66

5.9 Poop Side Plating 66

5.11 Bow and Stern Thruster Tunnels 67

5.13 Increased Thickness Plating 67

7 Bottom Shell Plating for Special Docking Arrangement for Vessels Over 90 m in Length 67

8 Moon Pools 68

8.1 General Arrangement 68

8.3 Moon Pool Bulkhead Scantlings 68

9 Compensation 68

11 Breaks 69

13 Bilge Keels 69

14 Bilge Plating 69

15 Higher-strength Materials 70

15.1 General 70

15.3 Bottom Plating of Higher-strength Material 70

15.5 Side Plating of Higher-strength Material 70

15.7 End Plating 70

FIGURE 1 Side Impact Plates 62

FIGURE 2 Recommended Bulwark Fitting 63

SECTION 3 Decks 71

1 General 71

3 Hull Girder Strength 71

3.1 Longitudinal Section Modulus Amidships 71

3.3 Strength Deck 71

3.5 Longitudinally Framed Decks 71

3.7 Superstructure Decks 71
3.9 Deck Transitions 72
3.11 Deck Plating 72
5 Deck Plating 72
5.1 Thickness 72
5.3 Effective Lower Decks 73
5.5 Reinforcement at Openings 73
5.7 Platform Decks 73
5.9 Superstructure Decks 73
5.11 Decks over Tanks 73
5.13 Watertight Flats 73
5.15 Retractable Tween Decks 73
5.17 Wheel Loading 74
7 Higher-strength Material 78
7.1 Thickness 78
7.3 Wheel Loading 78
9 Deck Covering Compositions 79

TABLE 1 Applicable Thickness Equations 75
TABLE 2 Minimum Thickness Equations 77

FIGURE 1 Decks and Tiers Allocation 76
FIGURE 2 Wheel Loading Curves of "K" 76

SECTION 4 Bottom Structures 80
1 Double Bottoms 80
1.1 General 80
1.3 Testing 80
3 Center and Side Girders 80
3.1 Center Girder 80
3.3 Pipe Tunnels as an Alternative Arrangement of Center Girders 81
3.5 Docking Brackets for Center Girder and Side Girders 81
3.7 Side Girders 81
5 Solid Floors 81
5.1 General 81
5.3 Tank-end Floors 82
5.5 Floor Stiffeners 82
7 Open Floors 82
7.1 General 82
7.3 Bottom Shell Frames and Reverse Frames 82
7.5 Center and Side Brackets 83
7.7 Struts 83
9 Inner-bottom Plating 83
9.1 Inner-bottom Plating Thickness 83
9.3 Center Strakes 84
9.5 Inner Bottom Plating for Vessels Intended to Use Grabs 84

9.6 Optional Supplementary Requirement for Vessels Intended to Use Grabs 84
9.7 Wheel Loading 85
11 Bottom and Inner-bottom Longitudinals 85
11.1 General 85
11.3 Bottom Longitudinals 85
11.5 Inner Bottom Longitudinals 86
13 Single Bottoms with Longitudinal or Transverse Frames 86
13.1 General 86
13.3 Bottom Girders and Transverses 88
13.5 Center Girder 89
13.7 Frames 89
15 Fore-end Strengthening 90
15.1 General 90
15.3 Extent of Strengthening 90
15.5 Longitudinal Framing 90
17 Higher-strength Materials 91
17.1 General 91
17.3 Inner-bottom Plating 91
17.5 Bottom and Inner-bottom Longitudinals 91
17.7 Center Girders, Side Girders, and Floors 91
19 Structural Arrangements and Details 92
19.1 Structural Sea Chests 92
19.3 Drainage 92
19.5 Manholes and Lightening Holes 92
19.7 Air and Drainage Holes 92
19.9 Fixed Ballast 92
21 Machinery Space 93
21.1 General 93
21.3 Engine Foundations 93
21.5 Thrust Foundations 93
21.7 Shaft Stools and Auxiliary Foundations 93

TABLE 1 Extent of Strengthening 90

FIGURE 1 Double-bottom Solid Floors 82
FIGURE 2 Double-bottom Open Floors 83
FIGURE 3 Longitudinal Framing 86
FIGURE 4 Round Bottom Floors with Deadrise 87
FIGURE 5 Transverse Bottom Frames with Longitudinal Side Girders 87
FIGURE 6 Longitudinal Frames with Transverse Webs 88

SECTION 5 Frames 94

1 General 94
1.1 Basic Considerations 94
1.3 Holes in Frames 94
1.5 End Connections 94
1.7 Standard and Cant Frame Spacing 94
3 Side Frames 95
3.1 Transverse Frames 95
3.3 Raised Quarter Decks 97
3.5 Fore-end Frames 97
3.7 Panting Frames 97
3.9 Side Stringers 98
3.11 Frames with Web Frames and Side Stringers 98
3.13 Panting Webs and Stringers 98
3.15 Side Frame Brackets 98
3.17 Longitudinal Frames 98
3.19 Machinery Space 98
5 Tween-Deck Frames Below and Above the Bulkhead Deck 99
5.1 General 99
5.3 Transverse Tween-deck Frames 99
5.5 Longitudinal Tween-deck Frames 100
7 Forepeak Frames 100
7.1 General 100
7.3 Frame Scantlings 100
9 After-peak Frames 100
9.1 General 100
9.3 Frame Scantlings 100
11 Vessels Subject to Impact Loads 101

FIGURE 1 Zones of Framing 95
FIGURE 2 Side Frames 96
FIGURE 3 Side Frames 96
FIGURE 4 Side Frames 97

SECTION 6 Web Frames and Side Stringers 102

1 General 102
3 Web Frames 102
3.1 Web Frames Amidships and Aft 102
3.3 Web Frames Forward 103
3.5 Proportions 104
3.7 Stiffeners 104
3.9 Tripping Brackets 104
3.11 Tween-deck Webs 104

5 Side Stringers 104
5.1 Side Stringers 104
5.3 Proportions 104
5.5 Stiffeners 105
5.7 Tripping Brackets 105
7 Structural Arrangements and Details 105
7.1 Brackets of Girders, Webs, and Stringers 105
7.2 Overlap of Brackets 105
7.3 End Connections 105
9 Peak Stringers 106
9.1 Peak Stringer-plate Thickness 106
9.3 Peak Stringer-plate Breadth 106
11 Vessels Subject to Impact Loads 106

FIGURE 1 Web-frame Arrangements 103

SECTION 7 Beams and Longitudinals 107
1 General 107
1.1 Arrangement 107
1.3 Design Head 107
3 Beams and Longitudinals 107
3.1 Strength Requirement 107
3.3 Deep Reinforced Beams 110
3.5 Beams at the Head of Web Frames 110
3.7 End Connections 110
4 Deck Fittings Support Structures for Vessels of More Than 500 GT 111
4.1 General 111
4.3 Design Loads 111
4.5 Supporting Structures 113
4.7 Scantlings 115
5 Container Loading 115
5.1 General 115
5.3 Strength Requirements 116
7 Higher-strength Materials 116
7.1 General 116
7.3 Longitudinals and Beams of Higher-strength Materials 116

TABLE 1 Decks Allocation 109
TABLE 2 Values of h for Beams 110
TABLE 3 Values of f (Ordinary-strength Steel) 116

FIGURE 1 Application of Design Loads 113
FIGURE 2 Sample Arrangement 113
FIGURE 3 Attachment Point of Mooring Line 114
FIGURE 4 Attachment Point of Towing Line 114

SECTION 8 Pillars, Deck Girders, and Transverses 117

1 General 117
1.1 Arrangements – General 117
1.3 Container Loading 117
1.5 Cargo Loading 117
3 Pillars 117
3.1 Permissible Load 117
3.3 Calculated Load 118
3.5 Additional Pillars 118
3.7 Pillars under the Tops of Deep Tanks 119
3.9 Bulkhead Stiffening 119
3.11 Attachments 119
5 Deck Girders and Transverses 119
5.1 General 119
5.3 Deck Girders Clear of Tanks 119
5.5 Deck Transverses Clear of Tanks 120
5.7 Proportions 120
5.9 Tripping Brackets 121
5.11 End Attachments 121
5.13 Deck Girders and Transverses in Tanks 121
5.15 Hatch Side Girders 121
7 Hatch-end Beams 121
7.1 Hatch-end Beam Supports 121
7.3 Weather Deck Hatch-end Beams 122
7.5 Depth and Thickness 122
7.7 Tripping Brackets 122
7.9 Brackets 122
9 Higher-strength Materials 123
9.1 General 123
9.3 Girders and Deck Transverses 123

FIGURE 1 Deck Girders and Pillars 120
FIGURE 2 Hatch-end Beams 123

SECTION 9 Watertight Bulkheads and Doors 124

1 General 124
1.1 Application 124
1.3 Openings and Penetrations 124
1.5 Sluice Valves and Cocks 124
1.7 Strength Bulkheads 124
1.9 Testing 124
3 Arrangement of Watertight Bulkheads 125
3.1 Collision Bulkhead 125
3.3 After-peak Bulkhead 126
3.5 Machinery Spaces 126
3.7 Cargo Space Bulkheads 126
3.9 Chain Lockers 126

5 Construction of Watertight Bulkheads 127
5.1 Plating 127
5.3 Stiffeners 128
5.4 Stiffener End Brackets 128
5.5 Attachments 129
5.7 Girders and Webs 132
7 Construction of Corrugated Bulkheads 133
7.1 Plating 133
7.3 Stiffeners 133
7.5 End Connections 133
9 Watertight Doors 135
9.1 Doors Used While at Sea 135
9.3 Access Doors and Hatches Normally Closed at Sea 136
9.5 Doors or Ramps Dividing Large Cargo Spaces 139
9.7 Openings Closed at Sea 139
9.9 Construction 139
9.11 Testing Watertight Door at Manufacturer 139

TABLE 1A Thickness and Flanges of Brackets and Knees for Vessels ≥ 90 m (295 ft) in Length 131
TABLE 1B Thickness and Flanges of Brackets for Vessels < 90 m (295 ft) in Length 132
TABLE 2 Minimum Mechanical Properties for Butt-Welded Aluminum Alloys 138

FIGURE 1 Reference Point for Vessels with Bulbous Bow 125
FIGURE 2A Chain Lockers Arrangement 127
FIGURE 2B 127
FIGURE 3A Bracket Connections 130
FIGURE 3B 130
FIGURE 3C 130
FIGURE 4 Corrugated Bulkhead 133
FIGURE 5 Corrugated Bulkhead End Connections 134
FIGURE 6 Corrugated Bulkhead Upper Stool Credit 135

SECTION 10 Deep Tanks 140
1 General 140
1.1 Application 140
1.3 Arrangement 140
1.5 Construction 140
1.7 Drainage and Air Escape 140
1.9 Testing 140
3 Construction of Deep Tank Bulkheads and Tank Tops 141
3.1 Plating 141
3.3 Stiffeners 142
3.5 Tank-top Plating and Stiffeners 142
3.7 Girders and Webs 142

3.9 Corrugated Deep Tank Bulkheads....143
3.11 Anti-rolling Tank Bulkheads....143
5 Higher-strength Materials....143
5.1 General....143
5.3 Plating....143
5.5 Stiffeners....143

SECTION 11 Superstructures, Deckhouses, and Helicopter Decks....145
1 General Scantlings of Superstructures and Deckhouses....145
1.1 Side Plating....145
1.3 Decks....145
1.5 Frames....145
1.7 Breaks in Continuity....145
3 Exposed Bulkheads....145
3.1 General....145
3.3 Plating....146
3.5 Stiffeners....146
3.7 End Attachments....148
3.9 Deck Steps....148
5 Enclosed Superstructures and Deckhouses....150
5.1 Openings in Bulkheads....150
5.3 Doors for Access Openings....150
5.5 Sills of Access Openings....150
5.7 Portlights....150
5.9 Bridges and Poops....150
7 Open Superstructures and Deckhouses....150
9 Forecastle Structures....151
10 Aluminum Superstructures and Deckhouses....151
10.1 Scantlings....151
11 Helicopter Decks....151
11.1 General....151
11.3 Structure....152
11.5 Material....153
11.7 Arrangements....154
11.9 Safety....157

TABLE 1 Values of a....149
TABLE 2 Values of f....149
TABLE 3 Allowable Factors of Safety Based on Y for Helicopter Decks....153

FIGURE 1 Lower Ends of Deckhouse Stiffeners....148
FIGURE 2 Helideck Obstacle Limitation Sector: Single Main Rotor Helicopter....156
FIGURE 3 Helideck Obstacle Limitation Sector: Single Main Rotor Helicopter for Benign Climate Conditions as Accepted by the Coastal State....157

SECTION 12 Machinery Space and Tunnel 159

1 General 159
1.1 Arrangement 159
1.3 Testing of Tunnels 159
3 Machinery Foundations 159
3.1 Engine Foundations 159
3.3 Boiler Foundations 159
3.5 Thrust Foundations 160
3.7 Shaft Bearing and Auxiliary Machinery Foundations 160
5 Tunnels and Tunnel Recesses 160
5.1 Plating 160
5.3 Stiffeners 160
5.5 Beams, Pillars and Girders 160
5.7 Tunnels through Deep Tanks 160

SECTION 13 Stems, Stern Frames, Rudder Horns, and Propeller Nozzles 162

1 Stems 162
1.1 Plate Stems 162
1.3 Cast or Forged Stems 162
1.5 Bar Stems 162
3 Stern Frames 163
3.1 Rudder Gudgeons 163
3.3 Scantlings below the Propeller Boss 163
3.5 Stern Frames with Shoe Piece 165
3.7 Scantlings above the Propeller Boss 165
3.9 Secondary Members 165
3.11 Shoe Pieces 166
5 Rudder Horns 167
5.1 Scantlings – Single Pintle Rudders 167
5.3 Scantlings – Two Pintle Rudders 168
5.5 Rudder Horn Plating 169
5.7 Welding and Connection to Hull Structure 169
5.9 Floors 169
5.11 Shell Plating 169
5.13 Water Exclusion 169
7 Shaft Struts 171
7.1 V Strut 171
7.3 I Strut 171
7.5 Strut Length 171
9 Propeller Nozzles 172
9.1 Design Pressure 172
9.3 Nozzle Cylinder 172
9.5 Nozzle Section Modulus 173
9.7 Welding Requirement 175
11 Propulsion Improvement Devices (PID) as Hull Appendages 175
11.1 Application Scope 175
11.3 Plans and Documentation 175

11.5 Design and Arrangement 175
11.7 Structural End Connection 175
13 Inspection of Castings 175

TABLE 1 Coefficient c 172
TABLE 2 Coefficient ε 172
TABLE 3 Coefficient c_n 173
TABLE 4 Corrosion Allowance t_c 173

FIGURE 1 Stern Frame 164
FIGURE 2 Shoe Piece 167
FIGURE 3 Rudder Horn 170
FIGURE 4 Connection of Rudder Horn to Aft Ship Structure 171
FIGURE 5 Propeller Nozzle Section View 174

SECTION 14 Rudders and Steering Equipment 176
1 General 176
1.1 Application 176
1.3 Materials for Rudder, Rudder Stock and Steering Equipment 176
1.5 Expected Torque 177
1.7 Rudder Stops 177
3 Rudder Design Force 177
3.1 Rudder Blades without Cutouts 177
3.3 Rudders Blades with Cutouts 177
3.5 Rudders Blades with Twisted Leading-Edge 178
5 Rudder Design Torque 181
5.1 General 181
5.3 Rudders without Cutouts 181
5.5 Rudders Blades with Cutouts 182
5.7 Rudders with Twisted Leading Edge 182
7 Rudder Stocks 182
7.1 Upper Rudder Stocks 182
7.3 Lower Rudder Stocks 182
7.5 Rudder Trunk and Rudder Stock Sealing 183
9 Flange Couplings 185
9.1 General 185
9.3 Horizontal Couplings 185
9.5 Vertical Couplings 186
11 Tapered Stock Couplings 187
11.1 Coupling Taper 187
11.3 Keyed Fitting 188
11.5 Keyless Fitting 189
11.7 Locking Nut 190
13 Pintles 190
13.1 General 190
13.3 Push-up Pressure and Push-up Length 191

15 Supporting and Anti-Lifting Arrangements 192
15.1 Bearings 192
15.3 Rudder Carrier 193
15.5 Anti-lifting Devices 193
17 Double Plate Rudder 194
17.1 Strength 194
17.3 Side, Top and Bottom Plating 197
17.5 Diaphragm Plates 198
17.7 Connections of Rudder Blade Structure with Solid Parts 198
17.9 Welding and Design Details 200
17.11 Watertightness 200
19 Single Plate Rudders 201
19.1 Mainpiece Diameter 201
19.3 Blade Thickness 201
19.5 Arms 201
21 Steering Nozzles 201
21.1 Application Scope 201
21.3 Design Force 202
21.5 Design Torque 203
21.7 Nozzle Stock 203
21.9 Design Pressure 204
21.11 Plate Thickness 205
21.13 Section Modulus 205
21.15 Locking Device 205
21.17 Welding Requirement 205
23 Azimuthal Thruster 205
23.1 Application Scope 205
23.3 Plans and Documents 206
23.5 Locking Device 206
23.7 Design Force 206
23.9 Design Torque 208
23.11 Design Pressure 208
23.13 Nozzle Scantlings 208
23.15 Steering Tube 209
23.17 Section Modulus 209
23.19 Thruster Nozzle Top Connections 209
23.21 Nozzle Strut 209
23.23 Direct Analysis 210
23.25 Welding and Nondestructive Testing 211
25 Azimuthing Pod 211
25.1 General Remarks 211
25.3 Application Scope 212
25.5 Plans and Documents 213
25.7 Material Requirements 213
25.9 Locking Device 214
25.11 Direct Analysis 214
25.13 Direct Analysis Strength Criteria 214

25.15 Additional Requirements....215
25.17 Structural Transition....217
25.19 Service Accessibility....218
25.21 Air and Drainage Escape....218
25.23 Watertightness....218
25.23 Welding Requirements....218

TABLE 1A Coefficient k_c for Ordinary Rudders....179
TABLE 1B Coefficient k_c for High-Lift/Performance Rudders....179
TABLE 2 Coefficient k_ℓ....181
TABLE 3 Coefficient α....181
TABLE 4 Minimum Bearing Force B_{min}....191
TABLE 5 Bearing Reaction Force....193
TABLE 6 Allowable Bearing Surface Pressure....194
TABLE 7 Thickness of Side Plating and Vertical Diaphragm Plates....200
TABLE 8 Coefficient c_m....204
TABLE 9 Permissible Stress Level....215

FIGURE 1A Rudder Blade without Cutouts....180
FIGURE 1B Rudder Blade with Cutouts....180
FIGURE 2 Fillet Shoulder Radius....184
FIGURE 3 Welded Joint Between Rudder Stock and Coupling Flange....186
FIGURE 4 Tapered Couplings....187
FIGURE 5....195
FIGURE 6....195
FIGURE 7....196
FIGURE 8....197
FIGURE 9 Cross-section of the Connection Between Rudder Blade Structure and Rudder Stock Housing....199
FIGURE 10 Nozzle Geometry....203
FIGURE 11 An Illustration of Azimuthal Thruster....207
FIGURE 12 Pod Propulsion Unit....212
FIGURE 13 Hull Supporting Structure....217
FIGURE 14 Azimuthing Pod Internal Structure Access....218

SECTION 15 Protection of Deck Openings....229
1 General....229
3 Positions and Design Pressures....229
3.1 Positions of Deck Openings....229
3.3 Vertical Weather Design Pressures....229
3.5 Horizontal Weather Design Pressures....232
5 Hatchway Coamings....234
5.1 Height of Coamings....234
5.3 Coaming Plates....234
5.5 Coaming Stiffening....234

7 Hatchways Closed by Covers of Steel and Fitted with Gaskets and Clamping Devices 235
7.1 Strength of Steel Covers 235
7.3 Local Net Plate Thickness 236
7.5 Net Scantlings of Secondary Stiffeners 238
7.7 Net Scantlings of Primary Supporting Members 239
7.9 Cargo Loads 240
7.11 Container Loads 241
7.13 Loads due to Elastic Deformations of the Vessel's Hull 243
7.15 Strength Calculations 243
7.17 Buckling Strength of Hatch Cover Structures 244
7.19 Details of Hatch Covers 258
7.21 Hatch Coaming Strength Criteria 259
7.23 Closing Arrangements 262
7.25 Corrosion Addition and Steel Renewal 266
8 Hatchways Closed by Covers of Aluminum and Fitted with Gaskets and Clamping Devices 267
8.1 Strength of Aluminum Covers 267
9 Hatchways in Decks at Higher Levels 267
11 Hatchways in Lower Decks or within Fully Enclosed Superstructures 267
11.1 Steel Covers 267
11.3 Wheel Loading 268
13 Small Hatches on the Exposed Fore Deck 268
13.1 Strength 268
13.3 Primary Securing Devices 268
13.5 Requirements for Primary Securing 268
13.7 Secondary Devices 269
15 Other Hatchways 271
15.1 Hatchways within Open Superstructures 271
15.3 Hatchways within Deckhouses 271
17 Additional Requirements for Subdivision 272
17.1 External Opening below Damage Waterline 272
17.3 Internal Openings 272
19 Machinery Casings 272
19.1 Arrangement 272
19.3 Fiddleys, Funnels, and Ventilators 272
19.5 Casings within Open Superstructures 272
19.7 Casings within Enclosed Superstructures 272
19.9 Casings within Deckhouses 273
21 Miscellaneous Openings in Freeboard and Superstructure Decks 273
21.1 Manholes and Scuttles 273
21.3 Other Openings 273
21.5 Escape Openings 273
21.7 Companionway Sills 273
21.9 Mast Openings 274
21.11 Chain Pipe Opening 274

TABLE 1 Minimum Design Load $p_{H\min}$ 233
TABLE 2 Effective Breadth e_m of Plating of Primary Supporting Members 244
TABLE 3 Correction Factor F_1 246
TABLE 4 Coefficients e_1, e_2, e_3 and Factor B....247
TABLE 5 Buckling and Reduction Factors for Plane Elementary Plate Panels 248
TABLE 6 Moments of Inertia 258
TABLE 7 Permissible Nominal Surface Pressure p_n 265
TABLE 8 Corrosion Additions t_S for Hatch Covers and Hatch Coamings 266
TABLE 9 Scantlings for Small Steel Hatch Covers on the Fore Deck 269

FIGURE 1 Positions 1 and 2....231
FIGURE 2 Positions 1 and 2 for an Increased Freeboard....231
FIGURE 3 Determination of Normal Stress of the Hatch Cover Plating 237
FIGURE 4 Forces due to Container Loads....242
FIGURE 5 Partial Loading of a Container Hatch Cover 243
FIGURE 6 General Arrangement of Panel 245
FIGURE 7 Stiffening Parallel to Web of Primary Supporting Member ...250
FIGURE 8 Stiffening Perpendicular to Web of Primary Supporting Member 251
FIGURE 9 Dimensions of Stiffeners 257
FIGURE 10 Examples for Typical Coaming Stay Configurations....261
FIGURE 11 Example for Arrangement of Coaming Plates 262
FIGURE 12 Lifting Forces at a Hatch Cover 264
FIGURE 13 Arrangement of Stiffeners 270
FIGURE 14 Example of Primary Securing Method 271

SECTION 16 Protection of Shell Openings 277

1 Cargo, Gangway, or Fueling Ports....277
1.1 Construction....277
1.3 Location 277
1.5 Subdivision Requirements 277
3 Side Shell Doors and Stern Doors....278
5 Securing, Locking and Supporting of Doors 278
5.1 Definitions 278
7 Securing and Supporting Devices....278
7.1 General 278
7.3 Side Shell and Stern Doors....278
9 Securing and Locking Arrangement 278
9.1 General 278
9.3 Operation 278

11 Tightness 279
11.1 Side Shell and Stern Doors 279
11.3 Testing at Watertight Door Manufacturer 279
13 Side Shell Door and Stern Door Scantlings 279
13.1 General 279
13.3 Primary Structure 279
13.5 Secondary Stiffeners 279
13.7 Plating 279
13.9 Securing and Supporting Devices 279
15 Side Shell and Stern Door Design Loads 280
15.1 Design Forces for Primary Members 280
15.3 Design Forces for Securing or Supporting Devices of Doors Opening Inwards 280
15.5 Design Forces for Securing or Supporting Devices of Doors Opening Outwards 280
17 Allowable Stresses 281
17.1 Primary Structure and Securing and Supporting Devices 281
17.3 Steel Securing and Supporting Devices Bearing Stress 281
17.5 Tensile Stress on Threaded Bolts 281
19 Operating and Maintenance Manual 281
19.1 Manual 281
19.3 Operating Procedures 281

SECTION 17 Bulwarks, Rails, Freeing Ports, Portlights, Windows, Ventilators, Tank Vents and Overflows 282
1 Bulwarks and Guard Rails 282
1.1 Height 282
1.3 Strength of Bulwarks 282
1.5 Guard Rails 283
3 Access and Crew Protection 285
3.1 General 285
3.3 Access to Bow 285
5 Freeing Ports 288
5.1 Basic Area 288
5.3 Vessels with Less than Standard Sheer 289
5.5 Trunks 289
5.7 Open Superstructures 289
5.9 Details of Freeing Ports 289
7 Portlights 290
7.1 Location 290
7.3 Deadlights and Storm Covers 290
7.5 Construction 290
9 Windows 291
9.1 Location 291
9.3 Deadlights and Storm Covers 291
9.5 Construction 291
9.7 Window Glazing 292
9.9 Testing 292

11 Ventilators, Tank Vents and Overflows....293
11.1 General....293
11.3 Ventilators....293
11.5 Tank Vents and Overflows....293
11.7 Ventilators, Tank Vents and Overflows on the Fore Deck....293

TABLE 1 Acceptable Arrangement for Access....286
TABLE 2 760 mm (30 in.) High Tank Vents and Overflows Thickness and Bracket Standards....296
TABLE 3 900 mm (35.4 in.) High Ventilator Thickness and Bracket Standards....296

FIGURE 1 Bulwark Stanchion....283
FIGURE 2 Guardrail Stanchion....284
FIGURE 3 Guardrail Stanchion....284
FIGURE 4 Freeing Ports Area Adjustment....289

SECTION 18 Ceiling, Sparring, and Protection of Steel....297
1 Close Ceiling....297
3 Sparring....297
5 Corrosion Protection of Steel....297
5.1 All Spaces....297
5.3 Dedicated Salt Water Ballast Tanks and Double-side Skin Spaces....297
5.5 Void Spaces....297
5.7 Fuel Oil Tanks....297

SECTION 19 Weld Design....298
1 Fillet Welds....298
1.1 General....298
3 Tee Connections....298
3.1 Size of Fillet Welds....298
3.3 Length and Arrangement of Fillet....299
3.5 Intermittent Welding at Intersection....299
3.7 Welding of Longitudinal to Plating....299
3.9 Stiffeners and Webs to Hatch Covers....299
3.11 Thin Plating....299
5 Tee-Type End Connections....303
7 Ends of Unbracketed Stiffeners....303
9 Reduced Weld Size....303
9.1 General....303
9.3 Controlled Gaps....303
9.5 Deep Penetration Welds....303
11 Lapped Joints....303
11.1 General....303
11.3 Overlapped End Connections....303
11.5 Overlapped Seams....303

13 Plug Welds or Slot Welds 304
15 Full or Partial Penetration Corner or Tee Joints 304
17 Alternatives 304

TABLE 1 Weld Factors 300

SECTION 20 Guidance on Finite Element Analysis 305
1 General 305
1.1 Submittal Items....305
3 Structural Modeling 306
3.1 Finite Element Types....306
3.3 Model Types....306
3.5 Modeling Guidance 306
5 Boundary Conditions....307
7 Loads 307
9 Acceptance Criteria....307
9.1 Allowable Stresses 307
9.3 Buckling Strength 308

TABLE 1 Finite Element Type 306
TABLE 2 Stress Limits for Plate Element Models 308

APPENDIX 1 Calculation of Shear Stresses for Vessels Having Plane Plate Longitudinal Bulkheads.... 50
1 Methods of Calculation 50
3 Calculation of the Shear Flow Around Closed Sections....50
5 Calculation of m....50
7 Determination of N_i....51

APPENDIX 2 Loading Manuals.... 52
1 General 52
1.1 Application....52
3 Definitions 52
3.1 Loading Manual....52
5 Required Loading Guidance 52
5.1 Loading Manual....52
5.3 Modifications 52
7 Loading Manual 52
7.1 Required Information....52
7.3 Loading Conditions....53
7.5 Language 53
9 Annual Surveys....53

TABLE 1 Loading Conditions in the Loading Manual....53

APPENDIX 3 Buckling Strength of Longitudinal Strength Members for Vessels Over 61 m (200 ft) in Length 54

1 Application 54

3 Elastic Buckling Stresses 54

3.1 Elastic Buckling of Plates 54

3.3 Elastic Buckling of Longitudinals 55

5 Critical Buckling Stresses 57

5.1 Compression 57

5.3 Shear 58

7 Working Stress 58

7.1 Longitudinal Compressive Stress 58

7.3 Shear Stresses 58

9 Scantling Criteria 59

9.1 Buckling Stress 59

TABLE 1 Standard Deduction 57

TABLE 2 Number of Half Waves 57

APPENDIX 4 Guidelines for Calculating Bending Moment and Shear Force in Rudders and Rudder Stocks 219

1 Application 219

3 Spade Rudders 219

3.1 Rudder Blade 219

3.3 Lower Stock 220

3.5 Moment at Top of Upper Stock Taper 221

3.7 Bearing Reaction Forces 221

5 Rudders Supported by Shoe Piece 223

5.1 Shear Force, Bending Moment and Reaction Forces 223

7 Rudders Supported by a Horn with One Pintle 224

7.1 Shear Force, Bending Moment and Reaction Forces 224

9 Rudders Supported by a Horn Arranged with Two Pintles (Supports) 226

9.1 Shear Force, Bending Moment and Reaction Forces 226

FIGURE 1 Spade Rudder 223

FIGURE 2 Rudder Supported by Shoe Piece 224

FIGURE 3 Rudder Supported by a Horn with One Pintle 226

FIGURE 4 Rudder Supported by a Horn Arranged with Two Pintles (Supports) 228

APPENDIX 5 Hatch Cover Stiffeners of Variable Cross Section 275

1 Application 275

FIGURE 1 SM and I of Construction Elements 276

APPENDIX 6 Ice Operations 309

1 Application 309
3 General 309
5 Ice Management 309
7 Overview of ABS Ice Class Rules 310
9 IACS Polar Classes 311
9.1 Background Information 311
9.3 Description of IACS Polar Classes 313
9.5 Theoretical Background of Structural Requirements 313
9.7 Theoretical Background of Machinery Requirements 314
11 Polar Classes “Enhanced” Requirements 314
13 First Year Ice Classes 315
15 Baltic Ice Classes 316
17 Winterization 317
19 Direct Calculation 317
21 Ice Load Monitoring System 318

TABLE 1 Ice Class Notations 311
TABLE 2 Polar Class Descriptions 313
TABLE 3 List of Subjects Addressed in Enhanced Requirements 315
TABLE 4 First Year Ice Class Selection Guidance 316
TABLE 5 First Year Ice Conditions Severity Definitions 316

FIGURE 1 Ice Management System and Its Elements 310
FIGURE 2 Organization of ABS Ice Class Rules 310
FIGURE 3 Maximum Extent of Arctic Waters 312
FIGURE 4 Maximum Extent of Antarctic Waters 312

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 1 Longitudinal Strength

1 Application

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

i) Proportions: $L/B < 5$; $B/D > 3.0$

ii) Length: $L > 305$ m (1000 ft)

iii) Block Coefficient: $C_b < 0.6$

iv) Large deck opening

v) Vessels with large flare

vi) Vessels carrying heated cargoes

vii) Unusual type or design

3 Longitudinal Hull Girder Strength

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

The minimum required hull girder section modulus (see 3-1-2/1.1.3), *SM*, at amidships, is to be determined in accordance with the following equation:

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

where

C_1 = $0.044L + 3.75$ for $L < 61$ m

C_1 = $0.0134L + 3.75$ for $L < 200$ ft

C_2 = 0.01 (0.01, 0.000144)

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

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

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

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

3.3.1 Sign Convention of Bending Moment and Shear Force

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

3.3.2 Still-water Bending Moment and Shear Force

3.3.2(a) General. Still-water bending moment and shear force calculations, determining the bending moment and hull girder shear force values along the vessel's entire length, are to be submitted together with the distribution of lightship weights.

3.3.2(b) Design Cargo and Ballast Loading Conditions. The calculations are to consider the effect of bunker, fresh water and consumable stores at departure and arrival. Where their amount and disposition at any stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted in addition to those for departure and arrival conditions.

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

3.3.2(c) Ballast Tanks in Cargo Loaded Conditions. Cargo loading conditions involving partially filled peak tanks are not permitted.

3.3.2(d) Sequential Ballast Water Exchange. The requirement of 3-2-1/3.3.2(c) is not applicable to sequential method ballast water exchange. However, bending moment and shear force calculations for each de-ballasting or ballasting stage in the ballast water exchange sequence are to be included in the loading manual or ballast water management plan of any vessel that intends to employ the sequential ballast water exchange method.

3.5 Wave Loads

3.5.1 Wave Bending Moment Amidships

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

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

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

where

k_1 = 110 (11.22, 1.026)

k_2 = 190 (19.37, 1.772)

C_1 = $0.044L + 3.75$ $61 \le L < 90$ m

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

= 10.75 $300 < L \le 305$ m

C_1 = $0.0134L + 3.75$ $200 \le L < 295$ ft

= $10.75 - \left(\frac{984 - L}{328}\right)^{1.5}$ $295 \le L \le 984$ ft

= 10.75 $984 < L \le 1000$ ft

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

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

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

3.5.2 Envelope Curve of Wave Bending Moment

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

3.5.3 Wave Shear Force

The envelopes of maximum shearing forces induced by waves, $F_{w,}$ as shown in 3-2-1/Figure 3 and 3-2-1/Figure 4, may be obtained from the following equations.

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

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

where

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

C_1 = as defined in 3-2-1/3.5.1

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

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

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

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 1
Sign Convention

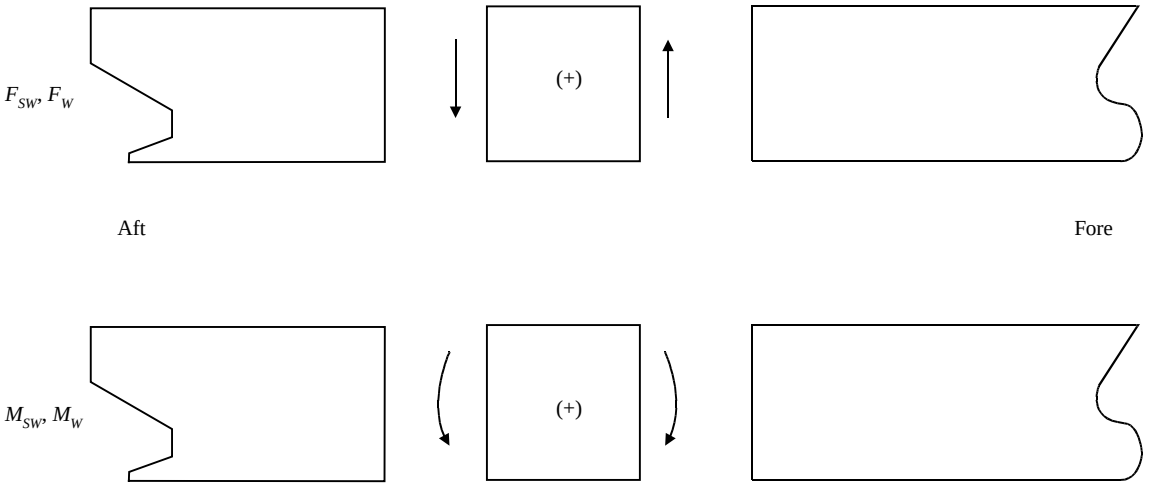


FIGURE 2
Distribution Factor *M*

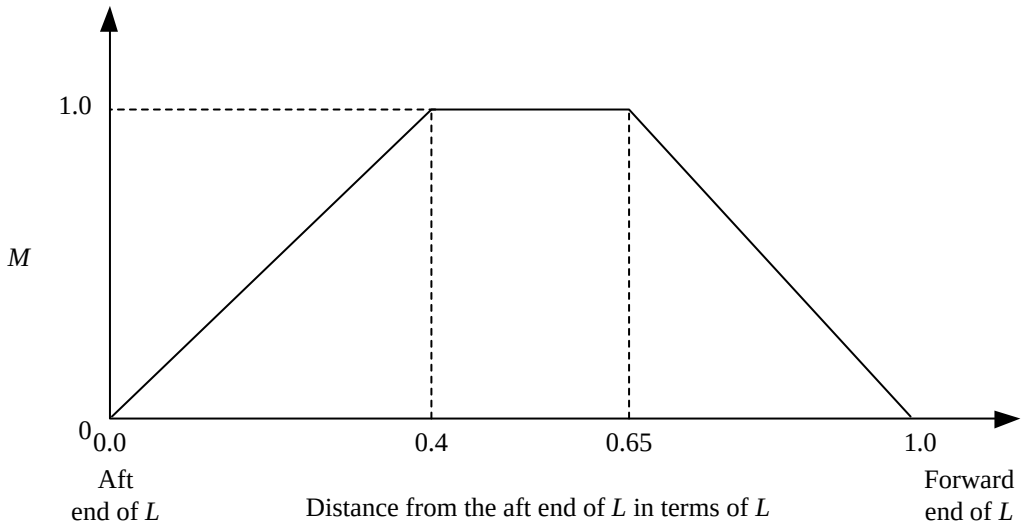


FIGURE 3
Distribution Factor F_1

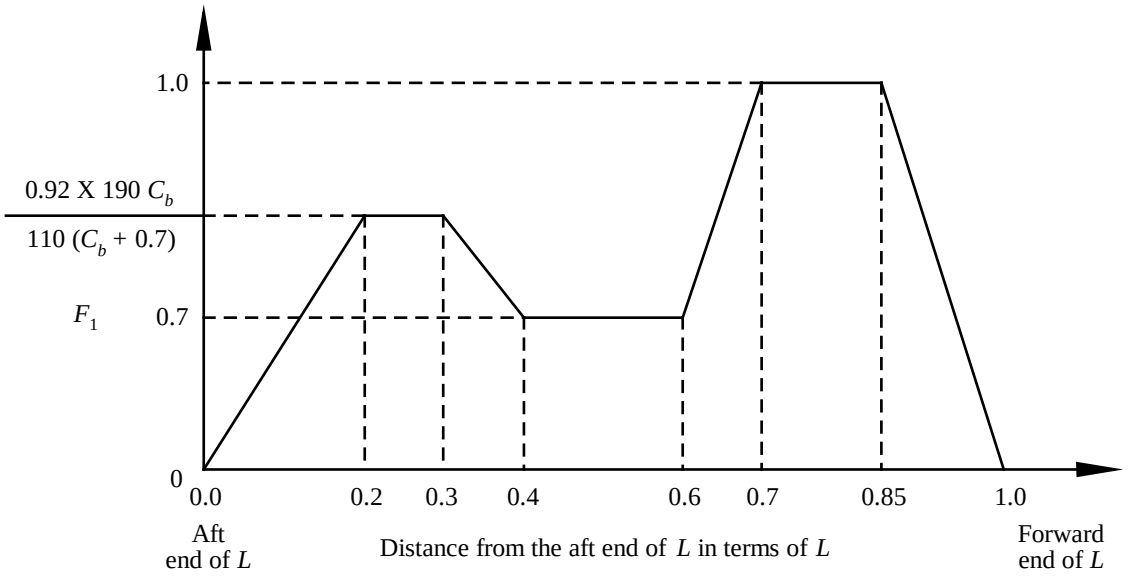
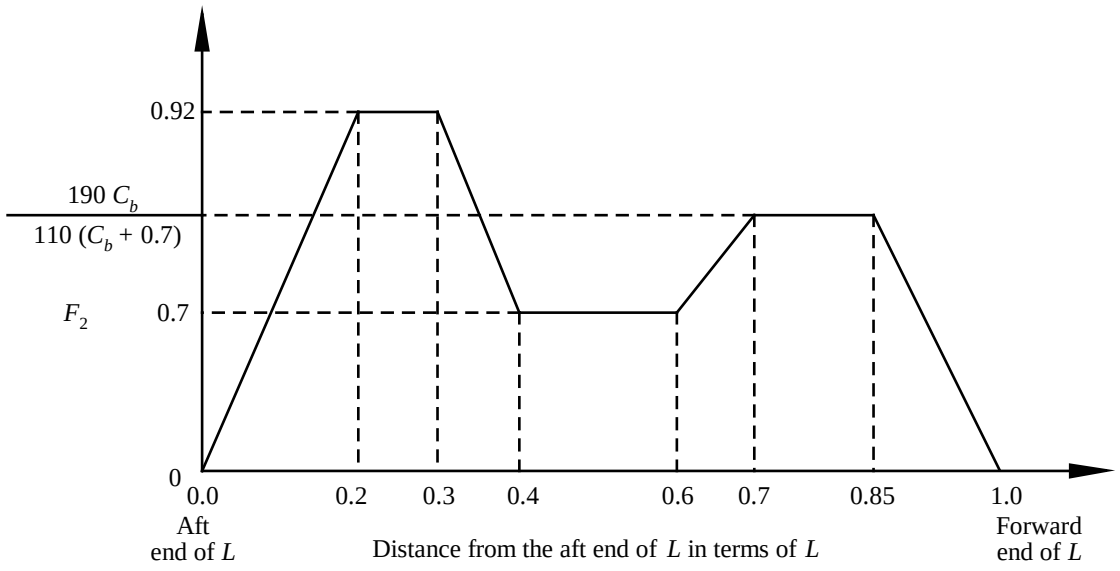


FIGURE 4
Distribution Factor F_2



3.7 Bending Strength

3.7.1 Hull Girder Section Modulus

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

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

where

M_t = total bending moment, as obtained below

f_p = nominal permissible bending stress

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

The total bending moment, M_t, is to be considered as the maximum algebraic sum (see sign convention in 3-2-1/3.1) of still-water bending moment and wave-induced bending moment, as follows:

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

where

M_{sw} = still-water bending moment in accordance with 3-2-1/3.3, in kN-m (tf-m, Ltf-ft).

M_w = maximum wave-induced bending moment in accordance with 3-2-1/3.5.1

3.7.1(b) Minimum Section Modulus (see 3-1-2/1.1.3) The minimum hull girder section modulus amidships is not to be less than obtained from the following equation:

$$SM = C_1C_2L^2B\,(C_b + 0.7) \quad \text{cm}^2\text{-m (in}^2\text{-ft)}$$

where

C_1 = as defined in 3-2-1/3.5.1

C_2 = 0.01 (0.01, 1.44×10^{-4})

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

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

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

3.7.1(c) Extension of Midship Section Modulus and Continuity of Structure (1 July 2012). In general, where the still-water bending moment envelope curve is not submitted or where 3-2-1/3.7.1(b) governs, scantlings of all continuous longitudinal members of the hull girder are to be maintained throughout 0.4*L* amidships and then may be gradually tapered beyond.

Where the scantlings are based on the still-water bending moment envelope curves, items included in the hull girder section modulus amidships are to be extended as necessary to meet the hull girder section modulus required at the location being considered.

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

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

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

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

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

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

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

3.7.2 Hull Girder Moment of Inertia

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

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

where

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

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

3.7.3 Hull Girder Strength Outside of 0.4L Amidships

The strength of the hull girder is to be checked at sections outside of 0.4*L* amidships. The required section modulus for the regions outside 0.4*L* amidships is to be obtained based on the total bending moment at the section considered and applying the permissible bending stress as given in 3-2-1/3.7.1(a). As a minimum hull girder bending strength checks are to be carried out at the following locations:

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

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

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

Buckling strength of members contributing to longitudinal strength and subjected to compressive and shear stresses is to be checked in accordance with 3-2-1/17, in particular in regions where changes in the framing system or significant changes in the hull cross-section occur.

3.9 Shearing Strength

3.9.1 General

In calculating the nominal total shear stress, f_s, due to still-water and wave-induced loads, the maximum algebraic sum of the shearing force in still-water F_{sw} and that induced by wave F_w at the station examined is to be used. The thickness of the side shell, and where fitted, the longitudinal bulkhead, is to be such that the nominal total shear stress f_s, as obtained from 3-2-1/3.9.2 or 3-2-1/3.9.4, are not greater than 11.0 kN/cm^2 (1.122 tf/cm^2, 7.122 Ltf/in^2).

3.9.2 Shearing Strength for Vessels without Effective Longitudinal Bulkheads

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

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

where

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

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 at the position under consideration, in cm (in.)

F_{sw} = hull girder shearing force in still-water, in kN (tf, Ltf)

F_w = F_{wp} or F_{wn}, as specified by 3-2-1/3.5.3, in kN (tf, Ltf), depending upon loading

3.9.3 Modification of Hull girder Shearing Force Peaks

The hull girder shearing force in still water, F_{sw}, to be used for calculating shear stresses in the side shell plating may be modified to account for the loads transmitted through the double bottom structure to the side shell through the transverse bulkhead. For this modification, unless a detailed calculation is performed, the following equation may be used as guidance to determine the shear force carried by the side shell at the transverse bulkhead (see 3-2-1/Figure 5).

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

where

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

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

F_{BA} = $(0.45 - 0.2\ell_A/b_A)W_A b_A/B$

F_{BF} = $(0.45 - 0.2\ell_F/b_F)W_F b_F/B$

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

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

b_A, b_F = breadth of the double bottom structure in the holds immediately abaft and forward of the bulkhead in question, respectively, in m (ft). For vessels having double skins with flat inner bottom, it may be measured to the inner skins.

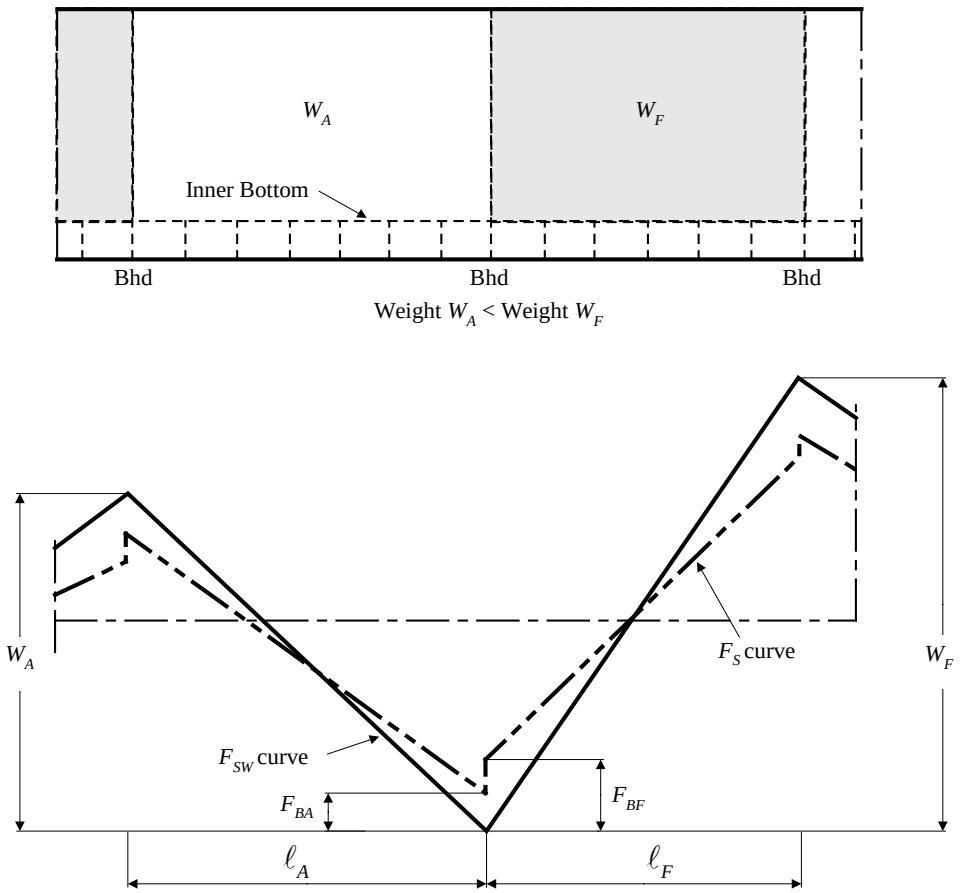
B = breadth of vessel, as defined in 3-1-1/5, in m (ft)

3.9.4 Shearing Strength for Vessels with Two or Three Plane Longitudinal Bulkheads

For vessels having continuous plane longitudinal bulkheads, the total shear stresses in the side shell and the longitudinal bulkheads are to be calculated by an acceptable method. In determining the still-water shear force, consideration is to be given to the effects of non-uniform athwartship distribution of loads. The method described in Appendix 3-2-A1 may be used as a guide in calculating the nominal total shear stress f_s related to the shear flow in the side shell or longitudinal bulkhead plating.

Alternative methods of calculation will also be considered.

FIGURE 5
Shear Force Distribution



5 Longitudinal Strength with Higher-Strength Materials *(1 July 2012)*

Vessels where the effective longitudinal material of either the upper or lower flanges of the main hull girder, or both, are constructed of materials having mechanical properties greater than those of ordinary-strength hull structural steel (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 and permissible shear stress may be modified as permitted by 3-2-1/5.3 and 3-2-1/5.5. Application of higher-strength material is to be continuous over the length of the vessel to locations where the stress levels will be suitable for the adjacent mild-steel structure. Higher-strength steel is to be extended to at least If_p/M_t above and below the neutral axis. Longitudinal framing members are to be continuous throughout the required extent of higher-strength steel.

5.1 Hull Girder Moment of Inertia

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

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

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

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

where

SM = section modulus as obtained from 3-2-1/3.7

Q = 0.78 for H32 strength steel

Q = 0.72 for H36 strength steel

Q = 0.68(1) for H40 strength steel

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

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 points or yield strengths will be specially considered.

5.5 Hull Girder Shearing Force

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

7 Loading Guidance

7.1 Loading Manual

All vessels are to be provided with a loading manual in accordance with Appendix 3-2-A2.

7.3 Allowable Stresses

7.3.1 At Sea

See 3-2-1/3.7.1 for bending stress and 3-2-1/3.9.1 for shear stress for vessels with ordinary strength steel material. For higher-strength steel, the allowable stress may be increased by a factor of $1/Q$ where Q is as defined in 3-2-1/5.5.

7.3.2 In Port

The allowable still water in-port stress is 13.13 kN/cm^2 (1.34 tf/cm^2, 8.5 Ltf/in^2) for bending and 10 kN/cm^2 (1.025 tf/cm^2, 6.5 Ltf/in^2) for shear. For higher-strength steel, the allowable stress may be increased by a factor of $1/Q$ where Q is as defined in 3-2-1/5.5.

9 Section Modulus Calculation

9.1 Items Included in the Calculation

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

- Deck plating (strength deck and other effective decks)
- Shell and inner bottom plating
- Deck and bottom girders

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

9.3 Effective Areas Included in the Calculation

In general, all openings are to be deducted from the sectional areas of longitudinal strength members to be used in the hull girder section modulus calculation, unless structural compensation of the cut-out is provided, except that small isolated openings need not be deducted, provided that these openings and the shadow area breadths of other openings in any one transverse section do not reduce the hull girder section modulus by more than 3%. The breadth or depth of such openings is not to be greater than 1200 mm (47 in.) or 25% of the breadth or depth of the member in which it is located whichever is less, with a maximum of 75 mm (3 in.) for scallops. The shadow area of an opening is the area forward and aft of the opening enclosed by lines drawn tangential to the corners of the opening and intersecting each other to form an included angle of 30 degrees.

9.5 Section Modulus to the Deck or Bottom

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

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

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

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

9.7.1 Top of Cargo Rails *(2017)*

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

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

where

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

x = distance, in m (ft), at the top of the cargo rail from the outboard edge of the continuous cargo rail web plate or pipe to the centerline of the vessel

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

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

9.7.2 Top of Longitudinal Side Walkways

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

11 Strength Decks

11.1 Definition

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

11.3 Tapering of Deck Sectional Areas

In general, the tapering of deck sectional areas beyond the amidship 0.4*L* is to be in accordance with 3-2-1/3.7.1(c). The deck sectional area at 0.15*L* from the ends may be one-half of the amidships deck area. In way of a superstructure beyond the amidship 0.4*L*, the strength deck area may be reduced to approximately 70% of the deck area required at that location if there were no superstructure.

13 Effective Lower Decks

To be considered effective, and in order to be included in calculating the hull girder section modulus, the thickness of the stringer plate and the deck plating is to comply with the requirements of 3-2-3/5. The sectional areas of lower decks used in calculating the section modulus are to be obtained as described in 3-2-1/9.3, but should exclude the cutout in the stringer plate in way of through frames. In general, where the still-water bending moment envelope curve is not submitted, or where 3-2-1/3.7.1(b) governs, these areas are to be maintained throughout the midship 0.4*L* and may be gradually reduced to one-half their midship value at 0.15*L* from the ends. Where bending moment envelope curves are used, the deck sectional areas are to be adequate to meet the hull girder section modulus requirements at the location being considered.

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

15 Longitudinal Deck Structures Inboard of Lines of Openings

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

Plating and stiffening members forming these structures may be included in the hull girder section modulus calculation, provided they are substantially constructed, well supported both vertically and laterally, and developed at their ends to be effectively continuous with other longitudinal structure located forward and abaft that point.

15.1 Effectiveness

The plating and longitudinal stiffening members of longitudinal deck structures complying with the basic requirements of the foregoing paragraph, supported by longitudinal bulkheads, in which the transverse slenderness ratio ℓ/r is not greater than 60, may be considered as fully effective in the hull girder section modulus. Longitudinal deck structures, not supported by longitudinal bulkheads, but of substantial construction having a slenderness ratio ℓ/r about any axis not greater than 60, based on the span between transverse bulkheads, or other major supports, may be considered as partially effective. The effective area, obtained as the product of the net sectional area of the longitudinal deck structure inboard of lines of hatch openings and the factor H_o, as given below, may be used in the hull girder section modulus calculations.

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

where

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

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

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

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

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

17 Buckling Strength for Vessels Over 61 m (200 ft) in Length *(2014)*

For vessels 90 m (295 ft) in length and greater, where the various strength members are subjected to compressive or shear stresses due to longitudinal bending, the stability of the local plate panels and the supporting members, including continuous cargo rails and walkways, are to be checked against buckling. Calculations, in accordance with Appendix 3-2-A3, are to be submitted for review.

For vessels between 61 m (200 ft) and 90 m (295 ft) in length, the deck and bottom plate panels are to be checked against buckling due to longitudinal bending. Calculations in accordance with Appendix 3-2-A3 are to be submitted for review.

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

PART
3

CHAPTER 2 Hull Structures and Arrangements

APPENDIX 1 Calculation of Shear Stresses for Vessels Having Plane Plate Longitudinal Bulkheads

1 Methods of Calculation

The nominal total shear stress f_s in the side shell or longitudinal bulkhead plating is related to the shear flow N at that point, by the following equation:

f_s = N/t, kN/cm^2 (tf/cm^2, Ltf/in^2)

N = shear flow, in kN/cm (tf/cm, Ltf/in)

t = thickness of the plating, in cm (in.)

3 Calculation of the Shear Flow Around Closed Sections

The shear flow of a closed and prismatic structure is expressed by the following equation.

N = $(F\,m/I) + N_i$, kN/cm (tf/cm, Ltf/in)

F = total shear force at the section under consideration, in kN (tf, Ltf)

m = first moment about the neutral axis of the section, in cm^3 (in^3), of the area of the longitudinal material between the zero shear level and the vertical level, at which the shear stress is being calculated

m = $\int_o^p Z\,t\,ds + \sum_{i=o}^{n} a_i z_i$ cm^3 (in^3)

I = moment of inertia of the section, in cm^4 (in^4)

N_i = constant shear flow around the cell regarded as an integration constant of unknown value arising from substituting the statically indeterminate structure by statically determinate one, in kN/cm (tf/cm, Ltf/in)

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

a = equivalent sectional area of the stiffener or girder attached to the deck, shell and bulkhead plating, in cm^2 (in^2)

s = length along girth and longitudinal bulkhead, in cm (in.)

5 Calculation of *m*

To calculate the value of m requires the knowledge or assumption of a zero shear point in the closed cell. As an example, in the case of a simplified tanker section, the deck point at the centerline is a known point of zero shear in the absence of the centerline girder. An arbitrary point may be chosen in the wing tank cell. Superposition of the constant N_i to the shear flow resulting from the assumption of zero shear point will yield to the correct shear flow around the wing cell.

7 Determination of N_i

N_i is determined by using Bredt's torsion formula, making use of the assumption that there is no twist in the cell section, i.e., the twist moment resulting from the shear flow around a closed cell should equal zero, or $\oint N \frac{ds}{t} = 0$. In a multicell structure of n number of cells, the formula can be written for the i^{th} cell as follows.

$$\oint_i N \frac{ds}{t} = \frac{F}{I} \oint_i m_i \frac{ds}{t} + N_{i-1} \int_{Div} \frac{ds}{t} + N_i \oint \frac{ds}{t} + N_{i+1} \int_{Div} \frac{ds}{t} = 0$$

Div = common division between cell i and the adjacent cells $i - 1$ and $i + 1$.

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

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

PART
3

CHAPTER 2 Hull Structures and Arrangements

APPENDIX 2 Loading Manuals

Note: These requirements are intended to satisfy Regulation 10(1) of the International Convention on Load Lines, 1966 and are applicable for vessels with freeboard length, L_f, of 65 meters (213 feet) and above.

1 General

1.1 Application

The requirements in this Appendix apply to all classed cargo vessels that are contracted for construction on or after 1 July 1998.

3 Definitions

3.1 Loading Manual

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

5 Required Loading Guidance

5.1 Loading Manual

The vessels are to be provided with a loading manual reviewed and stamped by ABS in accordance with 3-2-A2/7.

5.3 Modifications

Where modifications to the vessel or to the loading/trading pattern result in changes to the input information, a revised or new loading manual is to be submitted and a stamped copy is to be placed aboard the vessel to replace the existing manual.

Where changes due to modification of the vessel are such that the still water bending moments and shear forces corresponding to the new loading conditions are within ±2% of the existing allowable values, the existing allowable values need not be modified.

7 Loading Manual

7.1 Required Information *(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 upon which the design of this vessel is approved.

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

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

iv) Maximum allowable local lower decks and double bottom loading.

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

vi) Maximum allowable load on cargo deck. If the vessel is not intended to carry load on cargo deck 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 3-2-4/15.

7.3 Loading Conditions

The above information is to be based on the intended service conditions. See 3-2-A2/Table 1 for the selection of loading conditions.

7.5 Language

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

9 Annual Surveys

The requirements in 7-3-2/1.1.5 of the ABS *Rules for Survey After Construction (Part 7)* are to be complied with as follows:

At each Annual Survey, it is to be verified that the loading manual is onboard.

TABLE 1
Loading Conditions in the Loading Manual

1.	The loading manual is to include at least	
1.1	full load conditions, for both departure and arrival conditions,	
1.2	ballast conditions, for both departure and arrival conditions (see also 1.5)	
1.3	any other critical loading conditions on which the design of the vessel is based, including but not limited to:	
	1.3.1	anchor handling operations
	1.3.2	pipe laying and/or seabed trenching
	1.3.3	outboard weights lifting either with use of heavy cranes or A-frames
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/de-ballasting during the voyage.
	1.5.2	ballast exchange and its sequence, where intended,
	1.5.3	during loading/unloading where applicable,
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	homogeneous cargo if consistent with the service of the vessel	
2.2	heavy deck cargo with empty holds and/or tanks or non-homogeneous conditions	
2.3	cargo deck and/or lower decks or inner bottom cargoes	
2.4	cargoes of typical densities within the expected range	
2.5	high density cargoes	
2.6	part loaded conditions	
2.7	short voyages (e.g. half bunker)	
2.8	tank cleaning conditions	
2.9	docking conditions afloat	

PART
3

CHAPTER 2 Hull Structures and Arrangements

APPENDIX 3 Buckling Strength of Longitudinal Strength Members for Vessels Over 61 m (200 ft) in Length

1 Application

These requirements apply to plate panels and longitudinals subject to hull girder bending and shear stresses.

3 Elastic Buckling Stresses

3.1 Elastic Buckling of Plates

3.1.1 Compression

The ideal elastic buckling stress is given by:

$$\sigma_E = 0.9mE\left(\frac{t_b}{s}\right)^2 \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, lbf/in}^2\text{)}$$

For plating with longitudinal stiffeners (parallel to compressive stress):

$$m = \frac{8.4}{\Psi + 1.1} \quad \text{for } (0 \le \Psi \le 1)$$

For plating with transverse stiffeners (perpendicular to compressive stress):

$$m = c\left[1 + \left(\frac{s}{\ell}\right)^2\right]^2 \frac{2.1}{\Psi + 1.1} \quad \text{for } (0 \le \Psi \le 1)$$

where

E = 2.06×10^5 N/mm^2 (21,000 kgf/mm^2, 30×10^6 lbf/in^2)

t_b = net thickness of plating, in mm (in.), after making standard deductions as given in 3-2-A3/Table 1

s = shorter side of plate panel, in mm (in.)

ℓ = longer side of plate panel, in mm (in.)

c = 1.3 when plating stiffened by floors or deep girders

= 1.21 when stiffeners are angles or T-sections

= 1.10 when stiffeners are bulb flats

= 1.05 when stiffeners are flat bars

Ψ = ratio of smallest to largest compressive stress, σ_a (see 3-2-A3/7.1), varying linearly across panel.

3.1.2 Shear

The ideal elastic buckling stress is given by:

$$\tau_E = 0.9k_t E \left(\frac{t_b}{s}\right)^2 \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, lbf/in}^2\text{)}$$

where

$$k_t = 5.34 + 4\left(\frac{s}{\ell}\right)^2$$

E, t_b, s and ℓ are as defined in 3-2-A3/3.1.1.

3.3 Elastic Buckling of Longitudinals

3.3.1 Column Buckling without Rotation of the Cross Section

For the column buckling mode (perpendicular to plane of plating), the ideal elastic buckling stress is given by:

$$\sigma_E = \frac{EI_a}{c_1 A\ell^2} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, lbf/in}^2\text{)}$$

where

I_a = moment of inertia, in cm^4 (in^4), of longitudinal, including plate flange and calculated with thickness, as specified in 3-2-A3/3.1.1

A = cross-sectional area, in cm^2 (in^2), of longitudinal, including plate flange and calculated with thickness, as specified in 3-2-A3/3.1.1

ℓ = span, in m (ft), of longitudinal

c_1 = 1000 (1000, 14.4)

E = as defined in 3-2-A3/3.1.1

3.3.2 Torsional Buckling Mode

The ideal elastic buckling stress for the torsional mode is given by:

$$\sigma_E = \frac{\pi^2 EI_w}{10c_1 I_p \ell^2}\left(m^2 + \frac{K}{m^2}\right) + 0.385E\,\frac{I_t}{I_p} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, lbf/in}^2\text{)}$$

where

K = $c_2 \dfrac{C\ell^4}{\pi^4 EI_w}$

m = number of half waves given by 3-2-A3/Table 2

E = as defined in 3-2-A3/3.1.1

c_2 = 10^6 (10^6, 20736)

I_t = St. Venant's moment of inertia, in cm^4 (in^4), of profile (without plate flange)

= $c_3 \dfrac{h_w t_w^3}{3}$ for flat bars (slabs)

= $c_3 \dfrac{1}{3}\left[h_w t_w^3 + b_f t_f^3\left(1 - 0.63\dfrac{t_f}{b_f}\right)\right]$ for flanged profiles

c_3 = 10^{-4} (10^{-4}, 1.0)

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

= $c_3 \frac{h_w^3 t_w}{3}$ for flat bars (slabs)

= $c_3 \left(\frac{h_w^3 t_w}{3} + h_w^2 b_f t_f \right)$ for flanged profiles

I_w = warping constant, in cm^6 (in^6), of profile about connection of stiffener to plate

= $c_4 \frac{h_w^3 t_w^3}{36}$ for flat bars (slabs)

= $c_4 \left(\frac{t_f b_f^3 h_w^2}{12} \right)$ for "Tee" profiles

= $c_4 \frac{b_f^3 h_w^2}{12 \left(b_f + h_w \right)^2} [t_f (b_f{}^2 + 2 b_f h_w + 4 h_w{}^2) + 3 t_w b_f h_w]$ for angles and bulb profiles

c_4 = 10^{-6} (10^{-6}, 1.0)

h_w = web height, in mm (in.)

t_w = web thickness, in mm (in.), after making standard deductions, as specified in 3-2-A3/3.1.1

b_f = flange width, in mm (in.)

t_f = flange thickness, in mm (in.), after making standard deductions, as specified in 3-2-A3/3.1.1. For bulb profiles the mean thickness of the bulb may be used.

ℓ = span of profile, in m (ft)

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

C = spring stiffness exerted by supporting plate panel

= $\frac{k_p E \, t_p^3}{3s \left(1 + \frac{1.33 k_p h_w t_p^3}{s t_w^3} \right)}$ N (kgf, lbf)

k_p = $1 - \eta_p$, not to be taken less than zero

t_p = plate thickness, in mm (in.), after making standard deductions, as specified in 3-2-A3/3.1.1

η_p = $\frac{\sigma_a}{\sigma_{Ep}}$

σ_a = calculated compressive stress. For longitudinals, see 3-2-A3/7.1

σ_{Ep} = elastic buckling stress of supporting plate, as calculated in 3-2-A3/3.1

For flanged profiles, k_p need not be taken less than 0.1.

3.3.3 Web and Flange Buckling

For web plate of longitudinals the ideal buckling stress is given by:

$$\sigma_E = 3.8E\left(\frac{t_w}{h_w}\right)^2 \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, lbf/in}^2\text{)}$$

For flanges on angles and T-sections of longitudinals, the following requirements will apply:

$$\frac{b_f}{t_f} \le 15$$

b_f = flange width, in mm (in.), for angles, half the flange width for T-sections.

t_f = as built flange thickness, in mm (in.)

TABLE 1
Standard Deduction *(1 July 2012)*

Structure	*Standard Deduction*	*Limit Values min.-max. in mm (in.)*
— Compartments carrying dry bulk cargoes — One side exposure to ballast and/or liquid cargo Vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line	0.05*t*	0.5–1.0 (0.02–0.04)
— One side exposure to ballast and/or liquid cargo Horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line — Two side exposure to ballast and/or liquid cargo Vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line	0.10*t*	1.0 –3.0 (0.04–0.12)
— Two side exposure to ballast and/or liquid cargo Horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line	0.15*t*	1.5–4.0 (0.06–0.16)

TABLE 2
Number of Half Waves

	$0 < K \le 4$	$4 < K \le 36$	$36 < K \le 144$	$144 < K \le 400$	$(m-1)^2 m^2 < K \le m^2 (m+1)^2$
m	1	2	3	4	*m*

5 Critical Buckling Stresses

5.1 Compression

The critical buckling stress in compression, σ_c, is determined as follows:

$$\sigma_c = \sigma_E \qquad \text{when } \sigma_E \le \frac{\sigma_F}{2}$$

$$= \sigma_F\left(1 - \frac{\sigma_F}{4\sigma_E}\right) \qquad \text{when } \sigma_E > \frac{\sigma_F}{2}$$

where

σ_F = yield stress of material, in N/mm^2 (kgf/mm^2, lbf/in^2). σ_F may be taken as 235 N/mm^2 (24 kgf/mm^2, 34,000 lbf/in^2) for mild steel.

σ_E = ideal elastic buckling stress calculated according to 3-2-A3/3

5.3 Shear

The critical buckling stress in shear, τ_c, is determined as follows:

$$\tau_c = \tau_E \qquad \text{when } \tau_E \le \frac{\tau_F}{2}$$

$$= \tau_F \left(1 - \frac{\tau_F}{4\tau_E}\right) \qquad \text{when } \tau_E > \frac{\tau_F}{2}$$

where

$$\tau_F = \frac{\sigma_F}{\sqrt{3}}$$

σ_F = as given in 3-2-A3/5.1

τ_E = ideal elastic buckling stress in shear calculated according to 3-2-A3/3.1.2

7 Working Stress

7.1 Longitudinal Compressive Stress

The compressive stresses are given in the following formula:

$$\sigma_a = c_5 \frac{M_w + M_{sw}}{I_n} y \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, lbf/in}^2\text{)}$$

$$= \text{minimum } 30/Q \text{ N/mm}^2 \text{ (}3.1/Q \text{ kgf/mm}^2\text{, } 4400/Q \text{ lbf/in}^2\text{)}$$

where

M_{sw} = still water bending moment, as given in 3-2-1/3.7.1(a), in kN-m (tf-m, Ltf-ft)

M_w = wave bending moment, as given in 3-2-1/3.7.1(a), in kN-m (tf-m, Ltf-ft)

I_n = moment of inertia, in cm^4 (in^4), of the hull girder

y = vertical distance, in m (ft), from the neutral axis to the considered point

Q = as defined in 3-2-1/5.3 (1.0 for ordinary strength steel)

c_5 = 10^5 (10^5, 322,560)

M_w and M_{sw} are to be taken as sagging or hogging bending moments, respectively, for members above or below the neutral axis.

7.3 Shear Stresses

7.3.1 Vessels without Effective Longitudinal Bulkheads

The working shear stress, τ_a, in the side shell of vessels without effective longitudinal bulkheads is given by the following formula:

$$\tau_a = c_6 \frac{(F_{sw} + F_w) m_s}{2 t_s I} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, lbf/in}^2\text{)}$$

where

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

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

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

F_{sw} = hull girder shearing force in still water, in kN (tf, Ltf). See 3-2-1/3.3.

F_w = F_{wp} or F_{wn}, in kN (tf, Ltf), as specified by 3-2-1/3.5.3, depending upon loading

c_6 = 10 (10, 2240)

7.3.2 Vessels with Two or More Effective Longitudinal Bulkheads

The working shear stress, τ_a, in the side shell or longitudinal bulkhead plating is to be calculated by an acceptable method and in accordance with 3-2-1/3.9.4.

9 Scantling Criteria

9.1 Buckling Stress *(2017)*

The design buckling stress, σ_c, of plate panels and longitudinals (as calculated in 3-2-A3/5.1) is to be such that:

$$\sigma_c \geq \beta\sigma_a$$

where

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

= 1.1 for stiffeners

The critical buckling stress, τ_c, of plate panels (as calculated in 3-2-A3/5.3) is to be such that:

$$\tau_c \geq \tau_a$$

where

τ_a = working shear stress in the plate panel under consideration, in N/mm^2 (kgf/mm^2, lbf/in^2), as determined by 3-2-A3/7.3

Alternatively for transverse framing vessels between 61 meters (200 feet) and 90 meters (295 feet) in length, the deck and bottom plate may be taken not less than:

$$t = \frac{s}{45}\sqrt{\frac{SM_R}{SM_A}} \cdot \frac{1}{\sqrt{Q}} + t_k \quad \text{mm (in.)}$$

where

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

t_k = standard deduction as given in 3-2-A3/Table 1, in mm (in.)

s = frame spacing, in mm (in.)

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

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

Q = as defined in 3-2-1/5.3

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 2 Shell Plating

1 Application *(1 July 2012)*

Shell plating is to be of not less thickness than is required for purposes of longitudinal hull girder strength; including buckling strength, nor is it to be less than is required by this Section.

The shell plating is not to be less than:

$t_{sh\min} = sk\sqrt{qh}\ /254 + 2.5$ mm — but not less than 8.5 mm for side shell and 6.5 mm for bottom shell, or (s/150 + 2.5) mm, whichever is greater

$t_{sh\min} = sk\sqrt{qh}\ /460 + 0.10$ in. — but not less than 0.33 in. for side shell and 0.25 in. for bottom shell, or (s/150 + 0.10) in., whichever is greater

where

t = thickness, in mm (in.)

s = stiffener spacing, in mm (in.)

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

= 1.0 where $\alpha > 2$

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

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

Y = specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, lbs/in^2), as defined in 2-1-1/13 of the ABS *Rules for Materials and Welding (Part 2)*, for the higher-strength material or 0.7 of the specified minimum tensile strength, whichever is the lesser

h = the greatest of the following distances, in m (ft):

depth, D,

no less than $0.1L$ or $1.18d$, whichever is greater, if L is less than 90 m (295 ft)

in way of deep tanks, the distance from the lower edge of the plate under consideration to the top of the tank plus two thirds of the distance from the top of the tank to the top of the overflow [or a point located above the top of the tank at a distance not less than given in column (e) of 3-2-7/Table 2, appropriate to the vessel's length, if that would be greater]. If the specific gravity (SG) of liquid is greater than 1.05, the deep tank h is to be multiplied by the ratio of SG/1.05.

3 Shell Plating Amidships

3.1 Vessels with No Partial Superstructures above Uppermost Continuous Deck

In vessels that have no partial superstructures above the uppermost continuous deck, the thickness of the bottom and side plating is to be obtained from the appropriate equations where D_s is the molded depth, in m (ft), measured to the uppermost continuous deck.

3.3 Superstructures Fitted Above Uppermost Continuous Deck (Side Plating Extended)

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

3.5 Superstructures Fitted Above Uppermost Continuous Deck (Side Plating Not Extended)

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

3.7 In Way of Comparatively Short Superstructures

In way of comparatively short superstructure decks, or where the superstructure deck is not designed as the strength deck, the thickness of the bottom and side plating is to be obtained from the appropriate equations where D_s is the molded depth, in m (ft), measured to the uppermost continuous deck. In such cases, the thickness of the side plating above the uppermost continuous deck is to be specially considered, but in no case is the thickness to be less than that obtained from equations 1a and 1b in 3-2-3/Table 2, but substituting the frame spacing, in mm (in.), for s_b in lieu of the deck beam spacing.

3.9 Side Shell Plating *(1 July 2012)*

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

$$t_{shell1} = (s/645)\ \sqrt{(L-15.2)(d_s / D_s)}\ + 2.5 \quad \text{mm}$$

$$t_{shell2} = 0.035\ (L + 29) + 0.009s \quad \text{mm}$$

$$t_{shell1} = (s/1170)\ \sqrt{(L-50)(d_s / D_s)}\ + 0.1 \quad \text{in.}$$

$$t_{shell2} = 0.00042(L + 95) + 0.009s \quad \text{in.}$$

where

s = spacing of transverse frames or longitudinals, in mm (in.), not greater than 610 mm (24 in.) for t_{shell2} only

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

d_s = scantling draft, as defined in 3-1-1/9, in m (ft)

D_s = scantling depth, in m (ft), as defined in 3-2-2/3.1 through 3-2-2/3.7

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

3.11 Side Fenders *(1 July 2012)*

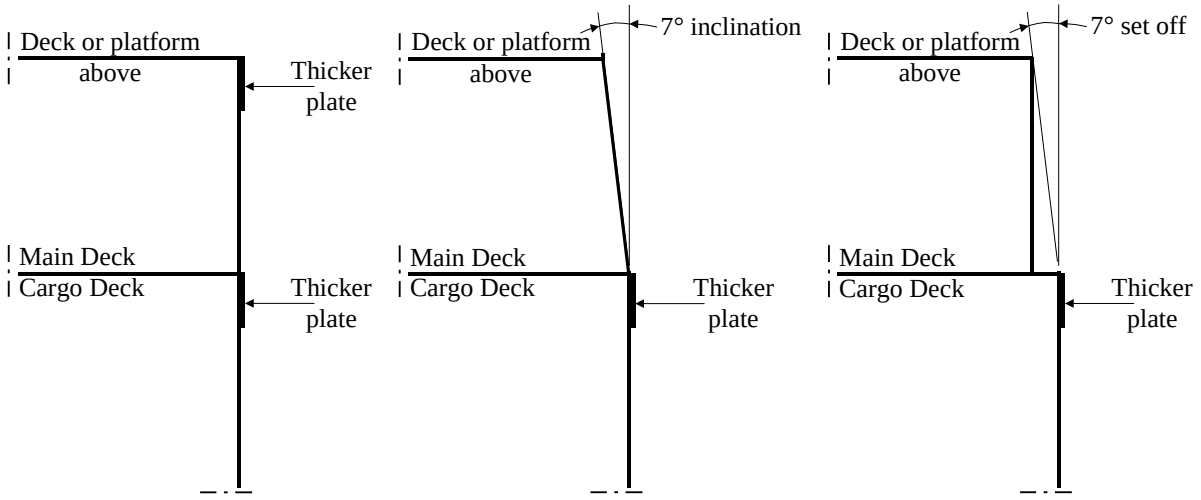
For vessels subject to impact loads during routine operations the minimum side shell thickness is to be $t = 1.25\ t_{shell2}$, unless effective permanent fenders as described in this Section are provided to protect the structure . Continuous longitudinal fenders are generally to be fitted on the side shell at cargo deck and at second deck above, if deck or platform there is fitted. The fenders are to extend from the stern to a point not less than 0.02*L* forward of the section at which the full deck's breadth starts decreasing; the area defined as an impact region. Additional fenders are to also be arranged diagonally at about 45° between the foregoing fenders, as necessary, to protect the side shell from the impact.

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

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

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

FIGURE 1
Side Impact Plates



3.13 Sheer Strake

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

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

$b = 1800$ mm for $L \geq 200$ m

$b = 0.06L + 31.5$ in. for $L < 656$ ft

$b = 71$ in. for $L \geq 656$ ft

where

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

b = width of sheer strake, in mm (in.)

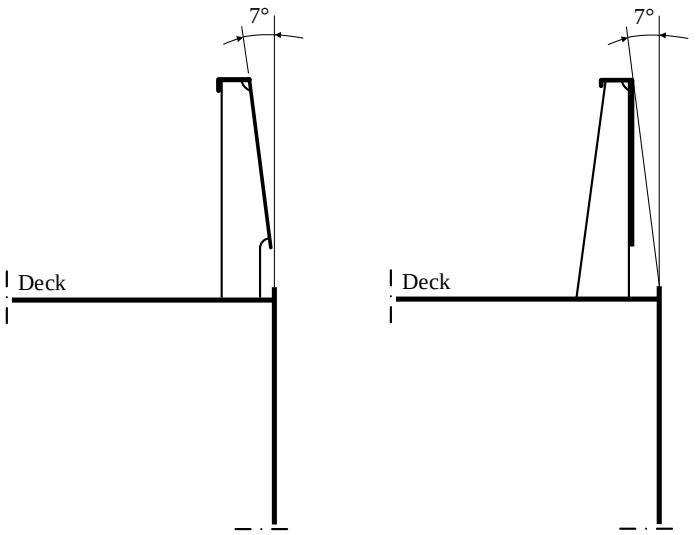
In general, the thickness of the sheer strake is not to be less than the thickness of the adjacent side shell plating, nor is it to be less than required by equation 1*b* or 2*b* in 3-2-3/Table 2, as appropriate, from *Decks-A* of 3-2-3/Table 1.

The thickness of the sheer strake is to be increased 25% in way of breaks of superstructures, but this increase need not exceed 6.5 mm (0.25 in.). Where breaks in way of the forecastle or poop are beyond the amidship 0.6*L*, this requirement may be reduced.

The top edge of the sheer strake is to be smooth and free of notches. Fittings and bulwarks are not to be welded to the top of the sheer strake within the amidships 0.8*L*, nor in way of superstructure breaks throughout (see 3-2-2/Figure 2).

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

FIGURE 2
Recommended Bulwark Fitting *(2017)*



3.15 Bottom Shell Plating Amidships

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

3.15.1 Bottom Shell Plating *(1 July 2012)*

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

Transverse Framing

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

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

Longitudinal Framing

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

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

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

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

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

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

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

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

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

iii) Adequate buckling strength is maintained.

$R_n = 1 \Big/ \sqrt{(f_p / \sigma_t)(1 - SM_R / SM_A) + 1}$, but may not be taken less than 0.85 nor more than 1.0

where

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

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

K = 0.5 for transverse framing and 0.34 for longitudinal framing

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

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

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

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

SM_R/SM_A is not to be taken less than 0.70

H = wave parameter, in m (ft)

= $(5.48L^2 + 16{,}045L)10^{-6} + 3.703$ m $\quad 61 \le L \le 220$ m

= $(4.5L - 0.0071L^2 + 103)10^{-2}$ m $\quad 220 < L \le 305$ m

= $(1.474L^2 + 16{,}055L)10^{-6} + 12.15$ ft $\quad 200 \le L \le 722$ ft

= $(4.5L - 0.00216L^2 + 335)10^{-2}$ ft $\quad 722 < L \le 1000$ ft

After all the allowable corrections are made, the bottom shell thickness amidships is not to be less than:

$t_{bottom} = 0.035(L + 29) + 5.5$ mm

$t_{bottom} = 0.00042(L + 95) + 0.216$ in.

where: L, as defined in 3-2-2/3.9.

3.15.2 Minimum Bottom Shell Plating

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

Transverse Framing

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

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

where

s = frame spacing, in mm (in.), but is not to be less than $2.08L + 438$ mm ($0.025L + 17.25$ in.)

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

Note: R_b (as defined below) for transverse framing may not be taken less than 0.85 or $1.2285 - L/533.55$ for SI or MKS units ($1.2285 - L/1750$ for US units), whichever is greater, where L is as defined above, but is not to be taken less than 122 m (400 ft).

Longitudinal Framing

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

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

where

s = frame spacing, in mm (in.), but is not to be less than $1.83L + 385$ mm ($0.022L + 15.2$ in.) or 813 mm (32 in.), whichever is less

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

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

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

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

iii) Adequate buckling strength is maintained.

$R_b = \sqrt{SM_R / SM_A}$ but is not to be taken less than 0.85 nor more than 1.0

where

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

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

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

5 Shell Plating at Ends

5.1 Minimum Shell Plating Thickness

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

$t = 0.035(L + 29) + 0.009s$ mm

$t = 0.00042(L + 95) + 0.009s$ in.

where

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

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

5.3 Immersed Bow Plating

The thickness t of the plating below the scantling draft forward of $0.16L$ from the stem is not to be less than is given by the following equation, but need not be greater than the thickness of the side shell plating amidships (see 3-2-2/1 and 3-2-2/3.9).

$t = 0.05(L + 20) + 0.009s$ mm

$t = 0.0006(L + 66) + 0.009s$ in.

where

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

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

5.5 Bottom Forward

Where the forward draft of the vessel in any of the submitted loading conditions is less than $0.04L$ m (ft), the plating on the flat of bottom forward, forward of the location given in 3-2-4/Table 1 is to be not less than required by the following equation:

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

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

where

s = frame spacing, in mm (in.)

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

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

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

The required thickness of the flat of bottom forward plating is also to be in accordance with the requirements given by 3-2-2/1, 3-2-2/3.13, 3-2-2/5.1, and 3-2-2/5.3, as appropriate.

5.7 Forecastle Side Plating

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

$$t = 0.0383(L + 114.5) + 0.006(s - S) \quad \text{mm}$$

$$t = 0.00046(L + 375) + 0.006(s - S) \quad \text{in.}$$

where

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

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

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

5.9 Poop Side Plating

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

$$t = 0.0334(L + 124.5) + 0.006(s - S) \quad \text{mm}$$

$$t = 0.0004(L + 408.5) + 0.006(s - S) \quad \text{in.}$$

where

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

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

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

5.11 Bow and Stern Thruster Tunnels

The thickness of the tunnel plating is not to be less than the greater thickness obtained from the following equations:

$$t_1 = 0.035(L + 29) + 0.009S \quad \text{mm}$$

$$t_2 = 0.008d + 3.3 \quad \text{mm}$$

$$t_1 = 0.00042(L + 95) + 0.009S \quad \text{in.}$$

$$t_2 = 0.008d + 0.13 \quad \text{in.}$$

where

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

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

d = inside diameter of the tunnel, in mm (in.), or 968 mm (38 in.), whichever is greater

Where the outboard ends of the tunnel are provided with bars or grids, the bars or grids are to be effectively secured, but arranged so, as to allow diver's access during underwater inspection of tunnels' interior.

5.13 Increased Thickness Plating

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

5.13.1 Spectacle Bossing

$$t = 0.084(L - 8) + 0.009s \quad \text{mm}$$

$$t = 0.001(L - 26) + 0.009s \quad \text{in.}$$

where

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

s = frame spacing, in mm (in.)

5.13.2 Other Plates on Stern Frame

$$t = 0.09(L - 5.5) + 0.009s \quad \text{mm}$$

$$t = 0.00108(L - 18) + 0.009s \quad \text{in.}$$

where

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

s = frame spacing, in mm (in.)

5.13.3 Boss and Heel Plates

The thickness of the boss and heel plating is to be at least 20% greater than the thickness of the spectacle bossing obtained in 3-2-2/5.13.1.

7 Bottom Shell Plating for Special Docking Arrangement for Vessels Over 90 m in Length

The thickness of the bottom shell plating strakes in way of the docking blocks used for drydocking the vessel is to be increased by 1.5 mm (0.06 in.). In such instances, the docking arrangement is to be indicated on the structural plans submitted for approval and on the docking plan being furnished to the vessel.

8 Moon Pools *(2016)*

8.1 General Arrangement

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

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

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

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

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

v) *(2017)* Means, such as moon pool covers, are to be provided to prevent personnel from falling into the moon pool.

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

8.3 Moon Pool Bulkhead Scantlings

Moon pool bulkhead is designed to comply with the following:

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

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

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

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

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

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

9 Compensation

Compensation is to be made where necessary for openings in the shell. In general, unless otherwise specifically required, openings in the shell are to have a minimum corner radius of 0.125 times the width of the opening, but not less than 150 mm (6 in.) and need not exceed a radius of 600 mm (24 in) in the bottom shell and side shell within 0.1D above the base line and below the gunwale and 450 mm (18 in) elsewhere in the side shell. Any minor openings which must unavoidably be cut in the plating are to be kept as small as possible and are to be circular or oval in form.

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

11 Breaks

Side shells of vessels having partial superstructures are to be specially strengthened in way of breaks to limit the local increase in stresses at these locations. The stringer plate thickness and the sheer strake thickness at the lower level is to be doubled or increased in thickness well beyond the break in both directions. The thickness increase is to be 25% in way of breaks in the superstructures, but the increase need not exceed 6.5 mm (0.25 in.). The side plating of the superstructure is to be increased in thickness in way of the break. The thickness of the sheer strake and the side shell plating below the sheer strake in way of the break are to be increased appropriately and are to extend well beyond the end of the superstructure in both directions in such a fashion as to provide a long gradual taper. Where the breaks of the forecastle or poop are beyond the amidship 0.6L, these requirements may be modified.

13 Bilge Keels

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

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

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

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

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

14 Bilge Plating *(2016)*

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

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

where

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

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

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

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

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

15 Higher-strength Materials

15.1 General

In general, applications of higher-strength materials for shell plating are to take into consideration the suitable extension of the higher-strength material above and below the bottom and deck, respectively, as required by 3-2-1/5.1. Calculations to show adequate provision against buckling are to be submitted. Care is to be taken against the adoption of reduced thickness of material that might be subject to damage during normal operation. The thickness of the bottom and side shell plating, where constructed of higher-strength materials, is to be not less than required for the purpose of longitudinal hull girder strength; nor is the thickness to be less than required by the foregoing paragraphs of this Section when modified as indicated in 3-2-2/15.3 and 3-2-2/15.5.

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

15.3 Bottom Plating of Higher-strength Material *(1 July 2012)*

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

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

where

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

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

The requirements $t_{\min}$ in 3-2-2/3.15.2 are to be used in the above equation with the factor $0.92/\sqrt{Q}$ substituted for Q. The value of $0.92/\sqrt{Q}$ is not to be less than 1.00.

C = 4.3 mm (0.17 in.)

Q = as defined in 3-2-1/5.3

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

15.5 Side Plating of Higher-strength Material

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

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

t_{hts}, t_{ms}, C and Q are as defined in 3-2-2/15.3

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

15.7 End Plating

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

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 3 Decks

1 General

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

3 Hull Girder Strength

3.1 Longitudinal Section Modulus Amidships

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

3.3 Strength Deck

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

3.5 Longitudinally Framed Decks

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

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

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

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

3.7 Superstructure Decks

Superstructure decks which are comparatively short (0.1*L* or less in length) (see 3-2-2/3.7 and 3-2-3/3.3) are to comply with the requirements of 3-2-11/1.3.

3.9 Deck Transitions

Where the effective areas in the same deck change, as in way of partial superstructures or over discontinuous decks, care is to be taken to extend the heavier plating well into the section of the vessel in which the lesser requirements apply, to obtain a good transition from one arrangement to the other. Partial decks within the hull are to be tapered off to the side shell or longitudinal bulkheads by means of long brackets. Where effective decks change in level, the change is to be accomplished by a very gradually sloping section or the deck material at each level is to be effectively overlapped and thoroughly connected together by longitudinal plate diaphragms or webs, of sufficient shear area to transmit the hull girder bending forces between the two levels of strength decks.

3.11 Deck Plating

Deck plating is to be of not less thickness than is required for purposes of longitudinal hull girder strength. The thickness of the stringer plate is to be increased 25% in way of breaks of superstructures, but this increase need not exceed 6.5 mm (0.25 in.). This requirement may be modified where the breaks of poop or forecastle are beyond the midship 0.6*L*. The required deck area is to be maintained throughout the amidship 0.4*L* of the vessel. From 0.4*L* amidship to the ends of the vessel, the deck area contributing to the hull girder strength may be gradually reduced in accordance with 3-2-1/11.3.

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

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

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

Where bending moment envelope curves are used to determine the required hull girder section modulus, the foregoing requirements for deck area may be modified in accordance with 3-2-1/11.3. Where so modified, the strength deck area is to be maintained as required in the preceding requirements to provide adequate structural continuity. The thickness of the deck plating is also not to be less than given in 3-2-3/5.1.

5 Deck Plating

5.1 Thickness

Generally, the thickness of deck plating is to be not less than obtained from the applicable equations specified in 3-2-3/Table 1.

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

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

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

where

t = thickness, in mm (in.)

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

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

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

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

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

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

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

5.3 Effective Lower Decks

For use as an effective lower deck in calculating the hull girder section modulus, the thickness of the plating is to be not less than obtained according to 3-2-3/Table 1 appropriate to the depth D_S and the deck's stringer plate is to be connected to the shell. In no case is the plating to be less than obtained from I or J in 3-2-3/Table 1, as appropriate.

5.5 Reinforcement at Openings

5.5.1 Openings in Strength Decks and Effective Decks

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

5.5.2 In Way of Machinery Space

In way of the machinery spaces, special attention is to be paid to the maintenance of lateral stiffness by means of webs and heavy pillars in way of deck opening and casings. Pillars are to extend down to the double bottom and are to be fitted in line with each other.

5.7 Platform Decks

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

5.9 Superstructure Decks

See 3-2-11/1.3.

5.11 Decks over Tanks

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

5.13 Watertight Flats

The thickness of watertight flats over tunnels, or watertight flats forming recesses or steps in bulkheads, is to be not less than the thickness required for the plating of ordinary bulkheads at the same level, plus 1 mm (0.04 in.).

5.15 Retractable Tween Decks

The thickness of retractable tween deck plating is not to be less than required by equation 6 of 3-2-3/Table 2. The edges of the deck panels are to be stiffened to provide the necessary rigidity.

The beams and girders, in association with the plating to which they are attached, are to have section modulus, SM, not less than obtained from the following equation.

$$SM = kchs\ell^2 \quad \text{cm}^3 \ (\text{in}^3)$$

where

k = 7.8 (0.0041)

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

= 1.00 for the section modulus to the deck plating

h = p/7.01m (p/715 m, p/44.7ft)

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

s = spacing of the beam or girder, in m (ft)

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

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

When retractable decks are intended for the operation or stowage of vehicles having rubber tires, the thickness of the deck plating is to be not less than required by 3-2-15/11.3. The retractable decks are to be secured against movement and effectively supported by the hull structure.

5.17 Wheel Loading *(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 the plating of an effective lower deck (see 3-2-3/5.3) is not to be less than obtained from the following equation:

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

where

k = 8.05 (25.2, 1.0)

K = $[21.99 + 0.316(a/s)^2 - 5.328(a/s) + 2.6(a/s)\,(b/s) - 0.895(b/s)^5 - 7.624(b/s)]10^{-2}$, derived from the curves indicated in 3-2-3/Figure 2

n = 1.0 for $\ell/s \geq 2.0$ and 0.85 for $\ell/s = 1.0$,

= $0.85 + 0.15(\ell/s - 1.0)$ for $1.0 < \ell/s < 2.0$

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

W = static wheel load, in kN (tf, Ltf)

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

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

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

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

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

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

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

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

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

TABLE 1
Applicable Thickness Equations *(2017)*

Decks	*Minimum Thickness Equation in Table 2*
A. Strength Deck or Long Superstructure Decks Outside Line of Openings	
1. With Transverse Beams	1a and 1b (note 1)
2. With Longitudinal Beams	2a and 2b (note 1)
B. Exposed Strength Deck within Line of Openings	3 (note 2)
C. Enclosed Strength Deck or Long Superstructure Decks within Line of Openings	5
D. Effective Lower Decks	
1. Second Deck:	
a. D_S > 15.2 m (50 ft)	1a
b. 15.2 m (50 ft) ≥ D_S ≥ 12.8 m (42 ft)	2a
c. D_S < 12.8 m (42 ft)	3
2. Third Deck:	
a. D_S > 17.7 m (58 ft)	1a
b. 17.7 m (58 ft) ≥ D_S ≥ 13.4 m (44 ft)	2a
c. 13.4 m (44 ft) ≥ D_S ≥ 9.8 m (32 ft)	3
d. D_S < 9.8 m (32 ft)	4
E. Exposed Forecastle Decks	
1. L > 122 m (400 ft)	2a
2. L ≤ 122 m (400 ft)	3
F. Exposed Poop Decks	
1. L > 100 m (330 ft)	3
2. L ≤ 100 m (330 ft)	5
G. Exposed Decks Above Poop/Forecastle Decks	4
H. Long Deckhouse Tops and other Enclosed Decks	5
I. Platform Decks in Enclosed Cargo Spaces	6
J. Enclosed decks in Accommodation spaces	7

Notes:

1 *(1 July 2012)* In small vessels where the required area for longitudinal strength is relatively small, it may be disposed in the stringer plate and in the strake alongside openings in plating of thickness not less than that obtained from the equations in 1a and 1b. In such cases the remainder of the plating may be obtained from the equation in 5.

2 *(1 July 2012)* Equation 3 applies amidships. At the forward and aft ends, plating is to be as required for the exposed forecastle and poop deck

FIGURE 1
Decks and Tiers Allocation *(2017)*

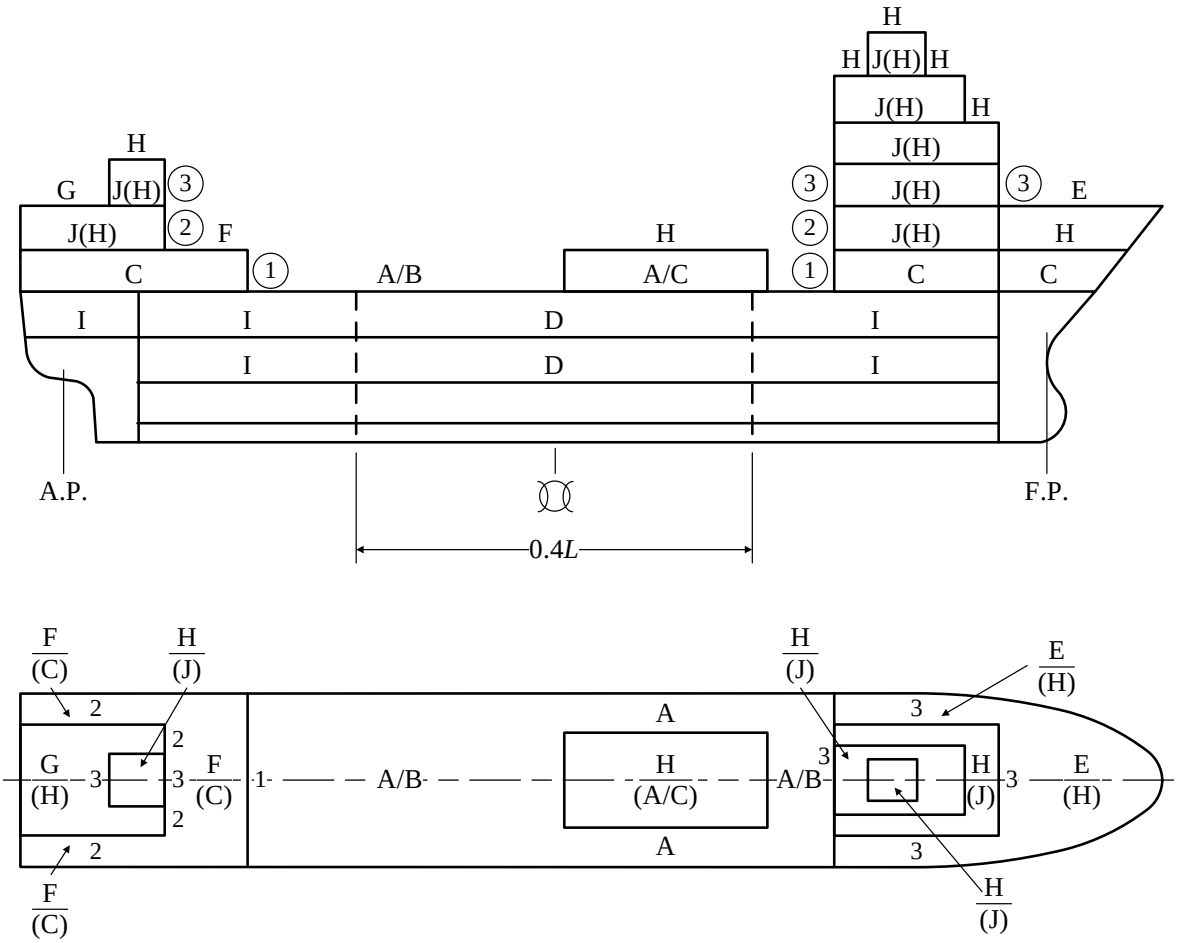


FIGURE 2
Wheel Loading Curves of "*K*"

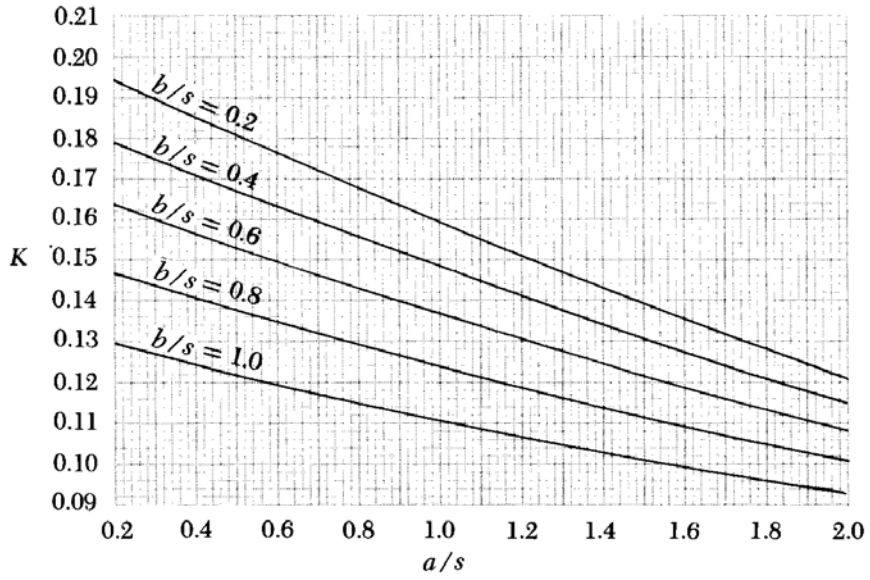


TABLE 2
Minimum Thickness Equations *(1 July 2012)*

Equation Number	*Equation*	
1a (notes 1,2)	$t = 0.01s_b + 2.3$ mm	for $s_b \le 760$ mm
	$t = 0.0066s_b + 4.9$ mm	for $s_b > 760$ mm
	$t = 0.01s_b + 0.09$ in.	for $s_b \le 30$ in.
	$t = 0.0066s_b + 0.192$ in.	for $s_b > 30$ in.
1b (notes 1,3)	$t = \dfrac{s_b(L + 45.73)}{25L + 6082}$ mm	
	$t = \dfrac{s_b(L + 150)}{25L + 19950}$ in.	
2a (notes 1,2)	$t = 0.009s_b + 2.4$ mm	for $s_b \le 760$ mm
	$t = 0.006s_b + 4.7$ mm	for $s_b > 760$ mm
	$t = 0.009s_b + 0.095$ in.	for $s_b \le 30$ in.
	$t = 0.006s_b + 0.185$ in.	for $s_b > 30$ in.
2b (notes 1,3)	$t = \dfrac{s_b(L + 48.76)}{26L + 8681}$ mm	for $L \le 183$ m
	$t = \dfrac{24.38s_b}{1615.4 - 1.1L}$ mm	for $183 < L \le 305$ m
	$t = \dfrac{s_b(L + 160)}{26L + 28482}$ in.	for $L \le 600$ ft
	$t = \dfrac{80s_b}{5300 - 1.1L}$ in.	for $600 < L \le 1000$ ft
3	$t = 0.01s_b + 0.9$ mm	for $s_b \le 760$ mm
	$t = 0.0067s_b + 3.4$ mm	for $s_b > 760$ mm
	$t = 0.01s_b + 0.035$ in.	for $s_b \le 30$ in.
	$t = 0.0067s_b + 0.134$ in.	for $s_b > 30$ in.
4	$t = 0.01s_b + 0.25$ mm	for $s_b \le 760$ mm
	$t = 0.0043s_b + 4.6$ mm	for $s_b > 760$ mm
	$t = 0.01s_b + 0.01$ in.	for $s_b \le 30$ in.
	$t = 0.0043s_b + 0.181$ in.	for $s_b > 30$ in.
5	$t = 0.009s_b + 0.8$ mm	for $s_b \le 760$ mm
	$t = 0.0039s_b + 4.3$ mm	for $s_b > 760$ mm
	$t = 0.009s_b + 0.032$ in.	for $s_b \le 30$ in.
	$t = 0.0039s_b + 0.17$ in.	for $s_b > 30$ in.
6	$t = Ks_b\sqrt{h} + a$ mm (in.) but not less than 5.0 mm (0.20 in.) $K = 0.00394$ (0.00218) $a = 1.5$ mm (0.06 in.) h = tween deck height in m (ft) When a design load is specified, h is to be taken as p/n where p is the specified design load in kN/m^2 (kgf/m^2, lbf/ft^2) and n is defined as 7.01 (715, 44.7)	
7	$t = 0.0058s_b + 1.0$ mm $t = 0.0058s_b + 0.04$ in. but not less than 4.5 mm (0.18 in.)	

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

TABLE 2 (continued)
Minimum Thickness Equations *(1 July 2012)*

Notes:

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

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

3 To extend over 0.4*L* amidships and tapered beyond in a manner the same as in 3-2-1/11.3. Vessels designed on still water bending moment envelope curves will be specially considered.

7 Higher-strength Material

7.1 Thickness

In general, proposed applications of higher-strength material for decks are to be accompanied by submission of calculations in support of adequate strength against buckling. Care is to be taken to avoid reducing thickness of material such as might be subject to damage during normal operation. The thickness of deck plating for longitudinal framed decks, where constructed of higher-strength material, is to be not less than required for longitudinal strength, nor is it to be less than obtained from the following equations, whichever is greater:

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

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

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

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

where

t_{ms1} = thickness of ordinary-strength steel, in mm (in.), as required by these Rules

t_{ms2} = thickness of ordinary-strength steel, in mm (in.), obtained from 3-2-3/Table 2, equation 2b

Q = as defined in 3-2-1/5.5, however the factor $0.92/\sqrt{Q}$ is not to be taken less than 1.0

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

7.3 Wheel Loading

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

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

where

t_{ms} = thickness of ordinary-strength steel, as obtained from 3-2-3/5.15

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

Y = specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, lbs/in^2), as defined in 2-1-1/13 of the ABS *Rules for Materials and Welding (Part 2)* for the higher-strength material or 0.72 of the specified minimum tensile strength, whichever is the lesser

9 Deck Covering Compositions

Deck covering compositions are to be of materials which are not destructive to steel, or they are to be effectively insulated from the steel by a noncorrosive protective covering. Samples may be taken by the Surveyor from the composition while it is being laid, in which case the samples are to be subject to independent analysis at the manufacturer's expense. The steel plating is to be thoroughly cleaned with alkaline solution before the composition is laid. Large areas of deck are to be divided by cabin sills, angles, etc., and unless otherwise approved, holdfasts are to be fitted not more than 915 mm (3 ft) apart. Deck coverings within accommodation spaces on the decks forming the crown of machinery and cargo spaces are to be of a type that will not ignite readily.

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

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 4 Bottom Structures

1 Double Bottoms

1.1 General

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

Where, for specific reasons, the inner bottom must be omitted, the arrangements are to be clearly indicated on the plans submitted for approval. A double bottom need not be fitted in way of deep tanks, provided the safety of the vessel in the event of bottom damage is not thereby impaired. It is recommended that the double bottom be arranged to protect the bilges as much as possible and that it be extended to the sides of the vessel.

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

1.3 Testing

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

3 Center and Side Girders

3.1 Center Girder *(1 July 2012)*

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

For vessels which have a length equal or greater than 90 m (295 feet), manholes may be cut in every frame space outside the amidship 0.75*L*. Elsewhere, the minimum practical number of manholes for adequate access and ventilation may be provided, but the depth of the manholes is not to exceed one-third the depth of the center girder. Compensation for the manholes within the amidship 0.75*L* is to be provided.

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

3.1.1 General

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

Center girder plates are to be of the thickness given by the following equations, between the peak bulkheads. In peaks, the center girder plates are to be of the thickness of the peak floors. Where longitudinal framing is adopted, the center girder plate is to be suitably stiffened between floors and docking brackets are to be provided in accordance with 3-2-4/3.7.

Where the length of the cargo hold is greater than 1.2*B* or exceeds 0.25*L*, or where the vessel is intended to carry heavy cargoes on double bottom, the thickness of center girder plates is to be specially considered based on the results of a direct structural calculations.

3.1.1(a) Thickness Amidships

$t = 0.056L + 5.5$ mm

$t = 0.00067L + 0.22$ in.

3.1.1(b) Thickness at Ends

85% of the thickness required amidships

3.3 Pipe Tunnels as an Alternative Arrangement of Center Girders

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

3.5 Docking Brackets for Center Girder and Side Girders

Docking brackets are to be provided on the girders when the spacing of the floors exceeds 2.4 m (8 ft), unless calculations are submitted to verify that the girders provide sufficient stiffness and strength for docking loads. Where the docking arrangement is such that the side girders or bulkheads are subject to docking loads, such arrangement is to be indicated on the submitted structural plan, and docking brackets are to be fitted on those members where the spacing of floors exceeds the foregoing limit.

3.7 Side Girders

Amidships and aft, side girders of the thickness obtained from the equation of 3-2-4/5 are to be so arranged that the distance from the center girder to the first side girder, the distance between the girders, and the distance from the outboard girder to the center of the margin plate does not exceed 4.8 m (16 ft). At the fore end, they are to be arranged as required by 3-2-4/13.5 or 3-2-4/13.7, as appropriate. Additional full or half-depth girders are to be fitted beneath the inner bottom in way of machinery and thrust seatings and beneath wide-spaced pillars. Where the bottom and inner bottom are both longitudinally framed, this requirement may be accordingly modified.

5 Solid Floors

5.1 General *(2017)*

Solid floors (see 3-2-4/Figure 1) of the thickness obtained from the following equations (and 3-2-4/5.5, where applicable), are to be fitted on every frame (600 mm to 800 mm) under machinery, under the outer ends of bulkhead stiffener brackets and at the forward end (see 3-2-4/13.5 or 3-2-4/13.7, as appropriate). For machinery spaces other than engine rooms and for generators installed in engine room, alternate spacing of the floors in way of machinery may be considered based on detailed structural analysis. Elsewhere, they may have a maximum spacing of 3.66 m (12 ft) in association with intermediate open floors (see 3-2-4/7), or longitudinal framing of the bottom and/or inner bottom plating. With the latter, the floors are to have stiffeners and/or brackets supporting each longitudinal or an equivalent arrangement is to be provided.

$t = 0.036L + 4.7 + c$ mm

$t = 0.00043L + 0.185 + c$ in.

where

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

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

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

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

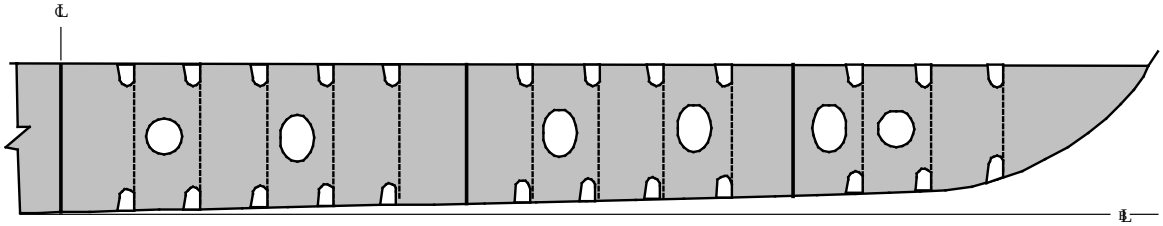
5.3 Tank-end Floors

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

5.5 Floor Stiffeners

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

FIGURE 1
Double-bottom Solid Floors



7 Open Floors

7.1 General

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

7.3 Bottom Shell Frames and Reverse Frames *(2014)*

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

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

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

where

s = spacing of frames, in m (ft)

c = 1.0 without struts

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

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

ℓ = the greatest distance, in m (ft), between the connecting brackets or intercostals, as shown in 3-2-4/Figure 2. Where effective struts are fitted and the tank top is intended to be uniformly loaded with cargo, ℓ may be taken as 85% of the distance between supports, as determined above.

7.5 Center and Side Brackets

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

7.7 Struts *(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 3-2-8/3.1. The calculated load W is to be determined by:

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

where

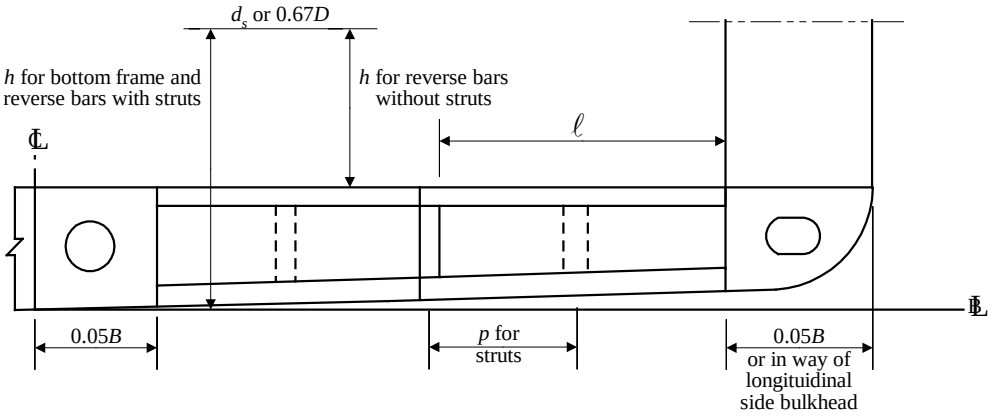
n = 10.5 (1.07, 0.03)

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

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

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

FIGURE 2
Double-bottom Open Floors



9 Inner-bottom Plating

9.1 Inner-bottom Plating Thickness

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

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

$$t = 0.000444L + 0.009s - c + b \quad \text{in.}$$

where

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

s = frame spacing, in mm (in.)

c = 0.5 mm (0.02 in.) with transverse framing

= 1.5 mm (0.06 in.) with longitudinal framing

b = 2.0 mm (0.08 in.) in way of hatchways when close ceiling, as defined in 3-2-18/1, is not fitted on the inner bottom

9.3 Center Strakes

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

9.5 Inner Bottom Plating for Vessels Intended to Use Grabs *(2018)*

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

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

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

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

where

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

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

Q is as defined in 3-2-1/5.5.

The thickness of sloping bulkhead plating of lower wing tanks and lower stool plating of transverse bulkheads within a vertical extent of 1.5 m (0.06 in.) above the inner bottom is not to be taken less than t_{g1} with the actual spacing of the sloping bulkhead and stool stiffeners.

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

9.6 Optional Supplementary Requirement for Vessels Intended to Use Grabs *(2018)*

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

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

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

where

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

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

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

s_e = 1000 mm (39.37 in.) where $W_g \le 20$ tonnes (19.684 Ltons)

= $1000 + \sqrt{(k_4 W_g - 31.2)10^3 - W_g^2/k_5}$ mm where W_g > 20 tonnes

= $39.37[1 + \left(\sqrt{(k_4 W_g - 31.2)10^3 - W_g^2/k_5}\right)/1000]$ in. where W_g >19.684 Ltons

k_4 = 1.58 (1.605) where W_g is in tonnes (Ltons)

k_5 = 1.0 (0.969) where W_g is in tonnes (Ltons)

Q is as defined in 3-2-1/5.5.

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

9.7 Wheel Loading

Where provision is to be made for the operation or stowage of vehicles having rubber tires, and after all other requirements are met, the thickness of the inner bottom plating is to be not less than obtained from 3-2-3/5.15.

11 Bottom and Inner-bottom Longitudinals

11.1 General

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

11.3 Bottom Longitudinals *(2014)*

Each bottom longitudinal frame similar to that shown in 3-2-4/Figure 3, in association with the plating to which it is attached, is to have a section modulus SM not less than that obtained from the following equation:

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

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

where

c = 1.3 without struts

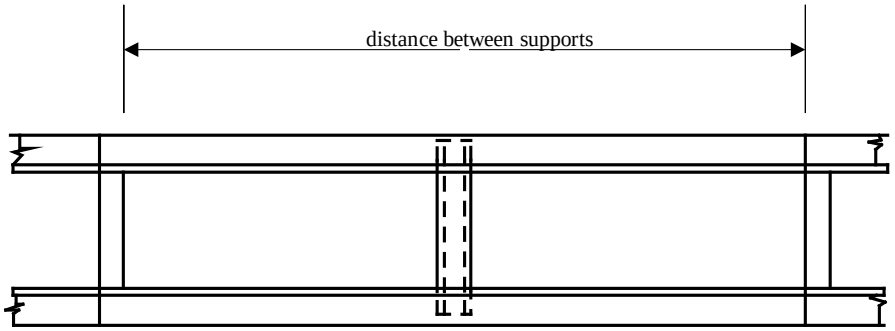
= 0.715 with effective struts

h = d_s or $0.67D_s$ in m (ft), as defined in 3-1-1/9, whichever is greater. In way of deep tanks, h is the greatest distance from the middle of ℓ to a point located at two-thirds of the distance from the top of the tank to the top of the overflow; a point located above the top of the tank at a distance not less than given in column (e) of 3-2-7/Table 2, appropriate to the vessel's length, whichever is greatest.

s = spacing of longitudinals, in m (ft)

ℓ = distance, in m (ft), between the supports, but is not to be taken as less than 1.83 m (6 ft) without struts or 2.44 m (8 ft) with struts. Where effective struts are fitted and the tank top is intended to be uniformly loaded with cargo, ℓ may be taken as 85% of the distance between supports subject to above minimum.

FIGURE 3
Longitudinal Framing



11.5 Inner Bottom Longitudinals *(2014)*

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

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

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

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

iii) Adequate buckling strength is maintained.

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

where

n = 8.278 (0.852, 5.36)

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

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

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

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

13 Single Bottoms with Longitudinal or Transverse Frames

13.1 General

Where longitudinal frames supported by bottom transverses or transverse frames supported by longitudinal girders and bottom transverses are proposed for a non SOLAS vessel, 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 4, 3-2-4/Figure 5 and 3-2-4/Figure 6.

FIGURE 4
Round Bottom Floors with Deadrise

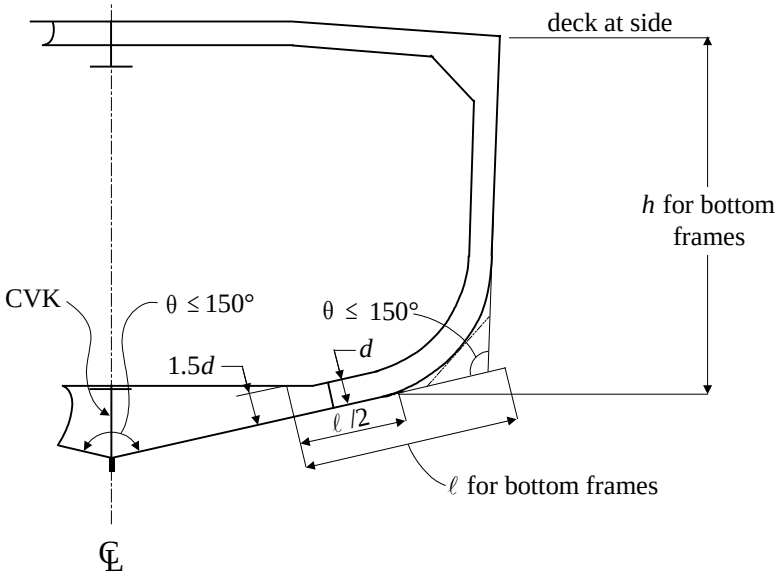


FIGURE 5
Transverse Bottom Frames with Longitudinal Side Girders

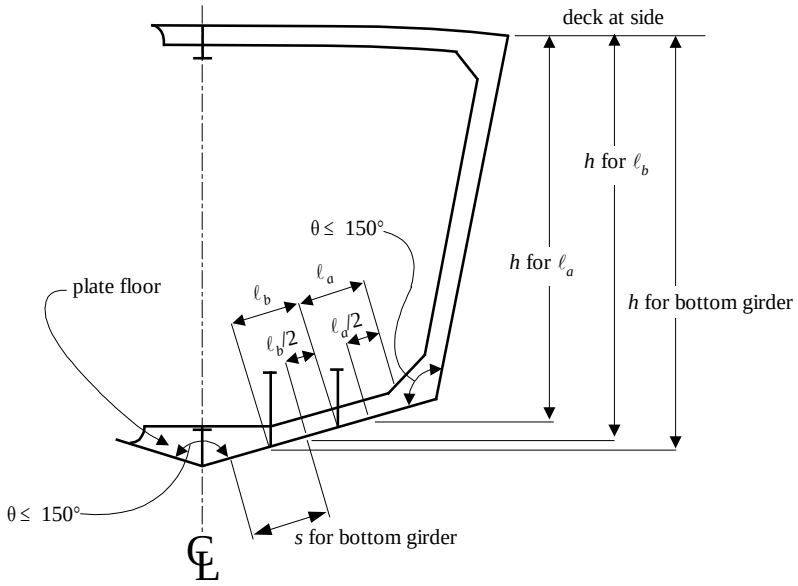
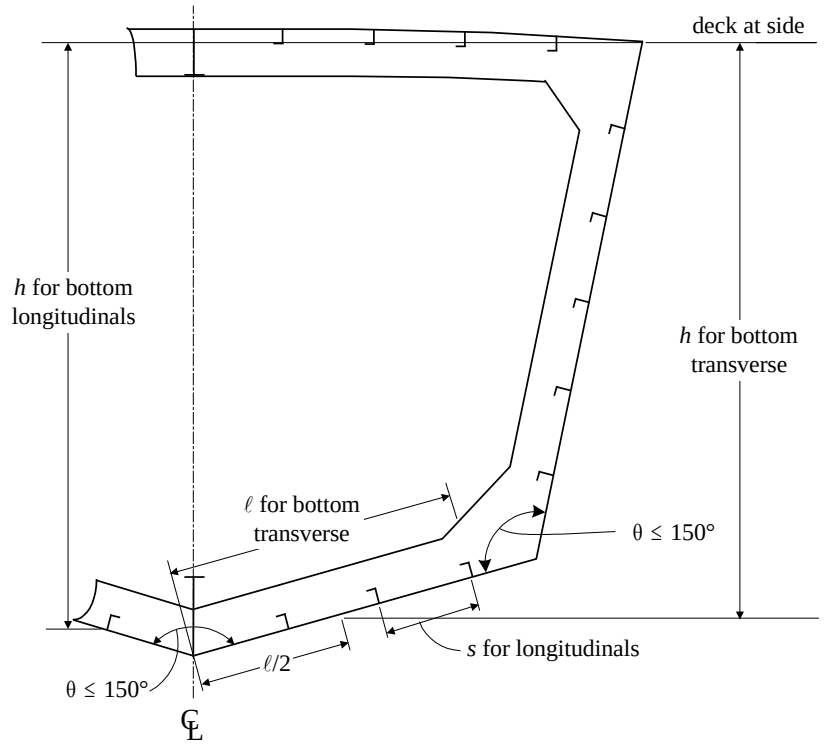


FIGURE 6
Longitudinal Frames with Transverse Webs



13.3 Bottom Girders and Transverses

13.3.1 Section Modulus

The section modulus, *SM*, of each bottom girder and transverse, where intended as a primary supporting member, in association with the plating to which it is attached, is not to be less than that obtained from the following equation:

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

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

where

c = 0.915

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

s = spacing, in m (ft)

ℓ = unsupported span, in m (ft).

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

13.3.2 Depth

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

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

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

where

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

ℓ is defined in 3-2-4/13.3.1.

13.3.3 Thickness

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

$t = 0.01h_w + 3$ mm

$t = 0.01h_w + 0.12$ in.

where

t = floor thickness, in mm (in.)

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

13.3.4 Non-prismatic Members

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

13.5 Center Girder

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

13.7 Frames

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

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

$SM = 0.0041chs\ell^2$ 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)

h = vertical distance, in m (ft), from the middle of ℓ to the deck at side. In way of a deep tank, h is the greatest of the distances, in m (ft), from the middle of ℓ to a point located at two-thirds of the distance from the top of the tank to the top of the overflow, a point located above the top of the tank not less than $0.01L + 0.15$ m ($0.01L + 0.5$ ft) or 0.46 m (1.5 ft), whichever is greatest.

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

15 Fore-end Strengthening

15.1 General

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

15.3 Extent of Strengthening

The flat of bottom forward is defined as being forward of the locations indicated in 3-2-4/Table 1. Aft of these locations, a suitable transition is to be obtained between the increased scantlings and structural arrangements of the flat of bottom forward and the structure aft of the locations given in 3-2-4/Table 1.

15.5 Longitudinal Framing

When longitudinal framing is used for the bottom and inner bottom, longitudinals and side girders are to be continued as far forward as practicable at not more than their amidship spacing. The section modulus of flat of bottom longitudinals forward of the location indicated in 3-2-4/Table 1 is to be not less than required by the following equation, nor less than required by 3-2-4/11.3.

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

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

Where

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

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

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

s = spacing of longitudinals, in m (ft)

ℓ = distance between floors, in m (ft)

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

15.7 Transverse Framing

Where the heavy weather ballast draft forward is less than 0.04*L* m (ft), solid floors are to be fitted on every frame, and additional full-depth and half-depth side girders are to be introduced so, that the spacing of full-depth girders forward of the location in 3-2-4/Table 1 does not exceed 2.44 m (8 ft) and that the spacing of alternating half and full-depth girders forward of the location in 3-2-4/Table 1 does not exceed 1.22 m (4 ft).

TABLE 1
Extent of Strengthening

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

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

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

17 Higher-strength Materials

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

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

17.3 Inner-bottom Plating

Inner-bottom plating constructed of higher-strength material and where longitudinally framed, is to be not less in thickness than required by 3-2-4/9.1 or 3-2-10/3.5, as modified by the following equation.

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

where

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

t_{ms} = thickness of mild steel, as required by 3-2-4/9.1 or 3-2-10/3.5, in mm (in.), increased where required by 3-2-4/9.1 for no ceiling

C = 3 mm (0.12 in.)

= 5 mm (0.20 in.) where the plating is required by 3-2-4/9.1 to be increased for no ceiling

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

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

17.5 Bottom and Inner-bottom Longitudinals

The section modulus of bottom and inner-bottom longitudinals, where constructed of higher-strength material and in association with the higher-strength plating to which they are attached, is to be determined as indicated in 3-2-4/11.3, except that the value may be reduced by the factor Q, as defined in 3-2-1/5.5.

17.7 Center Girders, Side Girders, and Floors

Center girders, side girders, and floors, where constructed of higher-strength materials, generally are to comply with the requirements of 3-2-4/3 or 3-2-4/5, but may be modified, as permitted, by the following equation.

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

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

where t_{hts},t_{ms}, are as defined in 3-2-4/17.3 and Q is as defined in 3-2-1/5.5.

19 Structural Arrangements and Details

19.1 Structural Sea Chests

In addition to the requirements of 3-2-4/1 and 3-2-4/9, where the inner-bottom or the double-bottom structure form part of a sea chest, the thickness of the plating is to be not less than:

$$t = 0.035(L + 29) + 0.009s \quad \text{mm}$$

$$t = 0.00042(L + 95) + 0.009s \quad \text{in.}$$

where

s = the maximum unsupported width of sea chest plating, in mm (in.)

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

The thickness need not exceed that required in 3-2-2/3.9 for side shell and 3-2-2/3.13 for bottom shell, as appropriate.

19.3 Drainage

Drain wells are to be provided for draining water that may gather on the inner bottom. Such wells are not to extend for more than one-half the depth of the double bottom nor less than 460 mm (18 in.) from the shell or from the inner edge of the margin plate and not less than 500 mm (20 in.) from a plane coinciding with the keel line, and are to be so arranged as to comply with 4-6-4/5. Plating forming drain wells is to be at least 2.5 mm (0.10 in.) greater than is otherwise required at that location unless corrosion-resistant material is used or special protective coatings are applied. Steel striking plates or other approved arrangements are to be provided in way of sounding pipes to prevent damage by the sounding rods.

19.5 Manholes and Lightening Holes *(1 July 2012)*

Manholes and lightening holes are to be cut in all non-tight /members, except in way of widely spaced pillars and those aligned with bulkheads' brackets above, to ensure accessibility and ventilation. The proposed locations and sizes of holes are to be indicated on the plans submitted for approval. Where the requirements of IMO Res.A.673(16) are to be applied, the minimum clear access opening of 600 mm × 800 mm for vertical openings and 600 mm × 600 mm for horizontal openings will be required. Manholes located in the tops of tanks are to be sufficient in size and number to secure free ventilation and provide ready access to all parts of the double bottom. It is recommended that two access manholes are being provided for each tank situated as far apart as possible. However, if this is not feasible, one of the openings for ventilation purposes may have smaller dimensions. Care is to be taken in locating the manholes to avoid the possibility of interconnection of the main subdivision compartments through the double bottom. Covers are to be of steel or equivalent material, and where no ceiling is fitted in the cargo holds, they are to be effectively protected from damage by the cargo.

19.7 Air and Drainage Holes

Air and drainage holes are to be cut in all parts of the structure to ensure free escape of air to the vents and free drainage of liquids to the suction pipes. It is recommended that air notches to have radius of not less than 25 mm (1 in.) and drainage scallops radius of not less than 35 mm (1.4 in.).

19.9 Fixed Ballast

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

21 Machinery Space

21.1 General

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

Consideration is to be given to the submittal of plans of the foundations for main propulsion units, reduction gears and thrust bearings and of the structure supporting those foundations to the machinery manufacturer for review. (Refer also to Section 3-2-12 and 4-3-2/7.)

21.3 Engine Foundations

21.3.1 Single Bottom Vessels (Non-SOLAS Vessel Only)

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

21.3.2 Double Bottom Vessels

On vessels with double bottoms, the engines are to be seated directly upon thick inner-bottom plating or upon thick seat plates on top of heavy foundations arranged to distribute the weight effectively. Additional intercostal girders are to be fitted within the double bottom to ensure the satisfactory distribution of the weight and the rigidity of the structure.

21.5 Thrust Foundations

Thrust blocks are to be bolted to efficient foundations extending well beyond the thrust blocks and arranged to distribute the loads effectively into the adjacent structure. Extra intercostal girders, effectively attached, are to be fitted in way of the foundations, as may be required.

21.7 Shaft Stools and Auxiliary Foundations

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

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 5 Frames

1 General

1.1 Basic Considerations

The required sizes and arrangements of frames are to be in accordance with this Section and as shown in 3-2-5/Figure 1. The equations apply to vessels which have well-rounded lines, normal sheer and bulkhead support not less effective than that specified in Section 3-2-9. Additional stiffness will be required where bulkhead support is less effective, where sheer is excessive or where flat surface areas are large. Frames are not to have less strength than is required for bulkhead stiffeners in the same location in association with heads to the bulkhead deck, and in way of deep tanks they are not to have less strength than is required for stiffeners on deep-tank bulkheads in the same location. Framing sections are to have sufficient thickness and depth in relation to the spans between supports.

1.3 Holes in Frames

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

1.5 End Connections

At the ends of un-bracketed frames, both the web and the flange are to be welded to the supporting member. At bracketed end connections, continuity of strength is to be maintained at the connection to the bracket and at the connection of the bracket to the supporting member. Welding is to be in accordance with 3-2-19/Table 1. Where longitudinal frames are not continuous at bulkheads, end connections are to effectively develop their sectional area and resistance to bending. Where a structural member is terminated, structural continuity is to be maintained by a suitable back-up structure, fitted in way of the end connection of frames, or the end connection is to be effectively extended by a bracket or flat bar to an adjacent beam, stiffener, etc.

1.7 Standard and Cant Frame Spacing

The standard frame spacing, S, amidships for vessels with transverse framing, may be obtained from the following equations. The spacing of cant frames is not to exceed the standard frame spacing.

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

$S = 1000$ mm for $270 < L \le 305$ m

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

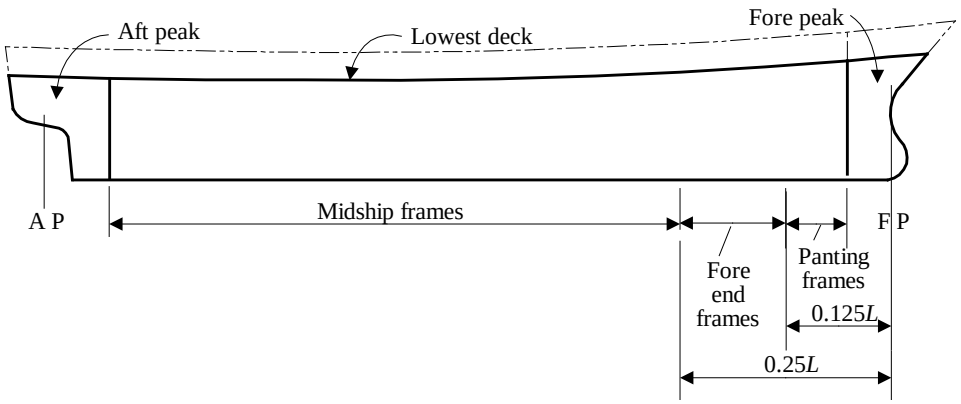
$S = 39.5$ in. for $890 < L \le 1000$ ft

where

S = standard frame spacing, in mm (in.)

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

FIGURE 1
Zones of Framing



3 Side Frames

3.1 Transverse Frames

3.1.1 Strength Requirement

The section modulus *SM* of each transverse frame located between 0.25*L* aft of the FP and the aft peak bulkhead. and below the lowest deck is to be obtained from the following equation, where ℓ is the span in m (ft) as shown in 3-2-5/Figure 2, 3-2-5/Figure 3, and 3-2-5/Figure 4 between the toes of brackets. The value of ℓ for use with the equation is not to be less than 2.1 m (7 ft).

$$SM = s\ell^2(h + bh_1/30)\,(7 + 45/\ell^3) \quad \text{cm}^3$$

$$SM = s\ell^2(h + bh_1/100)\,(0.0037 + 0.8/\ell^3) \quad \text{in}^3$$

where

s = frame spacing, in m (ft)

h = vertical distance, in m (ft), from the middle of ℓ to the scantling draft line or 0.4ℓ, whichever is greater

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

h_1 = $h_{FB} + h_{C1} + h_{C2} + h_{C3} + \ldots h_{Cn} + h_E + 0.5(h_{P1} + h_{P2} + \ldots h_{Pm})$

h_{FB} = vertical distance, in m (ft), from the deck at the top of the frame to the bulkhead or freeboard deck

$h_{Ci} \ldots h_{Cn}$ = heights of cargo spaces above the bulkhead/freeboard deck. Where the cargo load differs from 7.01 kN/m^3 (715 kgf/m^3, 44.7 lbf/ft^3) multiplied by the tween deck height in m (ft), the height of that tween deck is to be proportionately adjusted in calculating h_1.

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

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

= 0.0 m, if the exposed deck has no cargo loads

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

$h_{Pi} \ldots h_{Pm}$ = heights of accommodation spaces

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

3.1.2 Deck Longitudinals with Deep Beams

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

3.1.3 Sizes Increased for Heavy Load

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

FIGURE 2
Side Frames

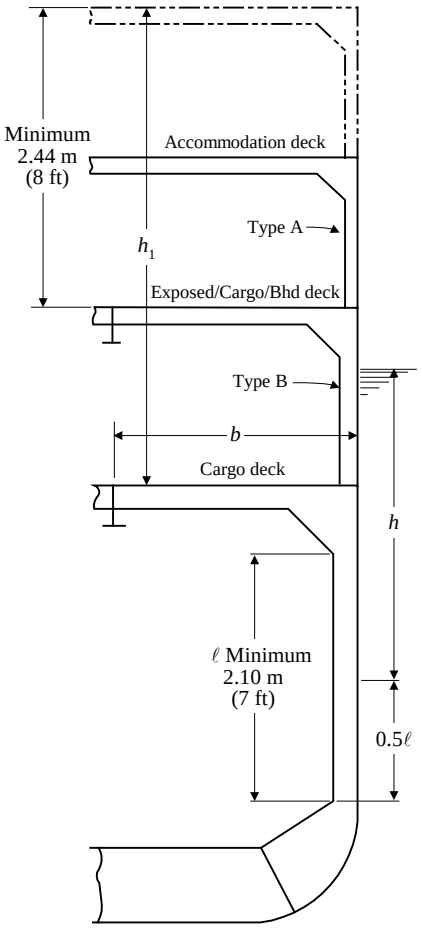


FIGURE 3
Side Frames

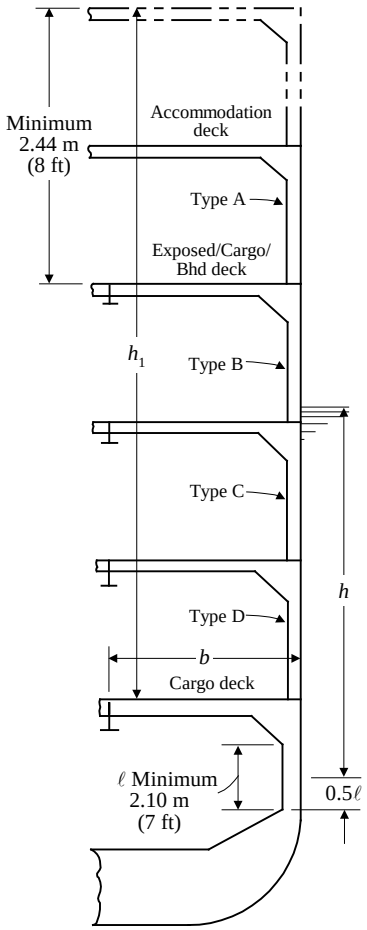
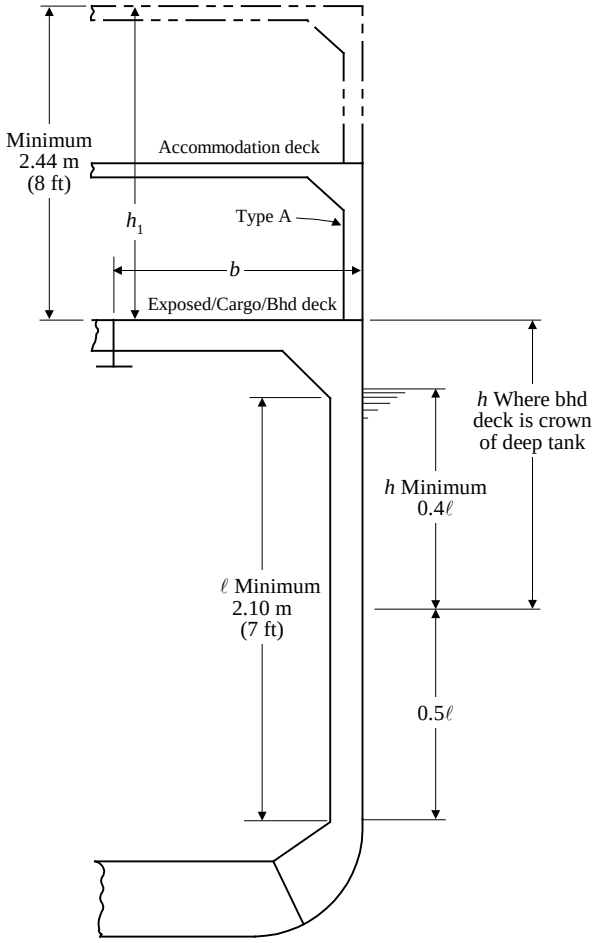


FIGURE 4
Side Frames



3.3 Raised Quarter Decks

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

3.5 Fore-end Frames

Each fore-end frame between 0.75*L* and 0.875*L* measured from the AP is to have a section modulus obtained from 3-2-5/3.1, where ℓ is to be the corresponding midship span plus one-half the sheer at 0.125*L* from the stem; the other factors are to be those obtained for midship frames adjusted for spacing if required. Where there is no sheer, no increase in length is required. In deep tanks, the unsupported span of frames is not to exceed 3.6 m (12 ft)

3.7 Panting Frames

Each panting frame between a point located at 0.875*L* forward of the AP and the forepeak bulkhead in vessels which have panting arrangements as per 3-2-5/3.13 is to have a section modulus as obtained from 3-2-5/3.1, where ℓ is to be the corresponding midship span plus the sheer in m (ft) at 0.125*L* from the stem. In vessels having normal sheer the other factors in 3-2-5/3.1 are to be the same as those used for midship frames, adjusted for spacing if required. Where there is no sheer, the value of *SM* in 3-2-5/3.1 is to be at least 25% greater than obtained for corresponding midship frames, adjusted for spacing. Where the sheer is less than normal, the increase is to be proportionate. Panting frames are to have depths not less than 1/20th of the actual span.

3.9 Side Stringers

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

3.11 Frames with Web Frames and Side Stringers

Where frames are supported by a system of web frames and side stringers of the sizes and arrangement obtained from Section 3-2-6, the section modulus of the frames is to be determined in accordance with 3-2-5/3.1, 3-2-5/3.5, and 3-2-5/3.7, where the length ℓ may be taken as the distance from the toe of the bracket to the lowest stringer plus 0.15 m (0.5 ft) but not less than 2.1 m (7 ft).

3.13 Panting Webs and Stringers

Abaft the forepeak and forward of the after peak, panting arrangements are to be provided so as to meet the effects of sheer and flatness of the hull form. Web frames are to be fitted at a gradually increasing spacing aft of the forepeak bulkhead and it is recommended that the first frame abaft the forepeak bulkhead be increased in size. Narrow stringers, similar to those described in 3-2-5/3.9, are to be fitted in this area in line with the stringers in the forepeak. At the after end, where due to the shape of the vessel the frames have longer unsupported span than the normal midship frames, stringers or frames of increased size may be required.

3.15 Side Frame Brackets

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

3.17 Longitudinal Frames

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

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

$$SM = 0.004\text{l}\, chs\ell^2 \quad \text{in}^3$$

where

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

c = 0.95

h = above 0.5*D* from the keel, the vertical distance, in m (ft), from the longitudinal frame to the bulkhead or freeboard deck, but is not to be taken as less than 2.1 m (7.0 ft).

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

ℓ = the unsupported span, in m (ft)

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

3.19 Machinery Space

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

5 Tween-Deck Frames Below and Above the Bulkhead Deck

5.1 General

The size of tween-deck framing is dependent upon the standard of main framing, arrangement of bulkhead support, requirements of special loading, etc. In the design of the framing, consideration is to be given to the provision of continuity in the framing from the bottom to the top of the hull; the standard is also contingent upon the maintenance of general transverse stiffness by means of partial bulkheads in line with the main bulkheads, or by the extension of deep frames at regular intervals to the tops of superstructures. Care is to be taken that the strength and stiffness of the framing at the ends of the vessel are proportioned to the actual unsupported length of the frame. Panting arrangements, comprised of webs and stringers, may be required in way of the forecastle side plating to meet the effects of flare, if applicable.

5.3 Transverse Tween-deck Frames

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

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

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

where

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

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

K = factor appropriate to the length of vessel and type of tween decks, A, B, C, or D, as shown in 3-2-5/Figures 2, 3, and 4.

Generally, all tween-deck frames above the bulkhead deck are Type A, except for those forward of 0.125*L* from the stem, which are to be type B.

Below the bulkhead deck; they are to be not less than required by the foregoing equations. In general, below the bulkhead deck and forward of the forepeak bulkhead, tween-deck frames are also not to be less than required by 3-2-5/7.

Type A	$K = 0.022L - 0.47$ m	
	$K = 0.022L - 1.54$ ft	
Type B	$K = 0.034L - 0.56$ m	
	$K = 0.034L - 1.84$ ft	
Type C	$K = 0.036L - 0.09$ m	for $L \le 180$ m
	$K = 0.036L - 0.29$ ft	for $L \le 590$ ft
	$K = 0.031L + 0.83$ m	for $180 < L \le 305$ m
	$K = 0.031L + 2.8$ ft	for $590 < L \le 1000$ ft
Type D	$K = 0.029L + 1.78$ m	
	$K = 0.029L + 5.84$ ft	

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

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

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

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

5.5 Longitudinal Tween-deck Frames

Longitudinal tween-deck frames are to be in accordance with 3-2-5/3.17. The section modulus of each longitudinal tween-deck frame forward of 0.125*L*, measured from either the stem or FP line depending on bow design, is to be not less than required by 3-2-5/5.3 for transverse frames in the same location, taking ℓ as the unsupported span along the frame's length. Particular attention is to be given to the buckling strength of the longitudinal tween-deck frames adjacent to the strength deck where scantling reductions are being considered for the use of higher-strength steel. See also 3-2-1/17 and Appendix 3-2-A3.

7 Forepeak Frames

7.1 General

Forepeak frames are to be connected to deep floors of not less thickness than that obtained from 3-2-4/5.1 for floors with transverse framing, but the thickness need not exceed 14.0 mm (0.56 in.), provided the stiffeners are not spaced more than 1.2 m (4 ft). The floors are to extend as high as necessary to give lateral stiffness to the structure and are to be stiffened on their upper edges. Care is to be taken in arranging the framing and floors such, as to avoid wide areas of unsupported plating adjacent to the stem. Angle ties are to be fitted across the tops of the floors and across all tiers of beams or struts to prevent vertical or lateral movement. Breast hooks are to be arranged at regular intervals at and between the stringers, extending throughout the entire range of forward drafts, as well as above and below the maximum and minimum forward draft waterlines. In general, the frames above the lowest deck are to be as required by 3-2-5/7.3, but in vessels with large flare or varying sheers on different decks accompanied with lengthened frames; stringers and webs or more robust frames may be required in this region.

7.3 Frame Scantlings

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

7.3.1 Beams or Struts on Every Frame without Stringer Plates

Where beams or struts are fitted on every frame in tiers of not more than 1.5 m (5 ft) apart, the section modulus *SM* of the frames is not to be less than determined by the above equation, nor is the section modulus to be less than obtained from the following equation, where ℓ is the length, in m (ft), of the longest actual span of the peak frame from the toe of the lowest deck beam knee to the top of the floor.

$$SM = (0.025L - 0.44)(7 + 45/\ell^3)\ell^2 \quad \text{cm}^3$$

$$SM = (0.085L - 5)(0.0037 + 0.8/\ell^3)\ell^2 \quad \text{in}^3$$

where

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

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

7.3.2 Where no Beams or Struts are Fitted

Where no beams or struts are fitted, the section modulus of frames is not to be less than twice that obtained from the equation in 3-2-5/7.3.1 in association with a length ℓ, as defined in 3-2-5/7.3.1.

9 After-peak Frames

9.1 General

After-peak frames are to be efficiently connected to deep floors. See 3-2-4/5.

9.3 Frame Scantlings

The section modulus *SM* of each after-peak frame is to be obtained from the following equation, in association with deep floors, tiers of beams, stringers, or struts arranged so that there is no more than 2.4 m (8 ft) distance between the supports at any part of the girth of the frame.

$$SM = 2.79sL - 36 \quad \text{cm}^3$$

$$SM = 0.016sL - 2.2 \quad \text{in}^3$$

where

s = frame spacing, in m (ft)

L = length as defined in 3-1-1/3.1, in m (ft), but is not to be taken less than 30 m (98.5 ft)

11 Vessels 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 above be provided. All side structural members in the impact region are to have end connections with brackets and adequate double continuous fillet welds at the ends. Scallop welds are not to be used in connections between side frames and shell plating.

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 6 Web Frames and Side Stringers

1 General

Web frames and, in the case of transverse framing, side stringers, similar to those shown in 3-2-6/Figure 1, where fitted in association with transverse or longitudinal frames of the sizes specified in 3-2-5/3.11 or 3-2-5/3.17, are to be of the sizes as required by this Section. It is recommended that webs and stringers be spaced not more than approximately 3 m (10 ft) apart. For webs in machinery spaces, see also 3-2-5/3.19.

Web frames and side stringers are to have not less strength than would be required for similar members on watertight bulkheads, and in way of deep tanks, they are to be at least as effective as would be required for similar members on deep-tank bulkheads.

3 Web Frames

3.1 Web Frames Amidships and Aft

Each web frame amidships to $0.875L$ forward of the aft perpendicular and aft is to have a section modulus SM not less than obtained from the following equation:

$$SM = 4.74cs\ell^2(h + bh_1/45K) \quad \text{cm}^3$$

$$SM = 0.0025cs\ell^2(h + bh_1/150K) \quad \text{in}^3$$

where

c = 1.5

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

ℓ = span, in m (ft), measured from the line of the inner bottom extended to the side of the vessel to the deck at the top of the web frames. Where effective brackets are fitted, the length ℓ may be modified as outlined in 3-2-6/7.1

h = vertical distance, in m (ft), from the middle of ℓ to the scantling draft line. The value of h is not to be less than 0.5ℓ

h_1 = $h_{FB} + h_{C1} + h_{C2} + h_{C3} + \ldots h_{Cn} + h_E + 0.5(h_{P1} + h_{P2} + \ldots h_{Pm})$

h_{FB} = vertical distance, in m (ft), from the deck at the top of the web frame to the bulkhead or freeboard deck

$h_{Ci} \ldots h_{Cn}$ = heights of cargo spaces above the bulkhead/freeboard deck. Where the cargo load differs from 7.01 kN/m^3 (715 kgf/m^3, 44.7 lbf/ft^3) multiplied by the tween-deck height in m (ft), the height of that tween-deck is to be proportionately adjusted in calculating h_1.

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

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

= 0.0 m, if the exposed deck has no cargo loads

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

$h_{Pi}…h_{Pm}$ = heights of passenger spaces

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

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

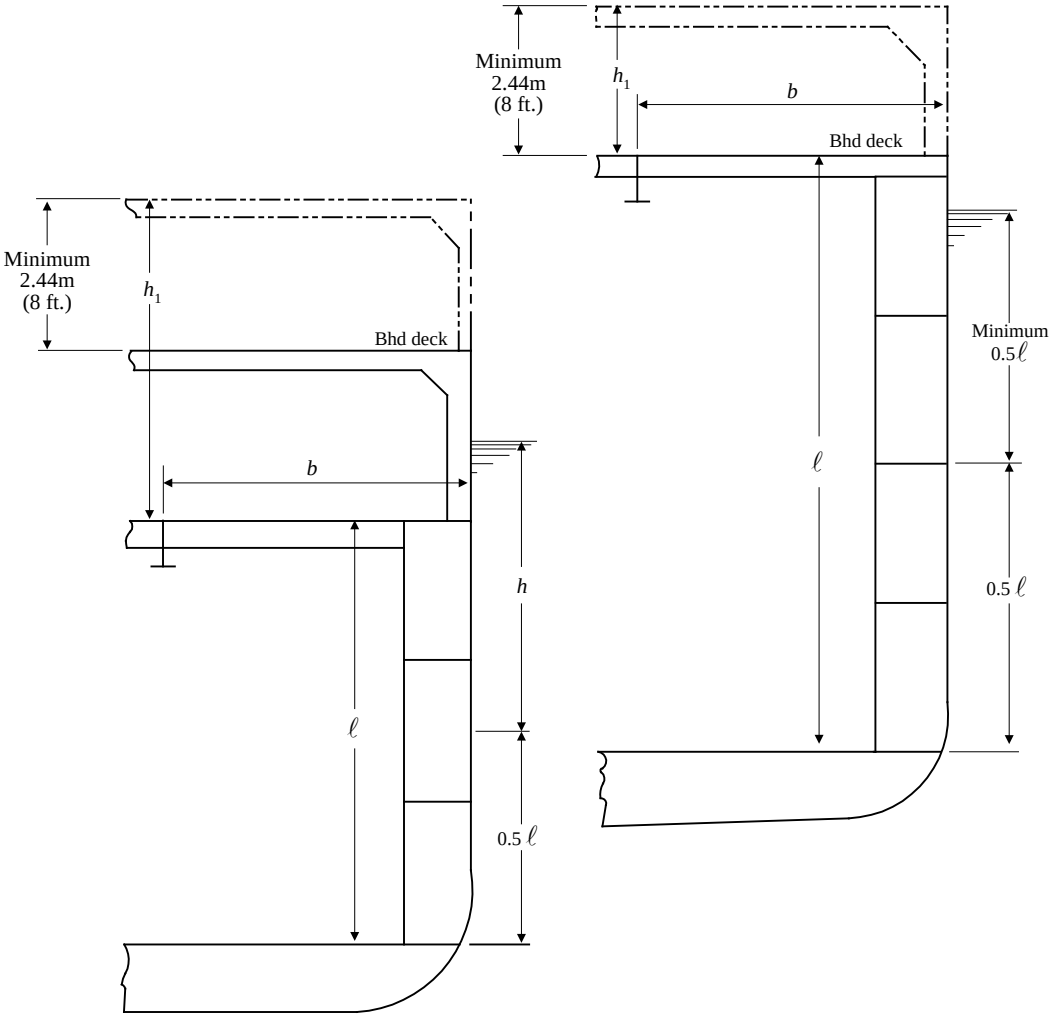
K = 1.0, where the deck is longitudinally framed and a deck transverse is fitted in way of each web frame

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

3.3 Web Frames Forward

The value of SM for the webs forward of 0.875L from the AP is to be increased 25%.

FIGURE 1
Web-frame Arrangements



3.5 Proportions *(1 July 2012)*

Webs and 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 3 times the depth of the slots for vessels 90 m (295 ft) in length and greater or 2.5 times the depth of the slots for vessels less than 90 m (295 ft) in length, or the slots are to be fitted with filler plates. The thickness is not to be less than 1 mm per 100 mm (0.01 in. per in.) of depth plus 3.5 mm (0.14 in.), but this need not exceed 14 mm (0.56 in.). Where the webs are in close proximity to boilers, the thickness of the webs, face bars, flanges, etc. are to be increased 1.5 mm (0.06 in.) above the foregoing requirements.

3.7 Stiffeners

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

3.9 Tripping Brackets

Tripping brackets are to be fitted at intervals of about 3 m (10 ft) and near the change of section. Where the breadth of the flanges on either side of the web exceeds 200 mm (8 in.), tripping brackets are to be arranged to support the flange.

3.11 Tween-deck Webs

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

5 Side Stringers

5.1 Side Stringers *(2017)*

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

$$SM = 4.74chs\ell^2 \quad \text{cm}^3$$

$$SM = 0.0025chs\ell^2 \quad \text{in}^3$$

where

c = 1.50

= 1.85 in the forepeak for vessels 61 m (200 ft) or greater in length

h = vertical distance, in m (ft), from the middle of s to the scantling draft line, or 1.8 m (6 ft), whichever is greater

for stringers above the lowest deck or at a similar height in relation to the design draft, h is not taken less than K as given in 3-2-5/5.3.

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

ℓ = span, in m (ft), between web frames, or between web frame and bulkhead; where brackets are fitted, the length ℓ may be modified as per 3-2-6/7.1 below

5.3 Proportions

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 3 times the depth of the slots or the slots are to be fitted with filler plates and the thickness is not to be less than that determined by the equation in 3-2-6/9.1. Where the stringers are in close proximity to boilers, the thickness of the stringer plates, face bars, flanges, etc. are to be increased 1.5 mm (0.06 in.) above the normal requirements.

5.5 Stiffeners

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

5.7 Tripping Brackets

The arrangement of tripping brackets is to be in accordance with 3-2-6/3.9.

7 Structural Arrangements and Details

7.1 Brackets of Girders, Webs, and Stringers *(2014)*

Where end brackets are provided, they are to have scantlings not less than shown in 3-2-9/Table 1A for vessels 90 m (295 ft) or greater in length or 3-2-9/Table 1B for vessels less than 90 m (295 ft) in length. The value for ℓ, as defined in this Section and Sections 3-2-8, 3-2-9, and 3-2-10 may be modified in accordance with the following.

i) Where the girder, web frame or stringer is part of a continuous in -plane structure by attachment to another primary web member, the face plate on the bracket is to have the same scantlings as the face bar on the girder, web frame or stringer and the span ℓ may be measured onto the bracket by the amount of 25% of the bracket arm length

ii) Where the end bracket is welded to a girder, web or stringer, the span ℓ may be measured onto the bracket by the amount of 50% of the bracket arm length. For vessels 90 m (295 ft) or greater in length, the face plate on the bracket is to have the same scantlings as that on the girder, web or stringer.

In such cases the fillet weld throat area at the connection of the web and bracket to the bulkhead or deck is to be not less than the area of the web and face bar of the girder, web or stringer.

7.2 Overlap of Brackets *(1 July 2012)*

7.2.1 Vessels 90 m (295 ft) or Greater in Length

For vessels 90 m (295 ft) or greater in length, the minimum overlap of the bracket arm along the stiffener is not to be less than that shown in 3-2-9/Figure 3A.

Where a bracket laps a member, the width of overlap generally is to be twice the thinner plate thickness plus 25 mm (1 in.).

7.2.2 Vessels Less than 90 m (295 ft) in Length

For vessels less than 90 m (295 ft), the minimum overlap of the bracket arm along the stiffener is not to be less than obtained from the following equation:

$$x = 1.4y + 30 \quad \text{mm} \qquad\qquad x = 1.4y + 1.2 \quad \text{in.}$$

where

x = length of overlap along stiffener, in mm (in.)

y = depth of stiffener, in mm (in.)

Where a bracket laps a member, the width of overlap generally is to be twice the thinner plate thickness plus 25 mm (1 in.).

7.3 End Connections

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

The throat area of the welded end connections is to develop the strength of the member being attached.

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

9 Peak Stringers

9.1 Peak Stringer-plate Thickness

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

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

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

$t = 0.00017L + 0.28$ in. for $L \le 655$ ft

$t = 0.00008L + 0.34$ in. for $655 < L \le 1400$ ft

where

t = plate thickness, in mm (in.).

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

9.3 Peak Stringer-plate Breadth *(2014)*

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

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

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

$b = 0.098L + 0.25$ in. for $L \le 330$ ft

$b = 0.027L + 23.5$ in. for $330 < L \le 1400$ ft

where

b = breadth of peak stringer-plate, in mm (in.)

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

Where beams or struts are not fitted on every frame, the edge of the stringer is to be adequately stiffened by an 85 mm ($3^1/_2$ in.) flange or face bar.

For vessels between 61 meters (200 feet) and 90 meters (295 feet) in length, alternative designs meeting the requirements of side stringers in 3-2-6/5 may be accepted.

11 Vessels Subject to Impact Loads *(2014)*

For vessels subject to impact loads during routine operations, web frames and side stringers in the impact region are to have a section modulus 25% greater than that of regular requirement. All side structural members in the impact region are to have adequate double continuous fillet weld and end connections with brackets. Scallop welds are not to be used in connections between side frames and shell plating.

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 7 Beams and Longitudinals

1 General

1.1 Arrangement

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

Alternatively deck longitudinals may be fitted, supported by deck transverses .Longitudinals and deck transverse are to have adequate structural stability.

1.3 Design Head

Decks are to be designed at least to the scantling heads specified in this Section.

3 Beams and Longitudinals

3.1 Strength Requirement

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

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

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

where

c	=	0.540	for half beams, for beams with centerline support only, for beams between longitudinal bulkheads, and for beams over tunnels or tunnel recesses
	=	0.585	for beams between longitudinal deck girders. For longitudinal beams of platform decks and between hatches at all decks
	=	0.90	for beams at deep-tank tops supported at one or both ends at the shell or on longitudinal bulkheads
	=	1.00	for beams at deep-tank tops between longitudinal girders
	=	$1/(1.709 - 0.651k)$	for longitudinal beams of strength decks and of effective lower decks

k = $SM_R Y/I_A$

SM_R = required hull girder section modulus amidships in 3-2-1/3.7.1 or 3-2-1/5.5, whichever is applicable, in cm^2-m (in^2-ft)

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

I_A = hull girder moment of inertia of the vessel amidships, in cm^2-m^2 (in^2-ft^2)

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

s = spacing of beams, in m (ft)

ℓ = distance, in m (ft), from the inner edge of the beam knee to the nearest line of girder support or between girder supports, whichever is greater. Under the top of deep tanks and in way of bulkhead recesses, the supports are to be arranged to limit the span to not exceeding 4.8 m (16 ft)

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

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

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

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

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

= h_{cs}, in m (ft) or p/7.01 m (p/715 m, p/44.7 ft), whichever is greater, for lower decks and/or double bottoms intended to carry cargoes when uniform loading p exceeds 25.66 kN/m² (2617 kgf/m^2, 536 lbf/ft^2) and/or load density exceeds 7.01 kN/m^3 (715 kgf/m^3, 44.7 lbf/ft^3)

= for bulkhead recesses and tunnel flats it is the height, in m (ft), to the bulkhead deck at the centerline; where that height is less than 6.1 m (20 ft), the value of h is to be taken as 0.8 times the actual height plus 1.22 m (4 ft).

= for deep-tank tops it is not to be less than the greatest of the following distances but, the calculated section modulus is not to be less than would be required for cargo beams in the same location, if tank top supports the cargo space above:

- two-thirds of the distance from the top of the tank to the top of the overflow
- head given in column (e) of 3-2-7/Table 2, as appropriate to the length of the vessel,
- the height to the scantling draft line
- two-thirds of the distance from the top of the tank to the bulkhead or freeboard deck

Elsewhere, the value of h may be taken from the appropriate column of 3-2-7/Table 1 and 3-2-7/Table 2, as follows.

TABLE 1
Decks Allocation

Weather decks and decks covered only by houses:		*Column*
Freeboard decks having no decks below		a
Freeboard decks having decks below		b
Forecastle decks (first tier above freeboard deck)	See Note 1	c
Forecastle decks (second tier and higher above freeboard deck)		d
Bridge decks (first tier above freeboard deck)		c
Bridge decks (second tier and higher above freeboard deck)		d
Short bridges, with length not exceeding 0.1*L* (first tier above freeboard deck)		d
Poop decks (first tier above freeboard deck)		d
Poop decks (second tier and higher above freeboard deck)		e
Long superstructures forward of midship half-length (first tier above freeboard deck)		b
Long superstructures abaft midship half-length forward and forward of midship $^3/_5$ length aft (first tier above freeboard deck)		c
Long superstructures abaft midship $^3/_5$ length (first tier above freeboard deck)		d
Superstructure decks extending forward of amidships' 0.5*L* (second tier above freeboard deck)		c
Superstructure decks amidships (second tier above freeboard deck)		d
Superstructure decks containing only accommodation spaces (third tier and higher above freeboard deck)		f
Lower decks and decks within superstructures:		
Decks below freeboard decks		c
Freeboard decks		c
Superstructure decks		d
Accommodation decks		f
Decks to which side shell plating does not extend, tops of houses, etc.:		
First tier above freeboard deck		d
Second tier above freeboard deck	See Note 2	e (f)
Third and higher tiers above freeboard deck	See Note 2	f (g)

Notes

1 See also 3-2-11/9.

2 Where decks to which the side shell does not extend and are generally used only as the shelter against weather, the value of *h* may be reduced as given in brackets.

3 Buckling strength of the plating and framing of all decks is to be considered where they are part of the hull girder for vessels over 61 m (200 ft) in length.

TABLE 2
Values of *h* for Beams

L in ***Meters***	*a*	*b*	*c*	*d*	*e*	*f*	*g*
30	1.36	1.06	0.91	0.60	0.45	0.30	–
40	1.56	1.26	1.01	0.70	0.55	0.40	–
50	1.76	1.46	1.11	0.80	0.65	0.50	–
60	1.96	1.66	1.21	0.90	0.75	0.60	0.46
70	2.16	1.86	1.31	1.00	0.85	0.70	0.46
80	2.36	2.06	1.41	1.10	0.95	0.80	0.46
90	2.56	2.26	1.51	1.20	1.05	0.90	0.46
100	2.76	2.29	1.69	1.30	1.15	0.91	0.46
110	2.90	2.29	1.90	1.44	1.15	0.91	0.46
120	2.90	2.29	1.98	1.64	1.27	0.91	0.46
122 and above	2.90	2.29	1.98	1.68	1.30	0.91	0.46

L in ***Feet***	*a*	*b*	*c*	*d*	*e*	*f*	*g*
100	4.50	3.50	3.00	2.00	1.50	1.00	–
125	5.00	4.00	3.25	2.25	1.75	1.25	–
150	5.50	4.50	3.50	2.50	2.00	1.50	–
175	6.00	5.00	3.75	2.75	2.25	1.75	–
200	6.50	5.50	4.00	3.00	2.50	2.00	1.50
225	7.00	6.00	4.25	3.25	2.75	2.25	1.50
250	7.50	6.50	4.50	3.50	3.00	2.50	1.50
275	8.00	7.00	4.75	3.75	3.25	2.75	1.50
300	8.50	7.50	5.00	4.00	3.50	3.00	1.50
325	9.00	7.50	5.50	4.25	3.75	3.00	1.50
350	9.50	7.50	6.00	4.50	3.75	3.00	1.50
375	9.50	7.50	6.50	5.00	4.00	3.00	1.50
400 and above	9.50	7.50	6.50	5.50	4.25	3.00	1.50

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

3.3 Deep Reinforced Beams

Deep reinforced beams are to be arranged in way of concentrated loads such as the ends of deckhouses, in way of masts, windlasses, A-frames, rollers, hooks, bollards, winches, auxiliary machinery, etc.

3.5 Beams at the Head of Web Frames

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

3.7 End Connections *(1 July 2012)*

At the ends of unbracketed beams or longitudinals, located inside the line of openings or near the periphery of platform decks; both the web and flange are to be welded to the supporting member. At beam knees or at other bracketed end connections continuity of strength of the beam or longitudinal is to be maintained at the connection to the bracket and at the connection of the bracket to the supporting member.

Welding is to be in accordance with 3-2-19/Table 1 and the fillet weld throat area of the connection of the beam or longitudinal to the bracket and of the bracket to the supporting structure is to develop the strength of the beam or longitudinal.

Deck longitudinals outside the line of openings are to be continuous or, bracketed at the nearest transverse bulkheads such, as to effectively develop their sectional area and resistance to bending. However; non continuous longitudinals cannot be included into hull girder section modulus calculation [see also 3-2-1/3.7.1(c)].

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

4 Deck Fittings Support Structures for Vessels of More Than 500 GT *(1 July 2018)*

4.1 General

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:

4.1.1 Normal Towing

Normal towing is the towing operations necessary for maneuvering in ports and sheltered waters associated with the normal operations of the vessel.

4.1.2 Other Towing

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. See 3-5-1/15.9.

Shipboard fittings such as cleats, chocks, bitts, bollards, towing pad eyes, etc., for mooring and/or towing, winches and capstans are to be located on stiffeners and/or girders, which are part of the deck construction such, as to facilitate efficient distribution of the mooring and/or towing loads. The same attention is to be paid to the structural arrangements and strength of supporting structures of the recessed bitts, if fitted. Other arrangements may be accepted (for chocks in bulwarks, etc.) provided the strength is confirmed adequate for the intended service.

The requirements in this subsection are to be applied in conjunction with the requirements for mooring and towing equipment contained in Section 3-5-1.

4.3 Design Loads

Unless greater safe working load (SWL) and/or safe towing load (TOW) of shipboard fittings is specified by the applicant (see 3-2-7/4.3.3), the minimum design load to be used is the greater values obtained from 3-2-7/4.3.1 or 3-2-7/4.3.2, whichever is applicable:

4.3.1 Mooring Operations

The minimum design load for shipboard fittings for mooring operations is the applicable value obtained from 3-2-7/4.3.1(a) or 3-2-7/4.3.1(b):

4.3.1(a) Mooring Line Force. The minimum design load applied to supporting hull structures for shipboard fittings is to be 1.15 times the minimum breaking strength of the mooring line according to 3-5-1/Table 2. See Notes 1 and 2 in 3-2-7/4.3.1(b).

4.3.1(b) Mooring Winch and Capstan Force. The minimum design load applied to supporting hull structures for winches is to be 1.25 times the intended maximum brake holding load, where the maximum brake holding load is to be assumed not less than 80% of the minimum breaking strength of the mooring line according to 3-5-1/Table 2. 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 3-5-1/9.7 needs not to be taken into account for the loads applied to shipboard fittings and supporting hull structure.

4.3.2 Towing Operations

The minimum design load for shipboard fittings for towing operations is the applicable value obtained from 3-2-7/4.3.2(a) through 3-2-7/4.3.2(c), as applicable.

4.3.2(a) Normal Towing Operations. 1.25 times the intended maximum towing load (e.g., static bollard pull) as indicated on the towing and mooring arrangements plan.

4.3.2(b) Other Towing Service. 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)

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.

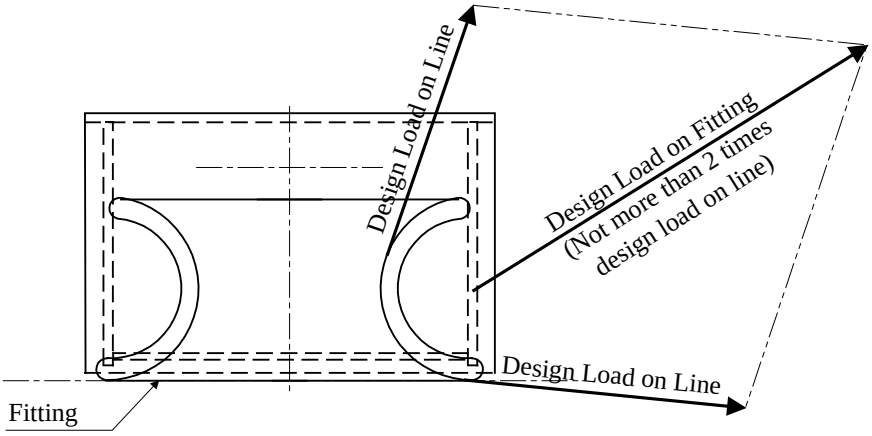
2 The increase of the minimum breaking strength for synthetic ropes according to 3-5-1/9.7 needs not to be taken into account for the loads applied to shipboard fittings and supporting hull structure.

4.3.2(c) For fittings intended to be used for, both, normal and other towing operations, the greater of the design loads according to 3-2-7/4.3.2(a) and 3-2-7/4.3.2(b).

4.3.3 Application of Design Loads

The design load is to be applied to fittings in all directions that may occur by taking into account the arrangement shown on the towing and mooring arrangements plan. Where the towing line takes a turn at a fitting, the total design load applied to the fitting is equal to the resultant of the design loads acting on the line, see 3-2-7/Figure 1 below. However, in no case does the design load applied to the fitting need to be greater than twice the design load on the line.

FIGURE 1
Application of Design Loads



When a specific SWL is applied for a shipboard fitting at the request of the applicant, by which the design load will be greater than the above minimum values, the strength of the supporting hull structures is to be designed for an increased load in accordance with the appropriate SWL/design load relationship given by 3-2-7/4.3 and 3-5-1/15.5.1.

When a safe towing load, TOW, greater than that determined according to 3-5-1/15.5.2 is requested by the applicant, the design load is to be increased in accordance with the appropriate TOW/design load relationship given by 3-2-7/4.3 and 3-5-1/15.5.2.

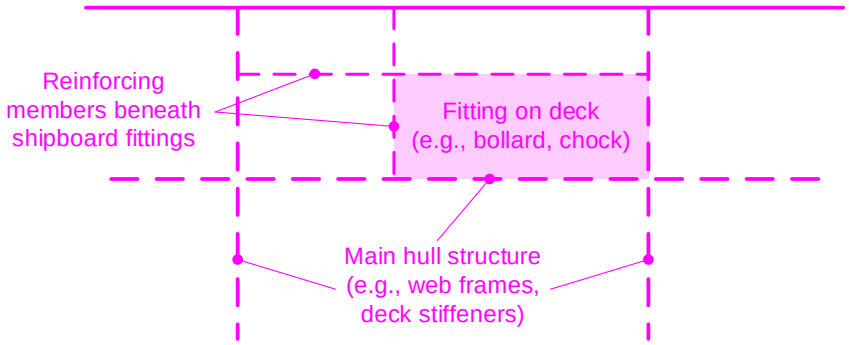
4.5 Supporting Structures

4.5.1 Arrangement and Applied Design Load

The design load applied to supporting hull structure for mooring operations and towing operations is to be in accordance with 3-2-7/4.3.1 and 3-2-7/4.3.2, respectively.

The arrangement of reinforced members beneath shipboard fittings, winches, and capstans is to consider any variation of direction (horizontally and vertically) of the mooring forces acting upon the shipboard fittings, see 3-2-7/Figure 2 for a sample arrangement. Proper alignment of fitting and supporting hull structure is to be verified.

FIGURE 2
Sample Arrangement *(1 July 2018)*

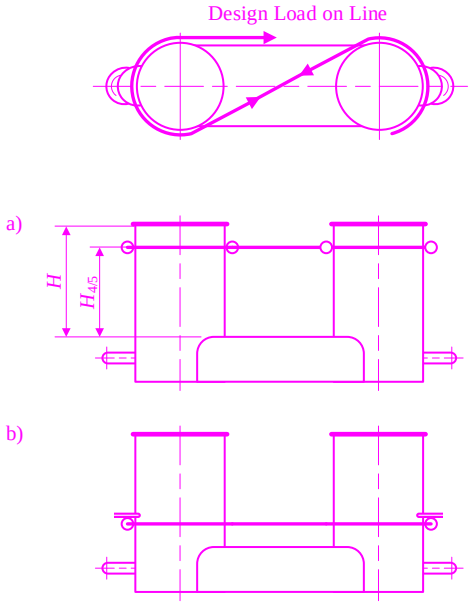


4.5.2 Line Forces

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

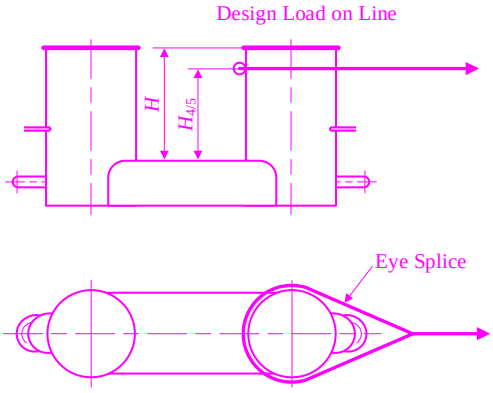
4.5.2(a) Mooring Operations. The acting point of the mooring force on shipboard fittings is to be taken at the attachment point of a mooring line or at a change in its direction. For bollards and bitts the attachment point of the mooring line is to be taken $^4/_5$ of the tube height above the base, see a) in 3-2-7/Figure 3 below. If fins are fitted to the bollard tubes to keep the mooring line as low as possible, the attachment point of the mooring line may be taken at the location of the fins, see b) in 3-2-7/Figure 3 below.

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



4.5.2(b) 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 3-2-7/Figure 4 below.

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



4.5.3 Allowable Stresses

Allowable stresses under the design load conditions as specified in 3-2-7/4.3 are as follows:

4.5.3(a) For strength assessment 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.

4.5.3(b) 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.

4.7 Scantlings

4.7.1 Net Scantlings

The net minimum scantlings of the supporting hull structure are to comply with the requirements given in 3-2-7/4.5. The net thicknesses, t_{net}, are the member thicknesses necessary to obtain the above required minimum net scantlings. The required gross thicknesses are obtained by adding the total corrosion additions, t_c, given in 3-2-7/4.7.2 and, where applicable, the wear allowance, t_w, given in 3-2-7/4.7.3 to t_{net}.

4.7.2 Corrosion Addition

The corrosion addition, t_c, is not to be less than the following values:

- For the supporting hull structure, according to 7-A-4/Table 1 for the surrounding structure.
- For pedestals and foundations on deck which are not part of a fitting according to an accepted industry standard, 2.0 mm (0.08 in.).
- For shipboard fittings not selected from an accepted industry standard, 2.0 mm (0.08 in.).

4.7.3 Wear Allowance

In addition to the corrosion addition given in 3-2-7/4.7.2 the wear allowance, t_w, for shipboard fittings not selected from an accepted industry standard is not to be less than 1.0 mm (0.04 in.), added to surfaces which are intended to regularly contact the line.

5 Container Loading

5.1 General

Where the vessel is to carry cargo or specialist equipment in containers intended for periodic or temporary installation on board, the exact locations of the container pads and the maximum total static load on the pads are to be indicated on the plans submitted for approval. Where the pads are not in line with the supporting structures, headers are to be provided to transmit the loads to these members. This requirement does not apply to containerized offshore supplies when carried on dedicated cargo decks.

5.3 Strength Requirements

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

$$SM = M/f$$

where

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

f = permissible maximum bending stress, as given in 3-2-7/Table 3

In determining the maximum bending moment, members may be considered fixed-ended, provided that the member is continuous over the adjacent spans or is effectively attached to a bulkhead stiffener or frame or has end connections in accordance with 3-2-7/3.7. Where this is not the case, the member is to be considered simply-supported. Where weather deck containers are supported by pedestals, the section modulus required by 3-2-7/3, with *h* equal to the distance between the deck and the underside of the container, but not greater than 50% of the value given in 3-2-7/Table 2, is to be added to the above required section modulus.

7 Higher-strength Materials

7.1 General

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

Higher strength steel members are to be continuous in way of transverse members of ordinary strength steel or of lesser strength higher strength steel.

7.3 Longitudinals and Beams of Higher-strength Materials

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

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

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

where *c*, *h*, *s* and ℓ are as defined in 3-2-7/3 and *Q* is as defined in 3-2-1/5.5.

TABLE 3
Values of *f* (Ordinary-strength Steel)

	kN/cm^2	tf/cm^2	Ltf/in^2
Effective longitudinal members	12.36	1.26	8
Transverse members and longitudinal members inside the line of openings	13.90	1.42	9

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

$$A = F/q$$

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

q = allowable average shear stress in the web, not to exceed 10.35 kN/cm^2 (1.055 tf/cm^2, 6.7 Ltf/in^2)

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 8 Pillars, Deck Girders, and Transverses

1 General

1.1 Arrangements – General

All pillars are to be aligned vertically or, in case of misalignment, an arrangement is to be provided for transmitting their loads to the supports below. The lowest pillars are to be fitted in line with a double-bottom girder or floor, or as close thereto as practicable. The seating under them is to be of ample strength and is to provide effective distribution of the load. Lightening holes are to be omitted in floors and girders directly under those pillars.

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

Special attention is to be paid to provide support in the form of bulkheads or deep webs at the ends and corners of deckhouses, in machinery spaces, at ends of partial superstructures and under heavy concentrated weights. For forecastle decks, see also 3-2-11/9.

1.3 Container Loading

Where it is intended to carry containers, the structure is to comply with 3-2-7/5.

1.5 Cargo Loading

Where it is intended to carry cargoes, the structure is to be calculated with use of head or height h, as applicable, according to 3-2-7/3.1.

3 Pillars

3.1 Permissible Load

The permissible load W_a of a pillar or strut obtained from the following equation should always be equal to or greater than the calculated load W, as determined in accordance with 3-2-4/7.7, 3-2-8/3.3, 3-2-8/3.5 or 3-2-8/3.7, as appropriate.

$$W_a = (k - n\ell/r)A \quad \text{kN (tf, Ltf)}$$

where

k = 12.09 (1.232, 7.83) ordinary strength steel
= 16.11 (1.643, 10.43) HT32 strength steel
= 18.12 (1.848, 11.73) HT36 strength steel
= 19.13 (1.951, 12.38) HT40 strength steel

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

r = least radius of gyration, in cm (in.)

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

n = 4.44 (0.452, 0.345) ordinary strength steel

= 7.47 (0.762, 0.581) HT32 strength steel

= 9.00 (0.918, 0.699) HT36 strength steel

= 9.76 (0.996, 0.758) HT40 strength steel

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

3.3 Calculated Load

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

$W = nbsh$ kN (tf, Ltf)

where

n = 7.04 (0.715, 0.02)

b = mean breadth of the area supported, in m (ft)

s = mean length of the area supported, in m (ft)

h = height above the area supported when there is no cargo space and/or cargo carried on or above the freeboard deck, in m (ft)

= for pillars spaced not more than two frame spaces: the distance from the deck supported to a point located 3.80 m (12.5 ft) above the freeboard deck.

= for widely-spaced pillars: the distance from the deck supported to a point 2.44 m (8 ft) above the freeboard deck, except for pillars located immediately below the freeboard deck, for which the value of h is not to be less than given in 3-2-7/Table 2, Column *a*. In measuring the distance from the deck supported to the specified height above the freeboard deck, the height for any tween-decks devoted to passenger or crew accommodation may be taken as the height given in 3-2-7/3 for bridge-deck beams.

= the height for any pillar under the first superstructure deck above the freeboard deck is not to be less than 2.44 m (8 ft).

= the height for any pillar is not to be less than the height given in 3-2-7/3 for the beams at the top of the pillar plus the sum of the heights given in the same paragraph for the beams of all complete decks and one-half the heights given for all partial superstructures above

= the height for pillars under bulkhead recesses or the tops of tunnels is not to be less than the distance from the recess or tunnel top to the bulkhead deck at the centerline.

Where the cargo load exceeds $h \times 7.01$ kN/m^2 the heads given above for cargo spaces below the freeboard deck are to be increased by the factor of cargo load kN/m^2/$h \times 7.01$ kN/m^2 ($h \times 44.7$ lbf/ft^2)

This adjustment to design heads may need to be included elsewhere where the implied cargo load in cargo spaces below the freeboard deck of $h \times 7.01$ kN/m^2 is used.

3.5 Additional Pillars

Additional pillars which are not directly in line with those above, or which are not on the lines of the girders, but which support the loads from above or the deck girders through a system of supplementary fore and aft or transverse girders, such as at hatch ends where the pillars are fitted only on the centerline, are to have the load W, for use with the equation proportionate to the actual loads transmitted to the pillars through the system of girders with modifications to the design value of h as described in 3-2-8/3.3.

3.7 Pillars under the Tops of Deep Tanks

Pillars under the tops of deep tanks are not to be less than required by the foregoing equation. They are to be of solid cross section (pipes and tubing not allowed) and to have not less area than cW cm^2 (in^2) where W and c are obtained as follows:

$$W = nbsh \qquad \text{kN (tf, Ltf)}$$

where

n = 10.5 (1.07, 0.03)

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

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

h = height, as required by 3-2-7/3.1, for beams at the top of tanks, in m (ft)

c = 0.1035 (1.015, 0.16) ordinary strength steel

= 0.0776 (0.761, 0.12) HT32 strength steel

= 0.069 (0.677, 0.107) HT36 strength steel

= 0.0655 (0.643, 0.102) HT40 strength steel

3.9 Bulkhead Stiffening

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

3.11 Attachments

Widely-spaced tubular or solid section pillars are to solidly bear at top and bottom and are to be attached by partial or full penetration welds properly proportioned to the size of the pillar. The attachments of stanchions or pillars under bulkhead recesses, tunnel tops or deep-tank tops, which may be subjected to tension loads, are to be developed by full penetration welds.

5 Deck Girders and Transverses

5.1 General

Girders and transverses of the sizes required by 3-2-8/5.3 through 3-2-8/5.15 are to be fitted to support the beams. In way of bulkhead recesses and the tops of tanks, they are to be arranged so, that the unsupported span of the beams does not exceed 4.8 m (16 ft). Additional girders are to be fitted under masts, king posts, deck machinery or other heavy concentrated loads. In way of deck girders or deep beams, the deck plating is to be of sufficient thickness and suitably stiffened to be considered an effective part of the girder.

5.3 Deck Girders Clear of Tanks

Each deck girder clear of tanks, similar to that shown in 3-2-8/Figure 1, is to have a section modulus SM as obtained from the following equation:

$$SM = 4.74cbh\ell^2 \quad \text{cm}^3$$

$$SM = 0.0025cbh\ell^2 \quad \text{in}^3$$

where

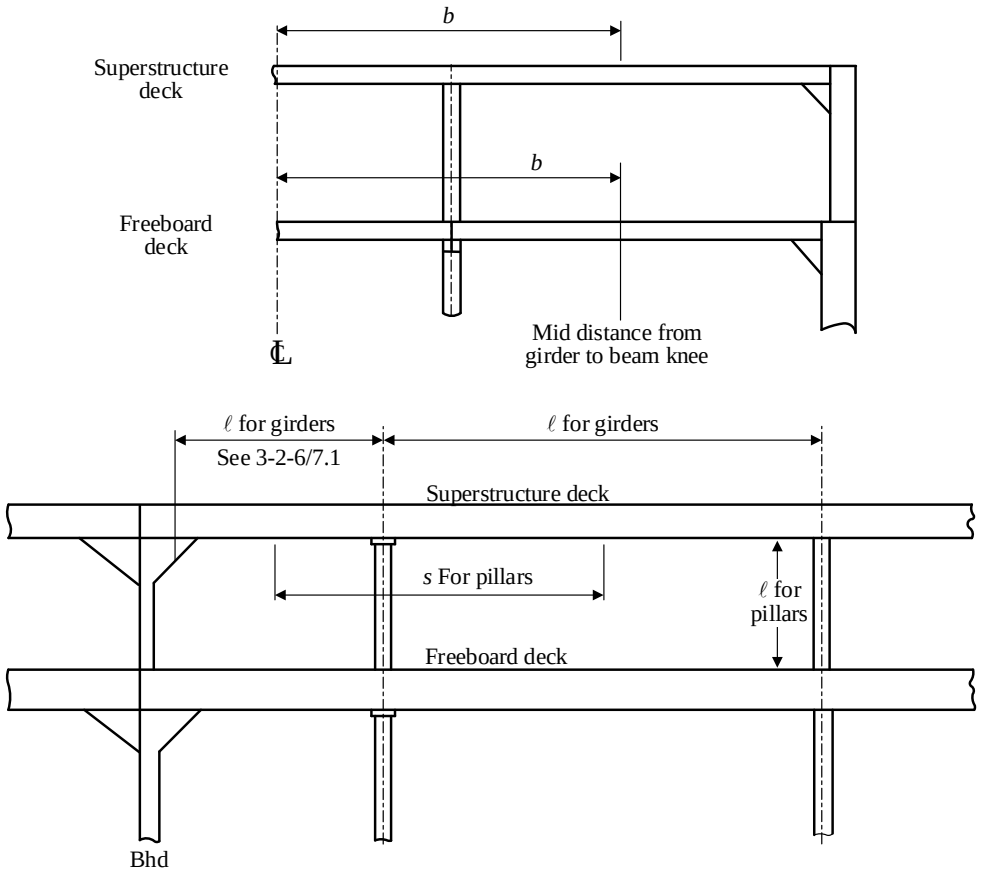
c = 1.0

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

h = height, as required by 3-2-7/3.1, for the beams supported, in m (ft)

ℓ = span between centers of supporting pillars, or between pillar and bulkhead, in m (ft). Where an effective bracket, in accordance with 3-2-6/7.1, is fitted at the bulkhead, the length ℓ may be modified.

FIGURE 1
Deck Girders and Pillars



5.5 Deck Transverses Clear of Tanks

Each deck transverse supporting longitudinal deck beams is to have a section modulus *SM*, as obtained from the equations in 3-2-8/5.3, where:

c = 1.0

b = spacing of deck transverses, in m (ft)

h = height, as required by 3-2-7/3.1, for the beams supported, in m (ft)

ℓ = span between supporting girders or bulkheads, or between girder and side frame, in m (ft). Where an effective bracket is fitted at the side frame or bulkhead, the length ℓ may be modified. See 3-2-6/7.1.

5.7 Proportions *(2014)*

Girders and transverses are to have a depth of not less than 0.0583ℓ (0.7 in. per ft of span ℓ). The depth is also not to be less than 3 times the depth of the cutouts for the beams or longitudinals for vessels 90 m (295 ft) in length and greater or 2.5 times the depth of the cutouts for the beams or longitudinals for vessels less than 90 m (295 ft) in length, unless effective compensation is provided for the cutouts. The thickness is not to be less than 1 mm per 100 mm (0.01 in. per in.) of depth plus 4 mm (0.16 in.). For vessels 90 m (295 ft) in length and greater, the thickness is not to be less than 8.5 mm (0.34 in.) where the face area is 38.7 cm^2 (6 in^2) or less, 10 mm with 64.5cm^2 (0.40 in. with 10 in^2), 12.5 mm with 129 cm^2 (0.50 in. with 20 in^2) and 15 mm with 193.5 cm^2 (0.60 in. with 30 in^2) or over. The thickness for intermediate area may be obtained by interpolation.

Alternative designs with stiffness equivalent to the specified depth/length ratio and the required section modulus may be considered, provided that the calculated results are submitted for review.

5.9 Tripping Brackets

Tripping brackets are to be fitted at intervals of about 3 m (10 ft.) and near any change of section. Where the breadth of the flange on either side of the web exceeds 200 mm (8 in.), tripping brackets are to be arranged to support the flange. Additional supports are to be provided for the flanges where their breadth exceeds 400 mm (16 in.).

5.11 End Attachments

The ends of deck girders and transverses are to be effectively attached by welding in which the fillet weld throat area develops the strength of the member being attached.

5.13 Deck Girders and Transverses in Tanks

Deck girders and transverses in tanks are to be obtained in the same manner as given in 3-2-8/5.3, except that the value of c is to be equal to 1.5 and the minimum depth of the girder is to be 0.0833ℓ (1 in. per ft of span ℓ). The minimum thickness, sizes and arrangements of the stiffeners, tripping brackets and end connections are to be the same as given in 3-2-8/5.7, 3-2-8/5.9, and 3-2-8/5.11.

5.15 Hatch Side Girders

Scantlings for hatch side girders supporting athwartship shifting beams or supporting hatch covers are to be obtained in the same manner as deck girders (3-2-8/5.3 through 3-2-8/5.13). Such girders along lower deck hatches at the bottom of trunks in which top covers are omitted are to be increased in proportion to the extra load which may be incurred due to loading up the trunks. The structure on which such hatch covers are seated is to be effectively supported.

Where deep coamings are fitted above a deck, such as at weather decks, the girder below deck may be modified so as to obtain a combined section modulus including the coaming and the horizontal coaming stiffener, of at least 35% greater than that required by 3-2-8/5.3.

Where hatch side girders are not continuous under deck beyond the hatchways to the nearest bulkheads, brackets extending for at least two frame spaces beyond the ends of the hatchways are to be fitted. Where hatch side girders are continuous beyond the hatchways, care is to be taken in proportioning their scantlings beyond the hatchway. Where the hatch side coaming is extended beyond the hatchway, it is not to be connected to the end bulkheads of superstructures or deckhouses, except where it is proven to be appropriate by detailed analysis.

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

7 Hatch-end Beams

7.1 Hatch-end Beam Supports

Each hatch-end beam, similar to that shown in 3-2-8/Figure 2, which is supported by a centerline pillar but without a pillar at the hatchway corner, is to have a section modulus SM not less than obtained from the following equations:

7.1.1 Where Deck Hatch-side Girders are Fitted Fore and Aft beyond the Hatchways

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

$$SM = 5.267K\,(AB + CD)\,h\ell\ 10^{-4} \quad \text{in}^3$$

7.1.2 Where Girders are not fitted on the Line of the Hatch Side beyond the Hatchway

$$SM = KABh\ell \quad \text{cm}^3$$

$$SM = 5.267KABh\ell\ 10^{-4} \quad \text{in}^3$$

where

A = length of the hatchway, in m (ft)

B = distance from the centerline to the midpoint between the hatch side and the line of the toes of the beam knees, in m (ft)

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

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

h = height for the beams of the deck under consideration, as given in 3-2-7/3.1, in m (ft)

ℓ = distance from the toe of the beam knee to the centerline plus 0.305 m (1 ft), in m (ft)

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

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

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

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

7.3 Weather Deck Hatch-end Beams

Weather deck hatch-end beams which have deep coamings above deck throughout the width of the hatch may have the flange area reduced from a point well within the line of the hatch side girder to approximately 0.5 of the required area at the centerline. In such cases, it is recommended that athwartship brackets be fitted above deck at the ends of the hatch-end coaming.

7.5 Depth and Thickness

The depth and thickness of hatch-end beams are to be similar to those required for deck girders by 3-2-8/5.7.

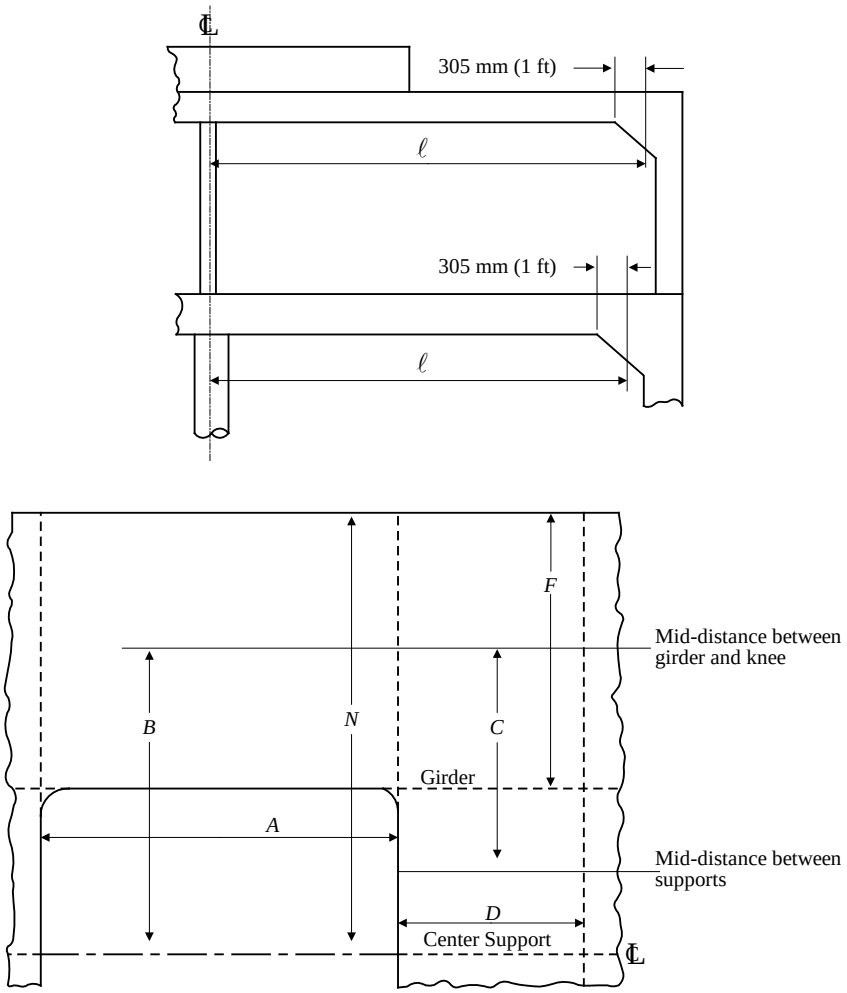
7.7 Tripping Brackets

The arrangement of tripping brackets is to be in accordance with 3-2-8/5.9.

7.9 Brackets

Brackets at the ends of hatch-end beams are to be generally as described in 3-2-6/7.1. Where brackets are not fitted, the length ℓ is to be measured to the side of the vessel and the face plates or flanges on the beams are to be attached to the shell by heavy horizontal brackets extending to the adjacent frame.

FIGURE 2
Hatch-end Beams



9 Higher-strength Materials

9.1 General

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

Higher strength steel members are to be continuous in way of transverse members of ordinary strength steel or of lesser strength higher strength steel.

9.3 Girders and Deck Transverses

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

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

where

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

Q = as defined in 3-2-1/5.

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 9 Watertight Bulkheads and Doors

1 General

1.1 Application

All vessels are to be provided with strength and watertight bulkheads in accordance with this Section. In all cases, the plans submitted are to clearly show the location and extent of the bulkheads. Watertight bulkheads constructed in accordance with these Rules will be recorded in the *Record* as **WT** (watertight), the symbols being prefixed in each case by the number of such bulkheads. Bulkheads which are deep tank boundaries are to have scantlings which comply with Section 3-2-10.

1.3 Openings and Penetrations

The number of openings in watertight subdivisions is to be kept to a minimum, compatible with the design and proper working of the vessel. Where penetrations of watertight bulkheads and internal decks (see 3-2-15/17.3) are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity. Relaxation in the water-tightness of openings above the freeboard deck may be considered, provided it is demonstrated that any progressive flooding can be easily controlled and that the safety of the vessel is not impaired.

Ventilation penetrations through watertight subdivision bulkheads are to be avoided. However where unavoidable, the ventilation ducting is to satisfy either watertight bulkhead requirements or watertight closing appliances are to be installed at the penetrations. For ventilation penetrations below the bulkhead deck or below damage equilibrium waterlines, the closing appliances are to be operable from the bridge. Where the penetration is located above the bulkhead deck and damage waterline, local manual controls may be provided at the closing appliances, on one or both sides of the bulkhead, so that the controls will be accessible in the prescribed flooded conditions.

1.5 Sluice Valves and Cocks

No valve or cock for sluicing purposes is to be fitted on a collision bulkhead. Where fitted on other watertight bulkheads, sluice valves or cocks are to comply with the requirements of 4-6-2/9.7.4.

1.7 Strength Bulkheads

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

1.9 Testing

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

3 Arrangement of Watertight Bulkheads

3.1 Collision Bulkhead

3.1.1 General

A collision bulkhead is to be fitted on all vessels. It is to be intact, without openings, except as permitted in 4-6-2/9.7.3. It is to extend, preferably in one plane, at least to the freeboard deck, but on vessels having long superstructures at the fore end, it is to be extended weathertight to the first superstructure deck above the freeboard deck. This extension need not be fitted directly over the bulkhead below, provided that the location of the extension meets the requirements in 3-2-9/3.1.2 and the part of the deck which forms the step or recess is made effectively weathertight.

3.1.2 Location *(1 July 2012)*

The collision bulkhead is to be located at any point not less than $0.05L_f$ or 10 m (32.8 ft), whichever is less, abaft of the reference point. At no point on vessels having 500 or more gross tonnage, except as specially permitted, is it to be further than $0.08L_f$ or $0.05L_f$ + 3 m (9.84 ft), whichever is greater, from the reference point.

3.1.3 Reference Point *(1 July 2012)*

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 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 (see 3-2-9/Figure 1) is the least of the following:

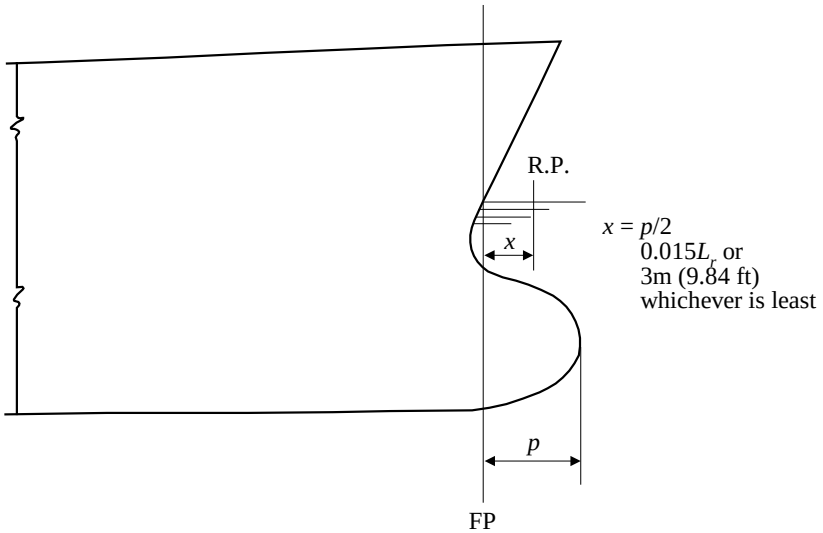
i) Half the distance between the forward end of L_f and the extreme forward end of the extension, $p/2$

ii) $0.015L_f$ or

iii) 3 m (9.84 ft)

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

FIGURE 1
Reference Point for Vessels with Bulbous Bow



3.3 After-peak Bulkhead

An after-peak bulkhead is to be fitted in all screw vessels arranged to enclose the shaft tubes in a watertight compartment. The bulkhead is to extend to the strength deck, or efficient partial bulkheads or deep transverse webs are to extend thereto. The requirement to enclose the shaft tubes in a watertight compartment may be specially considered where such an arrangement is proven to be impracticable provided it does not increase the risk to impair the watertight integrity of the hull.

The top of the aft peak tank is to be located above the summer load waterline.

3.5 Machinery Spaces

Machinery spaces are to be enclosed by watertight bulkheads which extend to the freeboard deck. In those cases where the length of the machinery space is unusually large in association with a small freeboard, the attention of designers is called to the desirability of extending the bulkheads to a deck above the freeboard deck, the fitting of an intermediate bulkhead, or the inclusion of a watertight deck over the machinery space which, in association with tight casings, might confine the amount of flooding in the event of damage in way of the machinery space. See 3-3-1/3.3.

3.7 Cargo Space Bulkheads

3.7.1 General

In addition to the foregoing required watertight bulkheads, the number and arrangement of cargo space bulkheads are to satisfy the subdivision and damage stability requirements in 3-3-1/3.3. Review procedures for this requirement are indicated in 3-3-1/5.

3.7.2 Carriage of Water Ballast and Liquid Cargoes in Cargo Holds

Where a cargo hold is intended to be used for the carriage of water ballast or liquid cargoes, the hold is in general to be completely filled and the scantlings of the inner bottom, side structure, transverse bulkheads, deck and hatch covers are also to be in accordance with Section 3-2-10. The hatch cover and securing devices are to be suitable for the internal loading. See 3-2-15/7.

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

3.9 Chain Lockers

Chain lockers and chain pipes are to be made watertight up to the weather deck. The arrangements are to be such that accidental flooding of the chain locker cannot result in damage to auxiliaries or equipment necessary for the proper operation of the vessel, nor in progressive flooding into other spaces. Bulkheads between separate chain lockers not forming a part of subdivision bulkhead (see 3-2-9/Figure 2A below) or bulkheads which form a common boundary of chain lockers (see 3-2-9/Figure 2B below), need not be watertight.

Where means of access into chain lockers are provided, they are to be closed by a watertight manhole cover secured by closely spaced bolts; doors are not permitted. Closely spaced bolts mean bolt spacing not exceeding 5 times bolt nominal diameter. Doors are not permitted.

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 3-2-15/21.11.

The arrangements on vessels that are not subject to the International Convention on Load Lines or its Protocol may be specially considered with respect to the safety of the vessel and the requirements of the flag administration.

FIGURE 2A
Chain Lockers Arrangement

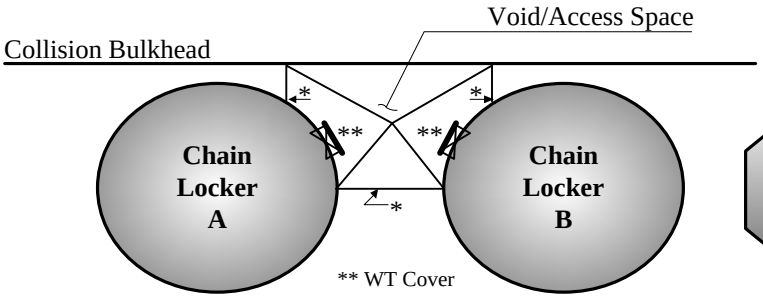
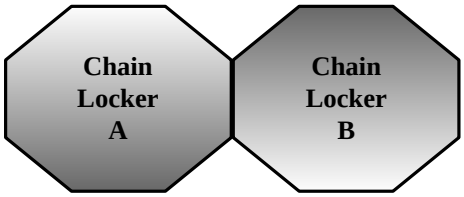


FIGURE 2B



5 Construction of Watertight Bulkheads

5.1 Plating

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

$t = sk\sqrt{qh}\,/c + 1.5$ mm — but not less than 6 mm or $s/200 + 2.5$ mm, whichever is greater

$t = sk\sqrt{qh}\,/c + 0.06$ in. — but not less than 0.24 in. or $s/200 + 0.10$ in., whichever is greater

where

t = thickness, in mm (in).

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

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

= 1.0 where $\alpha > 2$

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

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

Y = specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, lbs/in^2), as defined in 2-1-1/13 of the ABS *Rules for Materials and Welding (Part 2)* for the higher-strength material or 0.7 of the specified minimum tensile strength, whichever is the lesser

h = distance from the lower edge of the plate, in m (ft), to the bulkhead deck at center, if freeboard and bulkhead decks coincide

= not less than the distance from the lower edge of the plate, in m (ft), to the designated freeboard deck at center when freeboard deck is lower than the bulkhead deck (refer to 3-1-1/13.1).

c = 254 (254, 460) for collision bulkhead below freeboard or bulkhead deck

= 290 (290, 525) for other watertight bulkhead

The extension of the collision bulkhead above the freeboard deck is to have scantlings as required for the aft bulkhead of forecastles on the freeboard deck. The strength of the hinged door and its securing devices located in the extension, are to be sufficient to carry the load corresponding to the design head.

The plating of after-peak bulkheads below the lowest flat is not to be less than required for solid floors in the after peak space. See 3-2-5/9.

5.3 Stiffeners *(2016)*

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

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

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

where

k = 1.00 for stiffeners on watertight bulkheads

= 1.25 for stiffeners on collision bulkheads located below the freeboard deck

c = 0.56

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

ℓ = effective span between supports. Where end brackets are provided ℓ is measured to the point shown in 3-2-9/Figure 3A. Where flat bar end attachments or no end attachments are provided, ℓ is measured as shown in 3-2-9/Figure 3B.

h = distance from the middle of ℓ, in m (ft), to the bulkhead deck at center if freeboard and bulkhead decks coincide

= not less than the distance from the middle of ℓ, in m (ft), to the designated freeboard deck at center, when freeboard deck is lower than the bulkhead deck (see 3-1-1/13.1)

= where the distance indicated above is less than 6.1 m (20 ft), h is to be taken as 0.8 times the distance plus 1.22 m (4 ft)

The stiffeners on the extension of the collision bulkhead above the freeboard deck are to have scantlings as required for the aft bulkhead of forecastles on the freeboard deck.

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 3-2-1/5.3

5.4 Stiffener End Brackets *(1 July 2012)*

Where end brackets are provided, they are to have scantlings not less than shown in 3-2-9/Table 1A for vessels 90 m (295 ft) or greater in length or 3-2-9/Table 1B for vessels less than 90 m (295 ft) in length. The short arm of the bracket is to be not less than $^2/_3$ of the longer arm, as far as possible. In cases where the short arm is less than this, the effective length of the stiffener is to be measured to the point shown in 3-2-9/Figure 3C.

5.4.1 Overlap of Brackets for Vessels 90 m (295 ft) or Greater in Length

For vessels 90 m (295 ft) or greater in length, the minimum overlap is shown in 3-2-9/Figure 3A.

Where a bracket laps a member, the width of overlap generally is to be twice the thinner plate thickness plus 25 mm (1 in.).

5.4.2 Overlap of Brackets for Vessels Less than 90 m (295 ft) in Length

For vessels less than 90 m (295 ft) in length, the minimum overlap of the bracket arm along the stiffener is not to be less than obtained from the following equation:

$x = 1.4y + 30$ mm $\qquad$ $x = 1.4y + 1.2$ 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 width of overlap generally is to be twice the thinner plate thickness plus 25 mm (1 in.).

5.5 Attachments

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

FIGURE 3A
Bracket Connections

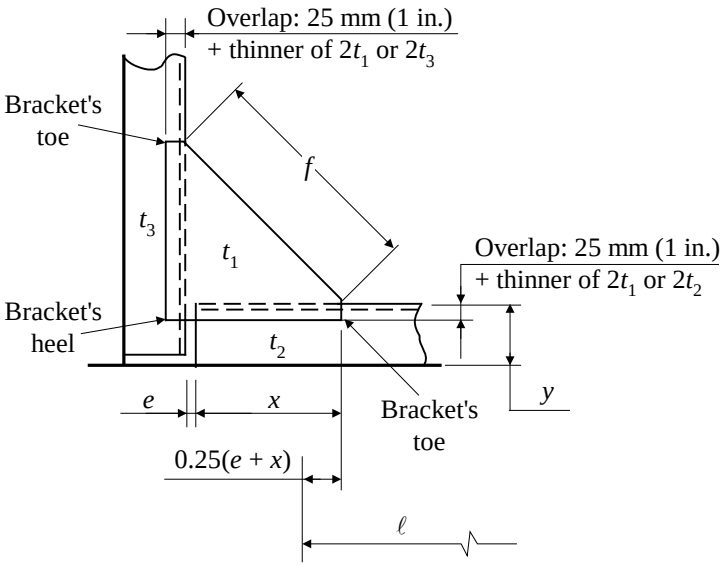


FIGURE 3B

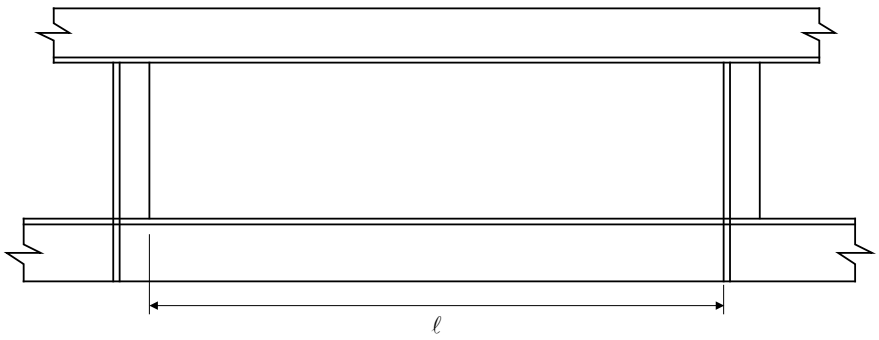


FIGURE 3C

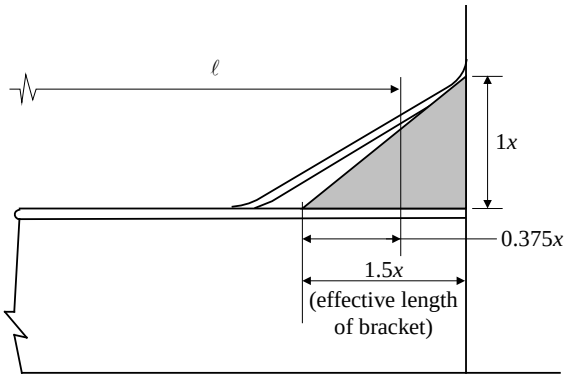


TABLE 1A
Thickness and Flanges of Brackets and Knees for Vessels ≥ 90 m (295 ft) in Length

Millimeters				Inches			
	Thickness				*Thickness*		
Depth of Longer Arm	*Plain*	*Flanged*	*Width of Flange*	*Depth of Longer Arm*	*Plain*	*Flanged*	*Width of Flange*
150	6.5			6.0	0.26		
175	7.0			7.5	0.28		
200	7.0	6.5	30	9.0	0.30	0.26	1 1/4
225	7.5	6.5	30	10.5	0.32	0.26	1 1/4
250	8.0	6.5	30	12.0	0.34	0.28	1 1/2
275	8.0	7.0	35	13.5	0.36	0.28	1 1/2
300	8.5	7.0	35	15.0	0.38	0.30	1 3/4
325	9.0	7.0	40	16.5	0.40	0.30	1 3/4
350	9.0	7.5	40	18.0	0.42	0.32	2
375	9.5	7.5	45	19.5	0.44	0.32	2
400	10.0	7.5	45	21.0	0.46	0.34	2 1/4
425	10.0	8.0	45	22.5	0.48	0.34	2 1/4
450	10.5	8.0	50	24.0	0.50	0.36	2 1/2
475	11.0	8.0	50	25.5	0.52	0.36	2 1/2
500	11.0	8.5	55	27.0	0.54	0.38	2 3/4
525	11.5	8.5	55	28.5	0.56	0.38	2 3/4
550	12.0	8.5	55	30.0	0.58	0.40	3
600	12.5	9.0	60	33.0		0.42	3 1/4
650	13.0	9.5	65	36.0		0.44	3 1/2
700	14.0	9.5	70	39.0		0.46	3 3/4
750	14.5	10.0	75	42.0		0.48	4
800		10.5	80	45.0		0.50	4 1/4
850		10.5	85				
900		11.0	90				
950		11.5	90				
1000		11.5	95				
1050		12.0	100				
1100		12.5	105				
1150		12.5	110				
1200		13.0	110				

Note: The thickness of brackets is to be suitably increased in cases where the depth at throat is less than 70% that of the arm of bracket or knee.

TABLE 1B
Thickness and Flanges of Brackets for Vessels < 90 m (295 ft) in Length *(1 July 2012)*

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

5.7 Girders and Webs

5.7.1 Strength Requirements

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

$$SM = 4.74kchs\ell^2 \quad \text{cm}^3$$

$$SM = 0.0025kchs\ell^2 \quad \text{in}^3$$

where

k = 1.00 for girders and webs on watertight bulkheads

= 1.25 for girders and webs on collision bulkheads

c = 1.00

h = as defined in 3-2-9/5.3, measured from the middle of s for girders and from the middle of ℓ for webs.

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

ℓ = span measured between the heels of the end attachments, in m (ft).Where brackets are fitted, the length ℓ may be modified as indicated in 3-2-6/7.1.

5.7.2 Proportions

Girders and webs are to have depths not less than 0.0832ℓ (1 in. per ft of span ℓ) plus one-quarter of the depth of the slots for the stiffeners; the thickness is not to be less than 1 mm per 100 mm (0.01 in. per in.) of depth plus 3 mm (0.12 in.) but need not exceed 11.5 mm (0.46 in.).

5.7.3 Tripping Brackets

Tripping brackets are to be fitted at intervals of about 3 m (10 ft), and near any change of section. Where the width of the face flange exceeds 200 mm (8 in.) on either side of the girder or web, tripping brackets are to be arranged to support the flange.

7 Construction of Corrugated Bulkheads

7.1 Plating

The plating of corrugated bulkheads is to be of the thickness required by 3-2-9/5.1 with the following modification. The spacing to be used is the greater of dimensions *a* or *c*, as indicated in 3-2-9/Figure 6. The angle ϕ is to be 45 degrees or more. Upper and lower stools may be provided to support the bulkheads.

7.3 Stiffeners

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

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

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

where

c = 0.56

h = as defined in 3-2-9/5.3

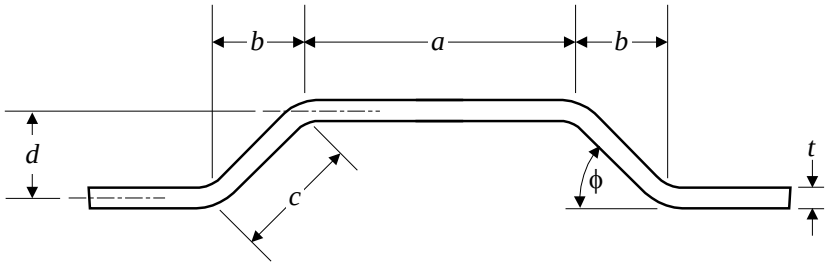
s = $a + b$ (See 3-2-9/Figure 4)

ℓ = distance between supporting members, in m (ft), both for vertical and horizontal corrugations. Where applicable, the distance ℓ may be measured between the upper and lower stools except, that the credit for upper stools of rectangular cross section is not to exceed twice the width of the cross section ("$2 \times b$" in 3-2-9/Figure 4) and trapezoidal cross section is not to exceed twice the width of the mid-segment ("b' + b" in 3-2-9/Figure 4)

The actual section modulus SM_A of the corrugation may be obtained from the following equation, where *a*, *t* and *d* are as indicated in 3-2-9/Figure 4.

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

FIGURE 4
Corrugated Bulkhead



7.5 End Connections *(2017)*

The structural arrangements and size of welding at the ends of corrugations are to be designed to develop the required strength of corrugated stiffeners. Joints within 10% of the depth of corrugation from the outer surface of corrugation, d_1, are to have double continuous welds with fillet size *w* not less than 0.7 times the thickness of bulkhead plating or penetration welds of equal strength. See 3-2-9/Figure 5 and 3-2-19/15.

Where no stools are fitted for the vertically corrugated bulkhead, the following requirements are to be complied with:

i) The corrugation webs are to be supported by brackets, beams, diaphragms or girders.

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

iii) The thickness and material properties of the floors in line with the corrugation flanges are to be at least equal to those provided for the corrugation flanges.

iv) Reinforcement may be required for access openings in supporting floors, girders, beams, and transverses.

v) Calculations or Finite Element analysis may be submitted for review to justify the design of the supporting structure in way of the connection. Finite Element Analysis shall comply with the ABS *Guidance Notes on SafeHull Finite Element Analysis of Hull Structures.*

FIGURE 5
Corrugated Bulkhead End Connections

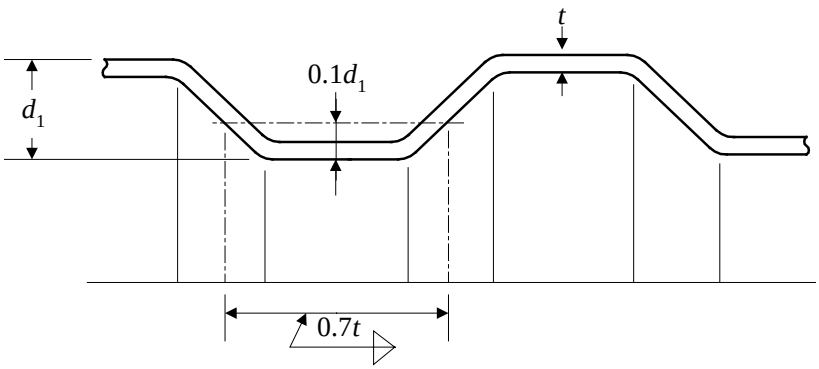
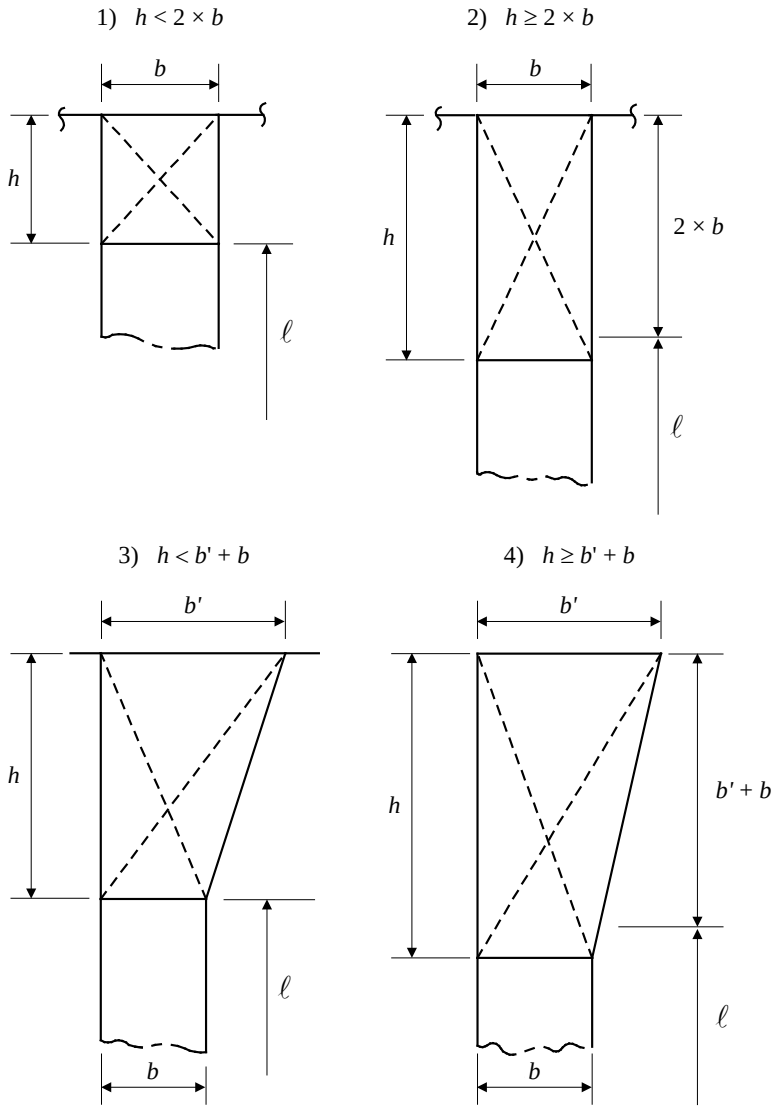


FIGURE 6
Corrugated Bulkhead Upper Stool Credit



9 Watertight Doors

9.1 Doors Used While at Sea

Doors that are used while at sea are to be sliding watertight doors capable of being remotely closed from the bridge and are also to be operable locally from each side of the bulkhead. Indicators are to be provided at the control position showing whether the doors are open or closed, and an audible alarm is to be provided which is to sound whenever the door is closed remotely by power. See also 4-9-7/1.3.3. The power operated doors, control systems and indicators are to be functional in the event of main power failure. Particular attention is to be paid to minimize the effect of control system failure. Each power-operated sliding watertight door is to be provided with an individual hand-operated mechanism. It is to be possible to open and close the door by hand at the door itself from each side. See also Section 4-9-7.

For vessels less than 80 m (262.4 ft) in length (L_f as defined in 3-1-1/3.3), hinged quick-acting doors, operable from both sides of the door, are permitted above a deck, the molded line of which at its lowest point at side, is at least 2.14 m (7 ft) above the deepest load line. Hinged quick-acting doors, operable from both sides, are also permitted for vessels less than 80 m (262.4 ft) in length, L_f, in way of inboard compartments that are not within the assumed extent of damage that may be applicable to the vessel.

9.3 Access Doors and Hatches Normally Closed at Sea *(1 July 2012)*

Access doors and hatches located in watertight bulkheads (see 3-2-15/17.3) and normally closed at sea may be constructed as hinged type fitted with gaskets and dogs spaced and designed so as to ensure the opening being made watertight. These closing appliances are to be provided with means of indicating locally and remotely on the bridge, whether they are open or closed. A notice is to be permanently affixed on both sides of each closing appliance to the effect that it is to be kept closed while at sea.

The primary securing devices of such doors are to be of a quick acting type (e.g., all door dogs are in closed/opened position simultaneously by a manually-operated single handle, central locking device or equivalent). Dogs (twist tightening handles) with wedges are not acceptable.

Additionally, where a vessel is a Type B ship over 100 m (328 ft) in length with a freeboard less than that based on Table B in Regulation 28 of the International Convention on Load Lines 1966, the final waterline after flooding with the sinkage, heel and trim accounted for is to be below the lower edge of those doors openings through which progressive down-flooding may take place, unless the doors are remotely operated. Doors separating a main machinery space from the steering gear compartment may be a hinged, quick acting type provided that the sill of such doors is above the summer load waterline.

9.3.1 Strength Requirements for Steel Access Doors and Hatches in Watertight Bulkheads

Where hinged steel doors or hatches are fitted, the thickness of the plating is to be not less than required by 3-2-9/5.1 nor less than the surrounding bulkhead plating. The maximum allowable stress and deflection under the design head h and the minimum plate thickness are as follows.

Maximum allowable stress	$0.8Y$, and not exceeding the critical buckling strength in compression
Maximum allowable deflection	0.0056ℓ
Plate thickness	$0.01s$, but not less than 6 mm (0.24 in.)

where Y and s are as defined in 3-2-9/5.1.

9.3.1(a) The effective depth of the door panel stiffeners is not to be less than 0.04ℓ. Stiffeners, whenever possible, are to be aligned with contact points of dogs/hinges All stiffeners are to be welded to the door panel edge stiffener. Each stiffener in association with the plating to which it is attached is to have section modulus SM not less than obtained from the following equation:

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

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

where

h = distance, in m (ft), from the middle of ℓ to the freeboard deck at center

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

ℓ = unsupported length of the stiffener, in m (ft)

9.3.1(b) Securing Arrangements (1 July 2012).

i) Arrangement and spacing are to be determined with due attention to the water-tightness, the type and the size of the door or hatch, as well as the stiffness of the door/hatch edges between the securing devices. For hinged watertight doors and for all watertight hatch covers, the securing devices are to be of adequate strength to carry the total load on the door or cover corresponding to the head to the bulkhead deck or freeboard deck and not exceeding the stress level given in 3-2-9/9.3.1.

ii) The sealing pressure between door/hatch cover and coaming sufficient to keep water-tightness is to be maintained by the securing devices. This packing line pressure should be at least 5 N/mm^2 (0.51 kgf/mm^2, 725 lbs/in^2) under the design head h applied from the opposite side to the door/hatch opening direction.

iii) The door/hatch edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices without distortion. The moment of inertia, I, of edge elements is not to be less than:

$$I = c_i\, p\, a^4 \quad \text{cm}^4\ (\text{in}^4)$$

where

c_i = 6 (58.8, 0.000218)

p = sealing line pressure, in N/mm derived from design head design pressure corresponding to the head to the bulkhead or freeboard deck h, plus 5 N/mm^2 (0.51 kgf/mm^2, 725 lbs/in^2)

a = spacing, in m, of securing devices.

The seals and arrangement of the securing devices are to be such that in the secured position, with the seal compressed to the manufacturer's requirements, there is to be complete peripheral steel to steel contact between the doors and hatch cover edge structure and the bulkhead frame around the opening.

9.3.2 Strength Requirements for Aluminum Access Doors and Hatches in Watertight Bulkheads

Watertight access doors/hatches are to withstand the water pressure to which they may be subjected, and tested for that pressure before installing on board. Doors in the lower parts of the vessel, which may be required to be opened at sea, are to be of the sliding type and are to be tested at the maker's facility. All other doors/hatches may be constructed hinged and fitted with gaskets and dogs spaced and designed so, as to ensure that the openings may be closed watertight. The maximum allowable stress and deflection under the design head h and the minimum plate thickness are as follows.

- Maximum allowable stress — the product of the maximum stress calculated under assumed loads and the factor 4.25 is not to exceed the minimum ultimate strength of the material.
- Maximum allowable deflection — 0.0022ℓ
- Plate thickness — is not to be less in thickness than $0.9Q_o$% of the spacing of stiffeners or $5.4Q_o$ mm ($0.22Q_o$ in.), whichever is greater.

9.3.2(a) Plating. Plating is to be of the thickness obtained from the following equations.

For $h \le 18$ m (59 ft)

$$t_{al} = \frac{0.9(Q_o + \sqrt{Q_o})}{2}\{s\,[(h + 6.1)/1830] + 3.05\} \quad \text{mm}$$

$$t_{al} = \frac{0.9(Q_o + \sqrt{Q_o})}{2}\{s\,[(h + 20)/6000] + 0.12\} \quad \text{in.}$$

For $h > 18$ m (59 ft)

$$t_{al} = \frac{0.9(Q_o + \sqrt{Q_o})}{2}\{s\,[(h + 21.5)/3000] + 3.05\} \quad \text{mm}$$

$$t_{al} = \frac{0.9(Q_o + \sqrt{Q_o})}{2}\{s\,[(h + 70.5)/9850] + 0.12\} \quad \text{in.}$$

where

t_{al} = thickness, in mm (in.)

h = distance, in m (ft), from lower edge of the door/hatch plate to the bulkhead or freeboard deck at center

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

Q_o = material factor obtained as below:

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

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

= $92000/(\sigma_y + \sigma_u)$ US Units

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

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

TABLE 2
Minimum Mechanical Properties for Butt-Welded Aluminum Alloys

Alloy	*Ultimate Tensile Strength (σ_u) N/mm^2 (kgf/mm^2, lbs/in^2)*	*Yield Strength (σ_y) (3) N/mm^2 (kgf/mm^2, lbs/in^2)*
5083 (1)	275 (28.1, 40000)	125 (12.7, 18000)
5086 (1)	240 (24.6, 35000)	95 (9.85, 14000)
5454 (1)	215 (21.8, 31000)	85 (8.45, 12000)
5456 (1)	290 (29.5, 42000)	130 (13.4, 19000)
6061-T6 (2)	165 (16.9, 24000)	105 (10.6, 15000)

Notes:

1 All tempers

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

3 For other alloys refer to Aluminum Association's *Aluminum Construction Manual*.

9.3.2(b) Stiffeners. Whenever possible the door panel stiffeners are to be aligned with dogs/hinges contact points. All stiffeners are to be welded to the door panel edge stiffener. The effective depth of the stiffener is to be not less than 0.065 of its unsupported length. Each stiffener, in association with the plating to which it is attached, is to have a section modulus *SM* as obtained from the following equations.

$$SM_{al} = 0.9Q_o\,(4.74hs\ell^2) \quad \text{cm}^3$$

$$SM_{al} = 0.9Q_o\,(0.00246hs\ell^2) \quad \text{in}^3$$

where

Q_o = material factor, as obtained in 3-2-9/9.3.2(a)

h = distance, in m (ft), from the middle of stiffener to the bulkhead or freeboard deck at center; where that distance is less than 6.1 m (20 ft), h is to be taken as 0.8 times the distance plus 1.22 m (4 ft)

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

ℓ = span of the stiffener, in m (ft)

9.3.2(c) Securing Arrangements. Securing arrangement and scantlings are to be equivalent to those described in 3-2-9/9.3.1(b) above.

9.5 Doors or Ramps Dividing Large Cargo Spaces

Watertight doors or ramps (see 3-2-15/17.3) of satisfactory construction may be fitted to internally to subdivide large cargo spaces provided it is demonstrated to ABS that such doors or ramps are essential.

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

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

9.7 Openings Closed at Sea

Closing appliances which are to be kept permanently closed at sea, to ensure the watertight integrity of internal openings in watertight bulkheads and decks (see 3-2-15/17.3), that are not fitted with a device preventing unauthorized opening are to be provided with a permanently affixed notice stating, that it is to be kept closed while at sea. Manholes fitted with closely bolted covers need not be so marked.

9.9 Construction

Watertight doors and securing devices are to be of ample strength to withstand the water pressure to which they may be subjected, in accordance with the preceding paragraphs. Door frames are to be carefully fitted to the bulkheads; where liners are required, the material is to be not readily injured by heat or by deterioration. Sliding doors are to be carefully fitted to the frames.

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

9.11 Testing Watertight Door at Manufacturer *(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 10 Deep Tanks

1 General

1.1 Application

This Section applies to all deep tanks where the requirements in this Section exceed those of Section 3-2-9.

1.3 Arrangement

The arrangement of all deep tanks, together with their intended content, liquid density and the height of the overflow or vent pipes, are to be clearly indicated on the tank plan submitted. Any oil tanks and all other tanks that carry flammable liquids are not to be arranged forward of the collision bulkhead. Fuel oil tanks of any volume are not to be used for ballast water. For tank protection requirements and **POT** notation refer to 4-6-4/17.

Tanks for fresh water or fuel oil, passive anti-rolling tanks or those that are not intended to be kept entirely filled in service are to have divisions or deep swashes to minimize the sloshing and dynamic stress on the structure.

1.5 Construction

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

Longitudinal tight divisions, which are fitted in tanks which are to be entirely filled or empty in service, may be of the scantlings required for watertight bulkheads by Section 3-2-9. In such cases the tanks are to be provided with feed tanks or deep hatches fitted with inspection plugs, in order to ensure, that the tanks on both sides of the bulkhead are kept full in service.

For additional requirements regarding high density cargo tanks, such as liquid mud or brine etc., refer to Part 5 of these Rules.

1.7 Drainage and Air Escape

Limber and air holes are to be cut in all parts of the structure so as to ensure free drainage to the suction pipes and the escape of air to the vents without entrapments. Efficient arrangements are to be made for draining the spaces above deep tanks.

1.9 Testing

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

3 Construction of Deep Tank Bulkheads and Tank Tops

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

3.1 Plating *(2017)*

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

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

$t = (sk\sqrt{qh}\ /460) + 0.1$ 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 = $(3.075\sqrt{\alpha} - 2.077)/(\alpha + 0.272)$ where $1 \le \alpha \le 2$

= 1.0 where $\alpha > 2$

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

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

Y = specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, lbs/in^2), as defined in 2-1-1/13 of the ABS *Rules for Materials and Welding (Part 2)*, for the higher-strength material or 0.7 of the specified minimum tensile strength, whichever is the lesser

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

- a point located two-thirds of the distance from the top of the tank to the top of the overflow
- a point located above the top of the tank at a distance not less than given in column (*e*) of 3-2-7/Table 2, appropriate to the vessel's length
- the load line
- a point located at two-thirds of the distance to the bulkhead or freeboard deck

h is also not to be less than h_1 or h_0 where rupture disks or spill valves are fitted, as obtained below:

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

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

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

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

where

ρ = 1.0 where the specific gravity of liquid is 1.05 or less

= specific gravity of liquid where it is in excess of 1.05

(The provisions under 3-2-10/3 need not be applied in addition hereto)

h_t = head from the center of the supported area or lower edge of the plating to the deck at side or, where such is fitted, to the top of the trunk deck at side for tanks within trunk

h_a = $9.95p_v$ ($9.75p_v$, $2.25p_v$)

p_v = pressure/vacuum valve pressure setting, in bar (kgf/cm^2, lbf/in^2)

h_s = head to the spill valve or rupture disc, where fitted, in m (ft)

P_s = relieving pressure of spill valve or rupture disc, where fitted, in bar (kgf/cm^2, lbf/in^2)

3.3 Stiffeners *(1 July 2012)*

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

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

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

where

c = 0.9

= 1.0 for stiffeners supported at both ends by horizontal girders

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

h = as defined in 3-2-10/3.1, in m (ft), from the middle of ℓ

ℓ = effective span between supports. Where end brackets are provided ℓ is measured to the point shown in 3-2-9/Figure 3A. Where flat bar end attachments or no bracket attachments are provided, ℓ is measured as shown in 3-2-9/Figure 3B.

Where end brackets are provided, it is to have the scantlings not less than shown in 3-2-9/Table 1. The short arm of the bracket is to be not less than $^2/_3$ of the longer arm, as far as possible. In cases where the short arm is less than this, the effective length of the stiffener is to be measured to the point shown in 3-2-9/Figure 3C.

Stiffeners are to be effectively connected to adjacent structures to avoid hard spots, notches and stress concentrations.

3.5 Tank-top Plating and Stiffeners

Tops of tanks are to have plating 1 mm (0.04 in.) thicker than would be required for vertical plating at the same level; the thickness is not to be less than required for deck plating in the tank's location. Beams, girders and pillars are to be as required by Sections 3-2-7 and 3-2-8.

3.7 Girders and Webs

3.7.1 Strength Requirements

Each girder and web which supports frames or beams in deep tanks is to have section modulus *SM* as required by Sections 3-2-6 and 3-2-8 or as required by this paragraph, whichever is greater. Those which support bulkhead stiffeners are to be as required by this paragraph. The section modulus *SM* is to be not less than obtained from the following equation.

$SM = 4.74chs\ell^2$ cm^3

$SM = 0.0025chs\ell^2$ in^3

where

c = 1.50

h = vertical distance, in m (ft), from the middle of s for girders and from the middle of ℓ for webs to the heights as defined in 3-2-10/3.1

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

ℓ = span measured between the heels of the end of the attachments, in m (ft). Where effective brackets are fitted, ℓ may be modified as indicated in 3-2-6/7.1.

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

3.7.2 Proportions *(1 July 2012)*

Girders, except deck girders (see 3-2-8/5.13), and webs are to have depths not less than 0.145ℓ where no struts or ties are fitted, and 0.0833ℓ where struts are fitted, plus one-quarter of the depth of the slots for the frames or stiffeners. In general, the depth is not to be less than 3 times the depth of the slots for vessels 90 m (295 ft) in length and greater or 2.5 times the depth of the slots for vessels less than 90 m (295 ft) in length, unless effective compensation is provided for stiffener cutouts. The thickness is not to be less than 1% of the depth plus 3 mm (0.12 in.) but need not exceed 11.5 mm (0.46 in.).

3.7.3 Tripping Brackets

Tripping brackets are to be fitted at intervals of about 3 m (10 ft) and near the change of section. Where the width of the face flange exceeds 200 mm (8 in.) on either side of the girder or web, tripping brackets are to be arranged to support the flange.

3.9 Corrugated Deep Tank Bulkheads

Where corrugated bulkheads are used as deep-tank boundaries, the scantlings may be developed from 3-2-9/7. The plating thickness *t* and value of *SM* are to be as required by 3-2-10/3.1 and 3-2-10/3.3, respectively, with $c = 0.90$.

3.11 Anti-rolling Tank Bulkheads *(2014)*

Where anti-rolling tanks are provided, the required scantlings may be calculated from the above Paragraphs 3-2-10/3.1 through 3-2-10/3.9 based on *h* measured to the point located above tank bottom as follows:

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

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 3-2-10/3.1 and 3-2-10/3.3 is to be applied.

5 Higher-strength Materials

5.1 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. Higher strength steel members are to be continuous in way of intersecting members of lesser strength steel. Calculations are to be submitted to show adequate provision to resist buckling.

5.3 Plating

Deep-tank plating of higher-strength material is to be of not less thickness than obtained by 3-2-10/3.1.

5.5 Stiffeners

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

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

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

where c, h, s and ℓ are as defined in 3-2-10/3.1 and Q is as defined in 3-2-1/5.5.

When high strength stiffeners are fitted on mild steel plating, care should be taken to ensure that the neutral axis of the plating and stiffener combination is such as to prevent overstressing of the plating. The section modulus of the plate should meet the requirements for ordinary strength steel and the section modulus of the stiffener flange may meet high strength material requirements. The high strength stiffeners are to be continuous at the transverse members. Sniped ends are not permitted, nor is the flange of the high strength member to be sniped. End brackets attached to the high strength stiffeners should be high strength and section modulus in way of the brackets should comply with the high strength steel requirements.

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 11 Superstructures, Deckhouses, and Helicopter Decks

1 General Scantlings of Superstructures and Deckhouses

1.1 Side Plating

Side plating of superstructures within the amidships 0.4*L* of the vessel is to be obtained from 3-2-2/3. At the forward and after 0.1*L* ends, the plating may be of the thickness obtained from 3-2-2/5.7 and 3-2-2/5.9 for forecastle and poop side plating respectively. Between amidships 0.4*L* and 0.1*L* from each end, the thickness of the plating is to be gradually tapered.

1.3 Decks

1.3.1 Superstructures *(2017)*

Decks of superstructures having lengths greater than 0.1*L* are to comply with the requirements of 3-2-3/5. Where they are of 0.1*L* or less in length the stringer plate may be the thickness of the side plating and the remainder of the deck plating is to meet the hull girder section modulus requirements of Section 3-2-1 if they are located within the 0.4*L* amidships. The thickness of the plating at the forward and aft 0.1*L* ends is to be obtained from 3-2-3/Table 1 for forecastle and poop deck plating, respectively.

1.3.2 Deckhouses

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

1.5 Frames

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

1.7 Breaks in Continuity

Breaks in the continuity of superstructures are to be strengthened (see 3-2-2/11). The arrangements in such areas are to be clearly shown on the plans submitted for approval.

3 Exposed Bulkheads

3.1 General *(2013)*

The scantlings of the exposed bulkheads of superstructures and deckhouses are to be in accordance with the following paragraphs, except that the requirements for house side stiffeners need not exceed the requirements of Section 3-2-5 for the side frames, directly below the deck on which the house is located.

In general, the first or lowest tier is that located on the freeboard deck or the actual lower deck from which the loadline can be assigned in accordance with the ICLL. Deckhouses or superstructure situated on a deck at least one standard superstructure above the freeboard deck or the lowest exposed deck may be considered the second tier. Higher tiers are defined in a likewise manner. A standard superstructure height is that defined in the *International Convention on Load Lines*, 1966.

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

Superstructures or deckhouses located within the amidships 0.4L and having lengths greater than 0.1L are to have effective longitudinal scantlings to give a hull girder section modulus throughout the superstructure or deckhouse equal to that of the main hull girder. The superstructure scantlings are to be in accordance with 3-2-11/1 and the house top and side plating of such deckhouses is to be not less than obtained from equation 5 in 3-2-3/Table 2.

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

3.3 Plating

3.3.1 For All Vessels

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

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

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

where s and h are as defined in 3-2-11/3.5; when determining h, y is to be measured to the middle of the plate.

3.3.2 Minimum Thicknesses *(1 July 2012)*

For exposed bulkheads on the lowest tier of a deckhouse or superstructure and for all exposed bulkheads of deckhouses situated completely or partially on a forecastle deck, the minimum required thickness is to be as follows:

For front bulkheads:

$$t = 6.0 + 0.01L_2 \quad \text{mm, but not less than 7.5 mm}$$

$$t = 0.24 + 0.00012L_2 \quad \text{in., but not less than 0.3 in.}$$

For side and end bulkheads:

$$t = 5.0 + 0.01L_2 \quad \text{mm, but not less than 6.5 mm}$$

$$t = 0.2 + 0.00012L_2 \quad \text{in., but not less than 0.26 in.}$$

For other tier bulkheads, the thickness is not to be less than:

$$t = 4.0 + 0.01L_2 \quad \text{mm, but not less than 5.0 mm}$$

$$t = 0.16 + 0.00012L_2 \quad \text{in., but not less than 0.2 in.}$$

where L_2 as defined in 3-2-11/3.5.

3.5 Stiffeners *(1 July 2012)*

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

$$SM = 3.5\,sh\ell^2 \quad \text{cm}^3$$

$$SM = 0.00185\,sh\ell^2 \quad \text{in}^3$$

where

s = spacing of stiffeners, in m (ft)

ℓ = tween deck height, in m (ft)

h = $a\,[(bf) - y]c$, the design head, in m (ft)

= for unprotected front bulkheads on the lowest tier, and for all unprotected front bulkheads of a deckhouse situated completely or partially on a forecastle deck, h is not to be taken less than 9.9 m (32.5 ft)

= for side and end bulkheads on the lowest tier, h is to be taken not less than 3.3 m (10.8 ft); h is to be not less than 3.3 m (10.8 ft) for all side and end bulkheads of a deckhouse situated completely or partially on a forecastle deck

= 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), in which L need not be taken greater than 250 m (820 ft)

a = coefficient given in 3-2-11/Table 1

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

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

C_b = block coefficient, as defined in 3-1-1/13.3, not to be taken as less than 0.6 nor greater than 0.8. For aft end bulkheads forward of amidships C_b may be taken as 0.8.

x = distance, in m (ft), between the after perpendicular and the bulkhead being considered. Deckhouse side bulkheads are to be divided into equal parts not exceeding $0.15L$ in length and x is to be measured from the after perpendicular to the center of each part considered.

L = length of vessel, in m (ft), but L_2 need not be taken as greater than 300 m (984 ft)

f = value determined from 3-2-11/Table 2, in m (ft).

y = vertical distance, in m (ft), from the summer load waterline to the midpoint of the stiffener span

c = $(0.3 + 0.7\ b_1/B_1)$ but is not to be taken as less than 1.0 for exposed machinery casing bulkheads. In no case is b_1/B_1 to be taken as less than 0.25.

b_1 = breadth of deckhouse at the position being considered, in m (ft)

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

The stiffening is to be arranged so that mullion stiffeners are continuous between decks, with horizontal stiffeners intercostal between the mullion stiffeners. The front, end and side stiffeners are to be in alignment with the stiffeners of the deck below.

The non-dimensional ratio of tween deck height to mullion stiffener depth is to not exceed 18 for front mullions and 30 for side mullions.

Flat bars are not to be used for mullion stiffeners, where used elsewhere, flat bars are to have a depth to thickness not greater than 10.

Alternative arrangements could be acceptable providing that it can be shown equivalent in strength and stiffness to the above requirements.

3.7 End Attachments *(2016)*

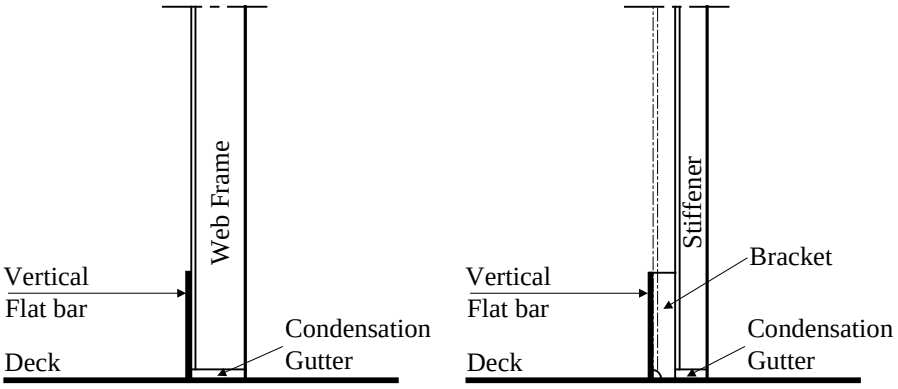
The upper and lower ends of all lowest tier bulkhead stiffeners, of all bulkhead stiffeners of the tiers on the forecastle deck and of all unprotected front bulkhead stiffeners are to be effectively attached. The end attachments are to be formed by end brackets, by welding all around flanges and webs to the deck plating or by lapping the stiffener onto the deck beam with the throat area of the weld not less than 80% of the area of the member being attached. The upper and lower ends of all lowest tier bulkhead stiffener webs and the 2nd tier unprotected front bulkhead stiffener webs are to be efficiently welded.

Alternatively the lower ends of deckhouse stiffeners may be supported by strong vertical flat bar attached to the web frame and/or stiffener flanges (refer to 3-2-11/Figure 1 below) provided the structural integrity of the deck/bulkhead connection is not impaired. The vertical flat bars are to have a depth to thickness not greater than 10.

The end attachments of the stiffener webs are to be designed to prevent stress concentration.

Where only the webs are welded on 3rd and higher tiers, the flange or face bar is to be sniped not more than 30°.

FIGURE 1
Lower Ends of Deckhouse Stiffeners



3.9 Deck Steps

The vertical part of steps in decks is to have plating of not less thickness than required for unprotected front bulkheads. The sizes of stiffeners are to be assessed on the basis of the length of the vessel, the actual height of the raised quarter deck and the arrangement of the structure.

TABLE 1
Values of *a*

Bulkhead Location	*SI Units and MKS Units*	*US Units*
Unprotected front, lowest tier	2.0 + *L*/120	2.0 + *L*/393.6
Unprotected front, 2nd tier	1.0 + *L*/120	1.0 + *L*/393.6
Unprotected front, 3rd tier	0.5 + *L*/150	0.5 + *L*/492
Protected front, all tiers	0.5 + *L*/150	0.5 + *L*/492
Sides, all tiers	0.5 + *L*/150	0.5 + *L*/492
Aft ends, aft of amidships, all tiers	0.7 + (*L*/1000) – 0.8*x*/*L*	0.7 + (*L*/3280) – 0.8*x*/*L*
Aft ends, forward of amidships, all tiers	0.5 + (*L*/1000) – 0.4*x*/*L*	0.5 + (*L*/3280) – 0.4*x*/*L*

TABLE 2
Values of *f*

Intermediate values of *f* may be obtained by interpolation

SI and MKS Units		*US Units*	
L, *m*	*f*, *m*	*L*, *ft*	*f*, *ft*
24	1.24	79	4.09
40	2.57	130	8.34
60	4.07	200	13.6
80	5.41	250	17.0
90	6.00	295	19.8
100	6.61	300	20.1
120	7.68	350	22.9
140	8.65	400	25.5
160	9.39	450	27.9
180	9.88	500	30.1
200	10.27	550	31.5
220	10.57	600	32.6
240	10.78	650	33.6
260	10.93	700	34.4
280	11.01	750	35.0
300 and greater	11.03	800	35.5
		850	35.8
		900	36.1
		984 and greater	36.2

Note The above table is based on the following equations:

L	*f*
SI Units and MKS Units	
L ≤ 150 m	(*L*/10)($e^{-L/300}$) – [1 – (*L*/150)^2]
150 < *L* < 300 m	(*L*/10)($e^{-L/300}$)
L ≥ 300 m	11.03
US Units	
L ≤ 492 ft	(*L*/10)($e^{-L/984}$) – [3.28 – (*L*/272)^2]
492 < *L* < 984 ft	(*L*/10)($e^{-L/984}$)
L ≥ 984 ft	36.2

5 Enclosed Superstructures and Deckhouses

5.1 Openings in Bulkheads

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

5.3 Doors for Access Openings *(2017)*

Doors for access openings into enclosed superstructures and deckhouses are to be made either of steel, aluminum or fiber reinforced plastic (if in compliance with statutory regulations and operational requirements) and are to be permanently attached to the bulkhead. Scantlings for door panels and stiffeners are to be obtained from 3-2-11/3.3 and 3-2-11/3.5 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 2 and to doors located on the exposed front bulkhead at all levels. The doors are to be provided with gaskets and clamping devices, or other equivalent arrangements and the doors are to be so arranged that they can be operated from both sides of the bulkhead. Doors located above Position 2 (refer to 3-2-15/3.1) of superstructure and deckhouses are to have strength compatible to adjacent bulkheads and may be of joiner-type construction (e.g., thin gauge steel sheeting surrounding a mineral wool core), provided they are verified to be weathertight to the satisfaction of the attending Surveyor.

Marine doors rated for the same design head as the bulkhead where they are located and which are designed and built to industry standards (the current versions of ASTM F1069, JIS F 2318, and BSI Standards BSMA 39) are considered acceptable as meeting requirements in this Section.

Doors are to open outwards and those in side bulkheads are to be hinged on the forward side.

5.3.1 Aluminum Doors

Aluminum doors are to have scantlings in accordance with 3-2-11/10.1. The ends of all stiffeners are to be attached to the door edge stiffeners

5.5 Sills of Access Openings *(2013)*

Except as otherwise provided in these Rules, the height of the sills of access openings in external bulkheads of enclosed superstructures and deckhouses is to be at least 380 mm (15 in.) above the deck.

For companionway sills see 3-2-15/21.7.

5.7 Portlights *(2013)*

Portlights in the end bulkheads of enclosed superstructures and deckhouses are to be of substantial construction and provided with efficient inside deadlights. Also see 3-2-17/7.

5.9 Bridges and Poops

A bridge or poop is not regarded as enclosed unless an alternate means of access is provided for the crew from any point on the exposed portion of the uppermost continuous deck to reach the machinery space or other working spaces within these superstructures when the bulkhead openings are closed.

7 Open Superstructures and Deckhouses

Superstructures and deckhouses with openings which do not fully comply with 3-2-11/5 are to be considered as open superstructures.

9 Forecastle Structures *(1 July 2012)*

Exposed forecastle structures on vessels with minimum freeboard are to be supported by girders in association with deep beams and web frames, preferably arranged in complete transverse belts and supported by lines of pillars extending continuously down into the structure below. Beams and girders are to be arranged, where practicable, to limit the spans to about 3 m (10 ft). Pillars are to be provided as required by 3-2-8/3.1. Main structural intersections are to be carefully developed with special attention given to pillar head and heel connections, and to the avoidance of stress concentrations.

10 Aluminum Superstructures and Deckhouses

10.1 Scantlings

Where deckhouses are constructed of aluminum alloys, the required plate thickness and stiffener section modulus, *SM*, are first to be determined as required for mild steel superstructures and deckhouses, and are then to be increased by the material factor, $(235/Y_{aw})^{0.50}$ or $235/Y_{aw}$, as indicated below.

For all deck and bulkhead plating and stiffeners, the required thickness and section modulus for aluminum alloy plate and shapes are obtained from the following equations:

- Plating:

$$t_{al} = t_s(Y_s/Y_{aw})^{0.50} \quad \text{mm (in.)}$$

- Stiffeners:

$$SM_{al} = Y_s/Y_{aw}SM_s \quad \text{cm}^3 \ (\text{in}^3)$$

where

t_{al} = minimum thickness of aluminum plate

t_s = required plate thickness for steel obtained from 3-2-11/1.3 and 3-2-11/3

SM_{al} = minimum section modulus of aluminum stiffeners

SM_s = minimum section modulus of steel stiffeners, as determined from 3-2-7/3 and 3-2-8/5 for deck stiffeners and 3-2-11/3.5 for bulkhead stiffeners

Y_s = 235 N/mm^2 (24 kgf/mm^2, 34,000 lbs/in^2)

Y_{aw} = minimum yield strength of the welded aluminum alloy under consideration at 0.20% offset in a 254 mm (10 in.) gauge length, in N/mm^2 (kgf/mm^2, lbs/in^2), obtained from 3-2-9/9.3.2

In addition, the aluminum stiffeners are to have a depth not less than that given below:

$$d_{al} = 3SM_s\, d_s/SM_{al}$$

where

d_{al} = minimum required depth for aluminum stiffeners

d_s = minimum required depth for steel stiffeners; not to be less than 100 mm (3.94 in.) depth for fronts and 80 mm (3.15 in.) for sides and ends

11 Helicopter Decks

11.1 General

Helicopter decks, where provided, are to meet the following structural and safety requirements. Attention is to be paid to various international and governmental regulations and guides regarding the operational and design requirements for helicopters landing on ships. See also Section 1-1-5 the ABS *Rules for Conditions of Classification (Part 1)* and 4-6-4/3.9.2 and 4-6-6/9 of these Rules.

Plans showing the arrangement, scantlings and details of the helicopter deck are to be submitted. The arrangement plan is to show the overall size of the helicopter deck and the designated landing area. If the arrangement provides for the securing of a helicopter or helicopters to the deck, the predetermined position(s) selected to accommodate the secured helicopter, in addition to the locations of deck fittings for securing the helicopter, are to be shown. The type of helicopter anticipated to use the facility is to be specified and calculations for appropriate loading conditions are to be submitted.

11.3 Structure

Scantlings of helicopter decks and supporting structure are to be determined on the basis of the following loading conditions, whichever is greater, in association with the allowable factors of safety shown in 3-2-11/Table 3. Plastic design considerations may be applied for deck plating and stiffeners.

Scantlings of helicopter decks and supporting structures are to be such that the resulting stress in members does not exceed:

$$Y/F_s$$

where

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

F_s = factor of safety, as given in 3-2-11/Table 3

11.3.1 Overall Distributed Loading

A minimum distributed loading of 2.01 kN/m^2 (205 kgf/m^2, 42 lbf/ft^2) is to be taken over the entire helicopter deck.

11.3.2 Helicopter Landing Impact Loading

A load of not less than 75% of the helicopter maximum take-off weight is to be taken on each of two square areas, 0.3 m × 0.3 m (1 ft × 1 ft). Alternatively, the manufacturer's recommended wheel impact loading will be considered. The deck is to be considered for helicopter landings at any location within the designated landing area. The structural weight of the helicopter deck is to be added to the helicopter impact loading when considering girders, stanchions, truss supports, etc. Where the upper deck of a superstructure or deckhouse is used as a helicopter deck and the spaces below are normally manned (quarters, bridge, control room, etc.), the impact loading is to be multiplied by a factor of 1.15.

11.3.3 Stowed Helicopter Loading

If provisions are made to accommodate helicopters secured to the deck in a predetermined position, the structure is to be considered for a local loading equal to the manufacturer's recommended wheel loading at maximum take-off weight, multiplied by a dynamic amplification factor based on the predicted motions of the vessel for this condition, as may be applicable for the vessel under consideration.

In addition to the helicopter load, a uniformly distributed loading of 490 N/m^2 (50 kgf/m^2, 10.5 lbf/ft^2), representing wet snow or ice, is to be considered, if applicable. For the girders, stanchions, truss supports, etc., the structural weight of the helicopter deck is also to be considered.

11.3.4 Loading due to Motions of Vessel

The structure supporting helicopter decks is to withstand the loads resulting from the motions of the vessel.

11.3.5 Special Landing Gear

Helicopters fitted with landing gear other than wheels will be specially considered.

11.3.6 Environmental Loading

Calculations are to consider anticipated wind and wave impact loading on helicopter decks and their supporting structures.

11.3.7 Bolted Connections *(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.

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

Y = specified minimum yield point or yield strength of the material as defined in 2-1-1/13 of the ABS *Rules for Materials and Welding (Part 2)*

	Plating	*Beams*	*Girders, Stanchions, Truss Supports, etc. (See Note 3)*
Overall Distributed Loading	1.67	1.67	1.67
Helicopter Landing Impact Loading	*(See Note 1)* 1.00 (2)	1.00	1.10
Stowed Helicopter Loading	1.00	1.10	1.25

Notes:

1 The minimum plate thickness t is generally not to be less than obtained from the following:

Beam spacing	t
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.

4 The minimum plate thickness for materials other than steel will be specially considered.

11.5 Material *(2017)*

In general, the construction of helicopter decks is to be of steel or another material with an equivalent ability to retain structural capacity in a fire. If the helicopter deck forms the deck head of a deckhouse or superstructure, it is to be insulated to A-60 class standard. Flag concurrence is required to satisfy SOLAS Ch. II-2/18 for the aluminum construction of a helicopter deck.

Where aluminum decks are used for helicopter decks above superstructures or deckhouses, the following arrangement is considered to have the equivalent fire integrity to steel, when tested in accordance with the listed below fire test.

In addition, in order for the arrangement to be considered to have equivalent fire integrity to steel helideck, an aluminum helicopter deck which is located 1 m (3.25 ft) or less above superstructure or deckhouses, a water spray system in accordance with 4-7-2/5.3.5 giving coverage to aluminum structure underneath the helicopter deck is to be provided.

11.5.1 Fire Test Procedures

i) Size of prototype helicopter deck is 7.6 m × 7.6 m (24.9 ft × 24.9 ft) with structural equivalence to the final product arrangement.

ii) If an aluminum gutter is incorporated in the test, the aluminum gutter should be placed at least on one side of the sample helideck panel.

iii) Sealant in panel joints should be non-combustible, and testing of the helicopter deck should be done without any topcoats or painting on the helicopter deck surface. The type of sealant must be reviewed and accepted by ABS.

iv) The static loads simulating actual helicopter weight are to be present on the helicopter deck.

v) An initial 284 liters (75 gallons) of fuel is to be poured over the helicopter deck area to a set fuel depth of 4-6 mm (0.16-0.24 in.). For the first 15 minutes, fuel is to be supplied at a rate of 147.6 liters per minute (39 gallons per minute) such that the deck is filled with fuel for the full 15 minutes. The depth of the fuel pool is to be limited to 4-6 mm (0.16-0.24 in.). After the first 15 minutes, no additional fuel is supplied, and the fire is allowed to burn until all fuel on the helicopter deck is consumed.

11.5.2 Fire Test Acceptance

The acceptance criteria are as follows (visual observations of the deck and sealing):

i) The helideck panel shall not collapse or be deformed between girders.

ii) The helideck panel support girders shall not collapse or be deformed.

iii) No fuel leakage shall occur in panel joints.

iv) No flames below deck or burn-through shall occur.

v) If an aluminum gutter is incorporated, no damage to the gutter is to be observed.

The test is to be witnessed by the Surveyor.

11.5.3 Other Arrangements of Helideck

If the aluminum helicopter deck does not meet the requirements of 3-2-11/11.5.1 and 3-2-11/11.5.2, and where the flag Administration has no specific requirements, the following conditions are to be satisfied:

i) There are to be no openings in the superstructure or deckhouse top directly below the helicopter deck.

ii) There are to be no openings in the exterior bulkheads directly below the helicopter decks.

iii) All windows/portlights in the exterior bulkheads directly below the helicopter decks are to be fitted with steel shutters.

iv) The helicopter deck is to be insulated to A-0 class if it is located 1 m (3.25 ft) or less above the top of the superstructure or deckhouse top.

v) The superstructure or deckhouse top and exterior bulkhead, including penetrations, except windows/portlights, is to be constructed as A-0 class divisions.

11.7 Arrangements

11.7.1 Size

In general, the helicopter deck is to be of sufficient size to contain a circle of a diameter equal to at least the rotor diameter D of the largest helicopter intended to use the facility. The helicopter deck is to have an approach/departure sector of at least 210° free of obstructions, as shown in 3-2-11/Figure 2. Objects the function of which requires that they be located on the helideck within approach/departure sector should be limited to landing nets (where required) and certain lighting system and should not exceed the surface of the landing area by more than 0.025 m. For single main rotor helicopters, within 150° limited obstacle sector out to a distance of 0.12D, measured from the point of origin of the limited obstacle sector, objects should not exceed a height of 0.25 m above deck (see hatched area in 3-2-11/Figure 2). Beyond that arc, out to a distance of an additional 0.21D, the maximum obstacle height is limited to a gradient of one unit vertically for each two units horizontally originating at a height of 0.05D above the level of the helideck (see 3-2-11/Figure 2)

For benign climates as determined by the coastal State, taking into account of the type of helicopter used, the conditions of wind, turbulence, sea state, water temperature and icing conditions, the helicopter deck is to be of sufficient size to contain a circle of a diameter not less than 0.83*D*. The helicopter deck is to have an approach/departure sector of at least 210° free of obstructions, as shown in 3-2-11/Figure 3. Objects the function of which requires that they be located on the helideck within approach/departure sector should be limited to landing nets (where required) and certain lighting system and should not exceed the surface of the landing area by more than 0.025 m. For single main rotor helicopters, within 0.415*D* to 0.5*D* objects should not exceed a height of 0.025 m. Within 150° limited obstacle sector out to a distance of 0.12*D*, measured from the point of origin of the limited obstacle sector, objects should not exceed a height of 0.05m above deck. Beyond that arc, out to a distance of an additional 0.21*D*, the maximum obstacle height is limited to a gradient of one unit vertically for each two units horizontally originating at a height of 0.05*D* above the level of the helideck (see 3-2-11/Figure 3).

11.7.2 Surface

The helicopter deck is to have a skid-resistant surface.

11.7.3 Grating Type Construction

Where the helicopter deck is constructed in the form of grating, the under deck should be such that the ground effect is maintained.

11.7.4 Drainage

The helicopter deck is to have drainage facilities to prevent the collection of liquids and prevent liquids from spreading to or falling on other parts of the vessel.

11.7.5 Projections

The helicopter deck is to be free of projections except that landing lights or other essential projections may be installed around the periphery of the deck provided they do not rise more than 150 mm (6 in.) above the level of the helicopter deck.

11.7.6 Tie Downs

The helicopter deck is to have recessed tie-down points for securing a helicopter.

FIGURE 2
Helideck Obstacle Limitation Sector: Single Main Rotor Helicopter

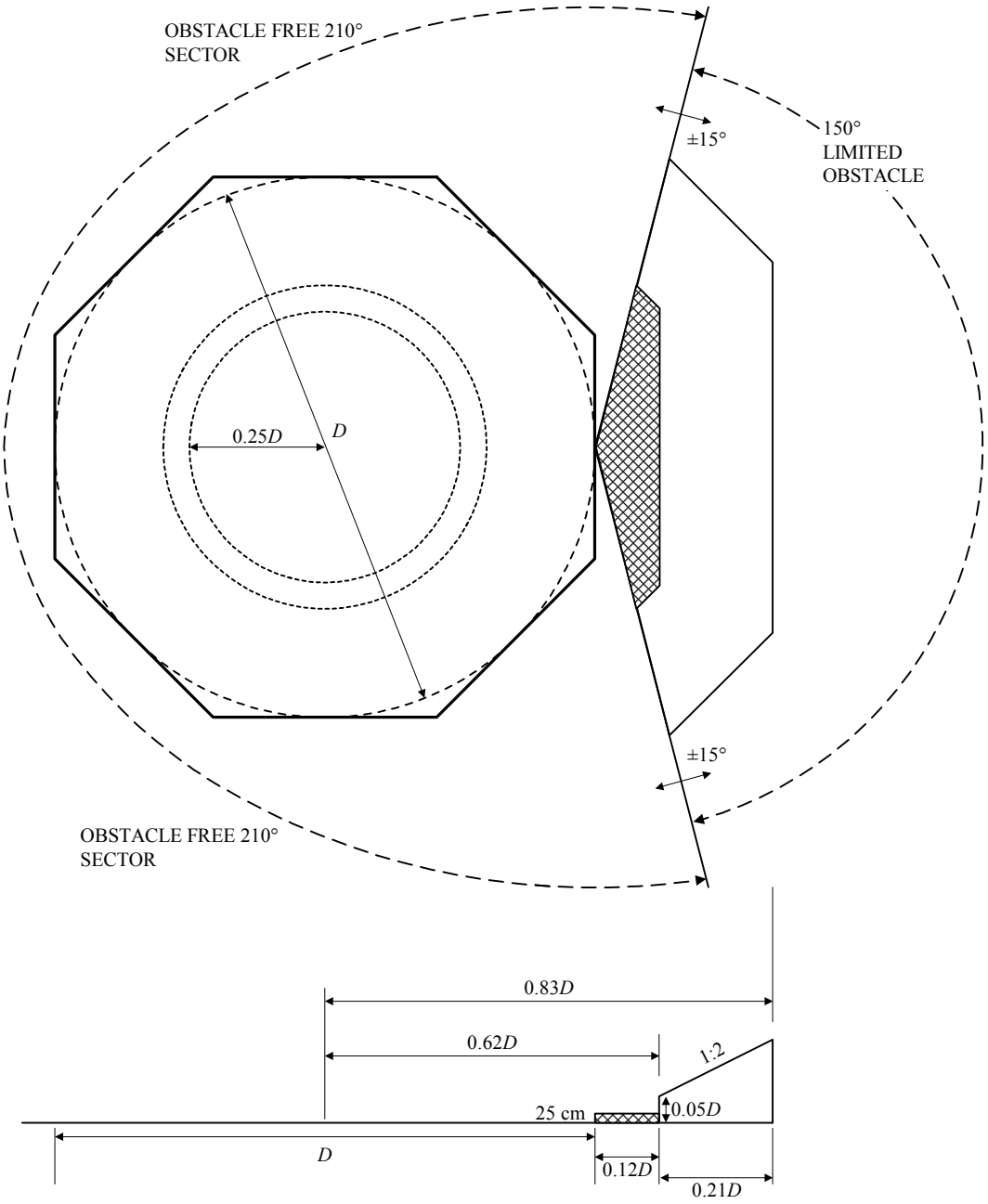
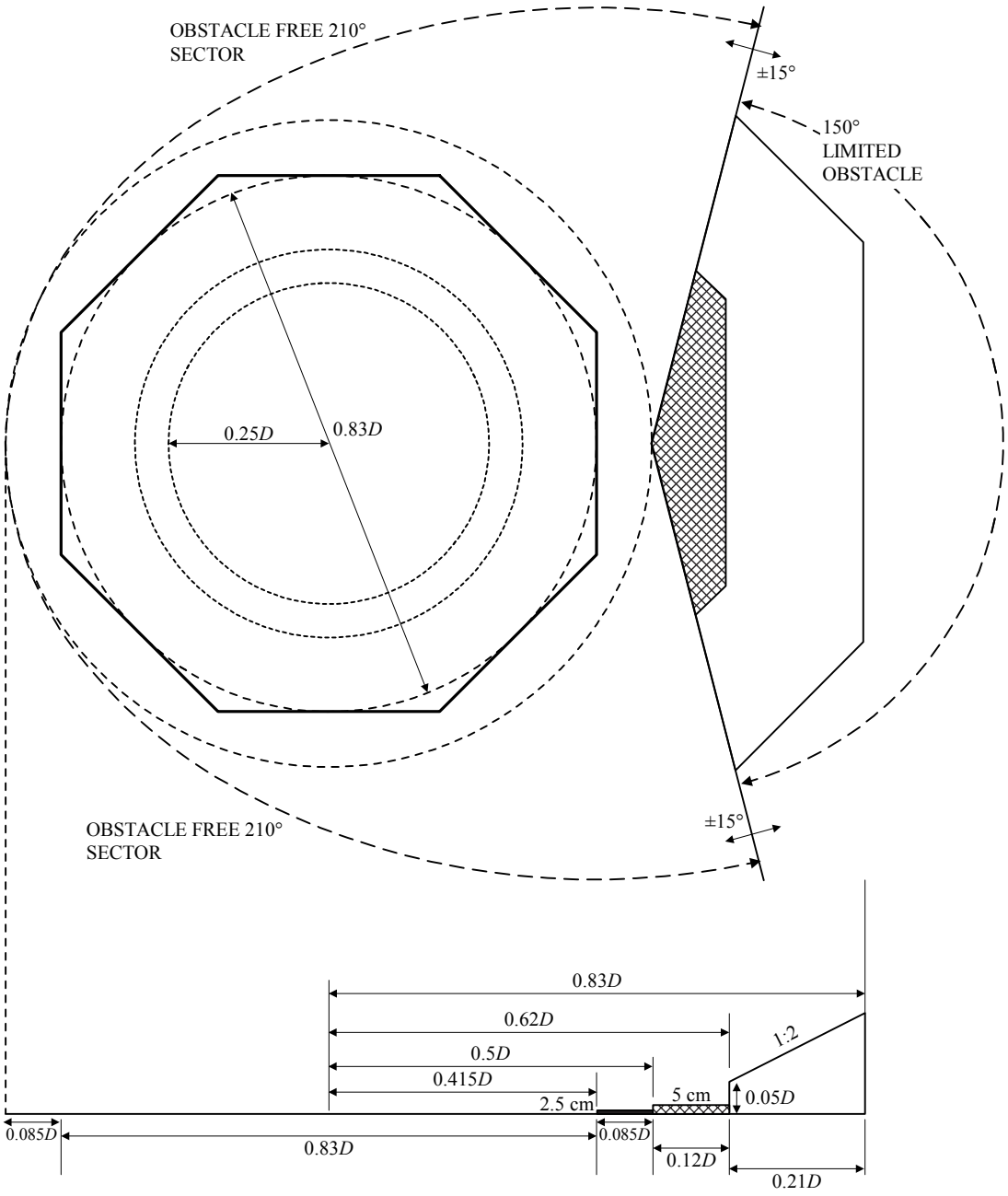


FIGURE 3
Helideck Obstacle Limitation Sector: Single Main Rotor Helicopter for Benign Climate Conditions as Accepted by the Coastal State



Note: Heights of 2.5 cm and 5 cm high shaded areas are not to scale.

11.9 Safety

11.9.1 Safety Net

For personnel protection, a safety net is to be provided around the periphery of the helicopter deck, except where structural protection exists. The net should be inclined upwards at an angle of 10° and outwards from below the edge of the helideck to a horizontal distance of 1.5 m and should not rise above the edge of the deck.

11.9.2 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 are complied with.

ii) Acceptance from the flag Administration.

iii) The firefighting equipment, which includes the hose reel, portable fire extinguishers, fixed foam system, is to provide coverage for the access/egress platforms and stairways. The capacity of the fixed foam system is to be increased to include the additional areas of protection for the aluminum access/egress platforms and stairways

iv) Where the helideck is also used as a firefighting station, the aluminum access/egress platforms and stairways are to meet the L3 fire integrity test, or equivalent as per 3-4-A1/Table 1 of the *Steel Vessel Rules*.

v) Where alternative means of fire protection (such as deluge system) are provided (typically along stairways or access under the helideck), and the arrangement and locations of the firefighting equipment, required in *i)* above are also available at or cover the access/egress route, the L3 performance test will not be necessary.

vi) Where the helideck is fitted with a refueling station, there is to be sufficient distance from the refueling station to at least one of the stairs, such that the aluminum stairs are not impacted by the fire at the refueling station.

In case of a fire outside the helideck area, access platforms and stairways are not to be considered part of an escape route.

Access/egress stairways and walkways to helidecks on vessels with **FFV** notation are to be made of steel. Please refer to 5-4-4/1.7 regarding restriction on the use of aluminum for access/egress stairways and walkways onboard vessels with **FFV** notation.

11.9.3 Visual Aids

Coastal States may have specific requirements that must be incorporated into the design. Where the Coastal State has no requirements, the following are to be complied with:

A wind direction indicator located in an unobstructed area readily visible to helicopters approaching the helicopter deck is to be provided.

11.9.4 Markings

The helicopter deck is to be marked (see 3-2-11/Figure 2) in a contrasting color as follows:

i) The perimeter with a continuous line of 300 mm (11.811 in.) in width

ii) Vessel identification

iii) Aiming circles, taking into account deck configuration, helicopter type and operational requirements

iv) A white "**H**" 4 m high, 3 m wide, with a stroke width of 0.75 m. located at the center of the landing area

11.9.5 Lights

Each helicopter deck is to be fitted with green lights visible omni-directionally from on or above the landing area. These lights should be equally spaced at intervals of not more than 3 m (9'-10") around the perimeter of the deck.

Helicopter deck floodlights, where fitted, should be located so as to avoid glare to pilots. The arrangement and aiming of floodlights should be such that helicopter deck markings are illuminated and that shadows are kept to a minimum.

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 12 Machinery Space and Tunnel

1 General

1.1 Arrangement

All parts of the machinery, shafting, etc., are to be efficiently supported and the adjacent structure is to be adequately stiffened. In twin-screw vessels it will be 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. 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 should be 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. Main propulsion units, reduction gear, shafting and main auxiliary foundations are to be submitted with relevant information on the equipment, loads and load paths, as well as design values for allowable bending, shear and buckling stresses.

1.3 Testing of Tunnels

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

3 Machinery Foundations

3.1 Engine Foundations

3.1.1 Single Bottom Vessels

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

3.1.2 Double Bottom Vessels

In vessels with double bottoms, the engines are to be seated directly upon thick inner-bottom plating or upon thick seat plates on top of heavy foundations arranged to distribute the weight effectively. Additional intercostal girders are to be fitted within the double bottom, to ensure the satisfactory distribution of the weight and the rigidity of the structure.

3.3 Boiler Foundations

Boilers, if provided, are to be supported by deep saddle-type floors or by transverse or fore-and-aft girders arranged to distribute the weight effectively. Where they are supported by transverse saddles or girders, the floors in way of boilers are to be suitably increased in thickness and specially stiffened (refer to 3-2-4/5). Boilers are to be installed such, as to 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 the foundations extending well beyond the thrust blocks and arranged so, as to distribute the loads effectively into the adjacent structure. Additional intercostal girders are to be fitted in way of the foundations, if necessary.

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 3-2-9/5.1 for watertight bulkheads; but the lowest strake of the plating is to be increased 1 mm (0.04 in.). Flat plating on the tops of tunnels or tunnel recesses is to be of the thickness required for watertight bulkhead plating at the same level. 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 two-thirds of the test head above the top of the tank

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 13 Stems, Stern Frames, Rudder Horns, and Propeller Nozzles

1 Stems

Depending on size and design of the vessel stems may be made of bent and welded steel plates, of formed cast or forged steel, or of steel bar.

1.1 Plate Stems *(2018)*

Plate stems, where used, are not to be less in thickness than required by the following equations, in the draft change zone (between the minimum draft and the maximum draft).

$t = (1.46 + L/12)\sqrt{q}$ mm $\quad L \le 245$ m

$t = 22\sqrt{q}$ mm $\quad 245 < L \le 305$ m

$t = (0.06 + L/1000)\sqrt{q}$ in. $\quad L \le 800$ ft

$t = 0.86\sqrt{q}$ in. $\quad 800 < L \le 1000$ ft

where

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 of the ABS *Rules for Materials and Welding (Part 2)*, for the higher-strength material or 72% of the specified minimum tensile strength, whichever is the lesser.

Above and below the draft change zone, the thickness may taper to the thickness of the shell at ends at the freeboard deck and to the thickness of the flat-plate keel at the forefoot, respectively.

1.3 Cast or Forged Stems

Cast or forged stems of special shape are to be proportioned to provide strength at least equivalent to that of a plate stem, and all joints and connections are to be at least that effective.

1.5 Bar Stems

In general the thickness of the bar stem should also not be less than twice the adjoining shell thickness. Bar stems are to have thickness and width not less than obtained from the following equations:

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

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

where

t = thickness, in mm (in.)

w = width, in mm (in.)

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

This thickness and width is to be maintained between the keel and scantling draft line. Above the scantling draft line they may be gradually reduced until the section area at the head is 0.7 of that obtained from the above equations.

Thicknesses and widths other than given above are acceptable, provided the section moduli and moments of inertia about the longitudinal axis are not less than calculated from above, nor is proportion of w/t more than 5.5.

3 Stern Frames

Stern frames may be fabricated from steel plates or made of cast steel. For applicable material specifications and steel grades, see 3-1-2/1.1.1 and 3-1-2/Table 2. The scantlings are to comply with 3-2-13/3.3 and 3-2-13/3.5. Stern frames of other material or construction will be specially considered.

3.1 Rudder Gudgeons

Rudder gudgeons are to be an integral part of the stern frame. The bearing length of the pintle is to be between 1.0 and 1.2 times the pintle diameter (refer to 3-2-14/13.1). The thickness of the pintle housing is not to be less than 25% of the pintle diameter.

3.3 Scantlings below the Propeller Boss

Except as modified in 3-2-13/3.5, the scantlings of stern frames of single screw vessels are to be in accordance with the following, as applicable:

3.3.1 Fabricated Stern Frame

The thickness t, width w, and $tw^2\sqrt{1+(2\ell/w)^2}$ respectively for fabricated stern frames are to be not less than those given by the following equations:

$t = 0.225\sqrt{L}$ cm $\qquad$ $t = \sqrt{L}/20.5$ in.

$w = 5\sqrt{L}$ cm $\qquad L < 81$ m $\qquad$ $w = 1.09\sqrt{L}$ in. $\qquad L < 265$ ft

$w = 45$ cm $\qquad L \geq 81$ m $\qquad$ $w = 17.7$ in. $\qquad L \geq 265$ ft

$$SM = tw^2\sqrt{1+(2\ell/w)^2}/6 = C_f L^{1.5}$$

where

t = thickness of side plating, in cm (in.) (See 3-2-13/Figure 1)

w = width of stern frame, in cm (in.) (See 3-2-13/Figure 1)

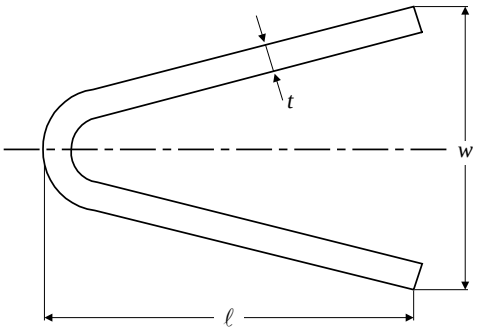
ℓ = length of stern frame, in cm (in.) (See 3-2-13/Figure 1)

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

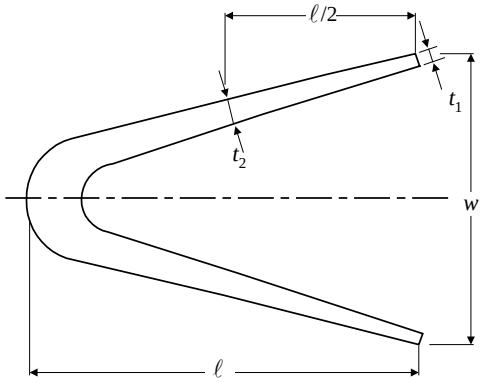
SM = section modulus about the longitudinal axis, in cm^3 (in^3)

C_f = 1.6 (1.6, 0.0164)

FIGURE 1
Stern Frame



a Fabricated



b Cast

3.3.2 Cast or Forged Stern Frame

The thicknesses t_1, t_2, and $\frac{(t_1 + t_2)}{2} w^2 \sqrt{1 + (2\ell / w)^2}$, respectively, for cast or forged stern frames are to be not less than given by the following equations:

$t_1 = 0.3\sqrt{L}$ cm but not less than 2.5 cm

$t_1 = \sqrt{L}/15.3$ in. but not less than 1 in.

$t_2 = 1.25 t_1$

$w = 5\sqrt{L}$ cm	$L < 81$ m	$w = 1.09\sqrt{L}$ in.	$L < 265$ ft
$w = 45$ cm	$L \geq 81$ m	$w = 17.7$ in.	$L \geq 265$ ft

$$SM = \frac{1}{24}(3t_1 + 5t_2) w^2 \sqrt{1 + (2\ell / w)^2} = C_c L^{1.5} K_g$$

where

w, ℓ, L = as defined in 3-2-13/3.3.1.

t_1 = thickness of casting at end. (See 3-2-13/Figure 1)

t_2 = thickness of casting at mid-length (See 3-2-13/Figure 1)

C_c = 1.6 (1.6, 0.0164)

K_g = q^e, cast or forged stern frame material factor

q = $235/Y$ N/mm^2 ($24/Y$ kgf/mm^2, $34000/Y$ lbs/in^2)

Y = specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, lbs/in^2) as defined in 2-1-1/13 of the ABS *Rules for Materials and Welding (Part 2)* for the higher-strength material, but is not to be taken as greater than $0.7U$ or 450 N/mm^2 (46 kgf/mm^2, 65000 lbs/in^2), whichever is lesser

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

e = 1.0 for $Y \le 235$ N/mm^2 (24 kgf/mm^2, 34000 lbs/in^2)

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

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

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

3.3.3 Bar Sternposts

Bar sternposts without propeller bosses are to have thicknesses and widths not less than that obtained from the following equations:

$t = 0.73L + 10$ mm $\qquad$ $t = 0.0088L + 0.39$ 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 3-1-1/3.1

Above the bottom shell plating, sternposts may be gradually reduced until the areas at their heads are half the areas obtained from the above equations.

Thickness or width less than given above are acceptable, provided the section modulus and moment of inertia about the longitudinal axis are not less than those of a plate having the minimum thickness and width given above, and with b/t not more than 4.0.

3.5 Stern Frames with Shoe Piece

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

3.7 Scantlings above the Propeller Boss

Above the propeller boss, the scantlings are to be in accordance with 3-2-13/3.5, except that in the upper part of the propeller aperture, where the hull form is full and centerline supports are provided, the thickness may be reduced to 0.8 of the requirements in 3-2-13/3.5, subject to the same minimum for a cast steel stern frame.

3.9 Secondary Members

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

Ribs or horizontal brackets of thickness not less than $0.8t$ or $0.8t_1$ are to be provided at suitable intervals. Where t or t_1 is reduced in accordance with 3-2-13/3.9 a proportionate reduction in the thickness of ribs or horizontal brackets may be made.

3.11 Shoe Pieces

The shoe-piece is to be sloped to avoid pressure from the keel blocks when docking and is to extend at least two frame spaces forward of the forward edge of the propeller boss.

The equivalent stress σ_e in the shoe piece at any section is not to exceed $115/K_g$ N/mm^2 ($11.7/K_g$ kgf/mm^2, $16700/K_g$ lbs/in^2) and is to be obtained from the following equation:

$$\sigma_e = n\sqrt{\sigma_b^2 + 3\tau^2} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, lbs/in}^2\text{)}$$

where

n = 1000 (1000, 2240)

K_g = shoe-piece material factor as defined in 3-2-14/1.3

σ_b = bending stress = $0.5C_R\ell/Z_v$

C_R = rudder force, as defined in 3-2-14/3

ℓ = horizontal distance between centerline of rudder stock and the section of the stern frame shoe piece in way of the aft edge of the propeller boss, in m (in.) (see 3-2-13/Figure 2)

Z_v = section modulus of shoe piece about the vertical axis at the particular section under consideration, in cm^3 (in^3)

τ = shear stress = $0.5C_R/A_s$

A_s = effective shear area in the transverse direction at the section of the shoe piece under consideration in, mm^2 (in^2)

In addition, shoe piece width is to be approximately twice the depth, and vertical and horizontal section modulus and sectional area are in no case to be less than required by the following equations.

Z_z = $k_z C_R \ell K_g$ 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 shoe piece about the vertical axis at the particular section under consideration

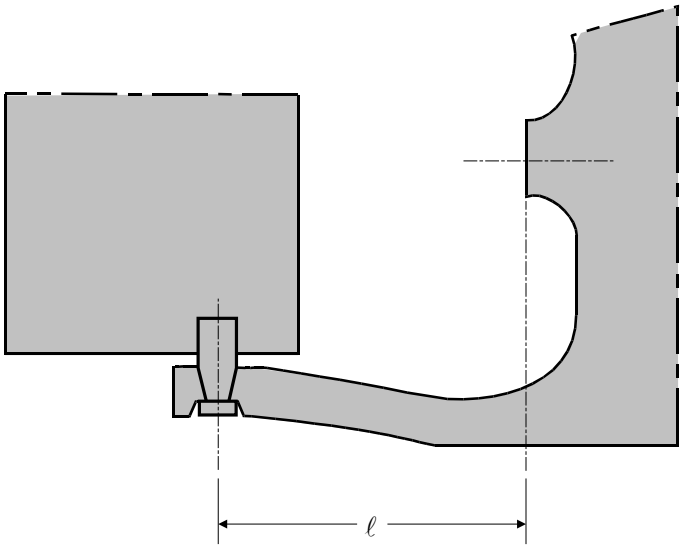
Z_y = minimum required section modulus of shoe piece about the transverse horizontal axis at the particular section under consideration

A_s = effective shear area in the transverse direction at the section of the shoe piece under consideration, in mm^2 (in^2)

k_z = 6.25 (61.3, 0.0967)

k_a = 10.4 (102, 0.161)

FIGURE 2
Shoe Piece



5 Rudder Horns

5.1 Scantlings – Single Pintle Rudders

The strength of the rudder horn is to be based on the most critical location at any point up to and in way of the connection into the hull. At no section is the equivalent stress σ_e in the rudder horn to exceed $120/K_h$ N/mm^2 ($12.2/K_h$ kgf/mm^2, $17400/K_h$ lbs/in^2) where σ_e is obtained from the following equation:

$$\sigma_e = n\sqrt{\sigma_b^2 + 3(\tau^2 + \tau_T^2)} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, lbs/in}^2\text{)}$$

where

n = 1000 (1000, 2240)

σ_b = bending stress = $C_R \ell_a \ell_v/(\ell_p SM)$

τ = shear stress due to bending = $C_R \ell_a/(\ell_p A_h)$

τ_T = shear stress due to torque = $0.5 C_R \ell_a \ell_h/(\ell_p at)$

C_R = rudder force, as defined in 3-2-14/3

ℓ_a = vertical distance, in m (ft), from the center of the neck bearing to the centroid of A (see 3-2-13/Figure 3a)

ℓ_p = vertical distance, in m (ft), from the center of the neck bearing to the center of the pintle bearing (see 3-2-13/Figure 3a)

ℓ_v = vertical distance, in m (in.), from the center of the pintle bearing to the section of the rudder horn being considered (see 3-2-13/Figure 3a)

ℓ_h = horizontal distance in, mm (in.), from the center of the pintle bearing to the center of area of the horizontal plane of the rudder horn at the section of the rudder horn being considered (see 3-2-13/Figure 3a)

SM = section modulus of the rudder horn about the longitudinal axis, in cm^3 (in^3), at the section of the rudder horn being considered

A_h = effective shear area of the rudder horn in the transverse direction at the section being considered, in mm^2 (in^2)

a = area, in mm^2 (in^2), enclosed by the outside lines of the rudder horn at the section of the rudder horn being considered

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

K_h = rudder horn material factor as defined in 3-2-14/1.3

In addition to meeting the above maximum equivalent stress criteria, the shear stress is not to be greater than τ indicated in the following equation.

τ = $48/K_h$ N/mm^2 ($4.9/K_h$ kgf/mm^2, $6960/K_h$ lbs/in^2)

Also, the section modulus about the longitudinal horizontal axis is not to be less than given in the following equation:

SM = $n_z C_R (\ell_a/\ell_p)\ell_v K_h$ cm^3 (in^3)

n_z = 14.9 (146.4, 0.230)

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

5.3 Scantlings – Two Pintle Rudders

The strength of the rudder horn is to meet the requirements for single pintle horns given in 3-2-13/5.1 above, with the following modified definitions of lever arm and component stresses.

ℓ_a = vertical distance, in m (ft), from the center of the upper pintle to the centroid of A (see 3-2-13/Figure 3b)

ℓ_p = vertical distance, in m (ft), from the center of the upper pintle bearing to the center of the lower pintle bearing (see 3-2-13/Figure 3b)

ℓ_v = vertical distance, in m (in.), from the center of the lower pintle bearing to the section of the rudder horn being considered up to the entry of the horn into the shell plating (see 3-2-13/Figure 3b)

ℓ_h = horizontal distance, in mm (in.), from the center of the lower gudgeon to the center of area of the horizontal plane of the rudder horn at the section of the rudder horn being considered (see 3-2-13/Figure 3b)

σ_b = bending stress

= $C_R \ell_a \ell_v/(\ell_p SM)$ between the upper and lower pintle gudgeons

= $C_R(\ell_v + \ell_a - \ell_p)/SM$ in SI or MKS units, above the upper pintle gudgeon

= $C_R[\ell_v + 12(\ell_a - \ell_p)]/SM$ in US units, above the upper pintle gudgeon

τ = shear stress due to bending = $C_R\ell_a/(\ell_p A_h)$ between the upper and lower pintle gudgeons

= C_R/A_h above the upper gudgeon

τ_T = shear stress due to torque = $0.5C_R\ell_a\ell_h/(\ell_p\ a\ t)$ between the upper and lower pintle gudgeons

= $0.5C_R\ell_h/(a\ t)$ above the upper gudgeon

5.5 Rudder Horn Plating *(1 July 2016)*

The thickness of the rudder horn side plating is not to be less than:

$$t = 2.4\sqrt{Lk} \quad \text{mm} \qquad t = 0.522\sqrt{Lk} \quad \text{in.}$$

where

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

k = K as defined in 3-2-14/1.3 for castings

= 1.0 for ordinary strength hull steel plate

= Q as defined in 3-2-1/5.5 for higher strength steel plate

5.7 Welding and Connection to Hull Structure *(1 July 2016)*

The following requirements are to apply:

i) The rudder horn plating is to be effectively connected to the aft ship structure (e.g., by connecting the plating to side shell and transverse/longitudinal girders) in order to achieve a proper transmission of forces, see 3-2-13/Figure 4. When the connection between the rudder horn and the hull structure is designed as a curved transition into the hull plating, special consideration should be given to the effectiveness of the rudder horn plate in bending and to the stresses in the transverse web plates

ii) Where the rudder horn does not have curved transitions into the shell plating, brackets or stringer are to be fitted internally in horn, in line with outside shell plate, as shown in 3-2-13/Figure 4.

iii) Transverse webs of the rudder horn are to be led into the hull up to the next deck or flat in a sufficient number.

iv) Strengthened plate floors are to be fitted in line with the transverse webs in order to achieve a sufficient connection with the hull.

v) Where a centerline bulkhead (wash-bulkhead) is fitted in the after peak, it is to be connected to the rudder horn.

vi) Scallops are to be avoided in way of the connection between shell plating and transverse webs in line with the aft face of the rudder horn and the webs in the rudder horn.

vii) The weld at the connection between the rudder horn plating and the side shell is to be full penetration. The welding radius is to be as large as practicable and may be obtained by grinding.

5.9 Floors

Heavy plate floors are to be fitted both in way of the after face of the horn and aligned with the webs required by 3-2-13/5.1 and 3-2-13/5.3. They are to be carried up to the first deck or flat above, if possible.

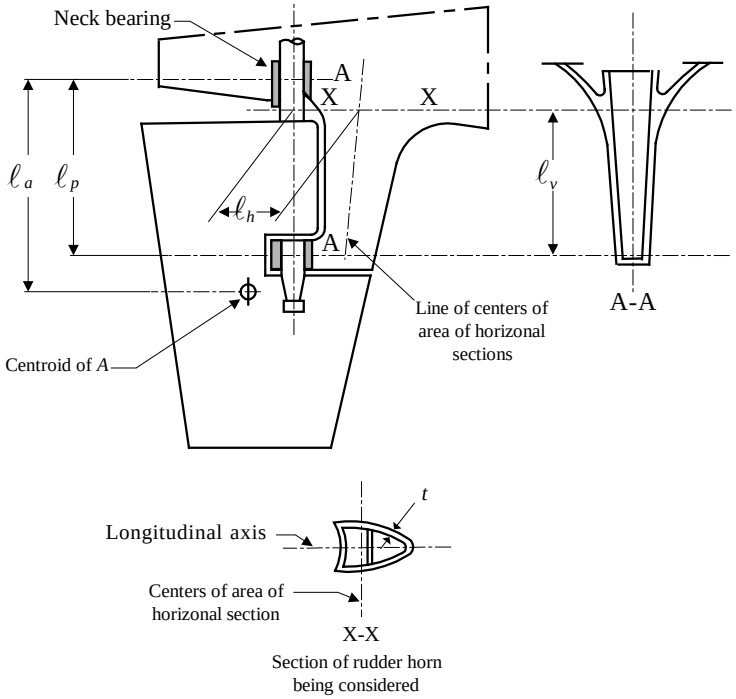
5.11 Shell Plating

Heavy shell plates are to be fitted in way of the heavy plate floors required by 3-2-13/5.9. Above the heavy floors, the heavy shell plates may be gradually reduced in thickness.

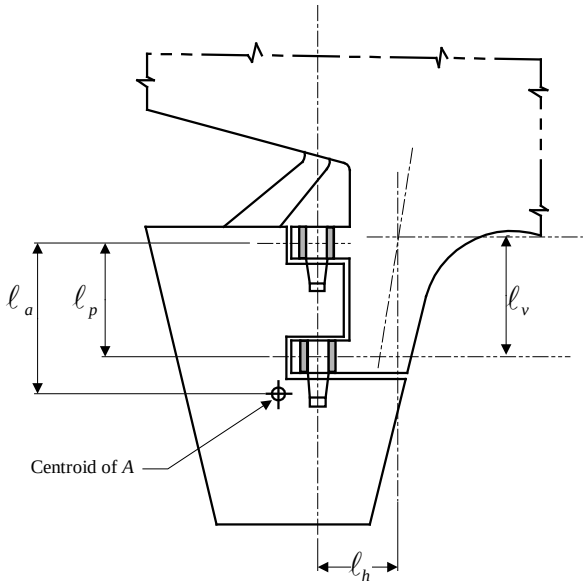
5.13 Water Exclusion

Rudder horns are to be provided with means for draining water, except where rudder horns are filled with an approved waterproof material, or equivalent.

FIGURE 3
Rudder Horn

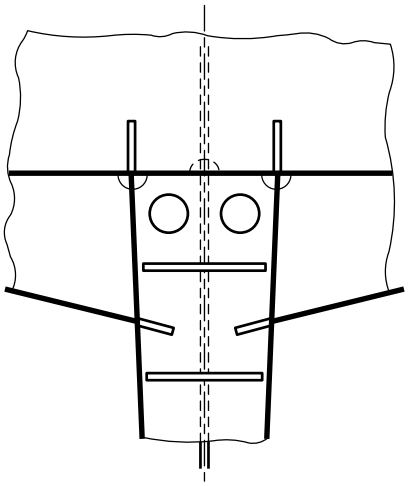


a) Single Pintle



b) Two Pintles

FIGURE 4
Connection of Rudder Horn to Aft Ship Structure *(1 July 2016)*



7 Shaft Struts

Tail-shaft (propeller-shaft) struts, where provided, may be of the V or I type. The thickness of the strut barrel or boss is to be at least one-fourth the diameter of the tail shaft. The length of the strut barrel or boss is to be adequate to accommodate the required length of propeller-end bearings. The following equations are for struts having streamlined cross-sectional shapes.

7.1 V Strut

The moment of inertia, *I*, and Section Modulus, *SM*, of each strut arm is not to be less than that obtained from the following equations:

$$I = 0.0044d^4 \quad \text{mm}^4 \ (\text{in}^4)$$

$$SM = 0.024d^3 \quad \text{mm}^3 \ (\text{in}^3)$$

where

d = required diameter of ABS Grade 2 tail shaft, in mm (in.)

Where the included angle is less than 45°, the foregoing scantlings are to be specially considered.

7.3 I Strut

The moment of inertia, *I*, and Section Modulus, *SM*, of the strut arm is not to be less than that obtained from the following equations:

$$I = 0.018d^4 \quad \text{mm}^4 \ (\text{in}^4)$$

$$SM = 0.068d^3 \quad \text{mm}^3 \ (\text{in}^3)$$

where

d = required diameter of ABS Grade 2 tail shaft, in mm (in.)

7.5 Strut Length

The length of the longer leg of a V strut or the leg of an I strut, measured from the outside perimeter of the strut barrel or boss to the outside of the shell plating, is not to exceed 10.6 times the diameter of the tail shaft. Where this length is exceeded, the width and thickness of the strut are to be increased, and the strut design will be given special consideration.

9 Propeller Nozzles

The requirements in this Subsection are applicable for propeller nozzles with inner diameter d of 5 meters (16.4 feet) or less. Nozzles of larger inner diameter are subject to special consideration, with all supporting documents and calculations to be submitted for review.

9.1 Design Pressure

The design pressure of the nozzle is to be obtained from the following:

$$p_d = 10^{-6} \cdot c \cdot \varepsilon \cdot \left(\frac{N}{A_p} \right) \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, lbs/in}^2\text{)}$$

where

c = coefficient as indicated in 3-2-13/Table 1

ε = coefficient as indicated in 3-2-13/Table 2, but not to be taken less than 10

N = maximum shaft power, in kW (hp)

A_p = propeller disc area

= $D^2 \frac{\pi}{4}$, in m^2 (ft^2)

D = propeller diameter, in m (ft)

TABLE 1
Coefficient c

Propeller Zone (see 3-2-13/Figure 4)	c		
	p_d *in N/mm^2*	p_d *in kgf/mm^2*	p_d *in lbs/in^2*
2	10.0	1.02	11620
1 & 3	5.0	0.51	5810
4	3.5	0.36	4067

TABLE 2
Coefficient ε

	p_d *in N/mm^2*	p_d *in kgf/mm^2*	p_d *in lbs/in^2*
ε	$21 - 0.02\left(\frac{N}{A_p}\right)$	$21 - 0.02\left(\frac{N}{A_p}\right)$	$21 - 0.16\left(\frac{N}{A_p}\right)$

9.3 Nozzle Cylinder

9.3.1 Shell Plate Thickness

The thickness of the nozzle shell plating, in mm (in.), is not to be less than:

$t = t_o + t_c$, but not less than 7.5 (0.3) mm (in.)

where

t_o = thickness obtained from the following formula:

= $c_n \cdot S_p \cdot \sqrt{p_d}\, K_n$ mm (in.)

c_n = coefficient as indicated in 3-2-13/Table 3

S_p = spacing of ring webs, in mm (in.)

p_d = nozzle design pressure, in N/mm^2 (kgf/mm^2, lbs/in^2), as defined in 3-2-13/5.3

t_c = corrosion allowance determined by 3-2-13/Table 4

K_n = nozzle material factor as defined in 3-2-14/1.3

TABLE 3
Coefficient c_n

	p_d *in N/mm*^{2}	p_d *in kgf/mm*^{2}	p_d *in lbs/in*^{2}
c_n	0.158	0.495	0.0132

TABLE 4
Corrosion Allowance t_c

Value of t_o	t_c *mm (in.)*
If $t_o \le 10.0$ (0.4)	1.5 (0.06)
If $t_o > 10.0$ (0.4)	the lesser of b_1, b_2
where b_1 = 3.0 (0.12) mm (in.) $b_2 = \left(\frac{t_o}{\sqrt{1/K_n}} + 5\right) \times 10^{-1}$ mm or $b_2 = \left(\frac{t_o}{\sqrt{1/K_n}} + 0.2\right) \times 10^{-1}$ in.	

9.3.2 Internal Diaphragm Thickness

Thickness of nozzle internal ring web is not to be less than the required nozzle shell plating for Zone 3 (see 3-2-13/Table 1 and 3-2-13/Figure 5 for reference).

9.5 Nozzle Section Modulus

The minimum requirement for nozzle section modulus is obtained from the following formula:

$$SM = d^2\, b\, V_d^2\, Q\, n \quad \text{cm}^3\ (\text{in}^3)$$

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 3-2-14/3.1

Q = reduction factor conditional on material type

= 1.0 for ordinary strength steel

= 0.78 for H32 strength steel

= 0.72 for H36 strength steel

= 0.68 for H40 strength steel

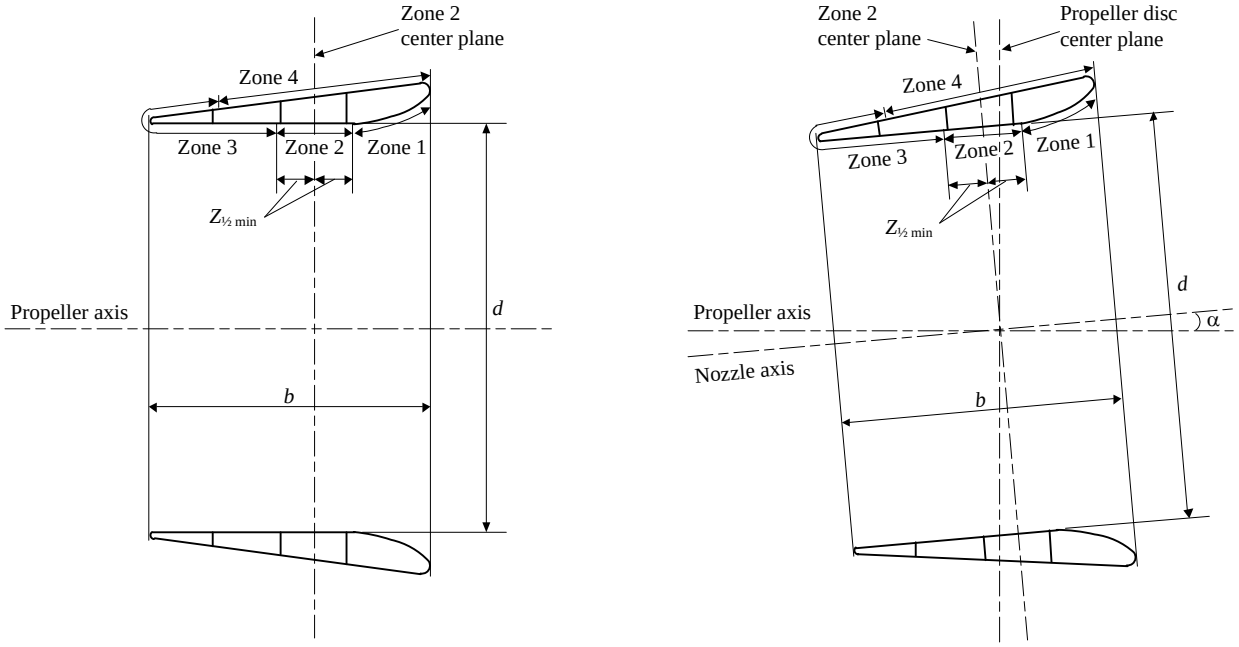
Q factor for steel having yield strength other than above is to be specially considered.

n = nozzle type coefficient

= 0.7 (0.0012) for fixed nozzles

= 1.0 (0.0017) for azimuth nozzles

FIGURE 5
Propeller Nozzle Section View *(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 3-2-13/Figure 5(a);

= $\frac{b}{8}\cos\alpha + \frac{d}{2}\tan\alpha$ where α is the tilt angle between the Zone 2 and propeller disc center planes, as shown in 3-2-13/Figure 5(b);

Zone 3 zone of nozzle inner and outer skin covering the tail vicinity, from aft end of Zones 2 to the aft end of Zone 4

Zone 4 zone of nozzle outer skin from the leading edge to the fore end of Zone 3

9.7 Welding Requirement

The inner and outer nozzle shell plating is to be welded to the internal stiffening ring webs with double continuous welds as far as practicable. Plug/slot welding is prohibited for the inner shell, but may be acceptable for the outer shell plating, provided that the nozzle ring web spacing is not greater than 350 mm (13.8 in.).

11 Propulsion Improvement Devices (PID) as Hull Appendages *(2017)*

11.1 Application Scope

The requirements in this Subsection are applicable for Propulsion Improvement Devices (PID) hull appendages including wake equalizing and flow separation alleviating devices (such as spoilers, wake equalizer, stern tunnels, pre-swirl fins, stators, and pre-swirl ducts) and post swirl devices (such as rudder thrust fins, post swirl stators, and rudder bulbs) that are permanently affixed to the hull structure.

11.3 Plans and Documentation

The following plans, details and calculations are to be submitted for approval:

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 in both the ahead and astern conditions.

11.5 Design and Arrangement

The following requirements are to be complied with for the propulsion improvement devices as outlined in 3-2-13/11.1. Devices of novel concept are to be specially considered with all the related drawings and documents submitted:

i) The structural materials are to be compatible with the mechanical and chemical properties of the hull strake to which it is attached. Examples of such design considerations are to have adequate structural strength for load bearing/transferring and acceptable galvanic potential between materials to reduce the risk of galvanic corrosion.

ii) PID end connections are to have a suitable transition for the particular application and to be effectively terminated in way of internal stiffening members.

11.7 Structural End Connection

Welded end connections of device structural component to the hull are to be designed and constructed in accordance with the following:

i) Welding at the connection is to be full penetration and is to be in accordance with Section 2-4-1 of the ABS *Rules for Materials and Welding (Part 2)* and Section 3-2-19, as applicable.

ii) Nondestructive volumetric and surface examinations are to be performed on the welds of the connection plates and the shell penetration. 100% Magnetic Testing (MT) and at least 10% Ultrasonic Testing (UT) is to be carried out on the welds of the connection plates and the shell penetration.

13 Inspection of Castings

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 14 Rudders and Steering Equipment

1 General

1.1 Application *(1 July 2016)*

Requirements specified in this Section are applicable to:

i) Ordinary profile rudders described in 3-2-14/Table 1A with rudder operating angle range from –35° to +35°.

ii) High-lift rudders described in 3-2-14/Table 1B, the rudder operating angle of which might be exceeding 35° on each side at maximum design speed.

iii) Other steering equipment other than rudders identified in Section 3-2-14.

Rudders not covered in 3-2-14/Table 1A nor in 3-2-14/Table 1B are subject to special consideration, provided that all the required calculations are prepared and submitted for review in full compliance with the requirements in this Section. Where direct analyses adopted to justify an alternative design are to take into consideration all relevant modes of failure, on a case by case basis. These failure modes may include, amongst others: yielding, fatigue, buckling and fracture. Possible damages caused by cavitation are also to be considered. Validation by laboratory tests or full scale tests may be required for alternative design approaches.

Rudders and other steering equipment provided on Ice Classed vessels are subject to additional requirements specified in 6-1-4/31 or 6-1-5/41 of the ABS *Rules for Building and Classing Steel Vessels (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 of steel, in accordance with the requirements of Chapter 1 of the ABS *Rules for Materials and Welding (Part 2)*, 3-1-2/Tables 2 and 3, 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 4-3-4/21.7.1i), is to be indicated on the submitted rudder or steering gear plan (see 4-3-4/1.11).

Note that the expected operating torque is not the design torque for rudder scantlings. The design torque is intended for the design of rudders and should not be directly compared with the torque expected during the sea trials or the rated torque of steering gear (see 4-3-4/1.11).

1.7 Rudder Stops

Structural rudder stops are to be fitted. Each structural stop as well as its attachment is to withstand rudder design force applied at stop's location. Where adequate positive mechanical stops are provided within the steering gear in accordance with 4-3-4/5.11, structural stops will not be required.

3 Rudder Design Force

3.1 Rudder Blades without Cutouts *(2014)*

The rudder force, C_R, upon which rudder scantlings are to be based, is to be obtained from the following equation:

$$C_R = nk_Rk_ck_\ell AV_R^2 \quad \text{kN (tf, Ltf)}$$

where

n = 0.132 (0.0135, 0.00123)

k_R = $(b^2/A_t + 2)/3$ but not taken more than 1.33

b = mean height of rudder area, in m (ft), as determined from 3-2-14/Figure 1A

A_t = sum of rudder blade area, A, and the area of rudder post or rudder horn within the extension of rudder profile, in m^2 (ft^2)

A = total projected area of rudder blade, as illustrated in 3-2-14/Figure 1A in m^2 (ft^2)

For steering nozzles, A is not to be taken less than 1.35 times the projected area of the nozzle.

k_c = coefficient depending on rudder cross section (profile type) as indicated in 3-2-14/Table 1A and 1B. For profile types differing from those in 3-2-14/Table 1A and 1B, k_c is subject to special consideration.

k_ℓ = coefficient as specified in 3-2-14/Table 2

V_R = vessel speed, in knots

= for ahead condition V_R equals V_d or $V_{\min}$, whichever is greater

= for astern condition V_R equals V_a, or $0.5V_d$, or $0.5V_{\min}$, whichever is greater

V_d = design speed, in knots, with vessel running ahead at the maximum continuous rated shaft rpm and at the summer load waterline

V_a = maximum astern speed, in knots

$V_{\min}$ = $(V_d + 20)/3$

Where there are any appendages such as rudder bulb fitted on the rudder, its effective areas are to be included in the area of the rudder blade if significant.

3.3 Rudders Blades with Cutouts

This paragraph applies to rudders with cutouts (semi-spade rudders), such that the whole blade area cannot be adequately defined by a single quadrilateral. See 3-2-14/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 3-2-14/3.1 is applicable for rudders with cutout(s), with A being the summation of sub-quadrilaterals that make up the whole area of the rudder blade. Rudder force distribution over each quadrilateral is to be obtained from the following equations:

$$C_{R1} = C_R A_1 / A \quad \text{kN (tf, Ltf)}$$

$$C_{R2} = C_R A_2 / A \quad \text{kN (tf, Ltf)}$$

where

C_R and A are as defined in 3-2-14/3.1.

A_1 and A_2 are as described in 3-2-14/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 3-2-14/3.1 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 3-2-14/3.1, (for rudder has multiple section profile types, A is the whole projected areas).

A_1 and A_2 are the projected areas of upper and lower blades separated at the deflector cross section, respectively. Where the effective projected area of rudder bulb (if present) forward of rudder leading edge is significant and needs to be counted, the proportioned bulb effective areas are added to A_1 and A_2 accordingly

Values of k_c for ahead and astern conditions are determined from one of the methods below as applicable, if the type of basic rudder profile is not provided:

a) k_c is taken from 3-2-14/Table 1A for twisted rudders of Categories 1 & 2;

b) k_c is taken from 3-2-14/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)*

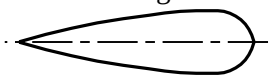
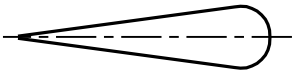
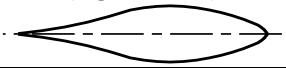
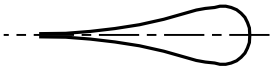
	Profile Type	k_c	
		Ahead Condition	*Astern Condition*
1	Single plate 	1.0	1.0
2	NACA-OO GÖttingen 	1.1	0.80
3	Flat side 	1.1	0.90
4	Mixed (e.g., HSVA) 	1.21	0.90
5	Hollow 	1.35	0.90
6	Twisted rudder of Cat. 1 & 2 	1.21 (if not provided)	0.90 (if not provided)

TABLE 1B
Coefficient k_c for High-Lift/Performance Rudders *(1 July 2016)*

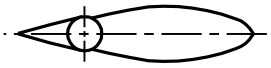
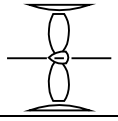
	Profile Type	k_c	
		Ahead Condition	*Astern Condition*
1	Fish tail (e.g., Schilling high-lift rudder) 	1.4	0.8
2	Flap rudder (or Twisted rudder of Cat. 3) 	1.7	1.3 (if not provided)
3	Rudder with steering nozzle 	1.9	1.5

FIGURE 1A
Rudder Blade without Cutouts

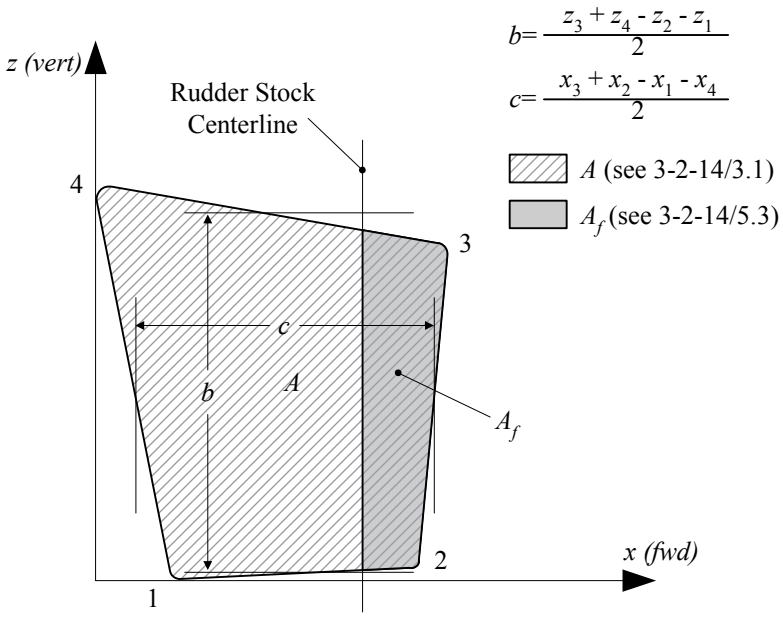
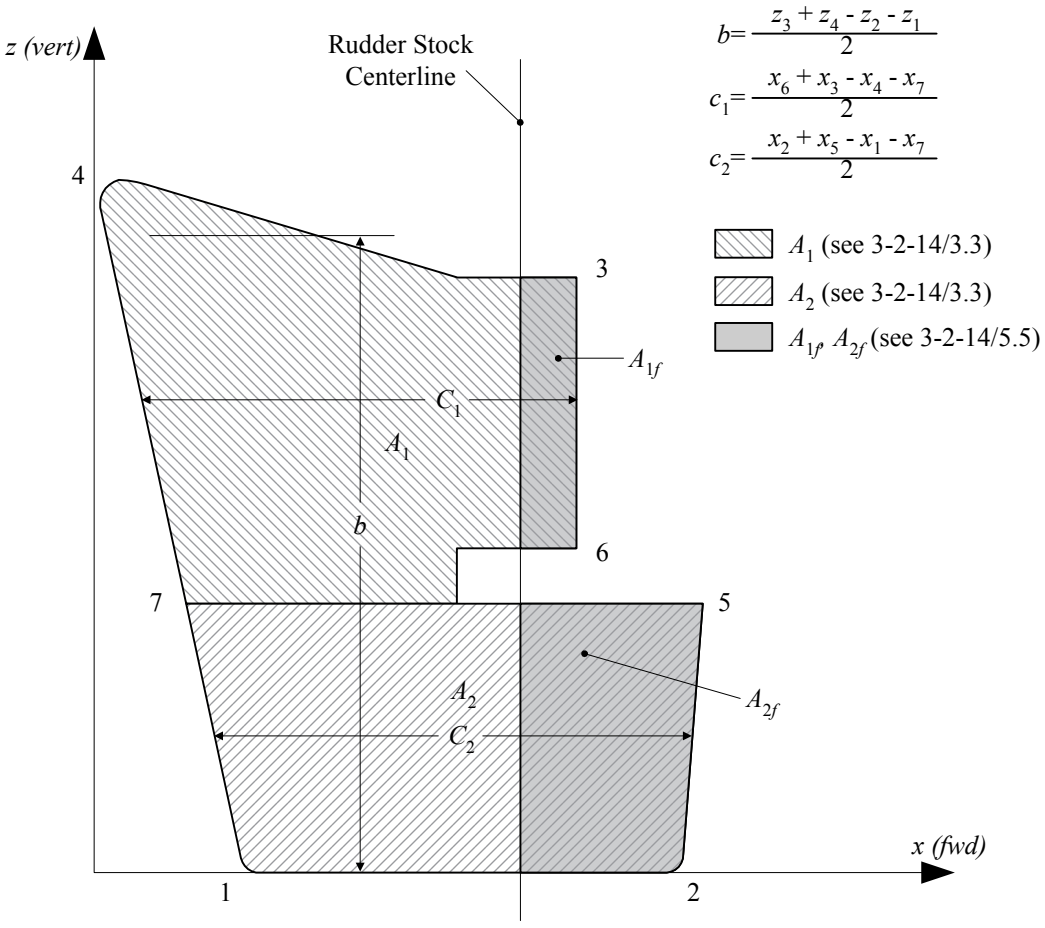


FIGURE 1B
Rudder Blade with Cutouts



5 Rudder Design Torque

5.1 General

The rudder design torque, Q_R, for rudder scantling calculations, is to be in accordance with 3-2-14/5.3 or 3-2-14/5.5 as applicable.

5.3 Rudders 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 3-2-14/3.1

r = $c(\alpha - k)$ but not less than $0.1c$ for ahead condition

c = mean breadth of rudder area as shown in 3-2-14/Figure 1A, in m (ft)

α = coefficient as indicated in 3-2-14/Table 3

k = A_f/A

A_f = area of rudder blade situated forward of the rudder stock centerline, in m^2 (ft^2), as shown in 3-2-14/Figure 1A

A = whole rudder area as described in 3-2-14/3.1

Where there are any appendages such as rudder bulb fitted on the rudder, effective areas are to be included in the area of the rudder blade if significant.

TABLE 2
Coefficient k_ℓ

Rudder/Propeller Layout	k_ℓ
Rudders outside propeller jet	0.8
Rudders behind a fixed propeller nozzle	1.15
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 3-2-14/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 3-2-14/3.3. Equations derived in this paragraph are based on a cutout blade with two quadrilaterals. Where more quadrilaterals are needed to define the rudder shape, similar rules apply.

Total rudder torque, Q_R, in ahead and astern conditions is to be obtained from the following equation:

$$Q_R = C_{R1} r_1 + C_{R2} r_2 \quad \text{kN-m (tf-m, Ltf-ft)}$$

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 3-2-14/Figure 1B

α = coefficient as indicated in 3-2-14/Table 3

k_1, k_2 = A_{1f}/A_1, A_{2f}/A_2 where A_{1f}, A_{2f} = area of rudder blade situated forward of the centerline of the rudder stock for each part of the rudder, as shown in 3-2-14/Figure 1B

C_R, C_{R1}, C_{R2}, A_1, A_2 are as defined in 3-2-14/3.3.

5.7 Rudders with Twisted Leading Edge *(2014)*

In general, rudder torque, Q_R, indicated in 3-2-14/5.3 is applicable for rudders with twisted leading edge, where C_R is obtained from 3-2-14/3.5.

7 Rudder Stocks

7.1 Upper Rudder Stocks

The upper stock is that part of the rudder stock above the neck bearing or above the top pintle, as applicable.

At the upper bearing or tiller, the upper stock diameter is not to be less than obtained from the following equation:

$$S = N_u \sqrt[3]{Q_R K_s} \quad \text{mm (in.)}$$

where

N_u = 42.0 (89.9, 2.39)

Q_R = total rudder torque, as defined in 3-2-14/5, in kN-m (tf-m, Ltf-ft)

K_s = material factor for upper rudder stock, as defined in 3-2-14/1.3

7.3 Lower Rudder Stocks *(2018)*

In determining lower rudder stock scantlings, values of rudder design force and torque calculated in 3-2-14/3 and 3-2-14/5 are to be used. Bending moments and shear forces, as well as the reaction forces are to be determined by direct calculation and are to be submitted for review. For rudders supported by shoe pieces or rudder horns, these structures are to be included in the calculation model to account for support of the rudder body. Guidance for calculation of these values is given in Appendix 3-2-A4.

The lower rudder stock diameter is not to be less than obtained from the following equation:

$$S_\ell = S \sqrt[6]{1 + (4/3)(M/Q_R)^2} \quad \text{mm (in.)}$$

where

S = upper stock required diameter from 3-2-14/7.1, in mm (in.)

M = bending moment at the section of the rudder stock considered, in kN-m (tf-m, Ltf-ft)

Q_R = rudder torque from 3-2-14/5, in kN-m (tf-m, Ltf-ft)

Above the neck bearing, a gradual transition is to be provided where there is a change in the diameter of the rudder stock.

The equivalent stress of bending and torsion, σ_c to be assessed from the aforementioned direct calculation in the transition is not to exceed 118 /K N/mm^2 (12.0/K kgf/mm^2, 17100/K lbs/in^2).

$$\sigma_c = \sqrt{\sigma_b^{\,2} + 3\tau^2} \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, lbs/in}^2\text{)}$$

where

K = material factor as defined in 3-2-14/1.3.

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

7.5 Rudder Trunk and Rudder Stock Sealing *(1 July 2016)*

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 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 3-2-14/1.3 for castings

= 1.0 for ordinary strength hull steel plate

= Q as defined in 3-2-1/5.5 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 3-2-14/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

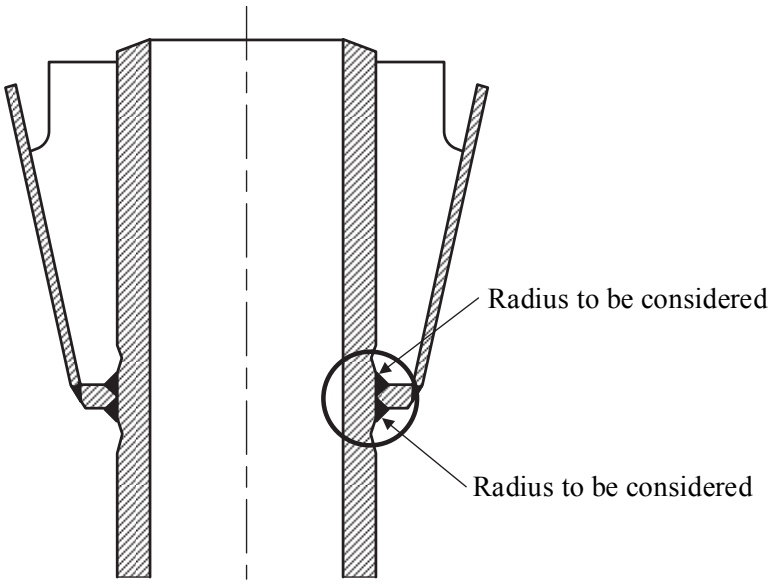
S_ℓ = rudder stock diameter axis defined in 3-2-14/7.3

σ = bending stress in the rudder trunk in N/mm^2 (kgf/mm^2, psi)

k = material factor as defined in 3-2-14/7.5iv)

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)*



9 Flange Couplings

9.1 General

Rudder flange couplings are to comply with the following requirements:

i) Couplings are to be supported by an ample body of metal worked out from the rudder stock. Couplings welded to or joined with rudder stock with use of equivalent method will be subject to special consideration.

ii) The smallest distance from the edge of the bolt holes to the edge of the flange is not to be less than two-thirds of the bolt diameter.

iii) Coupling bolts are to be fitted bolts.

iv) Suitable means are to be provided for locking the nuts in place.

In addition to the above, rudder flange couplings are to meet the type-specific requirements in 3-2-14/9.3 (horizontal couplings) or 3-2-14/9.5 (vertical couplings) as applicable.

9.3 Horizontal Couplings

9.3.1 Coupling Bolts

There are to be at least six coupling bolts in horizontal couplings, and the diameter, d_b, of each bolt is not to be less than obtained by the following equation:

$$d_b = 0.62\sqrt{d_s^3 K_b / (nrK_s)} \quad \text{mm (in.)}$$

where

d_s = required rudder stock diameter, S (3-2-14/7.1) or S_ℓ (3-2-14/7.3) as applicable, in way of the coupling

n = total number of bolts in the horizontal coupling, but not more than eight (8)

r = mean distance of the bolt axes from the center of the bolt system, in mm (in.), (mathematical average of the bolt axes distances from the axis of the stock)

K_b = material factor for bolts, as defined in 3-2-14/1.3

K_s = material factor for stock, as defined in 3-2-14/1.3

9.3.2 Coupling Flange

Coupling flange thickness is not to be less than the greater of the following equations:

$$t_f = d_{bt}\sqrt{K_f / K_b} \quad \text{mm (in.)}$$

$$t_f = 0.9 d_{bt} \quad \text{mm (in.)}$$

where

d_{bt} = calculated bolt diameter as per 3-2-14/9.3.1 based on a number of bolts, but not more than eight (8)

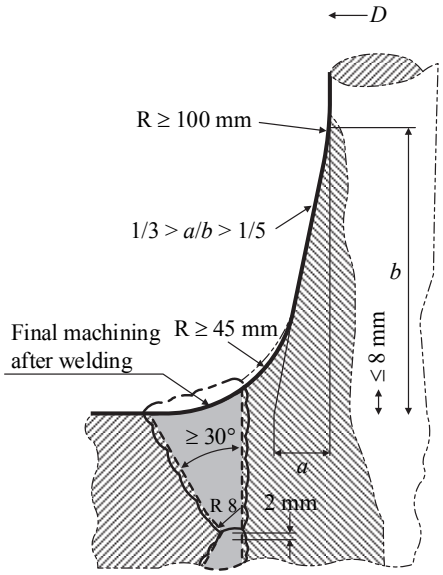
K_f = material factor for flange, as defined in 3-2-14/1.3

K_b = material factor of bolts, as defined in 3-2-14/1.3

9.3.3 Joint between Rudder Stock and Coupling Flange *(1 July 2016)*

The welded joint between the rudder stock and the flange is to be made in accordance with 3-2-14/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 of each bolt is not to be less than obtained from the following equation:

$$d_b = 0.81 d_s \sqrt{K_b / (nK_s)} \quad \text{mm (in.)}$$

where

n = total number of bolts in the vertical coupling, which is not to be less than 8

d_s, K_b, K_s as defined in 3-2-14/9.3.

In addition, the first moment of area, m, of the bolts about the center of the coupling is not to be less than given by the following equation:

$$m = 0.00043 d_s^3 \quad \text{mm}^3 \ (\text{in}^3)$$

where

d_s = diameter, in mm (in.), as defined in 3-2-14/9.3

9.5.2 Coupling Flange

Coupling flange thickness, t_f, is not to be less than d_b as defined in 3-2-14/9.5.1.

9.5.3 Joint between Rudder Stock and Coupling Flange *(1 July 2016)*

The welded joint between the rudder stock and the flange is to be made in accordance with 3-2-14/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 3-2-14/11.3 or 3-2-14/11.5 as applicable:

i) Tapered stocks, as shown in 3-2-14/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 3-2-14/Figure 4.

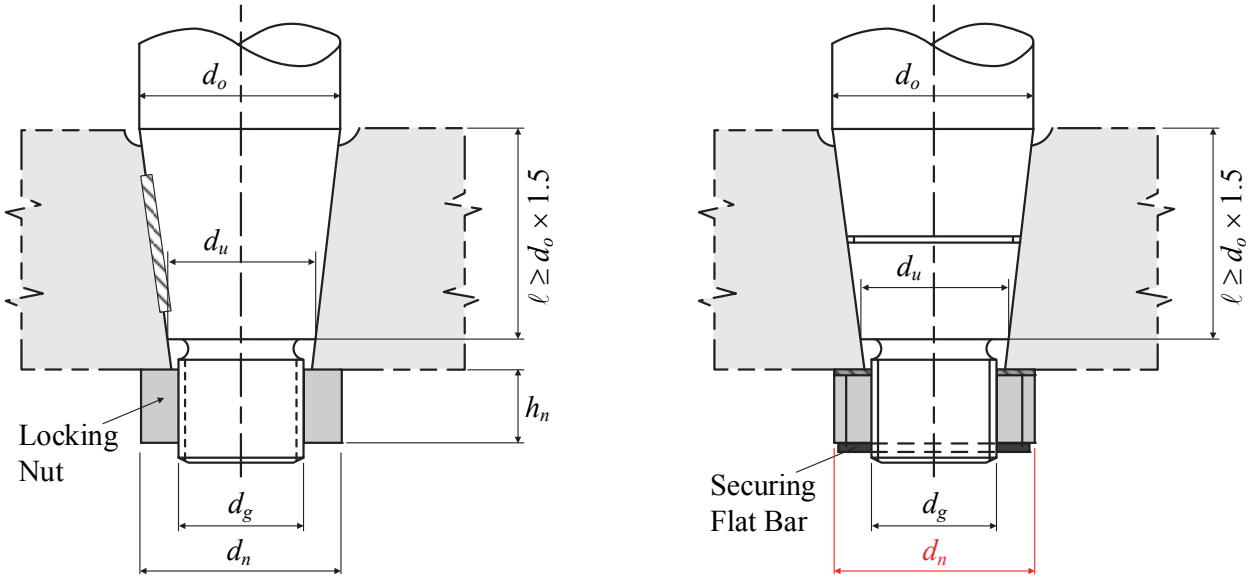
iv) The taper on diameter (c) is to be 1/12 to 1/8 for keyed taper couplings and 1/20 to 1/12 for couplings with hydraulic mounting/dismounting arrangements, as shown in the following table.

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 to protect 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 2016)*

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:

$$a_s = \frac{17.55 Q_F}{d_k \sigma_{F1}} \quad \text{cm}^2 \qquad\qquad a_s = \frac{27.20 Q_F}{d_k \sigma_{F1}} \quad \text{in}^2$$

where

Q_F = design yield moment of rudder stock, in N-m (kg-m, lbf-ft)

$$= 0.02664 \frac{d_t^{\,3}}{k} \quad \text{N-m}$$

$$= 0.002717 \frac{d_t^{\,3}}{k} \quad \text{kgf-m}$$

$$= 0.01965 \frac{d_t^{\,3}}{k} \quad \text{lbf-ft}$$

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 3-2-14/7.1

k = material factor for stock as given in 3-2-14/1.3

d_k = mean diameter of the conical part of the rudder stock, in mm (in.), at the key

σ_{F1} = minimum yield stress of the key material, in N/mm^2 (kgf/mm^2, psi)

The effective surface area of the key (without rounded edges) between key and rudder stock or cone coupling is not to be less than:

$$a_k = \frac{5 Q_F}{d_k \sigma_{F2}} \quad \text{cm}^2 \qquad\qquad a_k = \frac{7.749 Q_F}{d_k \sigma_{F2}} \quad \text{in}^2$$

where

σ_{F2} = minimum yield stress of the key, stock or coupling material, in N/mm^2 (kgf/mm^2, psi), whichever is less.

iv) In general, the key material is to be at least of equal strength to the keyway material. For keys of higher strength materials, shear and bearing areas of keys and keyways may be based on the respective material properties of the keys and the keyways, provided that compatibilities in mechanical properties of both components are fully considered. In no case, is the bearing stress of the key on the keyway to exceed 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 3-2-14/11.5v) and 3-2-14/11.5vi) for a torsional moment $Q'_F = 0.5 Q_F$. Notwithstanding the requirements in 3-2-14/11.5iii) and 3-2-14/11.5v), 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 2016)*

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) Preload stress is not to exceed 70% of the minimum yield strength of either the stock or the bore;

iii) Prior to applying hydraulic pressure, at least 75% of theoretical contact area of rudder stock and rudder bore is to be achieved in an evenly distributed manner;

iv) The upper edge of the upper main piece bore is to have a slight radius;

v) *Push-up Pressure.* The push-up pressure is not to be less than the greater of the two following values:

$$p_{req1} = \frac{2Q_F}{d_m^2 \ell \pi \mu_o} 10^3 \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{)} \qquad p_{req1} = \frac{2.901Q_F}{d_m^2 \ell \pi \mu_o} 10^8 \quad \text{psi}$$

$$p_{req2} = \frac{6M_b}{d_m \ell^2 d_m} 10^3 \quad \text{N/mm}^2 \text{ (kgf/mm}^2\text{)} \qquad p_{req2} = \frac{8.702M_b}{d_m \ell^2 d_m} 10^8 \quad \text{psi}$$

where

Q_F = design yield moment of rudder stock, as defined in 3-2-14/11.3iii)

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 (kg-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:

$$p_{perm} = \frac{0.8Y_G\left(1-\alpha^2\right)}{\sqrt{3+\alpha^4}} \qquad \text{N/mm}^2 \text{ (kgf/mm}^2\text{, psi)}$$

where

Y_G = specified minimum yield strength of the material of the gudgeon, 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.)

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

$$\Delta\ell_1 = \frac{p_{req}d_m}{E\left(\frac{1-\alpha^2}{2}\right)c} + \frac{0.8R_{tm}}{c} \quad \text{mm} \left(0.0394\left(\frac{p_{req}d_m}{E\left(\frac{1-\alpha^2}{2}\right)c} + \frac{0.8R_{tm}}{c}\right)\right. \quad \text{in.)}$$

$$\Delta\ell_2 = \frac{1.6Y_G d_m}{Ec\sqrt{3+\alpha^4}} + \frac{0.8R_{tm}}{c} \text{ mm } \left(0.0394\left(\frac{1.6Y_G d_m}{Ec\sqrt{3+\alpha^4}} + \frac{0.8R_{tm}}{c}\right) \text{ in.}\right)$$

R_{tm} = mean roughness, in mm (in.) taken equal to 0.01

c = taper on diameter according to 3-2-14/11.1iv)

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 3-2-14/11.5v).

Notwithstanding the above, the push up length is not to be less than 2 mm (0.08 in.).

Note: In case of hydraulic pressure connections the required push-up force P_e for the cone may be determined by the following formula:

$$P_e = p_{req} d_m \pi \ell \left(\frac{c}{2} + 0.02\right) \text{ N } \left(0.102\, p_{req} d_m \pi \ell \left(\frac{c}{2} + 0.02\right) \text{ kgf, } 0.225 p_{req} d_m \pi \ell \left(\frac{c}{2} + 0.02\right) \text{ lbf}\right)$$

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 3-2-14/11.5v) and 3-2-14/11.5vi), respectively.

viii) The locking nut is to be fitted in accordance with 3-2-14/11.7.

11.7 Locking Nut

Dimensions of the securing nut, as shown in 3-2-14/Figure 3, are to be proportioned in accordance with the following and the nut is to be fitted with an effective locking device.

Height	$h_n \geq 0.6 d_g$
Outer diameter of nut	$d_n \geq 1.2 d_u$ or $1.5 d_g$ whichever is greater
External thread diameter	$d_g \geq 0.65 d_o$

In the case of a hydraulic pressure secured nut, a securing device such as a securing flat bar is to be provided [see 3-2-14/9.1iv)].

13 Pintles *(1 July 2016)*

13.1 General

Generally, pintles assembled with use of a locking nut are to have a conical attachment to the gudgeons with a taper on diameter of:

1/12 to 1/8 for keyed and other manually assembled pintles with locking nut.

1/20 to 1/12 for pintle mounted with oil injection and hydraulic nut.

For rudders supported by shoe piece and pintle assembled without use of nut (refer to 3-2-A4/Figure 2), cylindrical attachment may be accepted on condition, that pintle bearing clearance allow enough space for angular inclination under associated rudder design force, to accept the connection as simple supported.

The diameter of the pintles is not to be less than obtained from the following equation.

$$d_p = k_1 \sqrt{BK_p} \quad \text{mm (in.)}$$

where

k_1 = 11.1 (34.7, 1.38)

B = bearing force, in kN (tf, Ltf), from submitted direct calculation but not to be taken less than B_{min} as specified in 3-2-14/Table 4

TABLE 4
Minimum Bearing Force B_{min}

Pintle Type		B_{min}
Conventional two pintle rudder		0.5 C_R
3-2-A4/Figure 3	lower pintle	0.5 C_R
3-2-A4/Figure 3	main pintle	$C_R \ell_a / \ell_p$ *
3-2-13/Figure 3	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

K_p = material factor for the pintle, as defined in 3-2-14/1.3

For rudders on horns with two pintles, as shown in 3-2-13/Figure 3b, calculations are to include pintle bearing forces with the vessel running ahead at the maximum continuous rated shaft rpm and at the lightest operating draft.

Threads and nuts are to be in accordance with 3-2-14/11.7.

The depth of the pintle boss is not to be less than D_p. In addition, the bearing length of the pintle is to be between 1.0 and 1.2 times the pintle diameter, where D_p is measured on the outside of the liner. The bearing pressure is to be in accordance with 3-2-14/15.1.

The thickness of the pintle housing is to be in accordance with 3-2-13/3.3.

13.3 Push-up Pressure and Push-up Length

The required push-up pressure for pintle bearings, in N/mm^2 (kgf/mm^2, psi), is to be determined by the following formula:

$$p_{req} = \frac{0.4 B_1 d_o}{d_m^2 \ell} \quad \text{N/mm}^2$$

$$p_{req} = \frac{0.04079 B_1 d_o}{d_m^2 \ell} \quad \text{kgf/mm}^2$$

$$p_{req} = \frac{0.0001394 B_1 d_o}{d_m^2 \ell} \quad \text{psi}$$

where

B_1 = supporting force in the pintle bearing, 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 3-2-14/11.5vi), using required push-up pressure and properties for the pintle bearing.

15 Supporting and Anti-Lifting Arrangements

15.1 Bearings

15.1.1 Bearing Surfaces

Bearing surfaces for rudder stocks, shafts and pintles are to meet the following requirements:

i) The length/diameter ratio (ℓ_b/d_ℓ) of the projected area of bearing surface is not to be greater than 1.2*

ii) The projected area of the bearing surface ($A_b = d_\ell\ \ell_b$) is not to be less than $A_{b\min}$,

where

d_ℓ = outer diameter of the liner, in mm (in.)

ℓ_b = bearing length, in mm (in.)

$A_{b\min}$ = $k_1 \dfrac{P}{p_a}$ mm^2 (in^2)

k_1 = 1000 (2240)

P = bearing reaction force, in kN (tf, Ltf), as specified in 3-2-14/Table 5

p_a = allowable surface pressure, as indicated in 3-2-14/Table 6 depending on bearing material, in N/mm^2 (kgf/mm^2, lbs/in^2)

* Request for bearing arrangement of length/diameter ratio greater than 1.2 is subject to special consideration provided that calculations are submitted to show acceptable clearance at both ends of the bearing.

15.1.2 Bearing Clearance

i) The clearance for metal bearings is not to be less than $d_i/1000 + 1.0$ mm ($d_i/1000 + 0.04$ in.) on the diameter, where d_i is the inner diameter of the bushing, in mm (in.).

ii) The clearance for non-metallic bearings is to be specially determined considering the material's swelling and thermal expansion properties. This clearance in general is not to be taken less than 1.5 mm (0.06 in.) on diameter*.

* Request of clearance less than 1.5 mm (0.06 in.) for non-metallic bearings is subject to special considerations provided that documented evidence, such as manufacturer's recommendation on acceptable clearance, expansion allowance and satisfactory service history with reduced clearances, are submitted for review.

15.1.3 Bearing Pressure

Bearing pressure is to be accordance with 3-2-14/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 3-2-14/15.1.5i).

- The bearing length L_p of the pintle is to be in accordance with 3-2-14/13.1ii).

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

Bearing Type	*P, Bearing Reaction Force kN (tf, Ltf)*
Pintle bearings	$P = B$ as defined in 3-2-14/13
Other bearings	*Calculation of P* is to be submitted. Guidelines for calculation can be found in Appendix 3-2-A4

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
aluminum-bronzes and manganese-bronzes(4)	9.0	0.92	1290
advanced synthetic compositions incorporating solid lubricant(4)	10.0	1.02	1430

Notes:

1 Indentation hardness test at 23°C (73.4°F) and with 50% moisture, according to a recognized standard. Synthetic bearing materials to be of approved type.

2 Higher values than given in the table may be taken if they are verified by tests, but in no case more than 10 N/mm² (1.02 kgf/mm², 1450 psi).

3 Stainless and wear-resistant steel in an approved combination with stock liner.

4 Material test certificates are to be submitted to support the review.

17 Double Plate Rudder

17.1 Strength *(1 July 2017)*

Rudder section modulus and web area are to be such that stresses indicated in the following Subparagraphs are not exceeded.

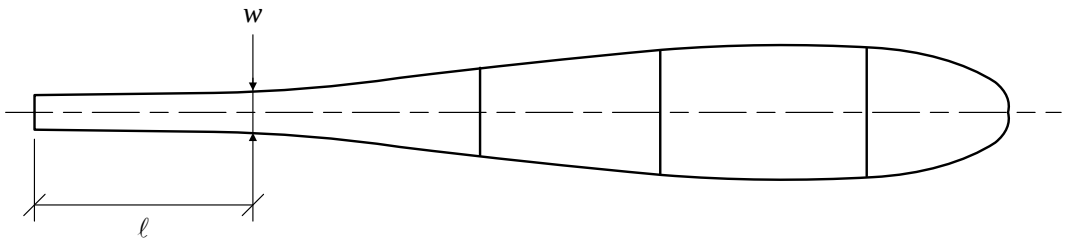
In calculating the section modulus of the rudder, the effective width of side plating is to be taken as not greater than twice the extreme athwartship dimension of the rudder in way of horizontal section being considered. Bolted cover plates on access or inspection openings to pintles or nuts are not to be considered effective in determining the section modulus of the rudder. In order for a cover plate to be considered effective, it is to be closed using a full penetration weld and confirmed suitable by non-destructive testing method. Smooth curvature or radii are to be provided at abrupt changes in section where stress concentrations occur, including in way of openings and cover plates. 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 obtained by direct calculation, which is to be submitted. Guidance for calculation of these values is given in Appendix 3-2-A4.

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 3-2-14/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 3-2-14/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)

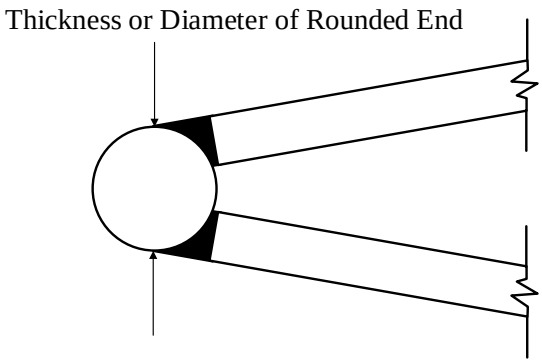
D = nominal boundary layer thickness at trailing edge

= $0.01C$

β_T = 0.77

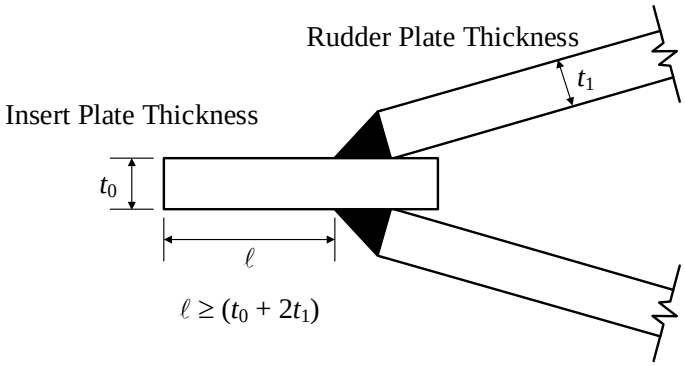
T = thickness or diameter of rounded end, in m (ft)

FIGURE 6 *(1 July 2017)*



ii) For a rudder trailing edge with a flat insert plate (see 3-2-14/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 3-2-14/3.1. The extension beyond the weld to rudder plate, ℓ, is to satisfy the following 3-2-14/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 3-2-14/3.1.

17.1.1 Clear of Cutouts

Allowable stresses for determining the rudder strength clear of cutouts are as follows:

Bending stress $\sigma_b = K_\sigma/Q$ N/mm^2 (kgf /mm^2, lbs/in^2)

Shear stress $\tau = K_\tau/Q$ N/mm^2 (kgf /mm^2, lbs/in^2)

Equivalent stress $\sigma_e = \sqrt{\sigma_b^{\,2} + 3\tau^2} = K_e/Q$ N/mm^2 (kgf/mm^2, lbs/in^2)

where

	SI units	*MKS units*	*US units*
K_σ	110	11.2	15,900
K_τ	50	5.1	7,300
K_e	120	12.2	17,400

Q = 1.0 for ordinary strength hull steel

= as defined in 3-2-1/5.5 for higher strength steel plate

17.1.2 In way of Cutouts

Allowable stresses for determining the rudder strength in way of cutouts (see 3-2-14/Figure 8) are as follows:

Bending stress $\sigma_b = K_\sigma/Q$ N/mm^2 (kgf/mm^2, lbs/in^2)

Shear stress $\tau = K_\tau/Q$ N/mm^2 (kgf/mm^2, lbs/in^2)

Equivalent stress $\sigma_e = \sqrt{\sigma_b^{\,2} + 3\tau^2} = K_e/Q$ N/mm^2 (kgf/mm^2, lbs/in^2)

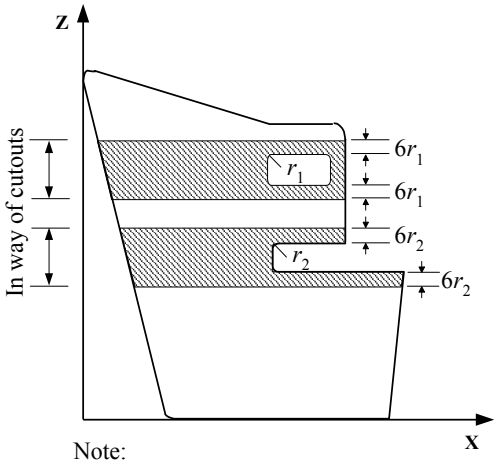
Where

	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

Q = 1.0 for ordinary strength hull steel

= as defined in 3-2-1/5.5 for higher strength steel plate

FIGURE 8



Note:
r_1 = corner radius of rudder plate in way of portable bolted inspection hole
r_2 = corner radius of rudder plate

17.3 Side, Top and Bottom Plating *(1 July 2016)*

The thickness of the rudder side or bottom plating is to be at least 2 mm (0.08 in.) greater than that required by 3-2-10/3.1 for deep tank plating in association with a head h measured to the summer load line and not less than obtained from the following equation, whichever is greater:

$$t = 0.0055s\beta\sqrt{k_1 d + \left(k_2 C_R / A\right)} \times \sqrt{Q} + k_3 \quad \text{mm (in.)}$$

where

Q = 1.0 for ordinary strength hull steel

= as defined in 3-2-1/5.5 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 loadline draft of the vessel, in m (ft)

C_R = rudder force according to 3-2-14/3, in kN (tf, Ltf)

A = rudder area, in m^2 (ft^2)

β = $\sqrt{1.1 - 0.5\left(s/b\right)^2}$ maximum 1.0 for $b/s \geq 2.5$

s = smaller unsupported dimension of plating, in mm (in.)

b = greater unsupported dimension of plating, in mm (in.)

The rudder side plating in way of the solid part is to be of increased thickness per 3-2-14/17.7.

17.5 Diaphragm Plates *(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 the horizontal diaphragms.

The thickness of diaphragm plates is not to be less than 70% of the required rudder side plate thickness or 8 mm (0.31 in.), whichever is greater. Openings in diaphragms are to have generous radii and the effects of openings are to be considered in the strength assessment as required in 3-2-14/17.1.

The diaphragm plating in way of the solid part is to be of increased thickness for vertical and horizontal diaphragm plates per 3-2-14/17.7.

17.7 Connections of Rudder Blade Structure with Solid Parts *(1 July 2016)*

Solid parts in forged or cast steel, which house the rudder stock or the pintle, are normally to be provided with protrusions.

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:

$$w_s = c_s S_\ell^3 \left(\frac{H_E - H_X}{H_E} \right) \frac{Q}{K_s} 10^{-4} \quad \text{cm}^3 \qquad w_s = 6.1 c_s S_\ell^3 \left(\frac{H_E - H_X}{H_E} \right) \frac{Q}{K_s} 10^{-9} \quad \text{in}^3$$

where

c_s = coefficient, to be taken equal to:

= 1.0 if there is no opening in the rudder plating or if such openings are closed by a full penetration welded plate

= 1.5 if there is an opening in the considered cross-section of the rudder

S_ℓ = rudder stock diameter, in mm (in.)

H_E = vertical distance between the lower edge of the rudder blade and the upper edge of the solid part, in m (ft)

H_X = vertical distance between the considered cross-section and the upper edge of the solid part as indicated in 3-2-14/Figure 9, in m (ft)

Q = material factor for the rudder blade plating as given in 3-2-14/17.1

K_s = material factor for the rudder stock as given in 3-2-14/1.3

The actual section modulus of the cross-section of the structure of the rudder blade is to be calculated with respect to the symmetrical axis of the rudder.

The breadth of the rudder plating to be considered for the calculation of section modulus is to be not greater than:

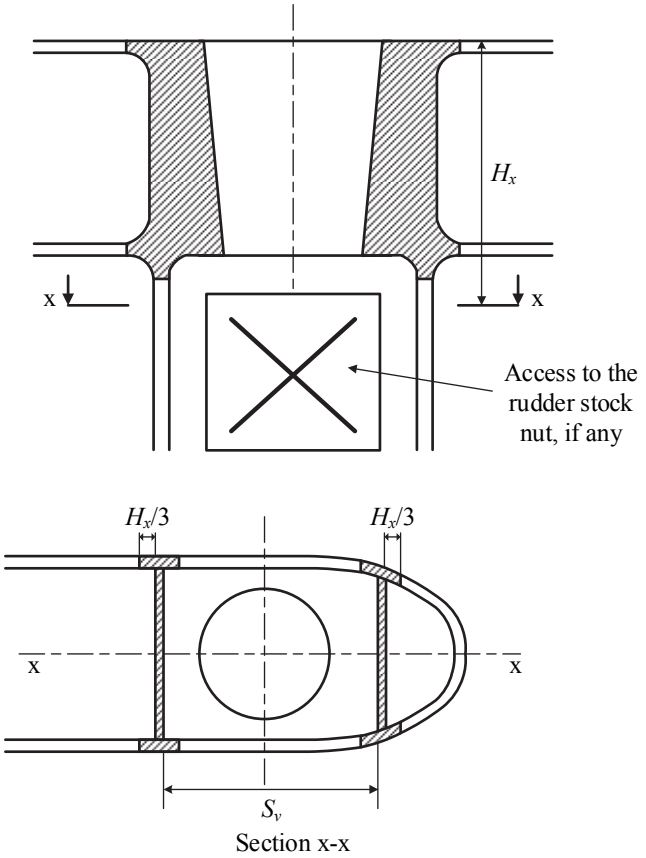
$$b = s_v + 2H_X/3 \quad \text{m (ft)}$$

where

s_v = spacing between the two vertical diaphragm, in m (ft) (see 3-2-14/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)*



Section x-x

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:

$$t_H = 1.2t \quad \text{mm (in.)}$$

$$t_H = 0.045d_S^2/s_H \quad \text{mm (in.)}$$

where

t = defined in 3-2-14/17.3

d_S = diameter, in mm (in.), to be taken equal to:

= S_ℓ as per 3-2-14/7.3, for the solid part housing the rudder stock

= d_p as per 3-2-14/13.1, for the solid part housing the pintle

s_H = spacing between the two horizontal diaphragm plates, in mm (in.)

The increased thickness of the horizontal diaphragms is to extend fore and aft of the solid part at least to the next vertical diaphragm.

The thickness of the vertical diaphragm plates welded to the solid part where the rudder stock is housed as well as the thickness of the rudder side plating under this solid part is to be not less than the values obtained, in mm (in.), from 3-2-14/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 3-2-14/17.3

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 3-2-14/7.3. For spade rudders, the lower third may be tapered down to 75% of the stock diameter at the bottom of the rudder.

19.3 Blade Thickness

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

$$t_b = 0.0015sV_R + 2.5 \quad \text{mm}$$

$$t_b = 0.0015sV_R + 0.1 \quad \text{in.}$$

where

s = spacing of stiffening arms, in mm (in.), not to exceed 1000 mm (39 in.)

V_R = speed, as defined in 3-2-14/3

19.5 Arms

The thickness of the arms is not to be less than the blade thickness obtained in 3-2-14/19.3. The section modulus of each set of arms about the axis of the rudder stock is not to be less than obtained from the following equation:

$$SM = 0.0005sC_1^2V_R^2Q \quad \text{cm}^3$$

$$SM = 0.0000719sC_1^2V_R^2Q \quad \text{in}^3$$

where

C_1 = horizontal distance from the aft edge of the rudder to the centerline of the rudder stock, in m (ft)

Q = 1.0 for ordinary strength hull steel

= as defined in 3-2-1/5.5 for higher strength steel plate

s, V_R are as defined in 3-2-14/21.3.

21 Steering Nozzles

21.1 Application Scope

Requirements in this Subsection are applicable to conventional steering nozzles, as illustrated in 3-2-14/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 3-2-14/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)

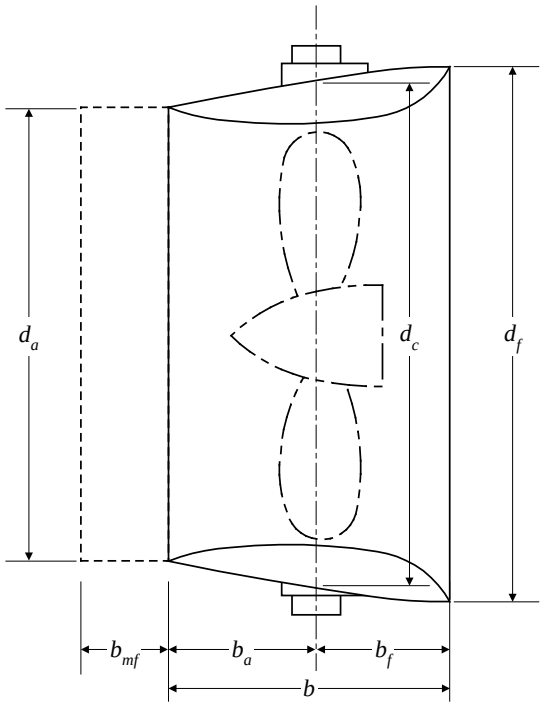
k_c = 1.9 for ahead condition

= 1.5 for astern condition

k_ℓ = 1.15, as specified in 3-2-14/Table 2

n, V_R are as defined in 3-2-14/3.1.

FIGURE 10
Nozzle Geometry



21.5 Design Torque

Design torque, Q_R, for steering nozzle is to be determined from the following equation for both ahead and astern conditions:

$$Q_R = C_R r \quad \text{kN-m (tf-m, Ltf-ft)}$$

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 3-2-14/Table 3.

A, C_R are as defined in 3-2-14/21.3.

21.7 Nozzle Stock

21.7.1 Upper Stock

The upper stock is that part of the nozzle stock above the neck bearing.

At the upper bearing or tiller, the upper stock diameter is not to be less than obtained from the following equation:

$$S = N_u \sqrt[3]{Q_R K_s} \quad \text{mm (in.)}$$

where

N_u = 42.0 (823.9, 2.39)

Q_R = as defined in 3-2-14/21.5

K_s = material factor for nozzle stock, as defined in 3-2-14/1.3

21.7.2 Lower Stock

In determining lower stock diameters, values of nozzle design force and torque calculated in 3-2-14/21.3 and 3-2-14/21.5 are to be used. Bending moments and shear forces, as well as the reaction forces are to be determined by direct calculation and are to be submitted for review. For nozzles supported by shoe pieces, these structures are to be included in the calculation. Calculation guidance for these values is given in Appendix 3-2-A4.

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 3-2-14/21.7.1, in mm (in.)

M = bending moment at the cross section of the nozzle stock considered, in kN-m (tf-m, Ltf-ft)

Q_R = design torque obtained from 3-2-14/21.5, in kN-m (tf-m, Ltf-ft)

Where there is a change in stock diameter above the neck bearing, a gradual transition is to be provided.

21.9 Design Pressure *(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 3-2-14/Table 8

C_{R1}, A_{eq} as defined in 3-2-14/21.3

p_d as defined in 3-2-13/9.1

TABLE 8
Coefficient c_m *(2015)*

Propeller Zone (see 3-2-13/Figure 5)	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:

$$= c_n \cdot S_p \cdot \sqrt{pK_n} \quad \text{mm (in.)}$$

c_n = coefficient as indicated in 3-2-13/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 3-2-14/21.9

t_c = corrosion allowance determined by 3-2-13/Table 4

K_n = nozzle material factor as defined in 3-2-14/1.3

21.11.2 Internal Diaphragm

Thickness of nozzle internal ring web is not to be less than the required nozzle shell plating for Zone 3 as illustrated in 3-2-13/Figure 5.

21.11.3 Movable Flap

Nozzle movable flap plate thickness, if present, is to comply with the following:

i) For double-plate movable flap, requirements in 3-2-14/17 are to be satisfied as applicable;

ii) For single-plate movable flap, requirements in 3-2-14/19 are to be satisfied as applicable;

21.13 Section Modulus

Steering nozzle is to have a section modulus at least equal to that specified in 3-2-13/9.5, where *n* is replaced by 1.0 (0.0017).

21.15 Locking Device

A mechanical locking device is to be provided:

i) To prevent the steering nozzle from rotating beyond the maximum operating angle at design speed

ii) To prevent steering nozzle from rotating toward undesired directions in the event of accident or damage

21.17 Welding Requirement

Steering nozzle welding procedures are to comply with 3-2-13/9.7.

23 Azimuthal Thruster

23.1 Application Scope *(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 3-2-14/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 (3-2-14/23.1) or as obtained from the following equation, whichever is greater:

$$C_R = nk_Rk_ck_\ell AV_R^2 = C_{R1} + C_{R2} \quad \text{kN (tf, Ltf)}$$

$$C_{R1} = nk_Rk_ck_\ell A_{eq} V_R^2 \quad \text{kN (tf, Ltf)}$$

$$C_{R2} = nk_Rk_ck_\ell A_{tb} V_R^2 \quad \text{kN (tf, Ltf)}$$

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 3-2-14/Figure 11(a), in m (ft)

b = nozzle length as shown in 3-2-14/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 $1.35 d_m b$, 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 3-2-14/Figure 11(a), in m (ft)

k_c = 1.9 for ahead condition

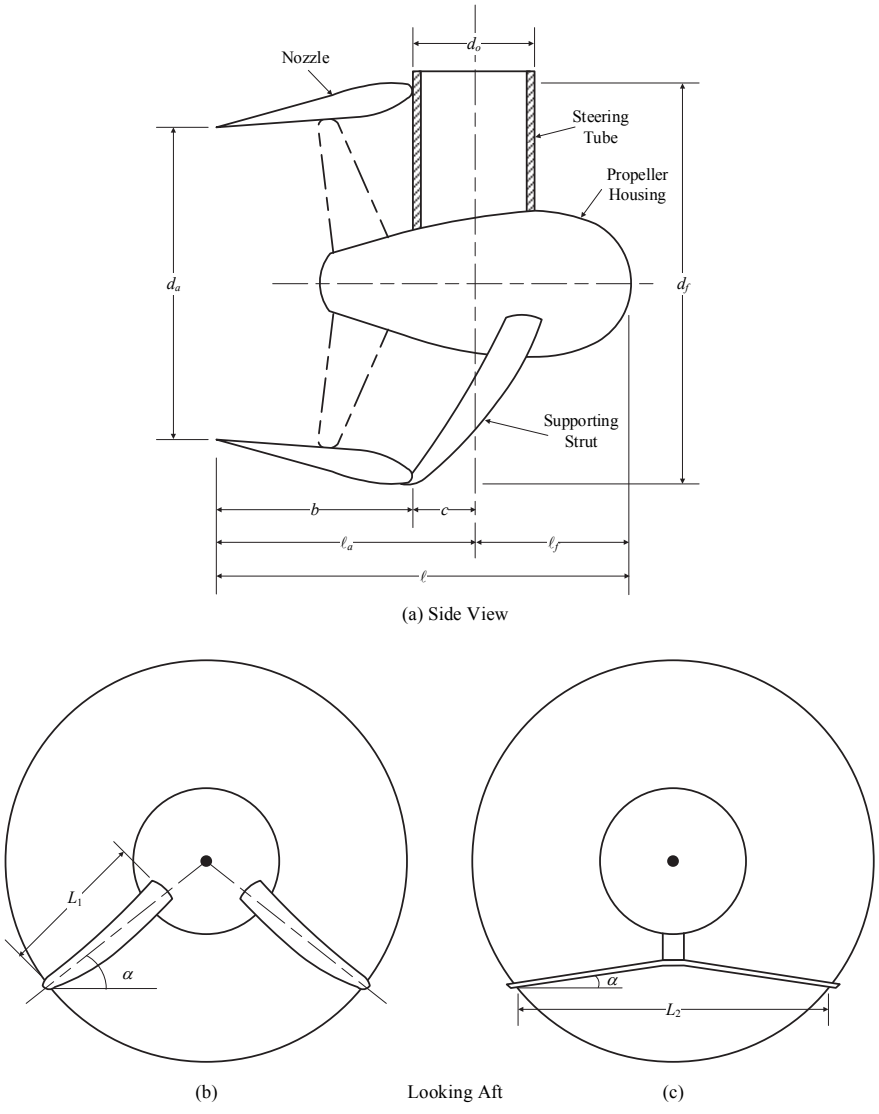
= 1.5 for astern condition.

k_ℓ = 1.15, as specified in 3-2-14/Table 2

n, V_R are as defined in 3-2-14/3.1.

**Note* Effective projected areas forward of the azimuthal thruster nozzle are the parts that actually contribute to generate lift force as the thruster turns. For example a torpedo shaped component, the projected profile area is to be proportionally reduced in order to be taken as the effective projected area. If this resultant effective projected area is too small to compare with the overall effective projected area, it may be discounted.

FIGURE 11
An Illustration of Azimuthal Thruster *(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 3-2-14/Table 3.

C_R and A are as defined in 3-2-14/23.7.

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 3-2-14/21.9.

C_{R1}, A_{eq} are as defined in 3-2-14/23.7.

23.13 Nozzle Scantlings

23.13.1 Nozzle Shell

The thickness of the nozzle shell plating, in mm (in.), is not to be less than the following:

$$t = t_o + t_c \text{ mm (in.), but not to be taken less than 7.5 mm (0.3 in.)}$$

where

t_o = $c_n\, S_p \cdot \sqrt{pK_n}$ mm (in.)

c_n = coefficient as indicated in 3-2-13/Table 3

S_p = nozzle ring web spacing, in mm (in.)

p = design pressure as defined in 3-2-14/23.11

t_c = corrosion allowance determined by 3-2-13/Table 4

K_n = material factor of the nozzle, as defined in 3-2-14/1.3

23.13.2 Internal Diaphragm

Thickness of nozzle internal ring webs and diaphragms are not to be less than that required by 3-2-13/9.3.2.

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 3-2-14/7.

where

Q_R is replaced by the design torque as defined in 3-2-14/23.9

K_s is replaced by material factor of the steering tube

M is the bending moment calculated at the section of the steering tube under consideration

23.17 Section Modulus

Azimuthal thruster nozzle is to have a section modulus at least equal to that specified in 3-2-13/9.5, where n is replaced by 1.1 (0.00187).

23.19 Thruster Nozzle Top Connections *(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 3-2-14/23.25.2.

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 3-2-14/9.3.2 or 3-2-14/9.5.2, as applicable.

iii) The coupling bolts are to be of fitted bolts and meet the scantling requirements specified in 3-2-14/9.3.1 or 3-2-14/9.5.1, 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 3-2-14/1.3iii)].

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 3-2-14/Figure 11(b)]

= W_p weight of transmission shaft, gear, and bearings, in kN (tf, Ltf), where α is less than or equal to 15° [see 3-2-14/Figure 11(c)]

A_{eqv} = equivalent area of nozzle supporting strut, in m^2 (ft^2)

= $L_1\, b_{avg}$, as illustrated in 3-2-14/Figure 11(b)

= $L_2\, b_{avg}$, as illustrated in 3-2-14/Figure 11(c)

L_{eqv} = equivalent length of nozzle supporting strut, in m (ft)

= L_1, as illustrated in 3-2-14/Figure 11(b)

= L_2, as illustrated in 3-2-14/Figure 11(c)

b_{avg} = average width of nozzle strut plate, in m (ft)

σ_F = minimum yield stress of the local material, in N/mm^2 (kgf/mm^2, psi)

p is as defined in 3-2-14/23.11.

23.23 Direct Analysis *(2017)*

Direct calculations may be accepted in lieu of applying prescriptive formulas presented in 3-2-14/23.7 to 3-2-14/23.21, provided that the following are complied with and satisfied:

23.23.1 Additional Information to Submit

Where the design is based on direct calculations such as FEM, the full analysis is to be submitted for review including:

i) Software used;

ii) FE model;

iii) Loading conditions and load cases including but not limited to normal, heavy duty, and crash stop;

iv) Applied loads and boundary conditions;

v) Stress and deflection results, and

vi) Any other data and information associated with the analysis;

23.23.2 Acceptance Criteria

The results of analysis verify the following:

i) The maximum nominal stress is not exceed 50% of the yield strength. For the crash stop load case, the maximum local stress in the nozzle and its connection is not to exceed 80% of the yield strength;

ii) The relative radial displacement, s_{rel}, between nozzle inner shell and propeller tip is not to exceed the following:

$$s_{rel} = 0.1 s_{cl} \quad \text{mm (in.)}$$

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 3-2-19 as applicable.

ii) The required extent of NDT is to be indicated on the drawings and plans.

iii) NDT is to be performed in accordance with the ABS *Guide for Nondestructive Inspection 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 3-2-13/7.9

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.

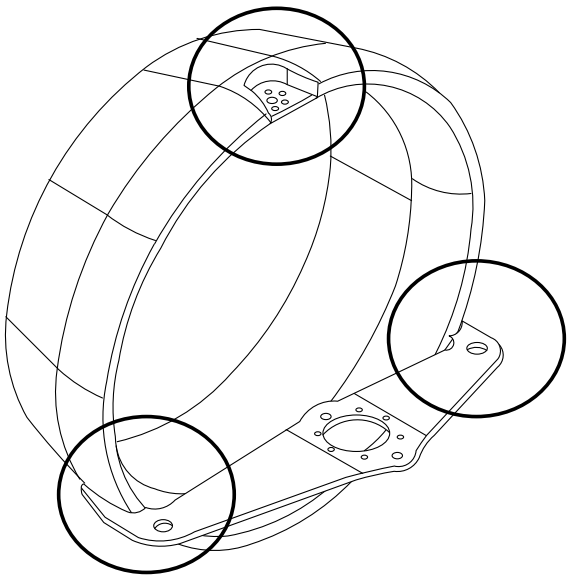
23.25.2 Connection Welding

Where the connections between nozzle and the hull/steering tube, strut and nozzle/propeller housing are welded (see figure below and 3-2-14/Figure 11), the following requirements are to be complied with:

i) Scantlings of the welded connection and welding type/size are to be specially considered and detailed stress analysis may be required to be submitted.

ii) Welding at the portion of the thruster assembly that penetrates the hull is to be of full penetration and in accordance with Section 2-4-1 of the ABS *Rules for Materials and Welding (Part 2)* and Section 3-2-19, as applicable.

iii) Volumetric or surface examination is to be performed on the welds of brackets and the shell penetration.



25 Azimuthing Pod

25.1 General Remarks

The requirements presented in 3-2-14/25 apply to the scantlings of the hull supports, strut, pod body, and pod fin if present. The requirements for steering unit, bearings, and other mechanical and electrical parts are offered in Part 4 of the *Steel Vessel Rules*.

A general illustration of azimuthing pod unit is given in 3-2-14/Figure 12, which consists of the following parts:

i) Slewing ring

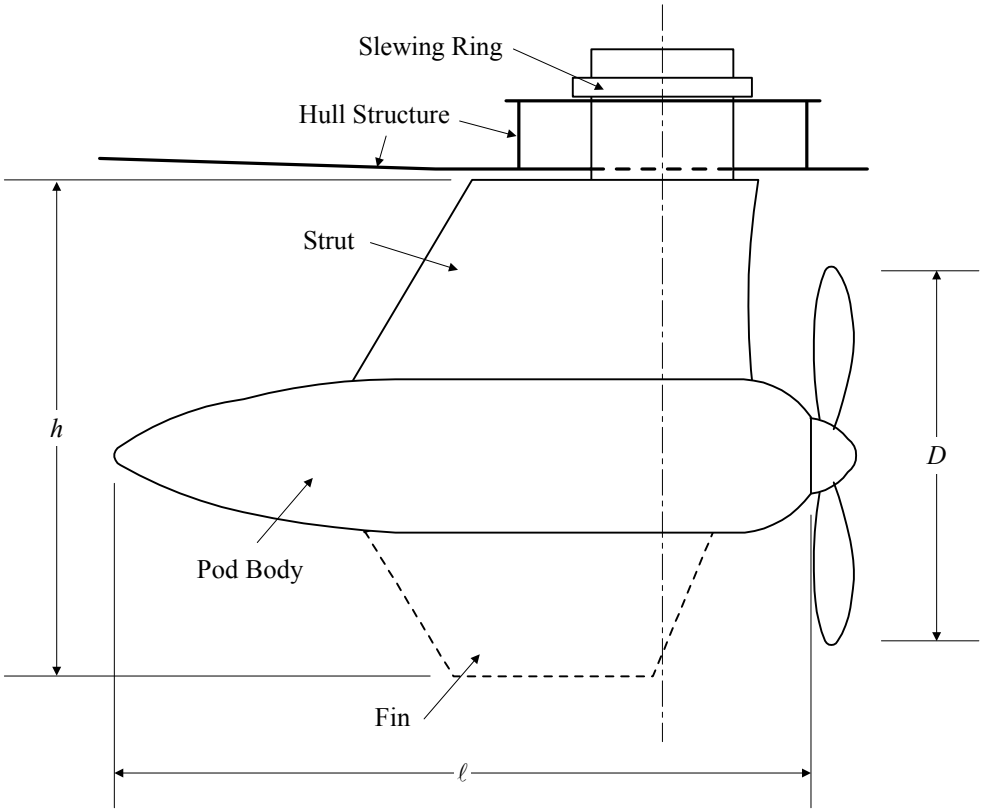
ii) Hull supporting structure

iii) Strut

iv) Pod body

v) Fin (if present)

FIGURE 12
Pod Propulsion Unit



25.3 Application Scope

Requirements hereafter apply to the azimuthing pod units with restrictions indicated below:

i) Units powered by electric propulsion motors

ii) Maximum operating angle at the design speed not to be greater than 35° on each side

iii) Units provided on Ice Classed vessels subject to additional requirements in Part 6, Chapter 1 of the *Steel Vessel Rules*, as applicable

iv) Units of features and specifications outside the above scope are subject to special considerations provided plans and documents specified in 3-2-14/25.5 are submitted to ABS in early design stage

25.5 Plans and Documents *(2016)*

The following plans and documents are to be submitted to ABS:

i) System description including a block diagram showing how the various components are functionally related

ii) Ship's maneuvering capability in the specified operating conditions

iii) Material grades, chemical and mechanical properties and welding specifications

iv) Nondestructive Testing (NDT) procedures for propulsion shaft, slewing ring bearings, gears, and couplings

v) Arrangement and scantlings in way of the pod unit and the hull supporting structure integration with the maximum loads on the structure marked

vi) Arrangements and scantlings of strut, pod body, fin (if present), and bearing mounting, also showing internal structures and assembly

vii) Drawings of detailed structural connection between structural components (i.e., bolted connections)

viii) Design loads for azimuthing pod, hull supporting structure, and propeller under all the specified design operating conditions

ix) Rated power, revolutions, and thrust

x) Power transmitted at the maximum torque condition

xi) Vibration analysis covering all operating speeds as specified in 4-3-8/1.7.3

xii) Maximum transient thrust, torque and other forces and moments experienced during all foreseeable operating modes permitted by the steering and propulsor drive control systems

xiii) Details of steering securing/locking (as specified in 3-2-14/25.9) and details of propeller shaft

xiv) Drawings of bearing arrangements with calculations of maximum bearing pressure and bearing lifetime calculation

xv) Manufacturer's limits on the seating flatness of the slewing ring

xvi) Thruster force calculations and predicted polar plots

xvii) Calculations of maximum hydrodynamic response to ship motions and accelerations, slamming, and pod/hull interaction for all the anticipated seagoing and operating conditions

xviii) Design loads for both the pod structure and propeller together with podded propulsion unit design operating modes

xix) The maximum anticipated loads calculated according to 3-2-14/25.11

xx) Fatigue analysis for local structure connections may be required

xxi) Supporting calculations for the interface between the hull structure and the podded propulsion unit (a finite element calculation would be considered an appropriate method)

xxii) Drawings of access and closing arrangements for pod unit inspection and maintenance

Note For specific requirements of machinery components, refer to Part 4 as applicable

25.7 Material Requirements *(2017)*

i) Azimuthing pod units are to be of steels manufactured, tested, and certificated in accordance with ABS *Rules for Materials and Welding (Part 2)* and 3-2-14/23.25, as applicable.

ii) Steels of specified tensile strength greater than 950 N/mm^2 (98.9 kgf/mm^2, 137,786 psi) or hardness of greater than 30 HRC are not to be used for pod fasteners at risk of coming in contacting with seawater.

iii) Material factors for local structure/component are to be obtained according to 3-2-14/1.3iv).

iv) Other requirements in 3-2-14/1.3i) through 3-2-14/1.3iii) are to be complied with, as applicable.

25.9 Locking Device *(2016)*

A locking device is to be provided and designed to meet the following:

i) To immediately prevent azimuthing pod from rotating beyond 35 degrees or the manufacturer's declared steering angle limit, whichever is smaller, in the event of steering system control failure during any operating mode

ii) To prevent azimuthing pod from rotating toward undesired directions in the event of accident or damage

iii) To keep each pod unit's slewing mechanism in its center (neutral) position in the event of steering system failure where more than one pod units are installed

iv) To keep the pod in position at the vessel's maneuvering speed of not less than 7 knots

25.11 Direct Analysis

The scantlings of the azimuth propulsion system and the associated hull supports are to be determined by the maximum pressure and loads obtained through direct calculations. The maximum anticipated service loads are to be determined by recognized acceptable methods, which include at least the following:

i) Gravity and buoyancy

ii) Forces of lift, drag, and thrust

iii) Maximum combined heave and pitch motions in way of hull and azimuthing pod interface

iv) Pod operates at maximum angle on each side while the ship travels at design speed

v) Maximum loads calculated for the crash stop obtained through a 180° rotation of the pod.

vi) Maximum loads calculated for the possible orientations of the system greater than the maximum angle at the relevant speed

vii) Any maneuvering conditions that are likely to give rise to high mean or vibratory loadings induced by the podded propulsion unit.

viii) Stern slamming pressure at speeds of 0 and 5 knots for all wave heights, following sea to beam sea.

ix) Rapid acceleration and deceleration maneuvers demands per the ship's operating manual.

x) The condition where the vessel travels ahead in a steady course under design oceangoing conditions while the azimuthing pod at its the maximum rated output.

Hydrodynamic analysis is to be carried out such that the structural response under the most severe load combination is not to exceed the normal operational requirements of the propulsion or steering system.

Finite element analysis is to be carried out to evaluate the structural design. The FE model developed for use with the stress criteria in 3-2-14/Table 9 should be discussed and agreed with ABS before analysis is commenced.

25.13 Direct Analysis Strength Criteria *(2017)*

The maximum stress on the strut, pod body, and hull structure obtained from the direct analysis according to 3-2-14/25.11 is to satisfy the strength checking criteria described in 3-2-14/Table 9.

Structure components showing localized stress concentration that is greater than the allowable stress indicated in 3-2-14/Table 9 may be accepted on a case by case basis, depending on the location and the scale of the localized stress, as well as the type of analysis or modeling criteria is used.

TABLE 9
Permissible Stress Level *(2017)*

Operating Condition	*Flow Angle*	*% of Material Yield Strength* σ_F*(2)*
Normal	±5°	40
Heavy Duty	±15°	60
Sea Trial	See Note 1	80
Crash/Accidental Load	0	90

Notes:

1 The smaller one of ±35° or the manufacturer's declared steering angle limit. See also 4-3-4/21.7.

2 σ_F = minimum specified yield strength of local material

25.15 Additional Requirements

(2017) The following verifications may be required by ABS on a case-by-case basis. Such a possible case where higher strength material is used so that plate thickness, structure stiffness, and connection wellness may be further verified.

25.15.1 Pod Strut

The pod strut is to have scantlings that meet the following requirements. Similar requirements also apply to the scantlings for pod fin, as applicable.

25.15.1(a) Strut Shell Plating. The plating thickness is not to be less than obtained from the following:

$$t = 0.0055 s\beta\sqrt{k_1\, d_{\max} + k_2\, p_{\max}} \times \sqrt{K} + k_3 \quad \text{mm (in.)}$$

where

s = smaller unsupported dimension of plating, in mm (in.)

β = $\sqrt{1.1 - 0.5(s/b)^2}$ maximum 1.0 for $b/s \geq 2.5$

b = greater unsupported dimension of plating, in mm (in.)

k_1 = 1.0 (1.0, 0.305)

k_2 = 0.1 (0.981, 10.7)

k_3 = 2.5 (2.5, 0.1)

$d_{\max}$ = vessel's maximum permissible draft in m (ft), but not be taken less than 6.1 m (20 ft)

$p_{\max}$ = maximum pressure obtained from direct calculation, in N/mm^2 (kgf/mm^2, psi)

K = plating material factor as defined in 3-2-14/1.3, as applicable

= 1.0 for ordinary strength steel plate

25.15.1(b) Strut Strength. Strut section modulus and web area are to be such that stresses indicated in 3-2-14/25.13, as applicable, are not exceeded.

25.15.1(c) Strut Diaphragm. Strut internal diaphragms are to be fitted such that:

i) Vertical and horizontal diaphragms of strut are to be effectively attached to each other and to the shell plating. In addition, the vertical diaphragms are to be spaced approximately 1.5 times the spacing of horizontal diaphragms.

ii) The thickness of strut internal diaphragm is not to be less than 70% of the required shell plate thickness or 8 mm (0.31 in.), whichever is greater.

iii) Openings in strut diaphragms are not to exceed one half their depths.

iv) Where diaphragms are inaccessible for welding, they are to be fitted with flat bars connecting to the side plating by continuous welds or by 75 mm (3 in.) slot welds spaced at 150 mm (6 in.) centers. The slots are to be fillet welded around the edges and filled with a suitable compound.

25.15.2 Pod Body

The minimum scantlings of the pod structure are not to be less than obtained from the following.

25.15.2(a) Pod Shell Plating. The shell plate thickness of the pod body is not to be less than the greatest t indicated below:

$$t_1 = 2.7r\sqrt{k_1 d_{\max} + k_2 p_{\max}} \times \sqrt{K} + k_3 \quad \text{mm (in.), or}$$

$$t_2 = sk_0\frac{\sqrt{(Kh)}}{c_f} + t_o \quad \text{mm (in.), or}$$

$$t_3 = 6.5\ (0.25) \quad \text{mm (in.), or}$$

$$t_4 = s/150 + t_o \quad \text{mm (in.)}$$

where

r = mean radius of pod body

k_0 = $(3.075\sqrt{\alpha} - 2.077)/(\alpha + 0.272)$ for $1 \le \alpha \le 2$

= 1.0 for $\alpha > 2$

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

h = distances, in m (ft), from the lower edge of the plate to the summer load line;

c_f = 254 (460)

t_o = 2.5 (0.1)

k_1, k_2, k_3, d, $p_{\max}$, K as defined in 3-2-14/25.15.1(a).

25.15.2(b) Pod Webs. The thickness of primary webs is not to be less than 70% of the adjacent shell plating or 10 mm, whichever is the greater.

25.15.2(c) Pod Stiffeners. The properties of the secondary stiffening are not to be less than obtained from 3-2-5/3.17 or 3-2-10/3.3, whichever is the greater.

25.15.3 Hull Support

Hull supporting structure, as illustrated in 3-2-14/Figure 13, in way of azimuthing pod unit is to comply with the following:

i) Hull girders connecting the slewing ring and the ordinary hull girders and floors are, in general, to be radially arranged for even transmission of loads and moments from the pod to the rest of the hull structure without unwarranted deflection.

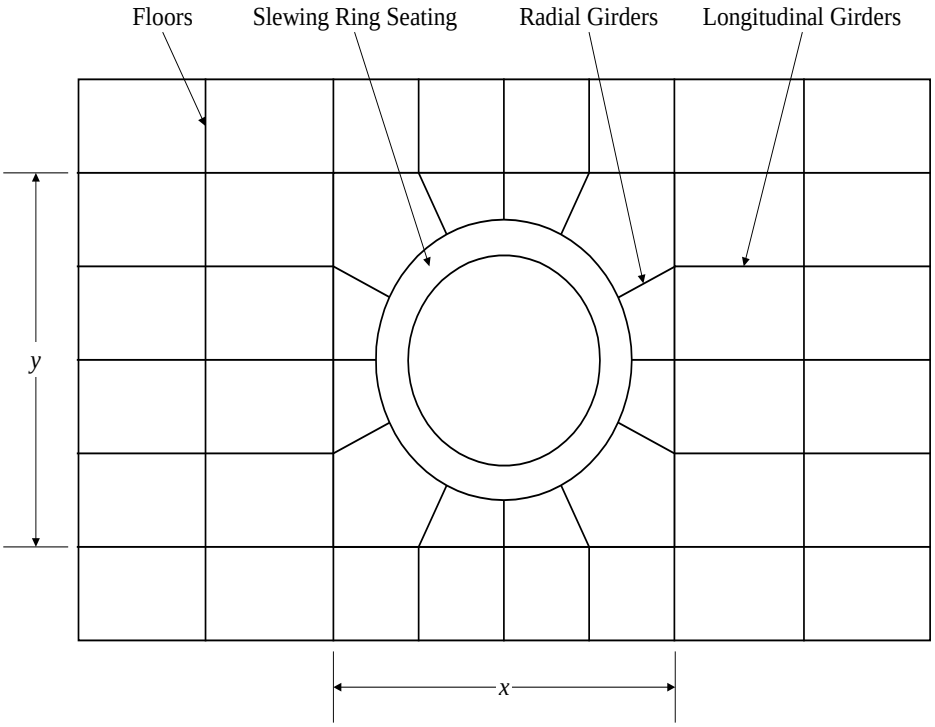
ii) Hull seating for the slew ring is to be sufficiently stiffened so that the flexure is within the manufacturer's specifications for the bearing.

iii) The minimum thickness for the girders of hull support is to be in accordance with 3-2-4/3.1, as applicable.

iv) Plate buckling of hull primary support members is to be below the ideal elastic deformation limit of the material.

v) Shell plating thickness in way of hull primary support structure is to be at least 50% thicker than as required for the adjacent shell plating.

FIGURE 13
Hull Supporting Structure



25.15.4 Slewing Bearing

Calculations of bearing stress are to be submitted for review and the equivalent stresses are to be lower than 80% of the yield strength of the bearing ring seating.

25.15.5 Connections *(2017)*

Where azimuthing pod fitted with a nozzle as illustrated in 3-2-14/Figure 11(c), the connections are to be evaluated according to 3-2-14/23.19.1 and/or 3-2-14/23.19.2, as applicable.

Nozzle Connection with Hull or Pod Body Calculations of bearing stress are to be submitted for review and the equivalent stresses are to be lower than 80% of the yield strength of the bearing ring seating.

The flange connection of propeller nozzle with pod body or hull is to comply with the following:

i) The attachments (base) of flange connection are to be supported by an ample body of metal worked out from both parts that are to be coupled together.

ii) The smallest distance from the edge of the bolt holes to the edge of the flange is not to be less than two-thirds of the bolt diameter.

iii) Coupling bolts are to be fitted bolts.

iv) The nuts are to be effectively locked in place.

25.15.6 Pod Web *(2017)*

The thickness of primary webs is not to be less than 70% of the adjacent shell plating or 10 mm (0.4 in.), whichever is the greater.

25.17 Structural Transition

The structural transitions of azimuthing pods are to avoid abrupt changes as much as practical. Structural transitions are to be smooth and gradual in way of the:

i) Strut from upper mounting with steering unit to the lower section

ii) Connection of strut and pod body with fillet radius not less than 75 mm (3 in.), in general

25.19 Service Accessibility *(2016)*

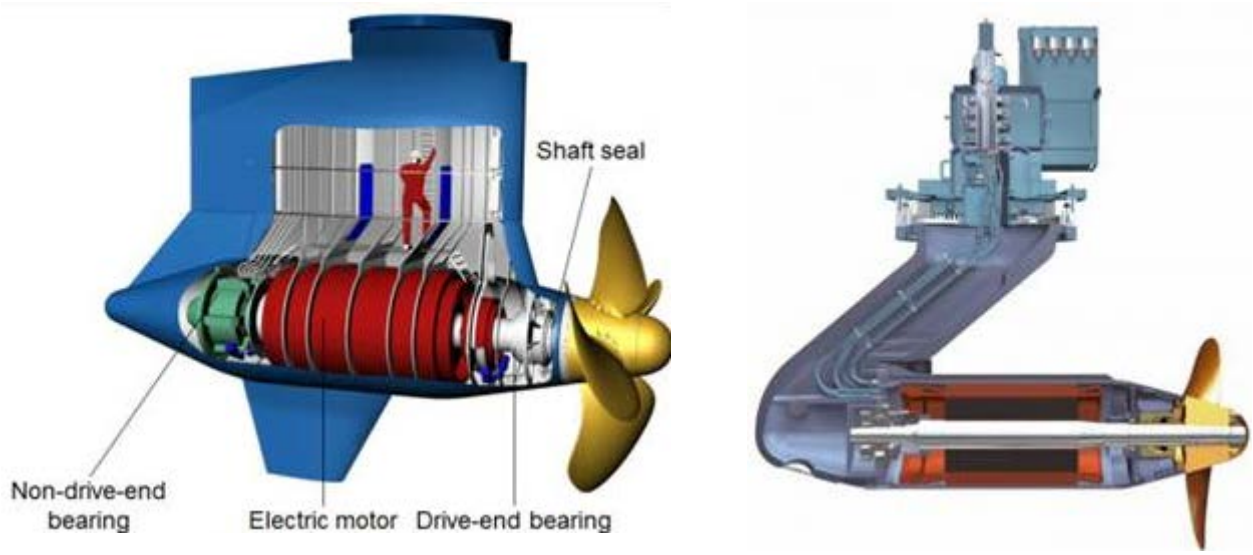
Azimuthing pod internal structures and parts including webs, frames, shafts, bearings, and seal arrangements are to be accessible for surveys and examinations in accordance with Section 3-7-1 as applicable. The design is to provide means for internal inspection as indicated in the following:

i) For units, as illustrated in 3-2-14/Figure 14(a) and alike, the internal structure and components are such as to allow direct access for survey and examination, or

ii) For compact version of azimuthing pods, as illustrated in 3-2-14/Figure 14(b) and alike, the unit is designed to be readily removable for survey or to have a sufficient number of access openings for boroscopic internal inspection.

iii) Where the design of the service access arrangement is different from those indicated in *i)* and *ii)* above, it is subject to special consideration.

FIGURE 14
Azimuthing Pod Internal Structure Access *(2016)*



(a) (b)

25.21 Air and Drainage Escape

Limber and air holes are to be cut in all parts of pod internal structure as required for drainage, free flow to the section pipes and the escape of air to vents.

25.23 Watertightness

Azimuthing pods are to be of watertight and are to be tested in accordance with 3-7-1/Table 1, as applicable.

25.23 Welding Requirements

Welding is to be in accordance with Section 2-4-1 of the ABS *Rules for Materials and Welding (Part 2)* and Section 3-2-19 of these Rules. Where inaccessible for welding inside the pod, it is recommended that webs, frames, and diaphragms be fitted with flat bars and the side plating be connected to these flat bars by continuous welds or by 75 mm (3 in.) slot welds spaced at 150 mm (6 in.) centers. The slots are to be fillet welded around the edges and filled with a suitable compound.

PART
3

CHAPTER 2 Hull Structures and Arrangements

APPENDIX 4 Guidelines for Calculating Bending Moment and Shear Force in Rudders and Rudder Stocks

1 Application

Bending moments, shear forces and reaction forces of rudders, stocks and bearings may be calculated according to this Appendix for the types of rudders indicated. Moments and forces on rudders of different types or shapes than those shown are to be calculated using alternative methods and will be considered based on submitted documents and calculations supporting the review.

3 Spade Rudders *(2014)*

3.1 Rudder Blade

3.1.1 Shear Force

For regular spade rudders as shown in 3-2-A4/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 3-2-14/3, in kN (tf, Ltf)

A = total projected area of rudder blade in m^2 (ft^2**)**, as defined in 3-2-14/3

c_ℓ, c_u and ℓ_R are dimensions as indicated in 3-2-A4/Figure 1(a), in m (ft).

For spade rudders with embedded rudder trunks let deep in the rudder blade, as shown in 3-2-A4/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-A4/3.1.1.

c_ℓ, c_b, c_u, ℓ_u, and ℓ_b are dimensions as illustrated in 3-2-A4/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-A4/3.1.1.

3.3 Lower Stock

3.3.1 Shear Force

For regular spade rudder, the shear force, V_ℓ, at any section of the lower stock between the top of the rudder and the neck bearing is given by the following equation:

$$V_\ell = C_R \quad \text{kN (tf, Ltf)}$$

For spade rudder with embedded rudder trunk, the shear force at any section of the stock between the top of the rudder and the neck bearing is given by the following equation:

$$V_\ell = \frac{M_2 - M_1}{\ell_u + \ell_\ell} \quad \text{kN (tf, Ltf)}$$

where C_R, ℓ_ℓ, and ℓ_u are as defined in 3-2-A4/3.1.1.

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 3-2-14/3

c_ℓ, c_u, ℓ_ℓ and ℓ_R are dimensions as indicated in 3-2-A4/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-A4/3.1.2.

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-A4/3.1.1

M_R = is the greater of M_1 and M_2, as defined in 3-2-A4/3.1.2

c_ℓ, c_u, ℓ_ℓ, ℓ_u and ℓ_R are dimensions as indicated in 3-2-A4/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:

$$P_u = -\frac{M_n}{\ell_u + \ell_\ell} \quad \text{kN (tf, Ltf)}$$

$$P_n = C_R + P_u \quad \text{kN (tf, Ltf)}$$

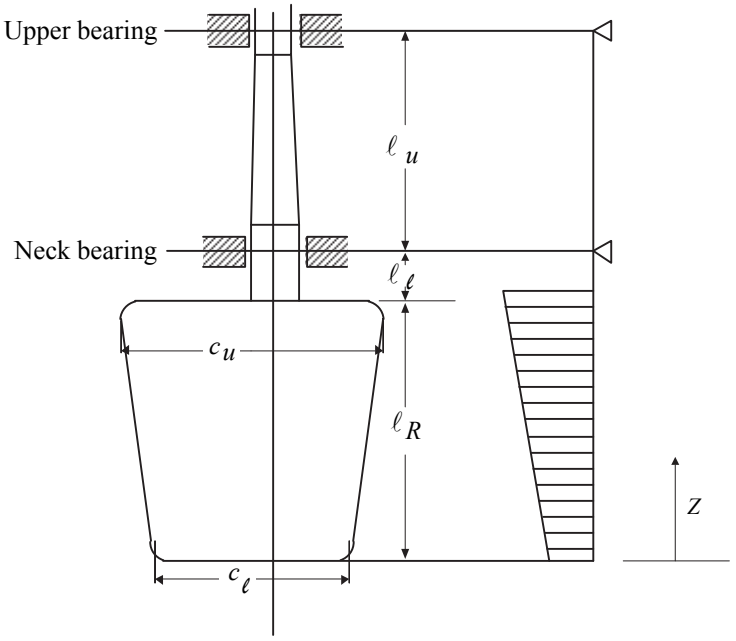
where

M_n = bending moment at the neck bearing, as defined in 3-2-A4/3.3.2

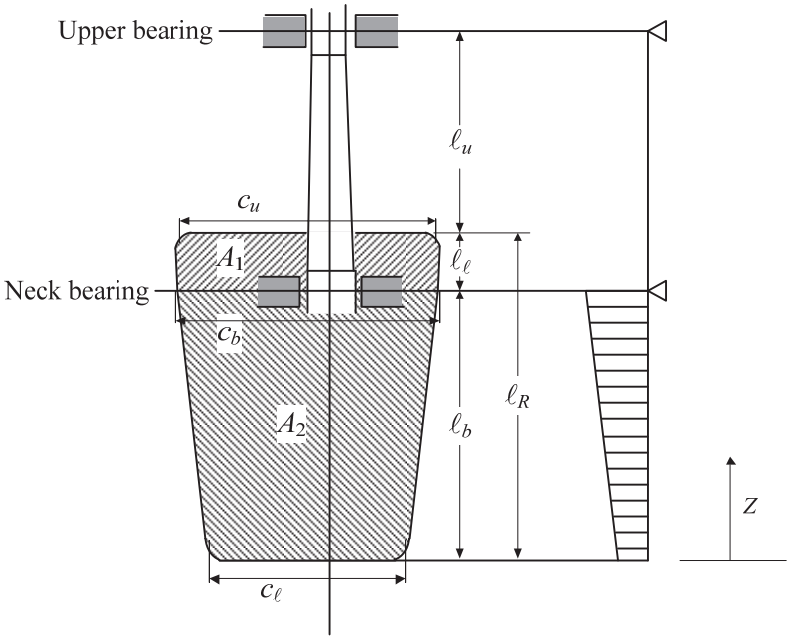
C_R = rudder force, as defined in 3-2-14/3

ℓ_u is as indicated in 3-2-A4/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 Shoe Piece

5.1 Shear Force, Bending Moment and Reaction Forces

Shear force, bending moment and reaction forces are to be assessed by the simplified beam model given in 3-2-A4/Figure 2.

w_R = rudder load per unit length

= $\frac{C_R}{\ell_R}$ kN/m (tf/m, Ltf/ft)

where

C_R = rudder force, as defined in 3-2-14/3

k_s = spring constant reflecting support of the shoe piece

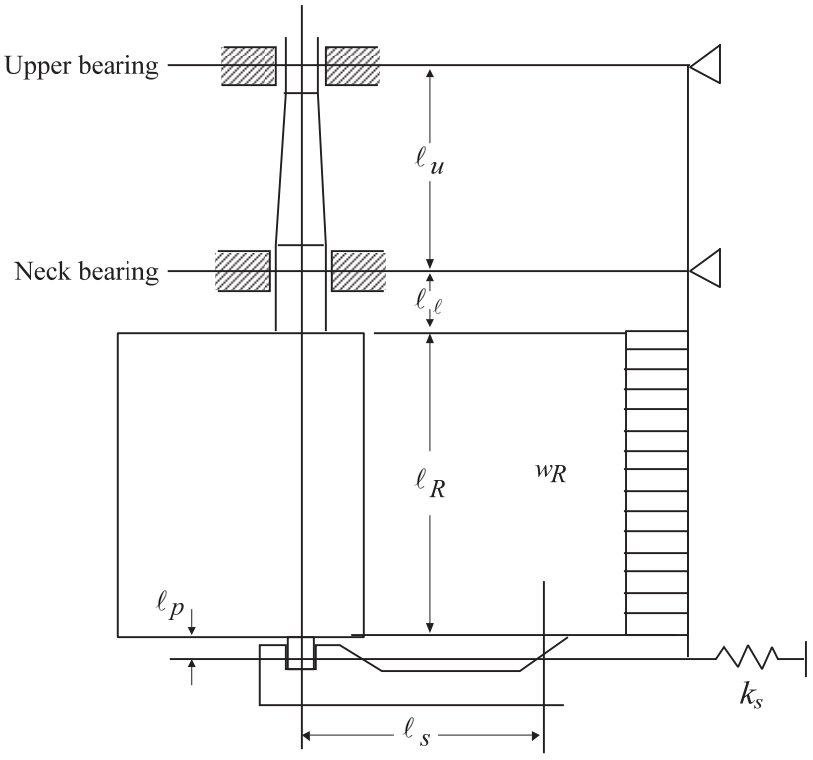
= $\frac{n_s I_s}{\ell_s^3}$ kN/m (tf/m, Ltf/ft)

n_s = 6.18 (0.630, 279)

I_s = moment of inertia of shoe piece about the vertical axis, in cm^4 (in^4)

ℓ_s, ℓ_R and ℓ_p are dimensions as indicated in 3-2-A4/Figure 2, in m (ft).

FIGURE 2
Rudder Supported by Shoe Piece



7 Rudders Supported by a Horn with One Pintle

7.1 Shear Force, Bending Moment and Reaction Forces

Shear force, bending moment and reaction forces are to be assessed by the simplified beam model shown in 3-2-A4/Figure 3.

w_{R1} = rudder load per unit length above pintle

$$= \frac{C_{R1}}{\ell_{R1}} \text{ kN/m (tf/m, Ltf/ft)}$$

w_{R2} = rudder load per unit length below pintle

$$= \frac{C_{R2}}{\ell_{R2}} \text{ kN/m (tf/m, Ltf/ft)}$$

where

C_{R1} = rudder force, as defined in 3-2-14/3.3

C_{R2} = rudder force, as defined in 3-2-14/3.3

k_h = spring constant reflecting support of the horn

$$= \frac{1}{\frac{\ell_h^3}{n_b I_h} + \frac{\Sigma\left(\frac{s_i}{t_i}\right) e^2 \ell_h}{n_t a^2}} \text{ kN/m (tf/m, Ltf/ft)}$$

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)

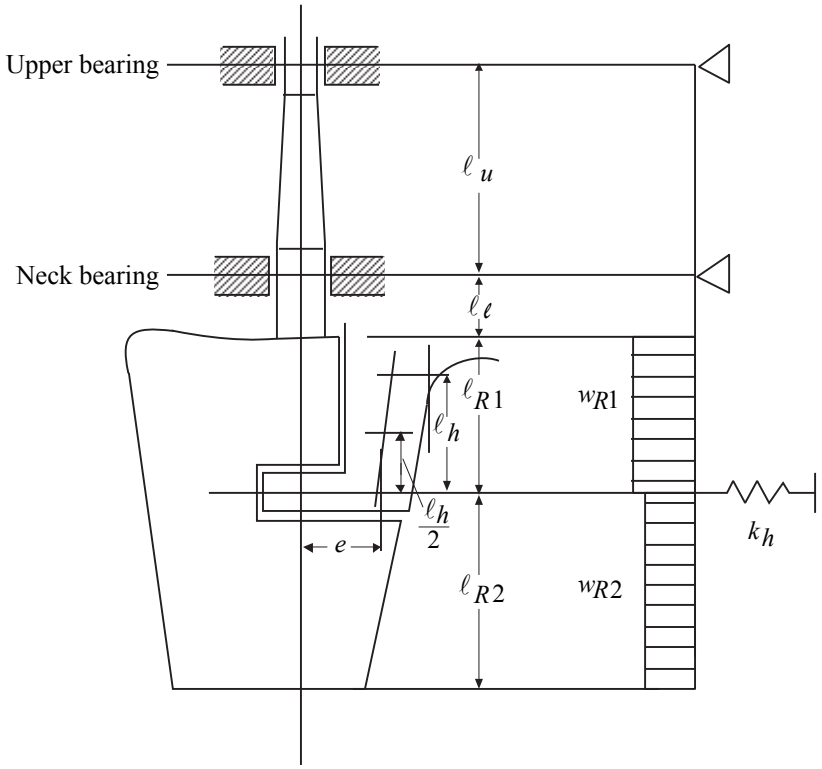
s_i = the girth length of each segment of the horn of thickness t_i, in cm (in.)

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-A4/Figure 3, in m (ft).

FIGURE 3
Rudder Supported by a Horn with One Pintle



9 Rudders Supported by a Horn Arranged with Two Pintles (Supports) *(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-A4/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 3-2-14/3.3

C_{R2} = rudder force, as defined in 3-2-14/3.3

ℓ_{R1} and ℓ_{R2} are dimensions as indicated in 3-2-A4/Figure 4, in m (ft).

In 3-2-A4/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-A4/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-A4/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-A4/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-A4/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-A4/Figure 4).

J_{th} = torsional stiffness factor of the rudder horn, in m^4 (ft^4)

$$= \frac{4F_T^2}{\sum_i \frac{u_i}{t_i}} \quad \text{for any thin wall closed section, in m}^4\ (\text{ft}^4)$$

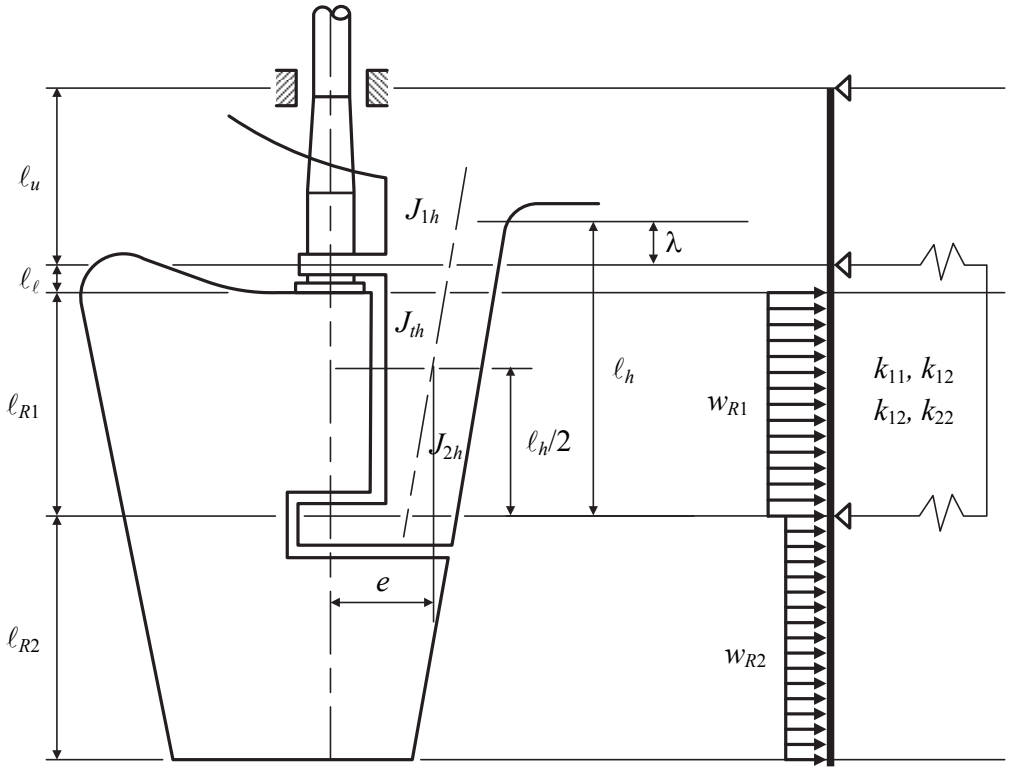
Note that the J_{th} value is taken as an average value, valid over the rudder horn height.

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 15 Protection of Deck Openings

1 General

All openings in decks are to be framed to provide efficient support and attachment to the ends of the half beams. The following requirements relate to vessels having minimum freeboards. For decks above the first deck above the freeboard deck (second and higher tiers above the freeboard deck), the heights of the coamings and the effectiveness of the closing arrangements may be modified. The arrangements and details for all hatchways are to be submitted for approval.

3 Positions and Design Pressures

3.1 Positions of Deck Openings

For the purpose of these Rules, two positions of deck openings are defined as follows.

Position 1 Upon exposed freeboard and raised quarter decks, and upon exposed superstructure decks situated forward of a point located $L_f/4$ from the forward end of L_f.

Position 2 Upon exposed superstructure decks situated abaft $L_f/4$ from the forward end of L_f and located at least one standard height of superstructure above the freeboard deck. Upon exposed superstructures decks situated forward of a point located $L_f/4$ from the forward end of L_f and located at least two standards heights of superstructure above the freeboard deck.

3.3 Vertical Weather Design Pressures *(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. The design vertical weather pressures need not be combined with cargo loads specified in 3-2-15/7.9 and 3-2-15/7.11.

3.3.1 Hatch Covers in Position 1

3.3.1(a) For ships of 100 m (328 ft) in length and above:

$$p_V = p_0 + (p_{FP} - p_0)(0.25 - x/L_f)/0.25 \quad \text{kN/m}^2 \text{ (tf/m}^2\text{, Ltf/ft}^2\text{)}$$

In no case is p to be less than p_0.

For a position 1 hatchway located at least one superstructure standard height higher than the freeboard deck:

$$p_V = 34.3 \quad \text{kN/m}^2$$

$$= 3.5 \quad \text{tf/m}^2$$

$$= 0.32 \quad \text{Ltf/ft}^2$$

3.3.1(b) For ships less than 100 m (328 ft) in length:

$$p_V = R\{15.8 + (L_f/N)[1 - (5/3)(x/L_f)] - 3.6x/L_f\} \quad \text{kN/m}^2 \text{ (tf/m}^2\text{, Ltf/ft}^2\text{)}$$

In no case is p_V to be less than:

$$p_V = 1.2897(0.15L_f + 11.6) \quad \text{kN/m}^2$$
$$= 0.1316(0.15L_f + 11.6) \quad \text{tf/m}^2$$
$$= 0.0121(0.0457L_f + 11.6) \quad \text{Ltf/ft}^2$$

For a position 1 hatchway located at least one superstructure standard height higher than the freeboard deck:

$$p_V = 1.2897\ (0.15L_f + 11.6) \quad \text{kN/m}^2$$
$$= 0.1316(0.15L_f + 11.6) \quad \text{tf/m}^2$$
$$= 0.0121(0.0457L_f + 11.6) \quad \text{Ltf/ft}^2$$

where

p_0 = 34.3 (3.5, 0.32) kN/m^2 (tf/m^2, Ltf/ft^2)

p_{FP} = pressure at the forward perpendicular

= $49.0 + a(L_f - 100)$ kN/m^2 for L_f in meters

= $5 + a(L_f - 100)$ tf/m^2 for L_f in meters

= $0.457 + a(L_f - 328)$ Ltf/ft^2 for L_f in feet

a = 0.0726 (0.0074, 0.000206) kN/m^2 (tf/m^2, Ltf/ft^2)

= 0.356 (0.0363, 0.00101) kN/m^2 (tf/m^2, Ltf/ft^2) for vessels with reduced freeboard

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 more than 100 m (328 ft) nor less than 24 m (79 ft)

x = distance, in m (ft), from the mid length of the hatch cover under examination to the forward end of L_f, or $0.25L_f$, whichever is less.

R = 1.0 (0.102, 0.00932)

N = 3 (3, 9.84)

3.3.2 Hatch Covers in Position 2

3.3.2(a) For ships of 100 m (328 ft) in length and above:

p_V = 25.5 kN/m^2 (2.6 tf/m^2, 0.238 Ltf/ft^2)

Upon exposed superstructure deck located at least one superstructure standard height higher than the lowest Position 2 deck:

$$p_V = 20.60 \quad \text{kN/m}^2$$
$$= 2.1 \quad \text{tf/m}^2$$
$$= 0.19 \quad \text{Ltf/ft}^2$$

3.3.2(b) For ships less than 100 m (328 ft) in length:

p_V = $25.5 - 0.142(100 - L_f)$ kN/m^2

= $2.6 - 0.0145(100 - L_f)$ tf/m^2

= $0.238 - 0.00041(328 - L_f)$ Ltf/ft^2

In 3-2-15/Figure 1, the positions 1 and 2 are illustrated for an example ship. Where an increased freeboard is assigned, the design pressures for hatch covers on the actual freeboard deck may be as required for a superstructure deck, provided the summer freeboard is such that the resulting draft will not be greater than that corresponding to the minimum freeboard calculated from an assumed freeboard deck situated at a distance at least equal to the standard superstructure height h_N below the actual freeboard deck, see 3-2-15/Figure 2.

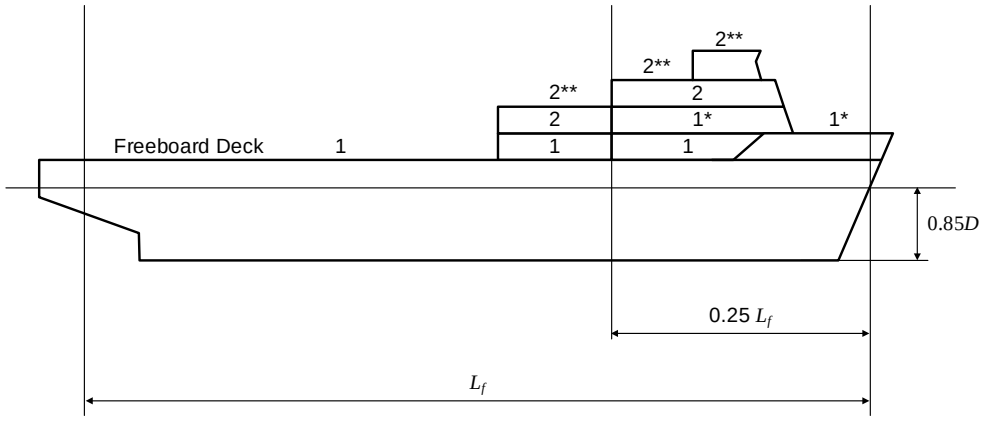
$$h_N = (1.05 + 0.01L_f) \quad \text{m}$$

where $1.8 \text{ m} \le h_N \le 2.3 \text{ m}$

$$h_N = 3.281\,(1.05 + 0.0031L_f) \quad \text{ft}$$

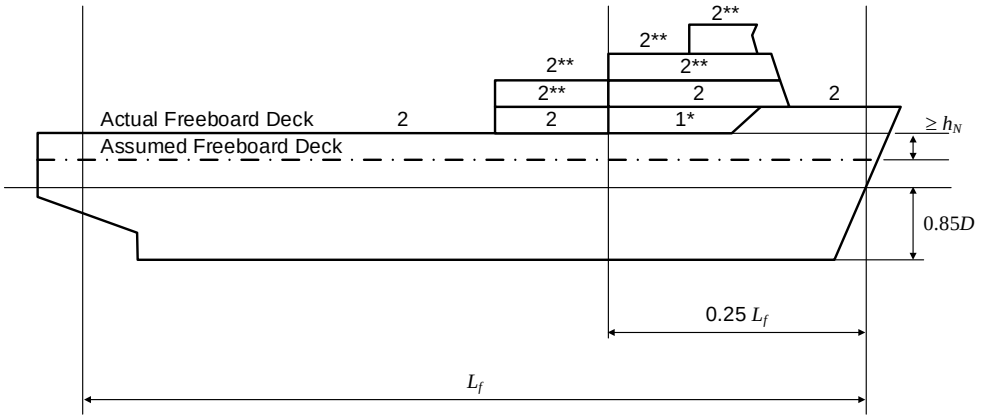
where $5.91 \text{ ft} \le h_N \le 7.55 \text{ ft}$

FIGURE 1
Positions 1 and 2 *(1 July 2016)*



* reduced load upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck
** reduced load upon exposed superstructure decks of vessels with L_f > 100m (328 ft) located at least one superstructure standard height above the lowest Position 2 deck

FIGURE 2
Positions 1 and 2 for an Increased Freeboard *(1 July 2016)*



* reduced load upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck
** reduced load upon exposed superstructure decks of vessels with L_f > 100m (328 ft) located at least one superstructure standard height above the lowest Position 2 deck

3.5 Horizontal 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 $L < 90$ m

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

= 10.75 for 300 m $\le L <$ 350 m

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

= $0.0122L + 4.1$ for $L <$ 295 ft

= $10.75 - \left(\frac{300 - 0.3048L}{100}\right)^{1.5}$ for 295 ft $\le L <$ 984 ft

= 10.75 for 984 ft $\le L <$ 1148 ft

= $10.75 - \left(\frac{0.3048L - 350}{150}\right)^{1.5}$ for 1148 ft $\le L \le$ 1640 ft

c_L = $\sqrt{0.011L}$ for $L <$ 90 m

= 1 for $L \ge$ 90 m

= $\sqrt{0.00336L}$ for $L <$ 295 ft

= 1 for $L \ge$ 295 ft

b_H = $1.0 + \left(\frac{\frac{x'}{L} - 0.45}{C_b + 0.2}\right)^2$ for $\frac{x'}{L} < 0.45$

= $1.0 + 1.5\left(\frac{\frac{x'}{L} - 0.45}{C_b + 0.2}\right)^2$ for $\frac{x'}{L} \ge 0.45$

a_H = $20 + \frac{e_H L_1}{12}$ for unprotected front coamings and hatch cover skirt plates

= $10 + \frac{e_H L_1}{12}$ for unprotected front coamings and hatch cover skirt plates, where the distance from the actual freeboard deck to the summer load line exceeds the minimum non-corrected tabular freeboard by at least one standard superstructure height h_N

= $5 + \frac{e_H L_1}{15}$ for side and protected front coamings and hatch cover skirt plates

$= 7 + \frac{e_H L_1}{100} - 8 \cdot \frac{x'}{L}$ for aft ends of coamings and aft hatch cover skirt plates abaft amidships

$= 5 + \frac{e_H L_1}{100} - 4 \cdot \frac{x'}{L}$ for aft ends of coamings and aft hatch cover skirt plates forward of amidships

L_1 = L, need not be taken greater than 300 m (984 ft)

C_b = block coefficient, as defined in 3-1-1/13.3, where $0.6 \le C_b \le 0.8$. When determining scantlings of aft ends of coamings and aft hatch cover skirt plates forward of amidships, C_b need not be taken less than 0.8.

x' = distance, in m (ft), between the transverse coaming or hatch cover skirt plate considered and aft end of the length L. When determining side coamings or side hatch cover skirt plates, the side is to be subdivided into parts of approximately equal length, not exceeding $0.15L$ each, and x' is to be taken as the distance between aft end of the length L and the center of each part considered.

z = vertical distance in m from the summer load line to the midpoint of stiffener span, or to the middle of the plate field

c_H = $0.3 + 0.7 \frac{b'}{B'}$,where b'/B' is not to be taken less than 0.25

b' = breadth of coaming in m at the position considered

B' = actual maximum breadth of ship in m on the exposed weather deck at the position considered.

e_H = 1(1, 0.3048)

R = 1 (0.102, 0.0093), as defined in 3-2-15/3.3.1

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

The design load p_H is not to be taken less than the minimum values given in 3-2-15/Table 1.

TABLE 1
Minimum Design Load $p_{H\min}$ (*1 July 2018*)

L in m (ft)	p_{Hmin} *in kN/m^2 (tf/m^2, Ltf/ft^2) for*	
	Unprotected Fronts	*Elsewhere*
≤ 50 (164)	30 (3.06, 0.279)	15 (1.53, 0.139)
> 50 (164) < 250 (820)	$R\left(25 + \frac{eL}{10}\right)$	$R\left(12.5 + \frac{eL}{20}\right)$
≥ 250 (820)	50 (5.1, 0.465)	25 (2.55, 0.232)

The horizontal weather design load need not be included in the direct strength calculation of the hatch cover, unless it is utilized for the design of substructures of horizontal supports according to the requirements of 3-2-15/7.23.2(c).

5 Hatchway Coamings

5.1 Height of Coamings

The height of coamings of hatchways is to be at least:

600 mm (23.5 in.) if in Position 1

450 mm (17.5 in.) if in Position 2

Where hatch covers are made of steel or other equivalent material and made tight by means of gaskets and clamping devices, these heights may be reduced or the coamings omitted entirely, provided that the safety of the vessel is not thereby impaired in any sea condition.

5.3 Coaming Plates *(1 July 2018)*

Where 3-2-15/7 is not applicable, coaming plates, where installed, are not to be less than 11 mm (0.44 in.) thick.

5.5 Coaming Stiffening *(2016)*

Except as noted below, coaming stiffening is to comply with the following:

i) Horizontal stiffeners are to be fitted on coamings in Position 1 at not more than 254 mm (10 in.) below the upper edge of the coaming.*

ii) The breadth of the stiffener's web is not to be less than 175 mm (7 in.) and thickness to fulfill 3-1-2/13.5 requirements.*

iii) Brackets or stays are to be fitted from the horizontal stiffener to the deck at intervals not exceeding 3 m (10 ft).*

iv) All exposed coamings other than Position 1 and which are 760 mm (30 in.) or more in height are to be similarly supported.*

v) Where the height of any exposed coaming exceeds 915 mm (36 in.), the arrangement of the stiffeners and brackets or stays is to be so as to provide equivalent support and stiffness.*

vi) Where coamings are protected, the arrangement of the stiffeners and brackets or stays may be modified.

vii) Where chocks are provided on the coaming to limit the horizontal movement of the hatch cover, the strength of the coaming and deck structure is to be adequate to withstand the load on these chocks. Similar consideration is to be given to pads supporting any weights located on hatch covers, if applicable.

* *Note:* Small hatches as specified in 3-2-15/13 need not comply with these requirements. (See the strength requirements for small hatches in 3-2-15/13.1)

7 Hatchways Closed by Covers of Steel and Fitted with Gaskets and Clamping Devices *(1 July 2018)*

7.1 Strength of Steel Covers

7.1.1 Stresses

The equivalent stress σ_e in steel hatch cover structures related to the net thickness shall not exceed $0.8Y$, where Y is specified minimum upper yield point strength of the material in N/mm^2 (kgf/mm^2, psi). For design loads according to 3-2-15/3.5 and 3-2-15/7.9 to 3-2-15/7.13, 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.

7.1.2 Deflection

The maximum vertical deflection of primary supporting members due to the vertical design load according to 3-2-15/3.3 is:

$$\delta_{v\max} = 0.0056\ell_g$$

where

ℓ_g = greatest span of primary supporting members

Where hatch covers are arranged for carrying containers and mixed stowage is allowed (i.e., a 40-foot container stowed on top of two 20-foot containers, particular attention should be paid to the deflections of hatch covers. Further the possible contact of deflected hatch covers within hold cargo has to be observed.

7.1.3 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.

7.1.4 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.

7.1.5 Net Scantling Approach

Unless otherwise quoted, the thicknesses t of the following sections are net thicknesses.

The net thicknesses are the member thicknesses necessary to obtain the minimum net scantlings required by 3-2-15/7.1 through 3-2-15/7.17 and 3-2.15/7.21.

The required gross thicknesses are obtained by adding corrosion additions, t_S, given in 3-2-15/Table 8.

Strength calculations using beam theory, grillage analysis or FEM are to be performed with net scantlings.

7.3 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 3-2-15/3.3 and 3-2-15/7.9.1, in kN/m^2 (tf/m^2, Ltf/ft^2)

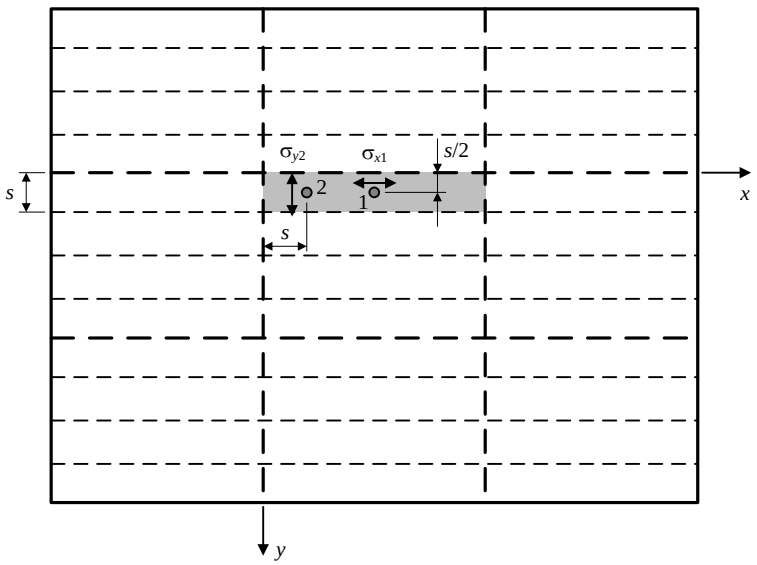
σ = maximum normal stress of hatch cover top plating, determined according to 3-2-15/Figure 3, N/mm^2 (kgf/mm^2, psi)

Y is as defined in 3-2-15/7.1

For flange plates under compression sufficient buckling strength according to 3-2-15/9.17 is to be demonstrated.

FIGURE 3
Determination of Normal Stress of the Hatch Cover Plating *(1 July 2018)*

$\sigma = \max[\sigma_{x1}\ (y = s/2);\ \sigma_{y2}\ (x = s)]$



7.3.1 Local Gross Plate Thickness of Hatch Covers for Wheel Loading

The local gross plate thickness of hatch covers subject to wheel loading is to be as given in, refer to 3-2-3/5.17.

Where the hatch cover is subject to other load as well, the hatch cover is to coupling with the applicable requirement in 3-2-15/7.

7.3.2 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 3-2-15/7.15 under consideration of permissible stresses according to 3-2-15/7.1.1. 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 3-2-15/7.3

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.

7.5 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:

$$Z = \frac{104}{Y} s_s \ell_s^2 p \quad \text{cm}^3, \text{ for design load according to 3-2-15/3.3}$$

$$= \frac{2793}{Y} s_s \ell_s^2 p \quad \text{in}^3$$

$$Z = \frac{93}{Y} s_s \ell_s^2 p \quad \text{cm}^3, \text{ for design loads according to 3-2-15/7.9.1}$$

$$= \frac{2498}{Y} s_s \ell_s^2 p \quad \text{in}^3$$

$$A_s = \frac{10.8 s_s \ell_s p}{Y} \quad \text{cm}^2, \text{ for design load according to 3-2-15/3.3}$$

$$= \frac{2418 s_s \ell_s p}{Y} \quad \text{in}^2$$

$$A_s = \frac{9.6 s_s \ell_s p}{Y} \quad \text{cm}^2, \text{ for design load according to 3-2-15/7.9.1}$$

$$= \frac{2149 s_s \ell_s p}{Y} \quad \text{in}^2$$

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 3-2-15/7.1

p is as defined in 3-2-15/7.3

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:

$$\frac{h}{t_w} \le 15k^{0.5}$$

where

h = height of the stiffener, in m (ft)

t_w = net thickness of the stiffener, in m (ft)

k = $235/Y$ ($23.963/Y$, $34084/Y$)

Y is as defined in 3-2-15/7.1

Stiffeners parallel to primary supporting members and arranged within the effective breadth according to 3-2-15/7.15.1 must be continuous at crossing primary supporting member and may be regarded for calculating the cross sectional properties of primary supporting members. It is to be verified that the combined stress of those stiffeners induced by the bending of primary supporting members and lateral pressures does not exceed the permissible stresses according to 3-2-15/7.1.1. The requirements of this paragraph are not applied to stiffeners of lower plating of double skin hatch covers if the lower plating is not considered as strength member.

For hatch cover stiffeners under compression sufficient safety against lateral and torsional buckling according to 3-2-15/7.17.3 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 3-2-15/7.1.1.

7.7 Net Scantlings of Primary Supporting Members

7.7.1 Primary Supporting Members

Scantlings of primary supporting members are obtained from calculations according to 3-2-15/7.15 under consideration of permissible stresses according to 3-2-15/7.1.1.

For all components of primary supporting members sufficient safety against buckling must be verified according to 3-2-15/7.17. For biaxial compressed flange plates this is to be verified within the effective widths according to 3-2-15/7.17.3(b).

The net thickness of webs of primary supporting members shall not be less than:

$$t = 6.5s \quad \text{mm}$$

$$= 0.078s \quad \text{in.}$$

but not less than 5 mm (0.20 in.)

where s is as defined in 3-2-15/7.3

7.7.2 Edge Girders (Skirt Plates)

Scantlings of edge girders are obtained from the calculations according to 3-2-15/7.15 under consideration of permissible stresses according to 3-2-15/7.1.1.

The net thickness of the outer edge girders exposed to wash of sea shall not be less than the largest of the following values:

$$t = 15.8s\sqrt{\frac{p_H}{0.95Y}} \quad \text{mm}$$

$$= 8.5s \quad \text{mm}$$

$$t = 23.652s\sqrt{\frac{p_H}{0.95Y}} \quad \text{in.}$$

$$= 0.102s \quad \text{in.}$$

but not less than 5 mm (0.20 in.)

where

p_H is as defined in 3-2-15/3.5.

Y is as defined in 3-2-15/7.1.

s is as defined in 3-2-15/7.3.

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)

7.9 Cargo Loads

7.9.1 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:

$$p_L = p_C(1 + a_a) \quad \text{kN/m}^2 \text{ (tf/m}^2\text{, Ltf/ft}^2\text{)}$$

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 = $m_0 - 5(m_0 - 1)\dfrac{x'}{L}$ for $0 \le \dfrac{x'}{L} \le 0.2$

= 1.0 for $0.2 < \dfrac{x'}{L} \le 0.7$

= $1 + \dfrac{m_0 + 1}{0.3}\left[\dfrac{x'}{L} - 0.7\right]$ for $0.7 < \dfrac{x'}{L} \le 1.0$

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.

7.9.2 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 3-2-15/7.9.1.

7.11 Container Loads

7.11.1 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 3-2-15/7.9.1.

The loads applied at each corner of a container stack resulting from heave, pitch, and the vessel's rolling motion are to be considered are to be determined as follows, see also 3-2-15/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 3-2-15/7.9.1.

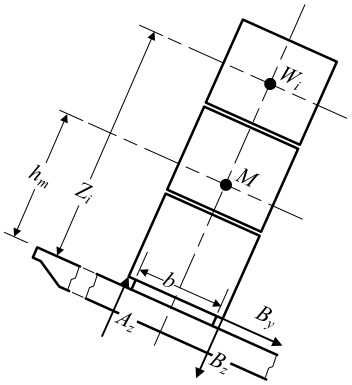
When strength of the hatch cover structure is assessed by grillage analysis according to 3-2-15/7.15, h_m and z_i need to be taken above the hatch cover supports. Force B_y does not need to be considered in this case.

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)*



7.11.2 Load Cases with Partial Loading

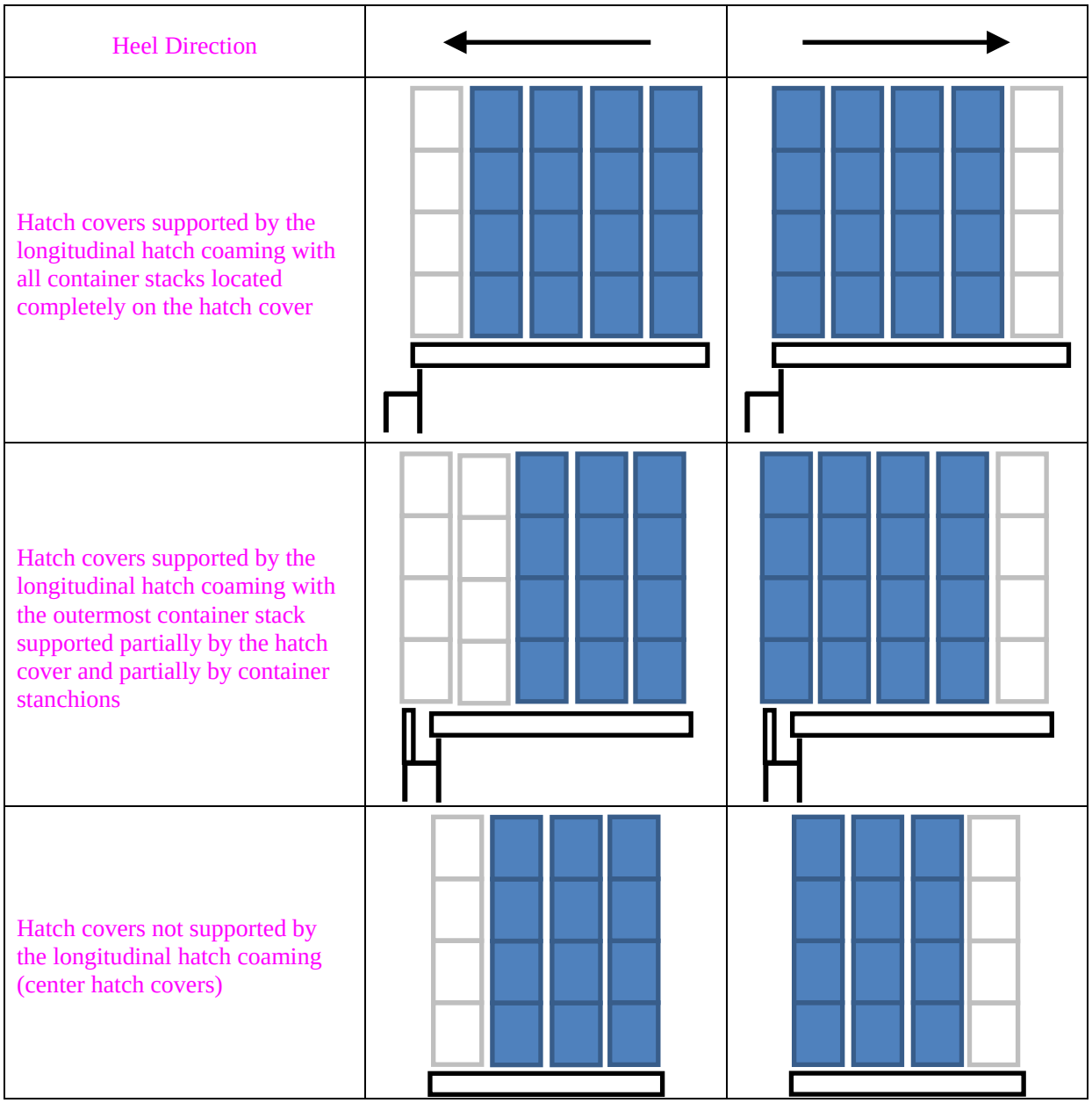
The load cases contained in 3-2-15/7.9.1 are also to be considered for partial non homogeneous loading which may occur in practice (e.g., where specified container stack places are empty). For each hatch cover, the heel directions, as shown in 3-2-15/Figure 5, are to be considered.

The load case “partial loading of container hatch covers” can be evaluated using a simplified approach, where the hatch cover is loaded without the outermost stacks that are located completely on the hatch cover. If there are additional stacks that are supported partially by the hatch cover and partially by container stanchions then the loads from these stacks are also to be neglected, see 3-2-15/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)*



7.13 Loads due to Elastic Deformations of the Vessel's Hull

Hatch covers, which in addition to the loads according to 3-2-15/3.3 to 3-2-15/3.5 and 3-2-15/7.9 to 3-2-15/7.11 are loaded in the vessel's transverse direction by forces due to elastic deformations of the vessel's hull, are to be designed such that the sum of stresses does not exceed the permissible values given in 3-2-15/7.1.1.

7.15 Strength Calculations

Strength calculation for hatch covers may be carried out by either, grillage analysis or FEM. Double skin hatch covers or hatch covers with box girders are to be assessed using FEM, see 3-2-15/7.15.2.

7.15.1 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 3-2-15/Figure 7.

The effective breadth of plating e_m of primary supporting members is to be determined according to 3-2-15/Table 2, considering the type of loading. Special calculations may be required for determining the effective breadth of one-sided or non-symmetrical flanges.

The effective cross sectional area of plates is not to be less than the cross sectional area of the face plate.

For flange plates under compression with secondary stiffeners perpendicular to the web of the primary supporting member, the effective width is to be determined according to 3-2-15/7.17.3(b).

TABLE 2
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

7.15.2 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.

7.17 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.)

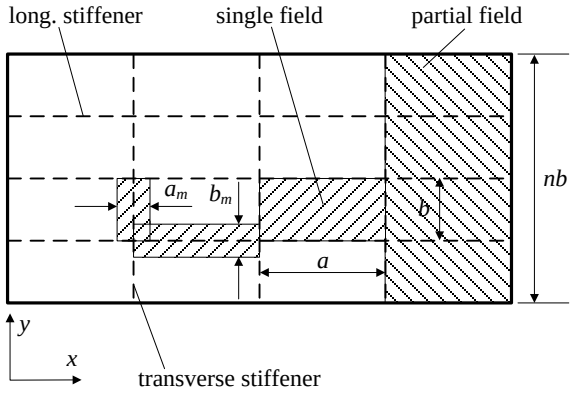
σ_{mx} = membrane stress in x-direction, in N/mm^2 (kgf/mm^2, psi)

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 3-2-15/Table 3.

TABLE 3
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 3-2-15/3.3

= 1.10 for hatch covers when subjected to loads according to 3-2-15/3.5 and 3-2-15/7.9 to 3-2-15/7.13

λ = reference degree of slenderness, taken equal to:

= $\sqrt{\frac{Y}{K\sigma_r}}$

K = buckling factor according to 3-2-15/Table 5

Y is as defined in 3-2-15/7.1.1.

E is as defined in 3-2-A3/3.1.1.

7.17.1 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 3-2-15/Table 4.

Where $\sigma_{mx} \leq 0$ (tension stress), $\kappa_x = 1.0$.

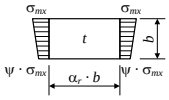
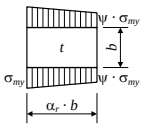
Where $\sigma_{my} \leq 0$ (tension stress), $\kappa_y = 1.0$.

The exponents e_1, e_2, and e_3 as well as the factor B are to be taken as given in 3-2-15/Table 4.

TABLE 4
Coefficients e_1, e_2, e_3 and Factor B *(1 July 2018)*

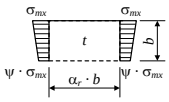
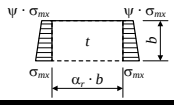
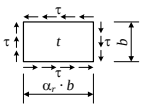
Exponents e_1 - e_3 and Factor B	*Plate Panel*
e_1	$1 + \kappa_x^4$
e_2	$1 + \kappa_y^4$
e_3	$1 + \kappa_x \kappa_y \kappa_\tau^2$
B σ_{mx} and σ_{my} positive (compression stress)	$(\kappa_x \kappa_y)^5$
B σ_{mx} or σ_{my} negative (tension stress)	1

TABLE 5
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 $1 \le \lambda_p^2 \le 3$ $c_1 = \left(1 - \dfrac{F_1}{\alpha_r}\right) \ge 0$ $H = \lambda - \dfrac{2\lambda}{c\left(T + \sqrt{T^2 - 4}\right)} \ge R$ $T = \lambda + \dfrac{14}{15\lambda} + \dfrac{1}{3}$
	$0 \ge \psi \ge -1$	$1 \le \alpha_r \le \dfrac{3(1 - \psi)}{4}$	$K = F_1\left[\left(1 + \dfrac{1}{\alpha_r^2}\right)^2 \cdot \dfrac{2.1(1 + \psi)}{1.1} - \dfrac{\psi}{\alpha_r^2}(13.9 - 10\psi)\right]$	
		$\alpha_r > 1.5$	$K = F_1\left[\left(1 + \dfrac{1}{\alpha_r^2}\right)^2 \cdot \dfrac{2.1(1 + \psi)}{1.1} - \dfrac{\psi}{\alpha_r^2}\left(5.87 - 1.87\alpha_r^2 + \dfrac{8.6}{\alpha_r^2} - 10\psi\right)\right]$	
	$\psi \le -1$	$1 \le \alpha_r \le \dfrac{3(1 - \psi)}{4}$	$K = 5.975F_1\left(\dfrac{1 - \psi}{\alpha_r}\right)^2$	
		$\alpha_r > \dfrac{3(1 - \psi)}{4}$	$K = F_1\left[3.9675\left(\dfrac{1 - \psi}{\alpha_r}\right)^2 + 0.5375\left(\dfrac{1 - \psi}{\alpha_r}\right)^4 + 1.87\right]$	

Explanations for boundary conditions ----- plate edge free
——— plate edge simply supported

TABLE 5 (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 	$1 \ge \psi \ge 0$	$\alpha_r > 0$	$K = \dfrac{4\left(0.425 + \dfrac{1}{\alpha_r^2}\right)}{3\psi + 1}$	$\kappa_x = 1$ for $\lambda \le 0.7$ $\kappa_x = \dfrac{1}{\lambda^2 + 0.51}$ for $\lambda > 0.7$
	$0 \ge \psi \ge -1$		$K = 4\left(0.425 + \dfrac{1}{\alpha_r^2}\right)(1 + \psi) - 5\psi(1 - 3.42\psi)$	
4 	$1 \ge \psi \ge -1$	$\alpha_r > 0$	$K = \left(0.425 + \dfrac{1}{\alpha_r^2}\right)\dfrac{3 - \psi}{2}$	
5 	-----	-----	$K = K_\tau \cdot \sqrt{3}$	$\kappa_\tau = 1$ for $\lambda \le 0.84$ $\kappa_\tau = \dfrac{0.84}{\lambda}$ for $\lambda > 0.84$
		$\alpha_r \ge 1$	$K_\tau = \left[5.34 + \dfrac{4}{\alpha_r^2}\right]$	
		$0 < \alpha_r < 1$	$K_\tau = \left[4 + \dfrac{5.34}{\alpha_r^2}\right]$	
Explanations for boundary conditions		- - - - - plate edge free ——— plate edge simply supported		

7.17.2 Webs and Flanges of Primary Supporting Members

For non-stiffened webs and flanges of primary supporting members sufficient buckling strength as for the hatch cover top and bottom plating is to be demonstrated according to 3-2-15/7.17.1.

7.17.3 Strength of Partial and Total Fields of Hatch Covers

7.17.3(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 3-2-15/7.17.3(c) through 3-2-15/7.17.3(d).

For u-type stiffeners, the proof of torsional buckling strength according to 3-2-15/7.17.3(d) can be omitted.

Single-side welding is not permitted to use for secondary stiffeners except for u-stiffeners.

7.17.3(b) Effective Width of Hatch Cover Top and Bottom Plating. For demonstration of buckling strength according to 3-2-15/7.17.3(c) through 3-2-15/7.17.3(d) the effective width of plating may be determined by the following formulae:

$b_m = \kappa_x \cdot b$ for longitudinal stiffeners, in mm (in.)

$a_m = \kappa_y \cdot a$ for transverse stiffeners, in mm (in.)

where

a and b are as defined in 3-2-15/7.17.

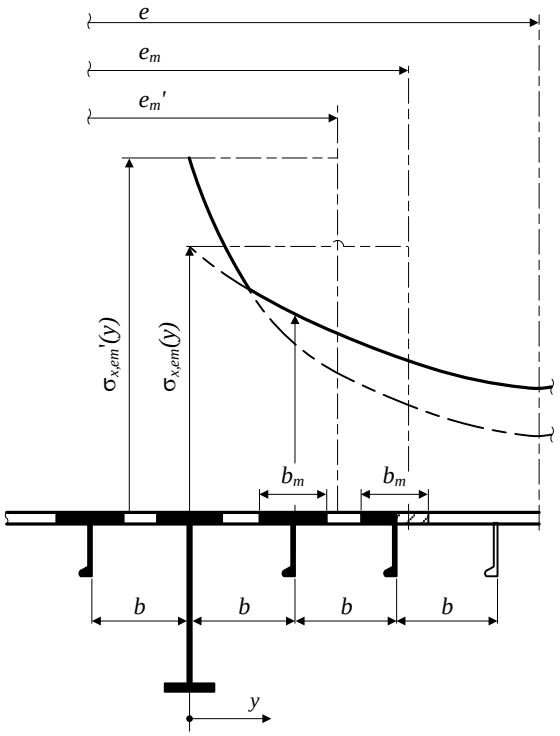
κ_x, κ_y are as defined in 3-2-15/7.17.1.

See also 3-2-15/Figure 6.

The effective width of plating is not to be taken greater than the value obtained from 3-2-15/7.15.1.

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*

$b < e_m$

$e'_m = nb_m$

$n = \left(\frac{e_m}{b}\right)$

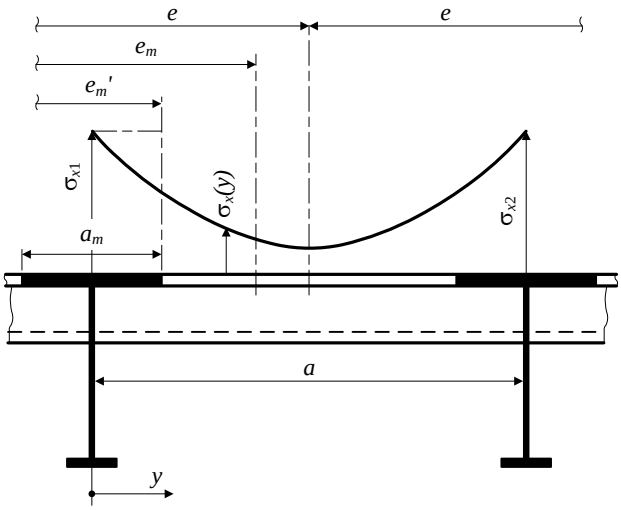
where

b_m = effective width of plating for transverse stiffeners, in mm (in.)

e and e_m are as defined in 3-2-15/7.15.

b and n are as defined in 3-2-15/7.17.

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 3-2-15/7.15.

a and n are as defined in 3-2-15/7.17.

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 3-2-15/7.15.

Shear stress distribution in the flange plates may be assumed linearly.

7.17.3(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 3-2-15/7.17, 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 3-2-15/7.17.3(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} = $F_{Kix}\frac{\pi^2}{a^2}(1 + c_{px})$, in N/mm^2 (kgf/mm^2, psi)

c_{px} = $\dfrac{1}{1+\dfrac{0.91\left(\dfrac{12\cdot 10^4 I_x}{t^3 b}-1\right)}{c_{xa}}}$, in N/mm^2 (kgf/mm^2)

c_{px} = $\dfrac{1}{1+\dfrac{0.91\left(\dfrac{12\cdot I_x}{t^3 b}-1\right)}{c_{xa}}}$, in psi

c_{xa} = $\left[\dfrac{a}{2b}+\dfrac{2b}{a}\right]^2$ for $a \geq 2b$

= $\left[1+\left(\dfrac{a}{2b}\right)^2\right]^2$ for $a < 2b$

ii) *For transverse stiffeners:*

c_{fy} = $c_S F_{Kiy}\frac{\pi^2}{(nb)^2}(1 + c_{py})$, in N/mm^2 (kgf/mm^2, psi)

c_{py} = $\dfrac{1}{1+\dfrac{0.91\left(\dfrac{12\cdot 10^4 I_y}{t^3 a}-1\right)}{c_{ya}}}$, in N/mm^2 (kgf/mm^2)

c_{py} = $\dfrac{1}{1+\dfrac{0.91\left(\dfrac{12 I_y}{t^3 a}-1\right)}{c_{ya}}}$, in psi

c_{ya} = $\left[\dfrac{nb}{2a}+\dfrac{2a}{nb}\right]^2$ for $nb \geq 2a$

= $\left[1+\left(\dfrac{nb}{2a}\right)^2\right]^2$ for $nb < 2a$

c_s = factor accounting for the boundary conditions of the transverse stiffener

= 1.0 for simply supported stiffeners

= 2.0 for partially constraint stiffeners

Z_{st} = net section modulus of stiffener (long. or transverse) including effective width of plating according to 3-2-15/7.17.3(b), in cm^3 (in^3)

Ψ, σ_{mx}, σ_{my}, τ, SF, t, a, and b are as defined in 3-2-15/7.17,

Y is as defined in 3-2-15/7.1.1,

E is as defined in 3-2-A3/3.1.1.

If no lateral load p is acting, the bending stress σ_b is to be calculated at the midpoint of the stiffener span for the flange which results in the largest stress value. If a lateral load p is acting, the stress calculation is to be carried out for both flanges of the stiffener's cross sectional area (if necessary for the biaxial stress field at the plating side).

7.17.3(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:

$$= \sqrt{\frac{Y}{\sigma_{KiT}}}$$

σ_{KiT} = $\frac{E}{I_P}\left(\frac{\pi^2 I_\omega 10^2}{a^2}\varepsilon + 0.385 I_T\right)$, in N/mm^2 (kgf/mm^2)

$$= \frac{E}{100 I_P}\left(\frac{\pi^2 I_\omega 10^2}{a^2}\varepsilon + 0.385 I_T\right), \text{ in psi}$$

For I_p, I_T, I_ω see 3-2-15/Figure 9 and 3-2-15/Table 6.

I_p = net polar moment of inertia of the stiffener related to the point C, in cm^4 (in^4)

I_T = net St. Venant's moment of inertia of the stiffener, in cm^4 (in^4)

I_ω = net sectional moment of inertia of the stiffener related to the point C, in cm^6 (in^6)

ε = degree of fixation taken equal to:

$$= 1 + 10^{-3}\sqrt{\frac{a^4}{\frac{3}{4}\pi^4 I_\omega\left(\frac{b}{t^3} + \frac{4h_w}{3t_w^3}\right)}}$$

where I_ω in cm^6 and b, t, h_w, and t_w in mm

$$= 1 + \sqrt{\frac{a^4}{\frac{3}{4}\pi^4 I_\omega\left(\frac{b}{t^3} + \frac{4h_w}{3t_w^3}\right)}}$$

where I_ω in in^6 and b, t, h_w, and t_w in inches

h_w = web height, in mm (in.)

t_w = net web thickness, in mm (in.)

b_f = flange breadth, in mm (in.)

t_f = net flange thickness, in mm (in.)

A_w = net web area

= $h_w t_w$, in mm^2 (in^2)

A_f = net flange area

= $b_f t_f$, in mm^2 (in^2)

e_f = $h_w + \frac{t_f}{2}$, in mm (in.)

SF, σ_{mx}, *a*, and *b* are as defined in 3-2-15/7.17.

Y is as defined in 3-2-15/7.1.1.

E is as defined in 3-2-A3/3.1.1.

ii) *Transverse Secondary Stiffeners.* For transverse secondary stiffeners loaded by compressive stresses and which are not supported by longitudinal stiffeners, sufficient torsional buckling strength is to be demonstrated in accordance with 3-2-15/7.17.3(d)i).

FIGURE 9
Dimensions of Stiffeners *(1 July 2018)*

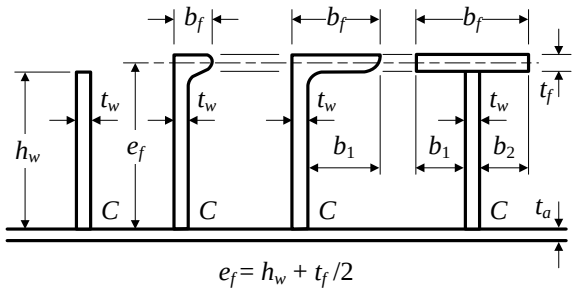


TABLE 6
Moments of Inertia *(1 July 2018)*

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			

7.19 Details of Hatch Covers

7.19.1 Container Foundations on Hatch Covers

The substructures of container foundations are to be designed for cargo and container loads according to 3-2-15/3.3 through 3-2-15/3.5 and 3-2-15/7.9 through 3-2-15/7.11 applying the permissible stresses according to 3-2-15/7.1.1.

7.19.2 Weathertightness

7.21.2(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.

7.21.2(b) Dispensation of Weathertight Gaskets. For hatch covers of cargo holds solely for the transport of containers, upon request by the owners and subject to compliance with the following conditions the fitting of weathertight gaskets according to 3-2-15/7.19.2(a) may be dispensed with:

- The hatchway coamings shall be not less than 600 mm (23.622 in.) in height.
- The exposed deck on which the hatch covers are located is situated above a depth $H(x)$. $H(x)$ is to be shown to comply with the following criteria:

  $H(x) \geq d + f_b + h$ m (ft)

  where

  f_b = minimum required freeboard for the vessel, in m (ft)

  h = 4.6 m (15.09 ft) for $\frac{x}{L_f} \leq 0.75$

  = 6.9 m (22.64 ft) for $\frac{x}{L_f} > 0.75$

L is as defined in 3-1-1/3.1.

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

d is as defined in 3-1-1/9.1.

- 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-watertight 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.

7.19.2(c) Drainage Arrangements. Cross-joints of multi-panel covers are to be provided with efficient drainage arrangements.

7.21 Hatch Coaming Strength Criteria

7.21.1 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:

$$t = 14.2s\sqrt{\frac{p_H}{0.95Y}} \quad \text{mm}$$

$$= 21.26s\sqrt{\frac{p_H}{0.95Y}} \quad \text{in.}$$

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 3-2-15/7.3.

p_H is as defined in 3-2-15/3.5.

Y is as defined in 3-2-15/7.1.1.

Longitudinal strength aspects are to be observed.

7.21.2 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 3-2-15/7.3.

p_H is as defined in 3-2-15/3.5.

Y is as defined in 3-2-15/7.1.1.

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 3-2-15/7.5.

p_H is as defined in 3-2-15/3.5.

Y is as defined in 3-2-15/7.1.1.

7.21.3 Coaming Stays

Coaming stays are to be designed for the loads transmitted through them and permissible stresses according to 3-2-15/7.1.1.

7.21.3(a) Coaming Stay Section Modulus. At the connection with deck, the net section modulus Z, in cm^3 (in^3) of the coaming stays designed as beams with flange (as shown in 3-2-15/Figure 10 a and b) is not to 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 3-2-15/3.5.

Y is as defined in 3-2-15/7.1.1.

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.

9.21.3(b) Web Thickness of Coaming Stays. At the connection with deck, the gross thickness t_w, in mm (in.), of the coaming stays designed as beams with flange (as shown in 3-2-15/Figure 10 a and b) shall not be less than:

$$t_w = \frac{2}{Y} \cdot \frac{e_s h_s p_H}{h_w} + t_s \quad \text{mm}$$

$$= \frac{373.34}{Y} \cdot \frac{e_s h_s p_H}{h_w} + t_s \quad \text{in.}$$

where

h_w = web height of coaming stay at its lower end, in m (ft)

t_s = corrosion addition according to 3-2-15/7.25, in mm (in.)

e_s and h_s are as defined in 3-2-15/7.21.3(a).

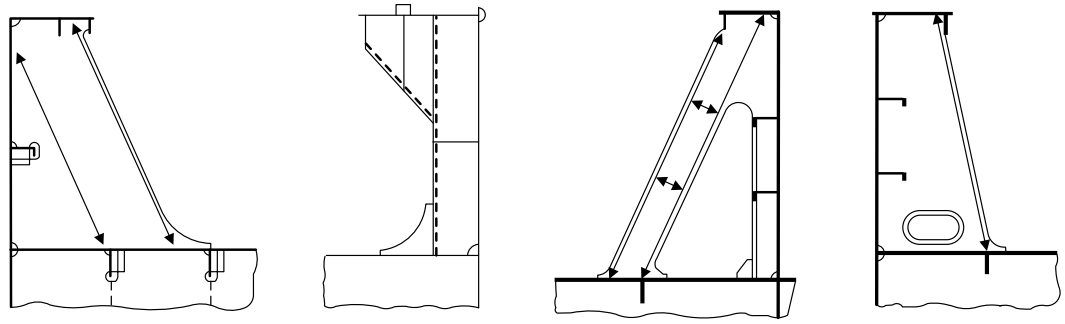
p_H is as defined in 3-2-15/3.5.

Y is as defined in 3-2-15/7.1.1.

For other designs of coaming stays, such as those shown in 3-2-15/Figure 10 c and d, the stresses are to be determined through a grillage analysis or FEM. The calculated stresses are to comply with the permissible stresses according to 3-2-15/7.1.1.

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)*



7.21.3(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.

7.21.4 Further Requirements for Hatch Coamings

7.21.4(a) Longitudinal Strength. Hatch coamings which are part of the longitudinal hull structure are to be designed according to the requirements for longitudinal strength.

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 $0.1L$ 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.

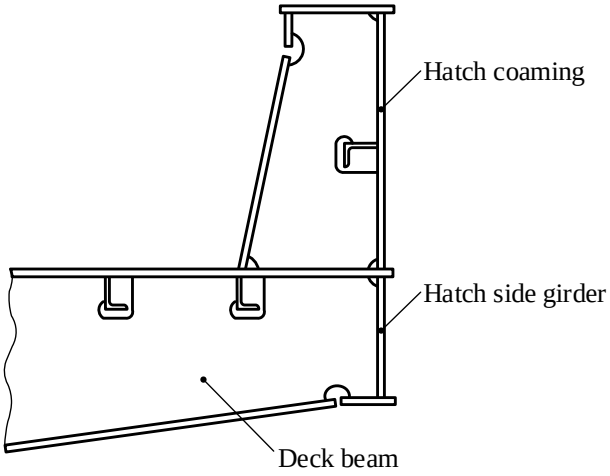
7.21.4(b) Local Details. Local details are to be adequate for the purpose of transferring the loads on the hatch covers to the hatch coamings and, through them, to the deck structures below. Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse, and vertical directions.

Structures under deck are to be checked against the load transmitted by the stays.

7.21.4(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.

7.21.4(d) Extend of Coaming Plates. Coaming plates are to extend to the lower edge of the deck beams or hatch side girders are to be fitted that extend to the lower edge of the deck beams. Extended coaming plates and hatch side girders are to be flanged or fitted with face bars or half-round bars. 3-2-15/Figure 11 gives an example.

FIGURE 11
Example for Arrangement of Coaming Plates *(1 July 2018)*



7.21.4(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.

7.23 Closing Arrangements

7.23.1 Securing Devices

7.23.1(a) General. Securing devices between cover and coaming and at cross-joints are to be provided to ensure weathertightness. Sufficient packing line pressure is to be maintained.

Securing devices must be appropriate to bridge displacements between cover and coaming due to hull deformations.

Securing devices are to be of reliable construction and effectively attached to the hatchway coamings, decks or covers. Individual securing devices on each cover are to have approximately the same stiffness characteristics.

Sufficient number of securing devices is to be provided at each side of the hatch cover considering the requirements of 3-2-15/7.7.2. 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.

7.23.1(b) Rod Cleats. Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

7.23.1(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.

7.23.1(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 3-2-15/7.7.2, in m (ft), not to be taken less than 2 m (6.5 ft)

k_ℓ = $0.28\left(\frac{235}{Y}\right)^{e_\ell}$ where Y in N/mm^2

= $2.75\left(\frac{23.963}{Y}\right)^{e_\ell}$ where Y in kgf/mm^2

= $2.317 \cdot 10^{-3}\left(\frac{34084}{Y}\right)^{e_\ell}$ where Y in psi

Y = minimum yield strength of the material as defined in 3-2-15/7.1.1, 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 3-2-15/7.7.2.

Rods or bolts are to have a gross diameter not less than 19 mm (0.75 in.) for hatchways exceeding 5 m^2 (54 ft^2) in area.

Securing devices of special design in which significant bending or shear stresses occur may be designed as anti-lifting devices according to 3-2-15/7.23.1(e). As load the packing line pressure q multiplied by the spacing between securing devices s_{SD} is to be applied.

7.23.1(e) Anti Lifting Devices. The securing devices of hatch covers, on which cargo is to be lashed, are to be designed for the lifting forces resulting from loads according to 3-2.15/7.11, see 3-2-15/Figure 12. Unsymmetrical loadings, which may occur in practice, are to be considered. Under these loadings the equivalent stress in the securing devices is not to exceed:

$$\sigma_V = \frac{42}{k_\ell} \quad \text{N/mm}^2$$

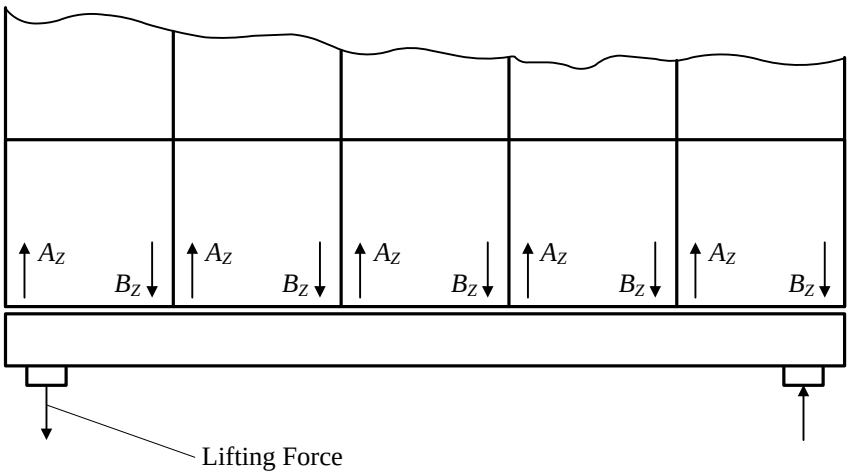
$$= \frac{42.08}{k_\ell} \quad \text{kgf/mm}^2$$

$$= \frac{50.41}{k_\ell} \quad \text{psi}$$

where k_ℓ is as defined in 3-2-15/9.23.1(d).

The partial load cases given in 3-2-15/Figure 5 may not cover all unsymmetrical loadings, critical for hatch cover lifting.

FIGURE 12
Lifting Forces at a Hatch Cover *(1 July 2018)*



7.23.2 Hatch Cover Supports, Stoppers and Supporting Structures

7.23.2(a) Horizontal Mass Forces. For the design of hatch cover supports, the horizontal mass force is to be calculated:

$$F_h = m_h a_h \quad \text{N}$$
$$= 0.102 m_h a_h \quad \text{kgf}$$
$$= 0.031 m_h a_h \quad \text{lbf}$$

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 3-5-1/11.1.2.

The accelerations in longitudinal direction and in transverse direction do not need to be considered as acting simultaneously.

7.23.2(b) Hatch Cover Supports. For the transmission of the support forces resulting from the load cases specified in 3-2-15/3.3 through 3-2-15/3.5 and 3-2-15/7.9, and of the horizontal mass forces specified in 3-2-15/7.23.2(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_{hmax} = 3.0

d_{hmin} = 1.0 in general

= 2.0 for partial loading conditions, see 3-2-15/9.11.1

p_n = see 3-2-15/Table 7

For metallic supporting surfaces not subjected to relative displacements the nominal surface pressure applies:

$p_{nmax} = 3p_n$ N/mm^2 (kgf/mm^2, 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 7
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 3-5-1/11.1.2.

For non-metallic, low-friction support materials on steel, the friction coefficient may be reduced but not to be less than 0.35.

Supports as well as the adjacent structures and substructures are to be designed such that the permissible stresses according to 3-2-15/7.1.1 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.

7.23.2(c) Hatch Cover Stoppers. Hatch covers shall be sufficiently secured against horizontal shifting. Stoppers are to be provided for hatch covers on which cargo is carried.

The greater of the loads resulting from 3-2-15/3.5 and 3-2-15/7.23.2(a) is to be applied for the dimensioning of the stoppers and their substructures.

The permissible stress in stoppers and their substructures, in the cover, and of the coamings is to be determined according to 3-2-15/7.1.1. In addition, the provisions in 3-2-15/7.23.2(b) are to be observed.

7.25 Corrosion Addition and Steel Renewal

7.25.1 Corrosion Addition for Hatch Covers and Hatch Coamings

The scantling requirements of the above sections imply the following general corrosion additions t_S:

TABLE 8
Corrosion Additions t_S for Hatch Covers and Hatch Coamings *(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)

7.25.2 Steel Renewal

Steel renewal is required where the gauged thickness is less than t_{net} + 0.5 mm (t_{net} + 0.02 in.) for

- Single skin hatch covers,
- The plating of double skin hatch covers, and
- Coaming structures the corrosion additions t_S of which are provided in 3-2-15/Table 8.

Where the gauged thickness is within the range t_{net} + 0.5 mm (t_{net} + 0.02 in.) and t_{net} + 1.0 mm (t_{net} + 0.04 in.), coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. Coating is to be maintained in condition with only minor spot rusting.

For the internal structure of double skin hatch covers, thickness gauging is required when hatch cover top or bottom plating renewal is to be carried out, or when this is deemed necessary , on the basis of the plating corrosion or deformation condition. In these cases, steel renewal for the internal structures is required where the gauged thickness is less than t_{net} mm (in.).

For corrosion addition t_S = 1.0 mm (0.04 in.) the thickness for steel renewal is t_{net} mm (in.) and the thickness for coating or annual gauging is when gauged thickness is between t_{net} mm (in.) and t_{net} + 0.5 mm (t_{net} + 0.02 in.).

8 Hatchways Closed by Covers of Aluminum and Fitted with Gaskets and Clamping Devices *(1 July 2018)*

8.1 Strength of Aluminum Covers

Explosion bonding is to be used for joining aluminum to steel. Such joints are to be protected to prevent galvanic corrosion. In addition, when one or both sides of aluminum to dissimilar metal joints are exposed to the weather, sea water or wet spaces, a minimum of 0.5 mm (0.02 in.) of plastic insulation shall be installed between faying surfaces and extend beyond the edge of the joint. Non-welded oil stops and stop waters are to be a plastic insulation tape or equivalent, which would provide a corrosion resistant system. Aluminum faying surfaces exposed to the weather, sea water or other corrosive environments are to be coated to minimize crevice corrosion in way of the faying surfaces.

Aluminum covers are not allowed on cargo decks. Where weathertight covers are of aluminum alloy, the maximum allowable stress, deflection and top plate thickness under the design loads calculated according to 3-2-15/3.3, but with pressure, p, of not less than 17.17 kN/m^2 (1.75 tf/m^2, 0.16 Ltf/ft^2) for Position 1 and not less than 12.75 kN/m^2 (1.3 tf/m^2, 0.119 Ltf/ft^2) for Position 2, are as follows:

- Maximum allowable stress — the product of the maximum stress thus calculated and the factor of 4.25 is not to exceed the minimum ultimate strength of the material.
- Maximum allowable deflection — 0.0028 times the span
- Top plate thickness — not less than $0.99Q_o$% of the spacing of stiffeners or $5.4Q_o$ mm ($0.22Q_o$ in.), if that be greater.

Q_o is the material factor as in 3-2-9/9.3.2, but is not to be taken less than 1.11

9 Hatchways in Decks at Higher Levels

Special consideration will be given to the omission of gaskets on covers of hatchways in decks located above Position 2, where it can be demonstrated that the closing arrangements are weathertight. The procedure for testing such covers will also be subject to special consideration. For tests during subsequent surveys, refer to 7-3-2/1.1.1(f) and 7-3-2/5.1.11 of the ABS *Rules for Survey After Construction (Part 7)*.

11 Hatchways in Lower Decks or within Fully Enclosed Superstructures

The following scantlings are intended for vessels of unrestricted service having conventional type covers. Scantlings for different types of covers or for vessels of restricted service will be separately considered.

11.1 Steel Covers

Where steel covers are fitted, the thickness of the plating is to be not less than required for platform decks in enclosed cargo spaces as obtained from 3-2-3/5.1. A stiffening bar is to be fitted around the edges, providing necessary rigidity to permit the covers to be handled without deformation. The effective depth of the framework is normally to be not less than 4% of its unsupported length. Each stiffener in association with the plating to which it is attached is to have section modulus SM not less than that obtained from the following equation:

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

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

where

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

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

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

ℓ = length of the stiffener, in m (ft)

11.3 Wheel Loading

Where provision is to be made for the operation or stowage of vehicles having rubber tires, the thickness of the hatch cover plating is to be not less than obtained from 3-2-3/5.17 for platform deck plating, except that the thickness of plate panels adjacent to the edges of the cover is to be at least 15% greater than that obtained from 3-2-3/5.17.

13 Small Hatches on the Exposed Fore Deck

The requirements of this Subsection apply to vessels with length, L, of 80 m (263 feet) or more as defined in 3-1-1/3.1 and to all small hatches [opening normally 2.5 m^2 (27 ft^2) or less] and located on the exposed fore deck within the forward 0.25L, where the deck in way of the hatch is less than 0.1L or 22 m (72.2 ft) above the summer load line, whichever is lesser.

13.1 Strength

For small rectangular steel hatch covers, the plate thickness, stiffener arrangement and scantlings are to be in accordance with 3-2-15/Table 9 and 3-2-15/Figure 13. Stiffeners, where fitted, are to be aligned with the metal-to-metal contact points required in 3-2-15/13.5 (see also 3-2-15/Figure 13). Primary stiffeners are to be continuous. All stiffeners are to be welded to the inner edge stiffener (see 3-2-15/Figure 14).

The upper edge of the hatchway coaming is to be suitably reinforced by a horizontal section, normally not more than 170 to 190 mm (6.9 to 7.5 in) from the upper edge of the coaming.

For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement is to provide strength and stiffness equivalent to the requirements for small rectangular hatches.

For small hatch covers constructed of materials other than steel, the required scantlings are to provide strength and stiffness equivalent to 235 N/mm^2 (24 kgf/mm^2, 34,000 psi) yield strength steel. Strength of small hatch covers constructed of aluminum alloy may be in accordance with 3-2-15/7.3.

13.3 Primary Securing Devices

The primary securing devices are to be such, that their hatch covers can be secured in place and made weathertight by means of a mechanism employing any one of the following methods:

i) Butterfly nuts tightening onto forks (clamps) or

ii) Quick acting cleats, or

iii) A central locking device.

Dogs (twist tightening handles) with wedges are not acceptable.

Emergency escape hatches need not comply with *i)* and *ii)* above.

13.5 Requirements for Primary Securing

The hatch cover is to be fitted with a gasket of elastic material. This is to be designed to allow a metal-to-metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged. The metal-to-metal contacts are to be arranged close to each securing device, in accordance with 3-2-15/Figure 13, and of capacity sufficient 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. A short bar for on/off tilting of quick acting cleats is acceptable.

For a primary securing method using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed to minimize the risk of butterfly nuts being dislodged while in use, by knuckling the forks' tips upward, and raising the top surface on the free end, or by any similar method. The plate thickness of un-stiffened steel forks is not to be less than 16 mm ($^5/_8$ in.). An example arrangement is shown in 3-2-15/Figure 14. Emergency escape hatches need not comply with the forgoing requirements in this paragraph.

For small hatch covers located in Position 1 on the exposed deck forward of the superstructure or deckhouse, the hinges are to be fitted on the fore edge such that the predominant direction of green water will cause the cover to close.

On small hatches located elsewhere the hinges are to be placed either on the fore edge or outboard edge, whichever is more practical for protection against green water coming from beam sea and/or bow quartering sea at their location.

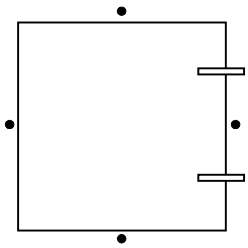
13.7 Secondary Devices

Small hatches on the fore deck are to be fitted with an independent secondary securing device, e.g., by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges. Emergency escape hatches need not comply with the forgoing requirements in this paragraph.

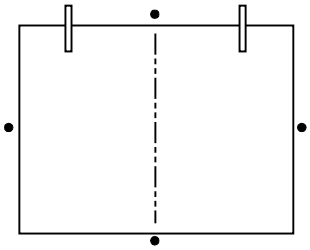
TABLE 9
Scantlings for Small Steel Hatch Covers on the Fore Deck

Nominal Size (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

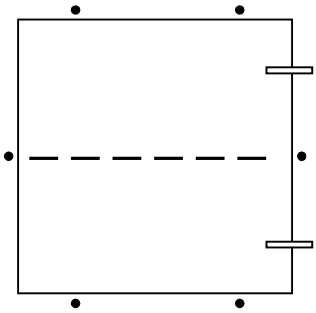
FIGURE 13
Arrangement of Stiffeners



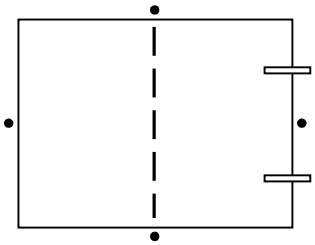
Nominal size 630 × 630



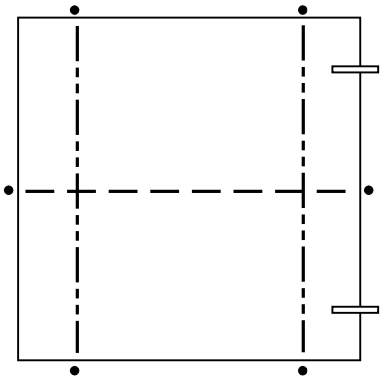
Nominal size 630 × 830



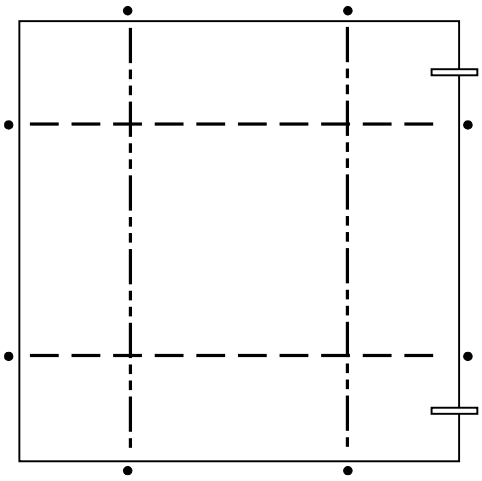
Nominal size 830 × 830



Nominal size 830 × 630



Nominal size 1030 × 1030



Nominal size 1330 × 1330

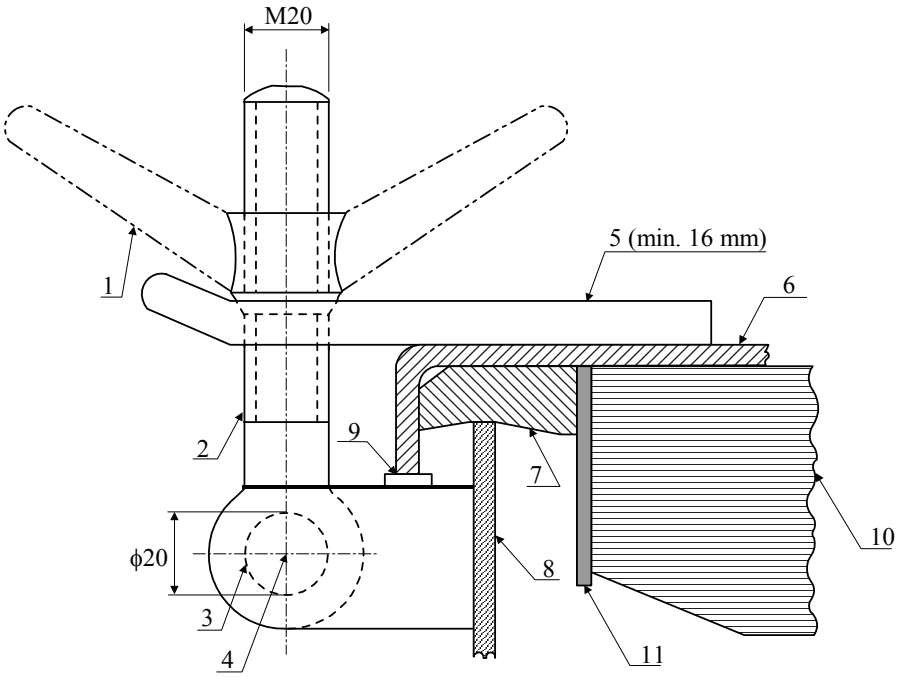
Hinge

Securing device/metal to metal contact

Primary stiffener

Secondary stiffener

FIGURE 14
Example of Primary Securing Method



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

(Note: Dimensions in millimeters)

15 Other Hatchways

15.1 Hatchways within Open Superstructures

Hatchways within open superstructures are to be considered as exposed.

15.3 Hatchways within Deckhouses

Hatchways within deckhouses may be flush or are to have coamings and closing arrangements related to the degree of protection offered by the deckhouse itself, in terms of construction and the means provided for the closing of all external deckhouse openings.

17 Additional Requirements for Subdivision

17.1 External Opening below Damage Waterline

All external openings leading to compartments assumed intact in the damage analysis, which are permitted by 3-3-1/3.3 to be below the final damage waterline, are to be watertight. Except for hatch covers, these openings are to be fitted with indicators on the bridge showing whether the closing appliances are open or closed.

17.3 Internal Openings

The openings and penetrations in internal decks required to be watertight for subdivision are to meet the corresponding requirements for watertight doors in 3-2-9/1.3 and 3-2-9/9.

19 Machinery Casings

19.1 Arrangement

Machinery-space openings in Position 1 or 2 are to be framed and efficiently enclosed by steel casings of ample strength, and, wherever practical, those openings in freeboard decks are to be located within superstructures or deckhouses. Where the machinery casings are exposed, plating and stiffeners are to be in accordance with the requirements in 3-2-11/3. Access openings in exposed casings are to be fitted with steel doors complying with the requirements of 3-2-11/5.3, the sills of which are to be at least 600 mm (23.5 in.) above the deck if in Position 1, and at least 380 mm (15 in.) above the deck if in Position 2. Where the vessel is assigned a freeboard less than that based on Table B as allowed by the International Convention on Load Lines, 1966, there are generally to be no openings giving direct access from the freeboard deck to the machinery space. A door, complying with the requirements of 3-2-11/5.3, may however be permitted in the exposed machinery casing, provided that it leads to a space or passageway that is as strongly constructed as the casing and is separated from the engine room by a second door complying with 3-2-11/5.3. The sill of the exterior door is not to be less than 600 mm (23.5 in.), and the sill of the second/interior door is to be not less than 230 mm (9 in.). Other openings in such casings are to be fitted with equivalent steel covers, permanently attached in their proper positions. See also 4-7-2/1.7.5 and 4-7-2/1.7.6.

19.3 Fiddleys, Funnels, and Ventilators

Coamings of any fiddley, funnel or machinery-space ventilator in an exposed position on the freeboard or superstructure deck are to be as high above the deck as reasonable and practicable. Fiddley openings are to be fitted with strong covers of steel or other equivalent material, permanently attached in their proper positions and capable of being secured weathertight.

19.5 Casings within Open Superstructures

Scantlings of casings within open superstructures are to be in compliance with 3-2-11/3 for exposed casings on superstructure decks. Where end bulkheads to the superstructures are not provided, the arrangements and scantlings of casings are to be in compliance with 3-2-11/3 for an exposed casing on the freeboard deck.

19.7 Casings within Enclosed Superstructures

The thickness of casings within enclosed superstructures is to be not less than obtained from the following equation:

$t = 4.6 + L/64 + (s - 760)/150$ mm but not less than 6.0 mm

$t = 0.146 + L/3500 + (s - 30)/150$ in. but not less than 0.24 in.

The thickness of casing sides in accommodation spaces, above the crown of the machinery space, is not to be less than obtained from the following equation:

$t = 4.5 + (s - 760)/150$ mm

$t = 0.18 + (s - 30)/150$ in.

where

L = length of vessel, as defined in 3-1-1/3.1, in m (ft) but need not be taken greater than 122 m (400 ft)

s = the stiffener spacing, in mm (in.), but is not to be taken less than 760 mm (30 in.)

Where accelerated corrosion is expected, maybe such as in way of wet spaces, the thickness of coaming plates ought to be increased. Where casings are used in lieu of girders or deep beams, the plating in way of them is to be suitably increased. Stiffeners are to be fitted in line with the beams and are to have a section modulus SM not less than obtained from the following equation:

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

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

where

c = 0.14

s = spacing of stiffeners, in m (ft)

h = tween-deck height, in m (ft)

ℓ = length of the stiffeners, in m (ft), between end supports

Casings which support girders or pillars are to be stiffened in such a manner as to provide supports not less effective than required for stanchions or pillars.

19.9 Casings within Deckhouses

Casings within deckhouses are to have scantlings, sill heights and closing arrangements to entrances related to the degree of protection offered by the deckhouse itself, in terms of construction and the means provided for closing of all external deckhouse openings.

21 Miscellaneous Openings in Freeboard and Superstructure Decks

21.1 Manholes and Scuttles

Manholes and flush scuttles in Position 1 or 2 or within superstructures other than enclosed superstructures are to be closed by covers capable of being made watertight. Unless secured by bolts spaced not more than 5 times the bolts' diameter, the covers are to be permanently attached.

21.3 Other Openings

Openings in freeboard decks other than hatchways, machinery-space openings, manholes and flush scuttles are to be protected by an enclosed superstructure or by a deckhouse, or companionway of equivalent strength and weathertightness. Any such opening in an exposed superstructure deck or in the top of a deckhouse on the freeboard deck, which gives access to a space below the freeboard deck or a space within an enclosed superstructure, is to be protected by a deckhouse or companionway as well. Doorways in such deckhouses or companionways are to be fitted with doors complying with the requirements of 3-2-11/5.3.

21.5 Escape Openings *(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.

21.7 Companionway Sills

In Position 1, the height above the deck of sills to the doorways in companionways is to be at least 600 mm (23.5 in.). In Position 2, they are to be at least 380 mm (15 in.).

21.9 Mast Openings

Openings penetrating decks and other structures to accommodate masts, kingposts and similar members are to be reinforced by fitting doublings or plating of increased thickness.

21.11 Chain Pipe Opening *(1 July 2012)*

Chain pipes through which anchor chains or wires are led are to be provided with permanently attached closing appliances minimizing the ingress of water. Steel, aluminum plate or a canvas cover with appropriate lashing arrangement will be acceptable for this purpose*. A cement and wire mesh arrangement is not permitted.

** 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 5 Hatch Cover Stiffeners of Variable Cross Section

1 Application

For 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 3-2-15/7.1 may be obtained from the following equations.

$$SM = \frac{C_1 K_1 ps\ell^2}{\sigma_a} \qquad \text{cm}^3\ (\text{in}^3)$$

$$I = C_2 K_2 ps\ell^3 \qquad \text{cm}^4\ (\text{in}^4)$$

where

C_1 = 125 (125, 1.5)

C_2 = 2.26 (22.1, 2.24×10^{-5}) for 3-2-15/7.1

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-A5/Figure 1.

σ_a = allowable stress given in 3-2-15/7.1, 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-A5/Figure 1

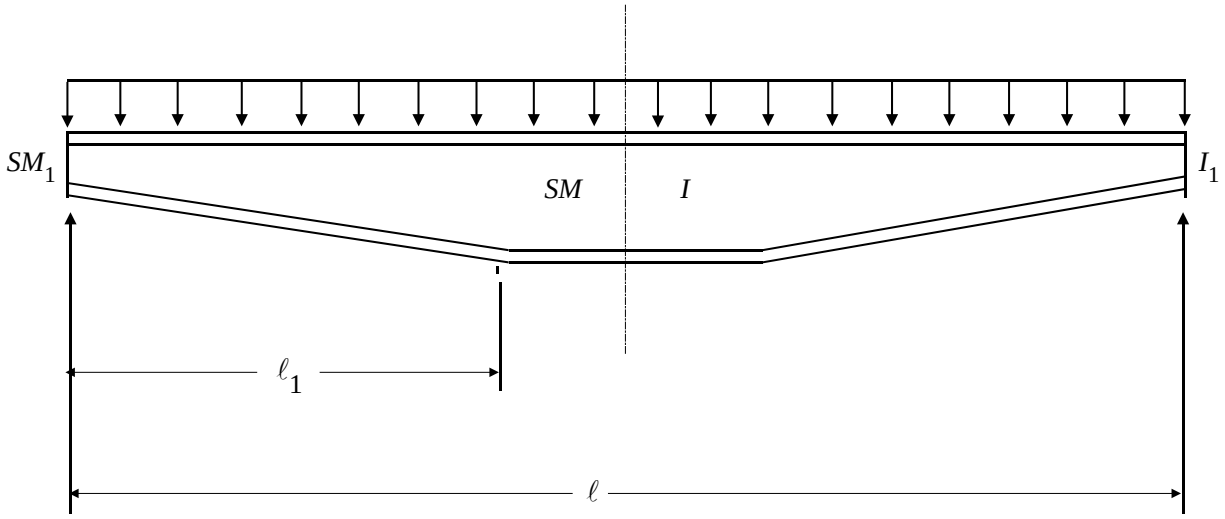
= I_1/I

p = design load given in 3-2-15/3.3, in kN/m^2 (tf/m^2, psi)

s = spacing of 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 16 Protection of Shell Openings

1 Cargo, Gangway, or Fueling Ports

1.1 Construction

Cargo, gangway, or fueling ports in the sides of vessels are to be capable of being made thoroughly watertight. Where frames are cut in way of such ports, web frames are to be fitted on each side of the opening and arrangements are to be provided for the support of the beams over the opening. Thick insert plates are to be fitted in the side shell to compensate for the openings. Doubler plates are not allowed.

Unless otherwise specifically required, openings in the side shell are to have a minimum corner radius of 0.1 times the width of the opening but need not exceed 450 mm (18 in.). Additionally, the minimum radius in way of narrow vertical ligaments between adjacent openings having the same depth is not to be less than 150 mm (6 in.).

Waterway angles and scuppers are to be provided on the deck in way of openings in cargo spaces below the freeboard deck or in cargo spaces within enclosed superstructures, to prevent the spread of any leakage water over the cargo space deck.

Indicators showing whether the ports in the side shell below the freeboard or superstructure deck are secured closed or open are to be provided on the navigation bridge.

In general, all outer doors are to open outwards. When unavoidable due to operational reasons, outer doors may open inwards when installed above freeboard deck.

1.3 Location

Unless especially approved, the lower edge of cargo, gangway, or fueling port openings is not to be below a line drawn parallel to the freeboard deck at side, which has at its lowest point the upper edge of the uppermost load line.

Cargo ports or similar openings having their lower edge below the line defined above are to be fitted with a second internal door of equivalent strength and water-tightness to the shell door, with a leakage detection device for the enclosed compartment between both doors. The drain from this compartment is to be led to the bilge with a screw-down valve, remotely controlled from an accessible location (see 4-6-4/3.3).

1.5 Subdivision Requirements

Openings in the shell plating below the deck, limiting the vertical extent of damage, are to be kept permanently closed while at sea. Should any of these openings be accessible during the voyage, their closing appliances are to be fitted with a device which prevents unauthorized opening. Should any of these openings be inaccessible during the voyage, their closing appliances are to be provided with a permanently affixed notice to the effect that it is to be kept closed.

3 Side Shell Doors and Stern Doors

Side shell doors fitted abaft of the collision bulkhead and stern doors leading into enclosed spaces are to meet the requirements of this Section. Stern doors and side shell doors may be situated either above or below the freeboard deck (see 3-2-16/1.1).

5 Securing, Locking and Supporting of Doors

5.1 Definitions

5.1.1 Securing Device

A device used to keep the door closed by preventing it from rotating about its hinges or its pivoted attachments to the vessel.

5.1.2 Supporting Device

A device used to transmit external or internal loads from the door to a securing device and from the securing device to the vessel's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the vessel's structure.

5.1.3 Locking Device

A device, which locks a securing device in the closed position.

7 Securing and Supporting Devices

7.1 General

Securing and supporting devices are to be arranged in accordance with this Subsection, and are to have scantlings as required by 3-2-16/13.9.

7.3 Side Shell and Stern Doors

Means are to be provided to prevent lateral or vertical movement of the side shell or stern doors when closed. Means are also to be provided for mechanically fixing the doors in the open position.

The means of securing and supporting the doors are to have strength and stiffness equivalent to the adjacent structure.

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.

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.

11 Tightness

11.1 Side Shell and Stern Doors

Side shell doors and stern doors are to be so fitted as to ensure watertightness.

11.3 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 Side Shell Door and Stern Door Scantlings

13.1 General

Scantlings of side shell doors or stern doors are to meet the requirements of this Subsection. In addition, where the doors are used as vehicle ramps, scantlings are not to be less than required for vehicle decks in Sections 3-2-3, 3-2-7, and 3-2-8.

13.3 Primary Structure

Scantlings of primary members are to be designed so that the allowable stresses indicated in 3-2-16/17.1 are not exceeded when the structure is subjected to the design loads indicated in 3-2-16/15. Normally, simple beam theory may be applied to determine the bending stresses. Members are 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 not less than required by Section 3-2-5 for frames in the same location.

In addition, stiffener webs are to have a net sectional area not less than that obtained from the following equation:

$$A = VQ/10 \quad \text{cm}^2 \; (A = VQ \quad \text{cm}^2, \; A = VQ/6.5 \quad \text{in}^2)$$

where

V = shear force, in kN (tf, Ltf), in the stiffener calculated using the uniformly distributed external pressure, p_e, given in 3-2-16/15

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

13.7 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.

13.9 Securing and Supporting Devices

Scantlings of securing and supporting devices are to be designed so that the allowable stresses indicated in 3-2-16/17.1 are not exceeded when the structure is subjected to the design loads indicated in 3-2-16/15. All load-transmitting elements in the design load path from the door through securing and supporting devices into the vessel structure, including welded connections, are to meet the strength standards required for securing and supporting devices. Where fitted, threaded bolts are not to carry support forces, and the maximum tensile stress in way of the threads is not to exceed the allowable stress given in 3-2-16/17.5.

In determining the required scantlings, the door is to be assumed to be a rigid body. Only those actively supporting and securing devices, which have an effective stiffness in the relevant direction, are to be included and considered when calculating the reaction forces on the devices. Small or flexible devices such as cleats intended to provide compression load on the packing material are not to be included in the calculations.

13.9.1 Bearing Pressure

The bearing pressure on steel-to-steel bearings is to be calculated by dividing the design force by the projected bearing area, and is not to exceed the allowable stress given in 3-2-16/17.3.

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 a failure of any single securing or supporting device, the stresses in the remaining devices do not exceed the allowable stresses indicated in 3-2-16/17.1 by more than 20% under the above design loads.

15 Side Shell and Stern Door Design Loads

15.1 Design Forces for Primary Members

The design force, in kN (tf, Ltf), for primary members is to be the greater of the following:

External force: $F_e = A\, p_e$

Internal force: $F_i = F_o + W$

15.3 Design Forces for Securing or Supporting Devices of Doors Opening Inwards

The design force, in kN (tf, Ltf), for securing or supporting devices of doors opening inwards is to be the greater of the following:

External force: $F_e = A\, p_e + F_p$

Internal force: $F_i = F_o + W$

15.5 Design Forces for Securing or Supporting Devices of Doors Opening Outwards

The design force, in kN (tf, Ltf), for securing or supporting devices of doors opening outwards is to be the greater of the following:

External force: $F_e = A\, p_e$

Internal force: $F_i = F_o + W + F_p$

where

A = area, in m^2 (ft^2), of the door opening

W = weight of the door, in kN (tf, Ltf)

F_p = total packing force, in kN (tf, Ltf). Packing line pressure is normally not to be taken less than 5.0 N/mm (0.51 kg/mm, 28.6 lbf/in).

F_o = F_c or kA, in kN (tf, Ltf), whichever is greater

k = 5 (0.51, 0.047)

F_c = accidental force, in kN (tf, Ltf), due to lose 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 with clear opening area of up to 2.5 m^2 (27 ft^2), such as bunker doors, pilot doors etc., the value of F_c may be reduced down to 150 kN (15.3 tf, 15.1 Ltf). However, where an additional structure such as an inner ramp or second door (refer to 3-2-16/1.3) capable of protecting the shell door from accidental forces due to lose cargo is provided, the value of F_c may be taken as zero.

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 $Z_G \geq d_s$

$p_e = k_2(d - Z_G) + k_1$ for $Z_G < d_s$

k_1 = 25.0 (2.55, 0.233)

k_2 = 10.0 (1.02, 0.0284)

d = summer loadline 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.

17 Allowable Stresses

17.1 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 lbs/in^2)

Bending Stress: σ = 120/Q N/mm^2 (12.2/Q kgf/mm^2, 17400/Q lbs/in^2)

Equivalent Stress: ($\sqrt{\sigma^2 + 3\tau^2}$): σ_e = 150/Q N/mm^2 (15.3/Q kgf/mm^2, 21770/Q lbs/in^2)

where Q as defined in 3-2-1/5.5.

17.3 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.

17.5 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 lbs/in^2).

19 Operating and Maintenance Manual

The following information is to be submitted for review.

19.1 Manual

An operating and maintenance manual for the doors is to be provided onboard and is to contain at least the following:

- Main particulars and design drawings
- Service conditions, e.g., service area restrictions, emergency operations, acceptable clearances for supports
- Maintenance and function testing
- Register of inspections and repairs

19.3 Operating Procedures

Documented operating procedures for closing and securing the doors are to be kept onboard and posted at an appropriate location.

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 17 Bulwarks, Rails, Freeing Ports, Portlights, Windows, Ventilators, Tank Vents and Overflows

1 Bulwarks and Guard Rails

1.1 Height *(2017)*

The height of bulwarks and guard rails on exposed parts of freeboard and superstructure decks, at the boundary of first tier deckhouses and at the ends of superstructures is to be at least 1.0 m (39.5 in.) from the deck surface. Where this height would interfere with the operation of the vessel, a lesser height may be approved if adequate protection is provided. Where approval of a lower height is requested, justifying information is to be submitted.

1.3 Strength of Bulwarks

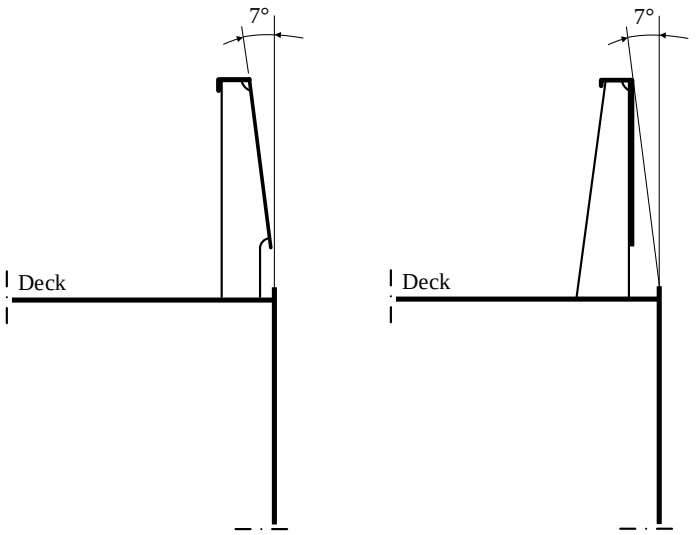
The strength of bulwark structures is to be in proportion to their height. The bulwark plating is to be kept clear of the sheer strake, it is to have both the upper and the lower edge effectively stiffened and it is to be supported by efficient stays.

Bulwarks on freeboard decks are to have stays spaced not more than 1.83 m (6 ft) apart. The stays are to be formed either of a flanged plate or built-up tee sections and are to be efficiently attached to the bulwark and deck plating.

Where it is intended to carry timber deck cargoes and cargo rails are not provided, the bulwark stays are not to be spaced over 1.52 m (5 ft) apart and shall have increased scantlings and strength of attachments to the deck and bulwark.

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. Gangways and other openings in bulwarks are to be kept well away from breaks of superstructures and thicker plates are to be fitted in way of mooring eyes.

FIGURE 1
Bulwark Stanchion *(2017)*



1.5 Guard Rails *(2017)*

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.

At least every third stanchion is to be supported by a bracket or stay. Dimensions and arrangement of stanchion and stays are to be as shown in 3-2-17/Figure 2. Where this arrangement would interfere with the safe traffic of persons on board, the following alternative arrangements of stanchions may be acceptable:

i) At least every third stanchion is to be of increased breadth, $kb_s = 2.9b_s$ at the attachment of the 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 the stanchion to the deck, or,

iii) Every stanchion is to be of increased breadth, $kb_s = 1.9b_s$ at the attachment of the stanchion to the deck.

where, b_s is not to be taken as less than 60 mm (2.36 in.) (see 3-2-17/Figure 3). The thickness of the flat bar stanchions is not to be less than 15 mm (0.59 in.).

For any of the above arrangements *i), ii)* or *iii)*, the following details are to be complied with:

iv) Flat steel stanchion required by *i), ii)* or *iii)* above is to be aligned with supporting member below the deck unless the deck plating thickness exceeds 20 mm (0.79 in.) and welded to deck with double continuous fillet weld with minimum leg size of 7.0 mm (0.28 in.) or as specified by the design standard.

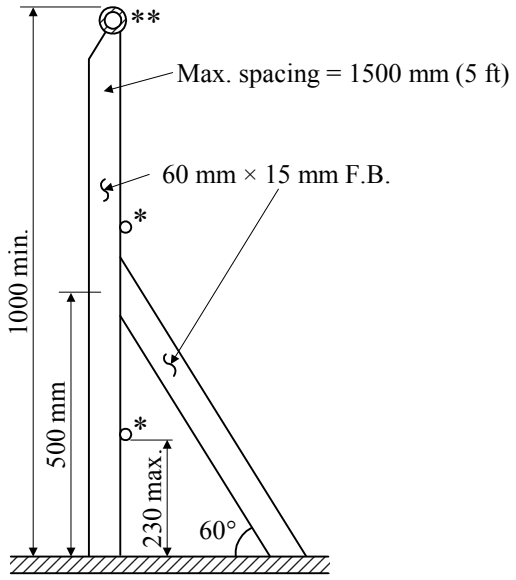
v) The underdeck supporting member of the stanchion is to be a minimum of 100 × 12 mm (4.0 × 0.5 in.) flat bar welded to deck by double continuous fillet weld (see 3-2-17/Figure 3).

Alternative arrangements could be acceptable providing that it can be shown equivalent in strength and stiffness to the above requirements or based on recognized international standards.

FIGURE 2
Guardrail Stanchion

** Top Rail = 42.4 mm outside diameter pipe with 2.6 mm minimum wall thickness (or pipes having an equivalent section modulus)

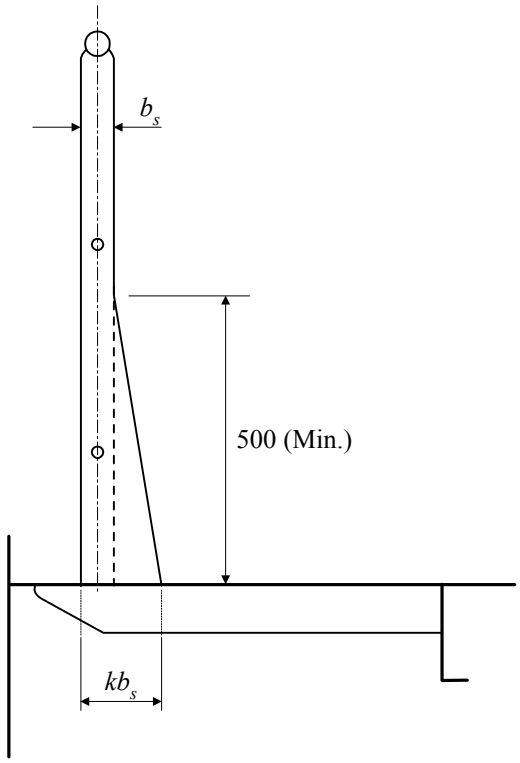
* = 20 mm solid round bar or 26.9 mm outside diameter pipe with 2.3 mm minimum wall thickness (or pipes having an equivalent section modulus)



Standard stanchion, rail, and stay sizes.

(Stay to be provided at every third stanchion)

FIGURE 3
Guardrail Stanchion



The clear opening below the lowest course is not to exceed 230 mm (9 in.). Where a foot-stop is installed at the deck level the clear opening below the lowest course may be measured from the top of the foot-stop. The clear distances between the lowest and the middle courses, as well as the middle and the upper courses are not to exceed 380 mm (15 in.).

The distance between the lower rail and the top of the sheerstrake is not to exceed 230 mm (9 in.).

For vessels with rounded gunwales, stanchions are to be placed on the flat of the deck.

Stanchion, rails and stays are to be provided with a protective coating.

3 Access and Crew Protection

3.1 General

Vessels with the keel laid or in similar stage of construction on or after 1 July 1998 are to meet the following requirements. Satisfactory means in the form of guard rails, lifelines, gangways or under-deck passages, etc., are to be provided for the protection of the crew in getting to and from their quarters, the machinery space, and all other parts (see 3-2-17/Table 1).

3.3 Access to Bow

Satisfactory means are to be provided enabling crew the safe access to the bow even in severe weather conditions.

TABLE 1
Acceptable Arrangement for Access *(2014)*

Offshore Support Vessel	*Locations of Access in Vessel*	*Assigned Summer Freeboard*	*Acceptable Arrangements According to Type of Freeboard Assigned*		
			Type B–100	*Type B–60*	*Type B & B+*
	1.1: Access to Midship Quarters				
	1.1.1. Between poop and bridge, or	≤ 3000 mm (≤ 118 in.)	a b e	a b c(1) e f(1)	a b c(1) c(2) c(4)
	1.1.2. Between poop and deckhouse containing living accommodation, or navigation equipment, or both.	> 3000 mm (> 118 in.)	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	≤ 3000 mm (≤ 118 in.)	a b c(1) c(2) e f(1) f(2)	a b c(1) c(2) e f(1) f(2)	
	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) 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)	

Note: Deviations from some or all of these requirements or alternative arrangements for such cases as vessels with very high gangways may be allowed, subject to agreement on a case-by-case basis with the relevant Flag Administration.

I. Construction Keys (a) through (f)

(a) A well-lighted and ventilated under-deck passageway with clear opening at least 0.8 m (2.6 ft) in width and 2.0 m (6.6 ft) in height, providing access to the locations in question and located as close as practicable to the freeboard deck.

(b) A permanently constructed gangway fitted at or above the level of the superstructure deck on or as near as practicable to the center line of the vessel, providing a continuous platform of a non-slip surface at least 0.6 m (2 ft) in width, with a foot-stop and guard rails extending on each side throughout its length. Guard rails are to be as required in 3-2-17/3.1 and 3-2-17/1.5, except that stanchions are to be fitted at intervals not more than 1.5 m (5 ft).

(c) A permanent walkway at least 0.6 m (2 ft) in width fitted at freeboard deck level consisting of two rows of guard rails with stanchions spaced not more than 3 m (10 ft). The number of courses of rails and their spacing are to be as required in 3-2-17/1.5. Hatchway coamings not less than 0.6 m (2 ft) in height may be regarded as forming one side of the walkway, provided that two rows of guard rails are fitted between the hatchways.

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 3-2-17/3.1 and 3-2-17/1.5, except that stanchions are to be fitted at intervals not more than 1.5 m (5 ft);
- provided with a foot-stop on each side;
- having openings, with ladders where appropriate, to and from the deck. Openings are to be not more than 40 m (131 ft) apart;
- having shelters of substantial construction, set in way of the gangway at intervals not exceeding 45 m (148 ft) if the length of the exposed deck to be traversed exceeds 70 m (230 ft). Every such shelter is to be capable of accommodating at least one person and be so constructed as to afford weather protection on the forward, port and starboard sides.

(f) A permanent and efficiently constructed walkway fitted at freeboard deck level on or as near as practicable to the center line of the vessel having the same specifications as those for a permanent gangway listed in (e), except for foot-stops. On ships certified for the carriage of liquids in bulk, the hatch coamings may be accepted as forming one side of the walkway provided a combined height of hatch coaming and hatch cover in the closed condition is not less than 1 m (3.3 ft) and two rows of guard rails are fitted between the hatchways.

II. Transverse Location Keys (1) through (5) - for Construction (c), (d) and (f) where specified in the Table

(1) At or near the centerline of vessel or fitted on hatchways at or near the centerline of vessel.

(2) Fitted on each side of the vessel.

(3) Fitted on one side of the vessel, provision being made for fitting on either side.

(4) Fitted on one side only.

(5) Fitted on each side of the hatchways as near to the centerline as practicable.

III. Notes:

1. In all cases where wire ropes are fitted, adequate devices are to be provided to enable maintaining their tautness.
2. A means of passage over obstructions, if any, such as pipes or other fittings of a permanent nature are to be provided.
3. Generally, the width of the gangway or walkway should not exceed 1.5 m (5 ft).

5 Freeing Ports

Where bulwarks on the weather portions of freeboard or superstructure decks form wells, such as passage between the bulwark and the cargo rail or the cargo deck between port and starboard cargo rails, or the passage between the bulwark and the deckhouse bulkhead etc., provision is to be made for rapidly freeing the decks of water and for draining them.

5.1 Basic Area

On freeboard decks

Except as provided in 3-2-17/5.3 and 3-2-17/5.5 and in cases where the sheer in way of the well is standard or greater than standard as defined in the International Convention on Load Lines 1966, the minimum freeing-port area A_{fp} on each side of the vessel for each well on the freeboard deck is to be obtained from the following equations:

1. Where the length of bulwark ℓ in the well is 20 m (66 ft) or less:

   $A_{fp} = 0.7 + 0.035\ell$ m^2 $\qquad$ $A_{fp} = 7.6 + 0.115\ell$ ft^2

2. Where the length of bulwark ℓ in the well exceeds 20 m (66 ft):

   $A_{fp} = 0.07\ell$ m^2 $\qquad$ $A_{fp} = 0.23\ell$ ft^2

In no case need ℓ be taken as greater than $0.7L_f$ where L_f is as defined in 3-1-1/3.3.

On superstructure decks

The minimum area for each well on superstructure decks is to be one-half of the area obtained from the above equations.

5.1.1 Basic Area Adjustments

If the bulwark or part of bulwark is more than 1.2 m (3.9 ft) in average height, the required area is to be increased by according to the following equations:

$A_{s>1.2} = 0.02\ell_s(h_b - 1.2)$ m^2 $\qquad$ $A_{s>1.2} = 0.02\ell_s(h_b - 3.9)$ ft^2 for sloped or curved parts

$A_{q>1.2} = 0.04\ell_q(h_b - 1.2)$ m^2 $\qquad$ $A_{q>1.2} = 0.04\ell_q(h_b - 3.9)$ ft^2 for quadrilateral parts

where

$A_{s>1.2}$, $A_{q>1.2}$ = additions to the basic area A, in m^2 (ft^2)

ℓ_s = length of height increase, in m (ft), measured horizontally from the point of intersection of the slope (or curve) at height of 1.2 m (3.9 ft) to the vertical at the highest point of slope (or curve)

ℓ_q = length of lifted quadrilateral part of bulwark, in m (ft), measured horizontally from the vertical at the highest point of slope (or curve)

h_b = full height of the lifted part of bulwark, in m (ft)

If the bulwark or part of bulwark is less than 0.9 m (3 ft) in average height, the required area may be decreased the effects of the following equations:

$A_{s<0.9} = 0.02\ell_s(0.9 - d_b)$ m^2 $\qquad$ $A_{s<0.9} = 0.02\ell_s(3.0 - d_b)$ ft^2 for sloped or curved parts

$A_{q<0.9} = 0.04\ell_q(0.9 - d_b)$ m^2 $\qquad$ $A_{q<0.9} = 0.04\ell_q(3.0 - d_b)$ ft^2 for quadrilateral parts

where

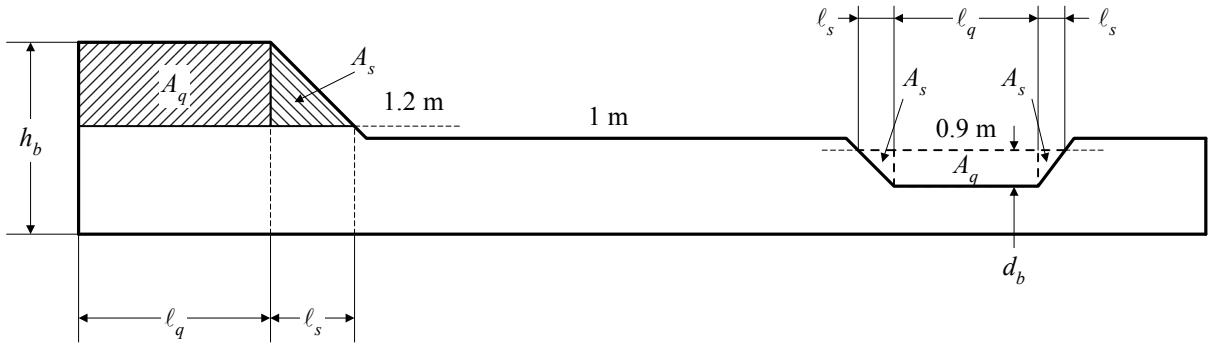
$A_{s<0.9}$, $A_{q<0.9}$ = deductions from the basic area A, in m^2 (ft^2)

ℓ_s = length of height decrease, in m (ft), measured horizontally from the point of intersection of the slope (or curve) at height of 0.9 m (3 ft) to the vertical from the lowest point of slope (or curve)

ℓ_q = length of lowered quadrilateral part of bulwark, in m (ft), measured horizontally from the vertical at the lowest point of slope (or curve)

d_b = depth of the concaved part of bulwark below 0.9 m (3 ft) line, in m (ft)

FIGURE 4
Freeing Ports Area Adjustment



5.3 Vessels with Less than Standard Sheer

In vessels without sheer the freeing port area calculated as described above is to be increased by 50%. Where the sheer is less than the standard, the percentage is to be obtained by interpolation.

5.5 Trunks

Where a vessel is fitted with a trunk, and open rails are not fitted on weather parts of the freeboard deck in way of the trunk for at least half their length, or where continuous or substantially continuous hatchway side coamings are fitted between detached superstructures, the minimum area of the freeing-port openings is to be calculated from the following table.

Breadth of hatchway or trunk b_t in relation to the breadth B of the vessel	*Area of freeing ports A_{fp} in relation to the total area of the bulwarks A_{bk}*
$b_t/B \le 0.4$	$A_{fp}/A_{bk} = 0.2$
$0.4 < b_t/B < 0.75$	$A_{fp}/A_{bk} = 0.1 + 0.114(2.5b_t/B - 1)$
$b_t/B \ge 0.75$	$A_{fp}/A_{bk} = 0.1$

5.7 Open Superstructures

In vessels having superstructures which are open at either or both ends, adequate provision for freeing the space within such superstructures is to be provided and the arrangements are to be subject to special approval.

5.9 Details of Freeing Ports

The lower edges of the freeing ports are to be as near the deck as practicable. Two-thirds of the freeing-port area required is to be provided in the half of the well nearest the lowest point of the sheer curve. When the height of the freeing port opening is greater than 230 mm (9 in.), such openings in the bulwarks are to be protected by horizontal rails or bars spaced not more than 230 mm (9 in.) apart. If shutters are fitted to freeing ports, an ample clearance is to be provided to prevent jamming and such shutters are only allowed on flat, not curved portions of the bulwarks. Hinges on shutters are to have pins or bearings of noncorrosive material and are to be located at or as near as possible to the top of the shutters.

7 Portlights *(2015)*

7.1 Location

Portlights are defined as being rectangular openings, or round or oval openings, with an area not exceeding 0.16 m^2 (1.7 ft^2).

No portlight is to be fitted in a position with its sill below a line drawn parallel to the freeboard deck at side and having its lowest point less than 0.025*B* or 500 mm (19.5 in.) above the maximum summer load waterline, whichever is greater. In addition, portlights are not to be fitted in spaces which are used for the carriage of cargo.

A portlight fitted in an external door is to be treated the same as a portlight in the adjacent bulkhead.

7.3 Deadlights and Storm Covers

Portlights to spaces below the bulkhead/freeboard deck or to spaces within enclosed superstructures or enclosed deckhouses on the first and second tiers above the freeboard deck are to be fitted with efficient hinged inside deadlights arranged such that they can be effectively closed and secured watertight, except as noted below:

i) Portlights fitted on second tier deckhouse with cabin bulkheads and doors in the second tier that separate the portlights from direct access leading below may be fitted without deadlights.

ii) Portlights in side bulkheads set inboard from the side shell in the second tier protecting direct access leading below may be fitted with external storm covers in lieu of deadlights provided the storm covers are accessible, permanently attached and capable of being effectively closed and secured weathertight.

iii) Portlights located in first tier deckhouse bulkheads where the deckhouse is not protecting openings leading below or is not considered buoyant in stability calculation may be fitted without deadlights.

Portlights located higher than the second tier above the freeboard deck may be fitted without deadlights. However, portlights fitted in the front bulkheads of deckhouses located in the first tier above the weather deck on the forecastle are to be fitted with inside deadlights or storm covers that are permanently attached and capable of being effectively closed and secured weathertight.

7.5 Construction

7.5.1 General

Portlights, together with their glasses and deadlights, are to comply with ISO 1751 or an equivalent national standard. However, portlight frames of cast iron or non-metallic materials are not permitted.

Where portlights are fitted in the side shell, in the sides of superstructures and in the front bulkheads of superstructures and deckhouses on weather decks, they are to be of Type A portlights (designated as per ISO 1751).

Where portlights are fitted in the ends of superstructures or the sides and ends of deckhouses, they are to be of Type B portlights (designated as per ISO 1751).

Deadlights and storm covers are to be of a strength equivalent to the adjacent bulkhead. Non-metallic deadlights and storm covers are not acceptable.

7.5.2 Non-opening Type

Where vessels are subject to damage stability requirements of 3-3-1/3.3, portlights that are submerged at any intermediate stage of flooding or the final damage equilibrium waterline are to be of non-opening type.

9 Windows

9.1 Location *(2017)*

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 (such as ISO 3903 and ISO 5779).

9.3 Deadlights and Storm Covers *(2015)*

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 *(2015)*

Window frames are to be metal or other approved material and 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 attention is to be paid to the windows installed in angled deckhouse 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.

9.7 Window Glazing *(2018)*

The thickness of the thermally toughened monolithic safety glass is to be not less than the greater of the following:

t = 9.5 mm (0.37 in.)

$$t = s\left(\sqrt{\frac{f_w \beta h_w}{4000}}\right) \text{ mm} \qquad t = s\left(\sqrt{\frac{f_w \beta h_w}{13123}}\right) \text{ in.}$$

where

t = required window thickness, in mm (in.)

ℓ = greater dimension of window panel, in mm (in.)

s = lesser dimension of window panel, in mm (in.)

h_w = pressure head for windows, in m (ft), given in the 3-2-11/3.5

β = $0.985 - 0.00357(\ell/s)^2 - 0.729/(\ell/s)$ $\quad \ell/s < 5$

= 0.75 $\quad \ell/s \geq 5$

f_w = as given below

i) f_w for superstructure sides or bulkheads of deckhouse located completely or partially on the superstructure or exposed forecastle deck:

	2nd Tier	*3rd Tier*	*4th Tier and above*
Front bulkhead	1.41	1.41	0.62
Side bulkhead	1.22	1.22	0.48
Aft bulkhead	1.04	0.70	0.32

Notes:

1 Bulkheads of deckhouses are considered to be completely or partially on the superstructure or exposed forecastle deck when any portion of the bulkhead is within one (1) ICLL standard superstructure height above the deck. When the bulkhead is entirely one standard superstructure or higher above the superstructure or exposed forecastle deck f_w is to be taken per 3-2-17/9.7ii).

2 The tiers indicated above represent the Tier location of the superstructure or exposed forecastle deck in relation to the freeboard deck.

ii) For deckhouses located other than *i)* above:

f_w = 1.0

The above requirements are for thermally toughened monolithic glass, which is to comply with ISO 21005 or an equivalent national standard. Alternatively, glazing with a flexural strength of not less than 160 N/mm^2 (23206 psi) approved by recognized standard is also acceptable.

Windows of glazing other than thermally toughened monolithic glass will be specially considered with regards to design, manufacture and testing.

9.9 Testing *(2018)*

All windows and portlights are to be hose-tested in position under a water pressure of at least 2 bar (2 kgf/cm^2, 30 lbs/in^2) at the time of construction and, if considered necessary, at subsequent surveys.

The flexural strength of the thermally toughened glass is to be verified by compliance with the proof loads in ISO 614.

11 Ventilators, Tank Vents and Overflows

11.1 General

Ventilators are to comply with the requirements of 3-2-17/11.3. Tank vents and overflows are to comply with the requirements in 3-2-17/11.5. In addition, for those located on the fore deck, the requirements given in 3-2-17/11.7 are to be complied with.

11.3 Ventilators

11.3.1 Construction of Coamings

Ventilators on exposed freeboard or superstructure decks to spaces below the freeboard deck or decks of enclosed superstructures are to have coamings of steel or other equivalent material. The minimum coaming-plate thickness is to be calculated from the following table.

Outer Diameter of a Ventilator d_v, in mm (in.)	*Coaming plate thickness t_c, in mm (in.)*
$d_v \leq 200$ (8)	7.5 (0.3)
200 mm < d_v < 457 mm 8 in. < d_v < 18 in.	$t_c = 7.5 + [2.5(d_v - 200)]/257$ mm $t_c = 0.3 + 0.01(d_v - 8)$ in.
$d_v \geq 457$ (18)	10 (0.4)

Coamings are to be secured to the stiffened deck plating. Coamings which are more than 900 mm (35.5 in.) high and which are not supported by or clamped to adjacent structures are to be bracketed at the deck attachment. Ventilators passing through superstructures, other than enclosed superstructures, are to have coamings of steel at the freeboard deck. Where a fire damper is located within a ventilation coaming, an inspection port or opening at least 150 mm (6 in.) in diameter is to be provided, to facilitate survey of the damper. The closure provided for the inspection port or opening is to maintain the watertight integrity and, if appropriate, the fire integrity of the coaming in question.

11.3.2 Height of Coamings

Ventilators in Position 1 are to have coamings at least 900 mm (35.5 in.) above the deck. Ventilators in Position 2 are to have coamings at least 760 mm (30 in.) above the deck (see 3-2-15/3 for definition of Positions).

11.3.3 Means for Closing Openings

Except as provided below, ventilator openings are to be provided with permanently attached closing appliances. Ventilators in Position 1, the coamings of which extend to more than 4.5 m (14.8 ft) above the deck, and in Position 2, the coamings of which extend to more than 2.3 m (7.5 ft) above the deck, need not be fitted with closing arrangements, unless unusual features or the design makes this necessary. See also 4-7-2/1.7.5 and 4-7-2/1.7.6.

11.5 Tank Vents and Overflows

Tank vents and overflows are to be in accordance with the requirements of 4-6-4/9.3 and 4-6-4/9.5 of these Rules. In addition, where applicable, the requirements given below in 3-2-17/11.7 are to be complied with.

11.7 Ventilators, Tank Vents and Overflows on the Fore Deck

11.7.1 Application *(2017)*

The requirements of this paragraph apply to all ventilators, tank vents and overflows of vessel with length, L of 80 meters (263 feet) or more, located on the exposed fore deck within the forward 0.25L and where the height of the exposed fore deck in way of the item is less than 0.1L or 22 meters (72 ft) above the scantling waterline, whichever is lesser.

11.7.2 Applied Loading to the Air Pipes and Ventilators

11.7.2(a) Pressure (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 as follows:

$$p = f \rho V^2 C_d C_s C_p \quad \text{kN/m}^2 \text{ (tf/m}^2\text{, Ltf/ft}^2\text{)}$$

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

= 0.8 for ventilator heads of cylindrical form with their axis in the vertical direction

= 1.3 for ventilator heads of non-cylindrical form with their axis in the horizontal direction

C_s = slamming coefficient, 3.2

C_p = protection coefficient:

= 0.7 for pipes and ventilator heads located immediately behind a breakwater or forecastle

= 1.0 elsewhere, including immediately behind a bulwark

11.7.2(b) Force. Forces acting in the horizontal direction on the pipe and its head (closing device) may be calculated from the above pressures using the largest projected area of each component.

11.7.3 Strength Requirements for Ventilators, Tank Vents and Overflows and their Closing Devices

11.7.3(a) Bending Moment and Stress. Bending moments and stresses in air pipes and ventilator pipes are to be calculated at penetration pieces, at weld or flange connections and at toes of supporting brackets. Bending stresses in the net section are not to exceed 0.8Y, where Y is the specified minimum yield stress or 0.2% proof stress of the steel at room temperature. Then, irrespective of corrosion protection, a corrosion addition of 2.0 mm (0.08 in.) is to be applied to the minimum pipe wall thickness needed to meet above limits.

11.7.3(b) Tank Vents and Overflows

i) For standard tank vents and overflows of 760 mm (30 in.) height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in 3-2-17/Table 3. Where brackets are required, minimum three radial brackets are to be fitted.

ii) Brackets are to be of gross thickness of 8 mm (0.32 in.) or more, of minimum length of 100 mm (4.0 in.) and height according to 3-2-17/Table 2, but need not extend over the head attachment flange. Bracket toes at the deck are to be supported.

iii) For other configurations; loads according to 3-2-17/11.7.2 are to be applied and supports determined to comply with the strength requirements above. Brackets, where fitted, are to be of thickness and length in proportion to their depth.

iv) Final (gross) pipe thickness is not to be taken less than as indicated in 4-6-4/9.3.2 and 4-6-4/9.5.6.

v) The minimum internal diameter of the air pipe or overflow is not to be less than 65 mm (2.5 in.).

11.7.3(c) Ventilators

i) For standard ventilators of 900 mm (35.4 in.) height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in 3-2-17/Table 3. Brackets, where required, are to be as described in 3-2-17/11.7.3(b)ii).

ii) For ventilators of height greater than 900 mm (35.4 in.), brackets or alternative means of support to the adjoining structure are to be provided. Coamings are not to be taken less than as indicated in 3-2-17/11.3 nor in 3-2-17/Table 3.

11.7.3(d) Components and Connections. All component parts and connections of the tank vents and overflows or ventilators are to be capable of withstanding the loads defined in 3-2-17/11.7.2.

11.7.3(e) Rotary Heads. Rotating type mushroom ventilator heads are not to be used for applications in this location.

TABLE 2
760 mm (30 in.) (3) High Tank Vents and Overflows Thickness and Bracket Standards

Nominal Pipe Size		*Minimum Fitted Gross Thickness*		*Maximum Projected Area of Head*		*Height (1) of Brackets*	
A	*B*						
mm	*in.*	*mm*	*in.*	*cm²*	*in²*	*mm*	*in.*
65	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 3-2-17/11.7.3(b)] need not extend over the head attachment flange.

2 Brackets are required where the as fitted (gross) thickness is less than 10.5 mm (0.41 in.) or where the tabulated projected head area is exceeded.

3 For other air pipe heights, the relevant requirements of 3-2-17/11.7.3 are to be applied.

TABLE 3
900 mm (35.4 in.) (2) High Ventilator Thickness and Bracket Standards

Nominal Pipe Size		*Minimum Fitted Gross Thickness*		*Maximum Projected Area of Head*		*Height (1) of Brackets*	
A	*B*						
mm	*in.*	*mm*	*in.*	*cm²*	*in²*	*mm*	*in.*
80	3	6.3	0.25	-	-	460	18.1
100	4	7.0	0.28	-	-	380	15.0
150	6	8.5	0.33	-	-	300	11.8
200	8	8.5	0.33	550	85	-	-
250	10	8.5	0.33	880	136	-	-
300	12	8.5	0.33	1200	186	-	-
350	14	8.5	0.33	2000	310	-	-
400	16	8.5	0.33	2700	419	-	-
450	18	8.5	0.33	3300	511	-	-
500	20	8.5	0.33	4000	620	-	-

Notes:

1 Brackets [see 3-2-17/11.7.3(b)] need not extend over the head attachment flange.

2 For other air pipe heights, the relevant requirements of 3-2-17/11.7.3 are to be applied.

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 18 Ceiling, Sparring, and Protection of Steel

1 Close Ceiling

Ceiling, where fitted, is to be laid either directly on a tightening and preserving compound or on battens. Except for holds intended exclusively for the carriage of containers on the inner bottom, ceiling is to be fitted under all hatchways, unless the inner bottom plating is increased by at least 2 mm (0.08 in.) (refer to 3-2-4/9.1).

3 Sparring

Sparring is to be fitted to the sides above the ceiling, if any, in all cargo spaces where it is intended to carry general cargo. The sparring is not to be less than 40 mm (1.625 in.) thick, finished, nor is it to provide less protection to the framing than is obtained from battens at least 140 mm (5.5 in.) wide, finished, and spaced 380 mm (15 in.) center to center. Sparring is to be bolted, fitted in cleats or in portable frames for convenience in removal. Sparring may be omitted in vessels engaged in the carriage containers and similar containerized or batched cargoes, if applicable. In such cases, the notation **NS** will be entered in the *Record*, indicating no sparring.

5 Corrosion Protection of Steel

5.1 All Spaces *(1 July 2018)*

Unless otherwise approved, all steel surfaces are to be suitably protected by an efficient corrosion prevention system, such as protective coatings and/or cathodic protection as applicable. For 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 Dedicated Salt Water Ballast Tanks and Double-side Skin Spaces

All dedicated seawater ballast tanks in all ships greater than or equal to 500 gross tonnage shall have an efficient corrosion prevention system, such as hard protective coatings or equivalent in accordance with SOLAS Regulation II-1/3-2. The scheme for the selection, application and maintenance of the system shall be approved by ABS, based on IMO Resolution A.798(19) and IACS UI SC 122. The scheme for the selection, application and maintenance of the system shall be approved by ABS, based on IMO Resolution A.798(19) and IACS UI SC 122.

The ABS *Guide for the Class Notation – Coating Performance Standard (CPS)* is provided as an aid in satisfying the protective coating requirements contained in the IMO PSPC and related Unified Interpretations from IACS and IMO.

Were a long retention period of salt water ballast is expected the use of inhibitors or sacrificial anodes should be considered. When such tanks are designed as dual purpose (for example brine/sea water ballast, brine/drill water or brine tank/chain locker) they are to have a hard, corrosion resistant coating applied as well.

5.5 Void Spaces

Void spaces are recommended to be coated.

5.7 Fuel Oil Tanks

Corrosion protective coating is not required for internal surfaces of spaces intended for the carriage of fuel oil, including cargo fuel oil and base oil (diesel oil).

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 19 Weld Design

1 Fillet Welds

1.1 General

1.1.1 Plans and Specifications *(2017)*

The actual sizes of fillet welds are to be indicated on detail drawings or on a separate welding schedule and submitted for approval in each individual case. In determining weld sizes based on the equations in this Section, the nearest 0.5 mm ($^1/_{32}$ in.) may be used.

1.1.2 Workmanship

Completed welds are to be to the satisfaction of the attending Surveyor. The gaps between the faying surfaces of members being joined should be kept to a minimum. Where the opening between members being joined exceeds 2.0 mm (0.08 in.) and is not greater than 5 mm ($^3/_{16}$ in.), the weld leg size is to be increased by the amount of the opening in excess of 2.0 mm (0.08 in.). Where the opening between members is greater than 5 mm ($^3/_{16}$ in.), corrective procedures are to be specially approved by the Surveyor.

1.1.3 Special Precautions

Special precautions, such as the use of preheat or low-hydrogen electrodes or low-hydrogen welding processes may be required where small fillets are used to attach heavy plates or sections. When heavy sections are attached to relatively light plating, the weld size may be required to be modified.

1.1.4 *(1 July 2015)*

For all welds in ballast tanks required to be in compliance with the IMO PSPC and/or IMO PSPC-COT Regulations, continuous welding is to be adopted.

3 Tee Connections

3.1 Size of Fillet Welds

Tee connections are generally to be formed by continuous or intermittent fillet welds on each side, as required by 3-2-19/Table 1. The leg size, *w*, of fillet welds (see figure in 3-2-19/Table 1) is obtained from the following equations:

$$w = t_{p\ell} \times C \times \frac{s}{\ell} + 2.0 \quad \text{mm}$$

$$w = t_{p\ell} \times C \times \frac{s}{\ell} + 0.08 \quad \text{in.}$$

$w_{\min}$ = $0.3t_{p\ell}$ or 4.5 mm (0.18 in.) [4.0 mm (0.16 in.) where 3-2-19/9 is applicable], whichever is greater.

where

ℓ = the actual length of weld fillet, clear of crater, in mm (in.)

s = the distance between successive weld fillets, from center to center, in mm (in.)

s/ℓ = 1.0 for continuous fillet welding

$t_{p\ell}$ = thickness of the thinner of the two members being joined, in mm (in.)

C = weld factors given in 3-2-19/Table 1

In selecting the leg size and spacing of matched fillet welds, the leg size for the intermittent welds is to be taken as not greater than the designed leg size w or $0.7t_{p\ell}$ + 2.00 mm ($0.7t_{p\ell}$ + 0.08 in.), whichever is less.

The throat size, t, is to be not less than 0.7 w.

For the weld size for $t_{p\ell}$ less than 6.5 mm (0.25 in.), see 3-2-19/3.11.

Alternatively, on vessels with length, L, below 90 m (295 ft) weld sizes and spacing may be assessed based on 3-2-16/Table 1 of ABS *Rules for Building and Classing Steel Vessels Under 90m in Length.*

3.3 Length and Arrangement of Fillet

Where an intermittent weld is permitted by 3-2-19/Table 1, the length of each fillet weld is to be not less than 75 mm (3 in.) for $t_{p\ell}$ of 7 mm (0.28 in.) or more, nor less than 65 mm (2.5 in.) for lesser $t_{p\ell}$. The unwelded length on one side is to be not more than $32t_{p\ell}$.

3.5 Intermittent Welding at Intersection

Where beams, stiffeners, frames, etc., are intermittently welded and pass through slotted girders, shelves or stringers, there is to be a pair of matched intermittent welds on each side of each such intersection, and the beams, stiffeners and frames are to be efficiently attached to the girders, shelves and stringers.

3.7 Welding of Longitudinal to Plating

Welding of longitudinals to plating is to have double continuous welds at the ends and in way of transverses equal in length to depth of the longitudinal. For deck longitudinals only, a matched pair of welds is required at the transverses.

3.9 Stiffeners and Webs to Hatch Covers

Unbracketed stiffeners and webs of hatch covers are to be welded continuously to the plating and to the face plate for a length at ends equal to the end depth of the member.

3.11 Thin Plating

For plating of 6.5 mm (0.25 in.) or less, the requirements of 3-2-19/3.1 may be modified as follows:

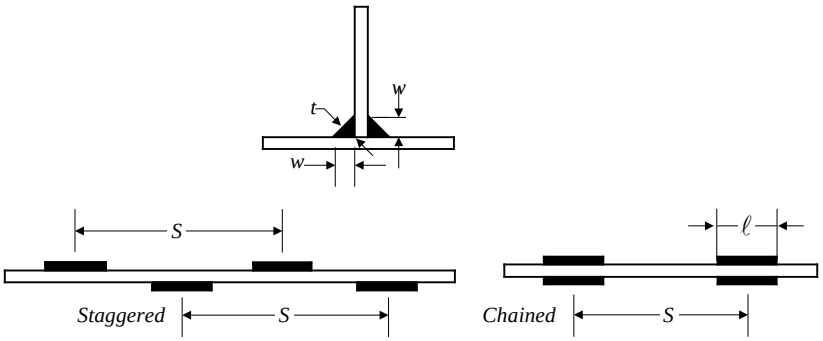
$$w = t_{p\ell} C \frac{s}{\ell} + 2.0\left(1.25 - \frac{\ell}{s}\right) \quad \text{mm}$$

$$w = t_{p\ell} C \frac{s}{\ell} + 0.08\left(1.25 - \frac{\ell}{s}\right) \quad \text{in.}$$

$w_{\min}$ = 3.5 mm (0.14 in.)

The use of the above equations for plating in excess of 6.5 mm (0.25 in.) may be also considered depending upon the location and the quality control procedures.

TABLE 1
Weld Factors



w = leg size in mm (in.) t = throat size in mm (in.)

I.	Periphery Connections	Factor C
	C = Continuous	
	DC = Double Continuous	
A.	Tight Joints	
1.	Strength deck to sheer strake (See 3-2-19/15)	0.42 DC
2.	Main longitudinal bulkhead to deck, bottom or inner bottom (See 3-2-19/15)	0.42 DC
3.	All other tight joints except corrugated bulkheads (See 3-2-9/7.5)	
	a. watertight bulkhead, $t_{p\ell} \le$ 12.5 mm (0.50 in.) where one side intermittent and the other side continuous	0.12 0.58 C
	b. watertight bulkhead, $t_{p\ell} \le$ 12.5 mm (0.50 in.) where double continuous	0.35 DC
	c. all other joints	0.35 DC
B.	Non-tight Joints	
1.	Platform decks	0.28 DC
2.	Swash bulkheads in deep tanks	0.20
3.	Non-tight bulkheads other than B2	0.15
II.	**Bottom Floors**	
1.	To Shell	
	a. in aft peak below waterline	0.25 DC
	b. in machinery space	0.20 DC
	c. flat of bottom forward	0.15
	d. in aft peak above waterline and in forward peak	0.15
	e. elsewhere (See note 3)	0.12
2.	To Inner Bottom	
	a. in machinery space	0.20 DC
	b. at forward end (fore end strengthening)	0.15
	c. elsewhere (See note 3)	0.12
3.	To Center or Side Girder	
	a. in way of engine	0.30 DC
	b. with longitudinal framing	0.30 DC
	c. with transverse framing	0.17
4.	To Margin Plate, Side Shell, Longitudinal Bulkhead or Rounded Bilge	0.35 DC
5.	Open Floor Bracket	
	a. to center girder	0.15
	b. to margin plate	0.30 DC

TABLE 1 (continued)
Weld Factors

III.	**Bottom Girder**	
1.	Center Girder	
	a. to inner bottom in way of engine	0.30 DC
	b. to inner bottom clear of engine, non-tight	0.23
	c. to shell, non-tight	0.25 DC
2.	Side Girder	
	a. to floors in way of transverse bulkheads	0.35 DC
	b. to shell — flat of bottom forward	0.23
	— elsewhere	0.15
	c. to inner bottom — in way of engine	0.23
	— elsewhere	0.15
IV.	**Web Frames, Stringers, Deck Girders and Deck Transverses**	
1.	To Plating	
	a. in tanks	0.20
	b. elsewhere	0.15
2.	To Face Plates	
	a. face area ≤ 64.5 cm^2 (10 in^2)	0.12
	b. face area > 64.5 cm^2 (10 in^2)	0.15
3.	End Attachment	
	a. unbracketed (see note 1)	0.55 DC
	b. bracketed	0.40 DC
V.	**Frames, Beams and Stiffeners**	
1.	To Shell	
	a. in aft peak below waterline	0.25 DC
	b. flat of bottom forward	0.25 DC
	c. 0.125*L* forward	0.15
	d. in aft peak above waterline and in forward peak	0.15
2.	Slab longitudinals	(see note 5)
3.	To plating elsewhere	0.12
4.	End attachment	
	a. unbracketed (see note 1)	0.45 DC
	b. bracketed	0.35 DC
VI.	**Hatch Covers**	
1.	Oil-tight Joints	0.40 DC
2.	Watertight Joints	
	Outside	0.40 C
	Inside	0.15
3.	Stiffeners and Webs to Plating and to Face Plate (see note 2)	0.12
4.	Stiffeners and Web to Side Plating or other stiffeners	
	— unbracketed (see note 1)	0.45 DC
	— bracketed	0.35 DC

TABLE 1 (continued)
Weld Factors

VII.	**Hatch Coamings and Ventilators**		
	1.	To Deck	
		a. at hatch or ventilator corner	0.45 DC
		b. elsewhere	0.25 DC
	2.	Coaming stays	
		a. to deck	0.20 DC
		b. to coaming	0.15 DC
VIII.	**Foundations (See 3-2-19/15)**		
	1.	Main Engine and Major Propulsive Auxiliaries	0.40 DC
	2.	Boilers and other Propulsive Auxiliaries	0.35 DC
	3.	Windlass and Major Deck Machinery	0.40 DC
	4.	Heavy Duty Specialist Offshore Equipment	0.45 DC
IX.	**Rudders—Diaphragms**		
	1.	To Side Plating	
		a. in way of rudder axis	0.45 DC
		b. elsewhere	0.20
		c. slot welds (see note 4)	0.45 DC
	2.	To Diaphragms	
		a. to vertical diaphragms in way of rudder axis	0.45 DC
		b. elsewhere	0.20
		c. to top and bottom casting in way of rudder axis	Full penetration welds
X.	**Superstructures/Deckhouses**		
	1.	To Side Shell Plating	Full penetration welds
	2.	To Decks and/or bulkheads to which they are attached	0.35 DC
	3.	External bulkheads and exposed decks connections	0.35 DC
	4.	Internal decks to external bulkheads	0.35 DC
	5.	Elsewhere	0.20

Notes

1 The weld size is to be determined from the thickness of the member being attached.

2 Unbracketed stiffeners and webs of hatch covers are to be welded continuously to the plating and to the face plate for a length at ends equal to the end depth of the member.

3 With longitudinal framing, the weld size is to be increased to give an equivalent weld area to that obtained without cut-outs for longitudinals.

4 The weld size is to be determined from the thickness of the side plating.

5 Slab longitudinals within $D_s/4$ from strength deck. For these slab longitudinals the leg size w and w_{min} in 3-2-19/3.1 may both be taken as $0.23t_{pl}$ + 1.0 mm ($0.23t_{pl}$ + 0.04 in.) with a minimum of 4.5 mm (0.18 in.), but need not be greater than 8 mm (0.3 in.). Where the slab longitudinal is located more than $D_s/4$ from the strength deck special consideration will be given to the weld size.

5 Tee-Type End Connections

Tee-type end connections where fillet welds are used are to have continuous welds on each side. In general, the leg sizes of the welds are to be in accordance with 3-2-19/Table 1 for unbracketed end attachment, but in special cases where heavy members are attached to relatively light plating, the sizes may be modified. Where only the webs of girders, beams and stiffeners are required to be attached to plating, it is recommended that the unattached face plate or flanges be cut back.

7 Ends of Unbracketed Stiffeners

Unbracketed stiffeners of shell, watertight and oil-tight bulkheads and house fronts are to have double continuous welds for one-tenth of their length at each end.

Unbracketed stiffeners of non-tight structural bulkheads, deckhouse sides and after ends are to have a pair of matched intermittent welds at each end.

9 Reduced Weld Size

9.1 General

Reduction in fillet weld sizes, except for slab longitudinals of thickness greater than 25 mm (1.0 in.), may be specially approved by the Surveyor in accordance with either 3-2-19/9.3 or 3-2-19/9.5, provided that the requirements of 3-2-19/3 are satisfied.

9.3 Controlled Gaps

Where quality control facilitates working to a gap between members being attached of 1 mm (0.04 in.) or less, a reduction in fillet weld leg size w of 0.5 mm (0.02 in.) may be permitted.

9.5 Deep Penetration Welds

Where automatic double continuous fillet welding is used and quality control facilitates working to a gap between members being attached of 1 mm (0.04 in.) or less, a reduction in fillet weld leg size of 1.5 mm (0.06 in.) may be permitted, provided that the penetration at the root is at least 1.5 mm (0.06 in.) into the members being attached.

11 Lapped Joints

11.1 General

Lapped joints are generally to have overlaps of not less width than twice the thinner plate thickness plus 25 mm (1.0 in.).

11.3 Overlapped End Connections

Overlapped end connections of longitudinal strength members within the midship 0.4L are to have continuous fillet welds on both edges each equal in size w to the thickness of the thinner of the two plates joined. All other overlapped end connections are to have continuous welds on each edge of size w such that the sum of the two is not less than 1.5 times the thickness of the thinner plate.

11.5 Overlapped Seams

Overlapped seams are to have continuous welds on both edges of the sizes required by 3-2-19/Table 1 for the boundaries of deep tank or watertight bulkheads, except that for seams of plates 12.5 mm ($^1/_2$ in.) or less clear of tanks one edge may have intermittent welds in accordance with 3-2-19/Table 1 for watertight bulkhead boundaries.

13 Plug Welds or Slot Welds

Plug welds or slot welds may be approved only for particular applications where access for welding from inside the hull or shell is impossible such as: very narrow recesses at ends, one side of rudder plating, fairleads or one side of box keel.

Where used in the body of doublers and similar locations, such welds may be spaced about 305 mm (12 in.) between centers in both directions. Doubler plates are not acceptable in way of equipment foundations where tensile forces normal to the doubler plates could exist and in tanks carrying flammable liquids.

15 Full or Partial Penetration Corner or Tee Joints

A full or partial penetration weld may be required for highly stressed (75% or more of the yield) or critical (e.g., oil/water boundary) joints.

Measures taken to achieve full or partial penetration corner or tee joints, where specified, are to be to the satisfaction of the attending Surveyor. The designer is to give consideration to minimize the possibility of lamellar tearing in such joints.

17 Alternatives

The foregoing are considered minimum requirements for electric-arc welding in hull construction, but alternative methods, arrangements and details will be considered for approval. See 2-4-3/5 of the ABS *Rules for Materials and Welding (Part 2)*. Fillet weld sizes may be determined from structural analyses based on sound engineering principles, provided that they meet the overall strength standards of these Rules.

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 20 Guidance on Finite Element Analysis

1 General

The intent of this Section is to provide guidance on the use on fine 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 component

1.1 Submittal Items *(2016)*

Submit a complete report documenting the analysis along with all structural drawings pertaining to the area of the structure that is being analyzed. The finite element model is to be submitted for review along with analysis 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 principals and any deviations in the model from the structural drawings.

iii) Plots of the structural models.

- *a)* Geometry
- *b)* Plate thickness

iv) Material properties and beam properties, if applicable.

v) Details of boundary conditions applied

vi) All loading conditions analyzed

vii) Data for load application*

viii) Summaries and plots of calculated deflections and reactions. Validate the load direction and global balance in the model.

ix) Summaries and plots of calculated stresses

x) Details of buckling assessments, if necessary

xi) Comparison table for design/drawing scantlings and FEA model scantlings

xii) Reference of software used in analysis, including its version and date

** 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 the type of finite element is guided by the complexity of the structural system or component being analyzed, the level of detail desired and the outcomes measured. Two node line element and three or four membrane/plate element 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 3-2-20/Table 1.

TABLE 1
Finite Element Type

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 appropriately included in the model.

ii) For beam elements, cross sectional properties are to be based on an effective width of the attached plating. The effective width of plating of beam elements is not to exceed the sum of one-half of the spacing on either side of the structural member or $^1/_3$ of the unsupported span of the member, whichever is less.

iii) Plate element meshing is to follow the stiffening system as far as practicable. The mesh size used should be adequate to represent the overall stiffness of the considered structure. For meshing of large systems such as deck, shell or bulkhead plate/framing systems, the mesh size is to not exceed the spacing between the frames. The mesh should be progressively and smoothly refined to capture structural details where important or found necessary.

iv) At least three elements are to be used, where practical, to model webs of primary supporting members such as girders, transverses, stringers and floors. Rod elements may be used to model flanges of primary supporting members and brackets. The cross sectional area of rods representing sniped or tapered flanges is to be considered proportionally using an average area over the length of the element.

v) The aspect ratio of plate elements, in general, is not to exceed three. The use of triangular plate elements is to be kept to a minimum.

vi) Shell elements are to be used for plate elements subjected to lateral loading.

5 Boundary Conditions

Boundary conditions applied are to reflect, as closely as possible, the actual support conditions of the structure.

The extent of 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.

7 Loads *(2017)*

Loads applied on a model are to be as required by the relevant rule or the design loads of the structural member, whichever is greater.

In addition to static loads, other loads such as hull girder and dynamic loads arising out of acceleration, ship motion, etc., are to be considered where applicable and relevant. If accelerations from model tests, recognized standards or direct calculations are not available, the 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 *(1 July 2012)*

9.1 Allowable Stresses *(2016)*

Unless otherwise specified in these Rules or relevant regulations, individual stress components and, as applicable, direct combinations of such stresses in beam or grillage models are not to exceed the allowable stress F.

$$F = F_y/FS$$

where

F_y = specified minimum yield strength of the material

FS = Factor of Safety

For static loadings:

= 1.67 for axial or bending stress

= 2.50 for shear stress

For loads combining static and dynamic:

= 1.25 for axial or bending stress

= 1.88 for shear stress

For plate element models, and unless otherwise specified in these Rules or relevant regulations, the Von-Mises equivalent stress is not to exceed the limits specified in 3-2-20/Table 2 for the specific mesh size.

TABLE 2
Stress Limits for Plate Element Models

Mesh Size	*Stress Limit*
1 × stiffener spacing (SS)	0.90 S_mF_y
$^1/_2$ × SS	0.95 S_mF_y
$^1/_3$ × SS	1.00 S_mF_y
$^1/_4$ × SS (1)	1.06 S_mF_y
$^1/_5$ × SS ~ $^1/_{10}$ × SS (1)	1.12 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 = 1.0 for mild steel

= 0.95 for HT 32

= 0.908 for HT 36

3 For intermediate mesh size, the stress limit may be obtained by linear interpretation

4 For longitudinally effective structure that is modeled without the hull girder loads, the allowable stresses are to be decreased by 10%

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.

The buckling strength of such locations/areas is to be in compliance with the latest version of the ABS *Guide for Buckling and Ultimate Strength Assessment for Offshore Structures*, or other recognized standard acceptable to ABS.

PART
3

CHAPTER 2 Hull Structures and Arrangements

APPENDIX 6 Ice Operations *(1 July 2012)*

1 Application

This Appendix provides guidance for Offshore Support Vessels intended for operation in ice infested waters. A general characterization of OSV ice operations is provided along with an overview of ice management roles. References are made to the various ABS ice class criteria and guidance.

3 General

In addition to conventional open water functions, Offshore Support Vessels may play unique roles in Arctic and other ice-infested waters, specifically through icebreaking operations and ice management. These roles are critical elements of Arctic offshore oil and gas operations as they can potentially extend the drilling season and reduce the frequency of disconnection events. An Offshore Support Vessel may be expected to maneuver more rigorously in ice than a traditional ice-strengthened transit ship due to ice management responsibilities and advanced propulsion systems; (e.g., podded propulsors and azimuthing thrusters). For this reason, special attention should be given to the strength of the stern region and appendages beyond the basic ice strengthening requirements.

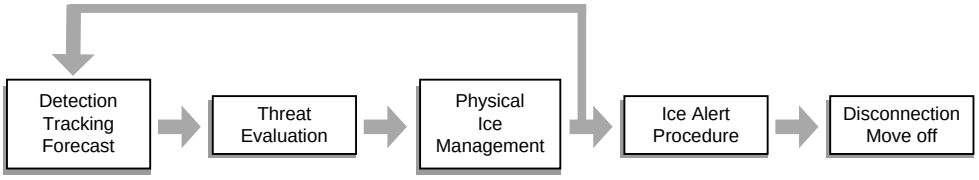
5 Ice Management

Ice management involves operational procedures that are used to reduce global and local design ice loads. Ice management is most commonly used to support floating systems in both sea ice and glacial ice environments and can significantly influence their design. It can also be used to mitigate the risk of deep draft ice features interacting with sea floor facilities. In certain cases, ice management can be used as a means of modifying ice loads on fixed structures, although this approach is not common. It is also a relevant consideration in terms of supporting other in-ice activities, such as EER systems and tanker offloading operations.

Floating structures that are deployed in ice-covered waters are often supported by highly capable ice management vessels, with the intended role of modifying the local ice environment, reducing ice loads on the structure and enhancing ice clearance around it. The requirement to identify potentially adverse ice features or situations requiring ice management, and then to deal with them in a timely manner, increases the range of environmental considerations that are normally associated with fixed structures. Fixed structures may also rely on ice management to ensure access to re-supply and offloading facilities and to clear potential escape routes for EER craft.

Ice management systems typically consist of a series of processes and procedures as shown schematically in 3-2-A6/Figure 1, below. In actual ice management operations, a sequence of events takes place in time at or near the site of the offshore facility. A similar sequence of events is considered, or assumed, during the design cycle of the ice management system.

FIGURE 1
Ice Management System and Its Elements *(1 July 2012)*



Physical ice management refers to the actual vessel operations that are intended to break up and clear sea ice and/or specific features within an ice cover, and deflect icebergs and small glacial ice masses. Specific approaches and techniques have been developed for both sea ice and glacial ice management that recognize the capabilities and limitations of the vessels and equipment involved and the ice conditions at hand.

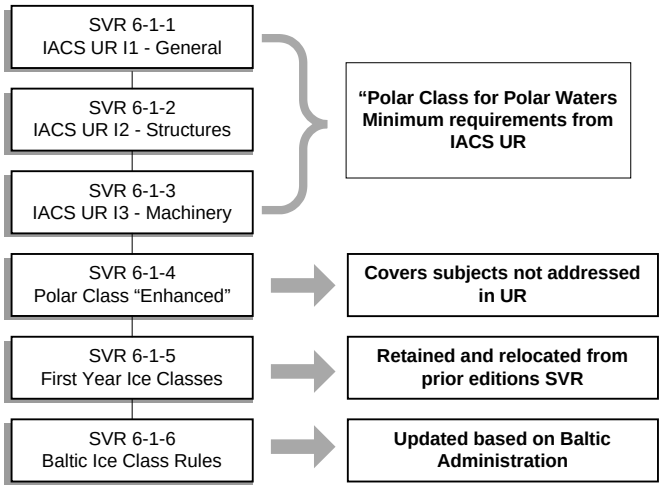
The criteria presented in this chapter can be applied to the design of offshore support vessels intended for physical ice management operations.

The rules for icebreakers (and ice going transit-vessels) outlined in Part 6, Chapter 1 of ABS *Rules for Building and Classing Steel Vessels (Steel Vessel Rules)* and ABS *Guide for Vessels Operating in Low Temperature Environments (LTE Guide)* can be applied in general for all Ice Management Vessel (IMV) designs. These publications give basic design criteria for the vessel's hull, machinery, deck outfitting, winterization, etc.

7 Overview of ABS Ice Class Rules

Part 6, Chapter 1 of the *Steel Vessel Rules* contains several systems of ice class notations. If operation in ice is anticipated, it is the vessel Owner's option to select which ice class notation system will be applied, and it is the Owner's responsibility to operate the vessel in a manner consistent with the basis underlying the technical criteria for the selected ice class. 3-2-A6/Figure 2 outlines the various ice class notation systems offered in Part 6, Chapter 1 of the *Steel Vessel Rules*.

FIGURE 2
Organization of ABS Ice Class Rules *(1 July 2012)*



The ice class notations are intended to indicate a vessel's ability to operate in specified conditions (i.e., geographic region, and ice and vessel parameters); considering a particular vessel operating profile (i.e., ice breaking or escorted); and possibly, particular ice-vessel interaction scenarios (e.g., an impact of the vessel bow with the ice). To accommodate the variations in the conditions affecting design, several ice class systems have been developed and included in the Rules. 3-2-A6/Table 1, reproduced from Section 6-1-1, *'Strengthening for Navigation in Ice'* of the *Steel Vessel Rules*, summarizes the offered Ice Class Notations of the Rules. The position of an entry in the table is only intended to provide a general impression of approximate correspondence between the systems of the offered ice class notations. The absolute strength of a particular hull structure can only be determined by appropriate analysis.

TABLE 1
Ice Class Notations *(2015)*

Polar Class (6-1-1, 6-1-2, 6-1-3)	*Polar Class, Enhanced (6-1-4)*	*First-year Ice Class (6-1-5)*	*Baltic Class (6-1-6)*
PC1	**PC1, Enhanced**		
PC2	**PC2, Enhanced**		
PC3	**PC3, Enhanced**		
PC4	**PC4, Enhanced**		
PC5	**PC5, Enhanced**		
PC6	**PC6, Enhanced**		**1AA**
PC7	**PC7, Enhanced**	**A0**	**1A**
		B0	**1B**
		C0	**1C**
		D0	
		E0	

Note: The shaded columns shaded are eligible for **Ice Breaker** class notation.

9 IACS Polar Classes

9.1 Background Information

The International Maritime Organization (IMO) issued guidelines for ships operating in Arctic Ice-covered Waters (IMO Arctic Guidelines, 2002). In 2009, updated Guidelines were approved to take account of technical, technological, and regulatory developments since their initial publication. In addition, application was extended to address ships operating in Polar waters, which includes both Arctic and Antarctic waters (IMO Guidelines for Ships Operating in Polar Waters 2009). 3-2-A6/Figures 3 and 4 show the Arctic and Antarctic waters as defined in the Guidelines.

The IMO is currently working on an initiative to prepare a comprehensive Polar Code for ships operating in polar waters to enhance the existing voluntary measures related to maritime safety and environmental protection in polar waters. Although it is at an early stage of development, there has been strong support to develop a risk-based code with functional requirements supported by prescriptive provisions, and the developed code is likely to be made mandatory under SOLAS and/or MARPOL.

Ships operating in Polar waters are exposed to a number of unique risks. Poor weather conditions and the relative lack of good charts, communication systems and other navigational aids pose challenges for mariners. The remoteness of the area makes rescue or clean-up operations difficult and costly. Cold temperatures may reduce the effectiveness of numerous components of the ship, ranging from deck machinery and emergency equipment to sea suctions. When ice is present, it can impose additional loads on the hull, propulsion system and appendages. The IMO Polar Guidelines address the criteria for (a) construction provisions (b) equipment (c) operations and (d) environmental protection and damage control. One of the most important aspects of the IMO 2009 Guidelines for ship designers, builders and operators is that the construction provisions refer to the IACS Unified Requirements (URs) Concerning Polar Class (IACS Requirements for Polar Class, 2007) developed by the International Association of Classification Societies (IACS).

FIGURE 3
Maximum Extent of Arctic Waters(1) *(1 July 2012)*

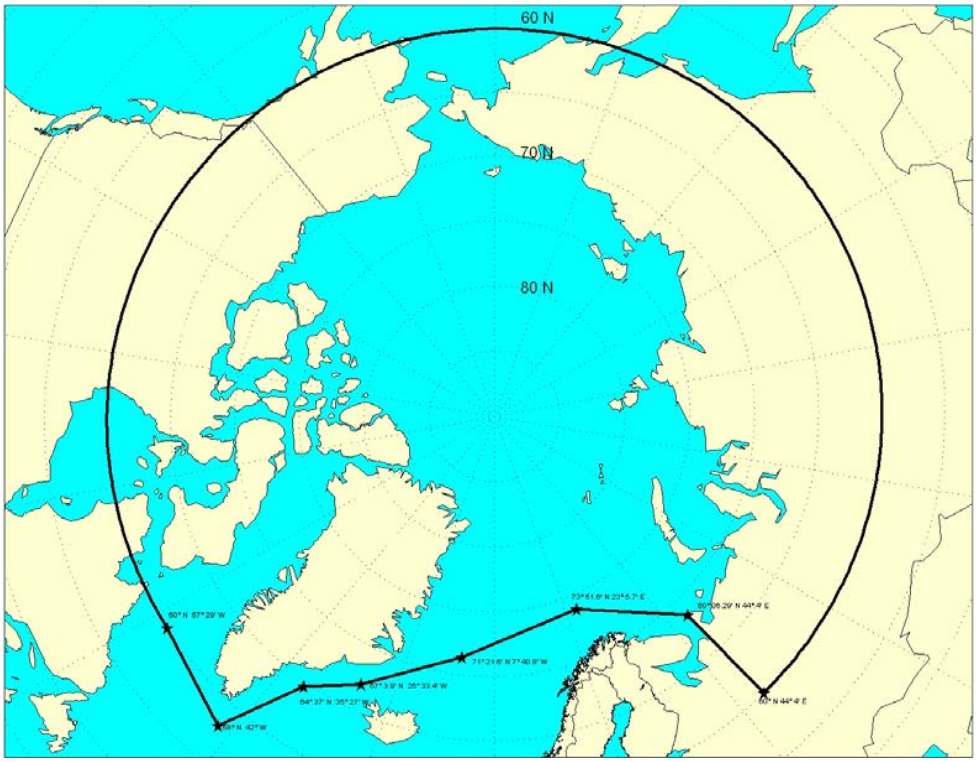
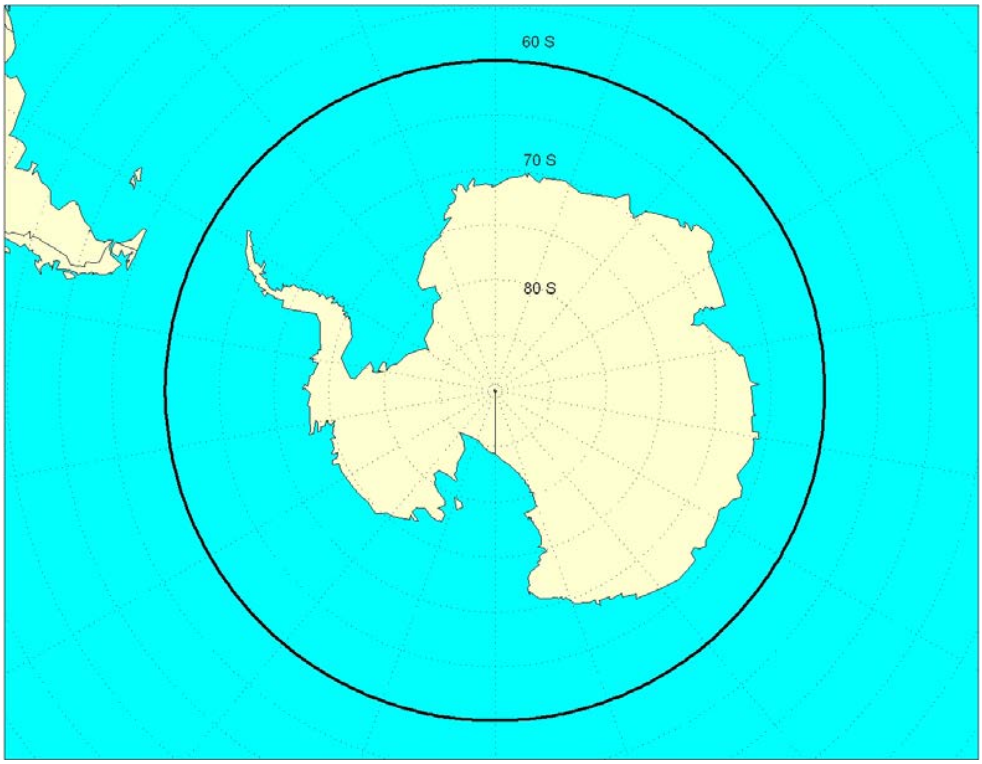


FIGURE 4
Maximum Extent of Antarctic Waters(1) *(1 July 2012)*



Source: 1 IMO Resolution A.1024(26) Guidelines for Ships Operating in Polar Waters
Note: Maps are for illustrative purposes only

9.3 Description of IACS Polar Classes

The International Association of Classification Societies (IACS) Unified Requirements for Polar Ships (UR I), adopted by ABS in Sections 6-1-1, 6-1-2, and 6-1-3 of the *Steel Vessel Rules*, are based on both Arctic and Antarctic navigation. The IACS Polar Class rules were implemented into the *Steel Vessel Rules* in January 2012, effectively replacing the previous general Arctic ice class notations (**A5** to **A1**).

There are seven ice classes in the Polar Class requirements (**PC1** to **PC7**). The IACS rules assume limited icebreaker assistance. The rules are based on an interaction scenario of a glancing impact with an ice floe on the bow shoulder. From this scenario, the ice loading is derived and then the local hull structure and scantling requirements are derived. The division of the IACS Polar Classes and the associated descriptions are reproduced in 3-2-A6/Table 2 below. The descriptions are intended to guide owners, designers and administrations in selecting an appropriate Polar Class to match the requirements for a vessel with its intended mission.

The classes are intended to cover the full range of ships in operation, providing flexibility to designers using uncomplicated descriptions of ice conditions. The lowest classes **PC6** and **PC7** have been approximately aligned with the highest *Finnish Swedish Ice Class Rules* (FSICR), 1AS and 1A respectively. The highest polar class (**PC1**) is intended to offer a level of capability analogous to that provided by an unrestricted open water class notation. It defines a ship which can operate year-round in all polar waters, subject to due caution on the part of the Master. This caution implies, for example, limiting speed in certain conditions, avoiding aggressive maneuvers, avoiding impacts with obvious glacial ice features, etc.

TABLE 2
Polar Class Descriptions *(1 July 2012)*

Polar Class	*Ice description based on WMO sea ice nomenclature*
PC1	Year-round operation in polar waters
PC2	Year-round operation in moderate multi-year ice condition
PC3	Year round operation in second year ice which may include multi-year ice inclusions
PC4	Year round operations in thick first-year ice which may include old ice inclusions
PC5	Year round operations in medium first-year ice which may include old ice inclusions
PC6	Summer-Autumn operations in medium first-year ice which may include old ice inclusions
PC7	Summer/Autumn operation in thin first year ice which may include old ice inclusions

9.5 Theoretical Background of Structural Requirements

Section 6-1-2 of the *Steel Vessel Rules* contains hull structural design criteria from the IACS Unified Requirements (UR I2) which provides definitions and requirements for hull area, design loads, shell plate requirements, framing requirements, corrosion/abrasion addition and steel renewal, material grades and longitudinal strength requirements. The design load for Polar Class ships takes a physics-based approach that ice loads can be rationally linked to the design scenario. The design scenario is a glancing collision with an ice edge, such as the edge of a channel or of a floe. The formulation of the load equation is derived from the solution of an energy based collision model in which the kinetic energy is equated to ice crushing energy. Ice thickness, ice crushing strength, hull form, ship size and ship speed are all taken into account. The flexural failure of the ice sheet is also considered as a limiting state due to the collision. The results are in close agreement with a variety of past studies and operational experience. The forces generated during a glancing impact are represented in ways that allow them to be used in developing scantlings for individual structural elements, grillages, and supporting structure.

Although most traditional ship structural rule formulations are based on elastic criteria, the IACS Requirements for Polar Class incorporate plastic design criteria. Using plastic design can help provide a better balance of material distribution to resist design and extreme loads. This is particularly important because extreme ice loads can be considerably in excess of design values. This is more likely for ice loads than for wave loading. The use of plastic methods should provide a considerable strength reserve, which may or may not be the case with elastic design. The selection of structural design criteria for plastic design

is more difficult than in elastic design of which the first onset of yield is relatively easy to predict, and thus offers a simple criterion for design. In plastic design, there are many possible limit states ranging from yield through final rupture. The selected design limit state represents a condition of substantial plastic stress, prior to the development of large plastic strains and deformations.

The shell plate thickness requirements are derived using ultimate strength criterion where the ultimate strength is determined when plastic folding occurs due to a perfectly plastic hinge formation. The local framing members in the side and bottom structures are to be dimensioned such that the effects of shear, bending, and both combined do not cause the development of plastic collapse mechanisms. The required section property requirements are derived from an analytical energy method considering three limit-states, two of which involve the combination of shear and bending while the third one is purely shear. Bending and shear interaction is treated rigorously by taking into account the actual section shape in the calculation procedure. The application of an iterative procedure should be advantageous to optimize the framing members considering shear and section modulus requirements. The scantling requirements are provided for both transversely and longitudinally framed structures.

In the original IACS UR, each classification society is left to establish the structural requirements for large web frames and load-carrying stringers. ABS has developed specific criteria for these structural members considering plastic behavior. Requirements for the web area (resistance to plastic shear force) and plastic section modulus (resistance to plastic moment) are provided in Section 6-1-2 of the *Steel Vessel Rules*.

9.7 Theoretical Background of Machinery Requirements

Section 6-1-3 of the *Steel Vessel Rules* contains machinery requirements adopted from the Unified Requirements (UR I3) related to the strength of main propulsion, steering gear, emergency and other essential auxiliary support systems. Propeller ice interaction load formulas form the basis of the propulsion line component strength calculations. The load formulas were developed through extensive international research and development efforts which included numerical simulations of propeller-ice interaction validated with full scale measurements and analyses of propeller damage service histories. The calculated loads are the expected, single occurrence, maximum values for a ship's entire service life in normal operating conditions. Design load formulas are provided for both open and ducted propellers and include the maximum backward and forward blade bending forces, blade spindle torque, propeller ice torque, and propeller ice thrust applied to the shaft. Response torque criteria in the propulsion line are determined on the basis of torsional vibration analysis considering specific torque excitation cases.

The propeller blades should be designed with respect to two overall limit states, namely *extreme static* and *fatigue*. The extreme criterion is based on the calculated maximum expected loads applied via finite element analysis with acceptance criteria for permissible stress levels. Propeller blade fatigue criterion is based on a load distribution for the ship service life and the S-N curve of the blade material. The propulsion line components should be designed according to the "selective strength principle" so that first damage does not cause significant risk to the ship's safety and other shaft line components. In most cases the propeller is considered the sacrificial component. Additional subjects in Section 6-1-3 of the *Steel Vessel Rules* include vertical and longitudinal acceleration criteria for equipment and machinery supports, provisions to protect systems from freezing and ingestion of ice, and specific requirements for sea inlets, ballast tanks, cooling water systems and ventilations systems.

11 Polar Classes "Enhanced" Requirements

While the IACS Polar UR presents the best available basis for the design of the next generation of ice-capable ships, it stipulates that the individual classification society should supply its own procedures and criteria for several design issues. Relative to existing ice strengthening standards the IACS UR is either silent or lacks explicit requirements for several items. Section 6-1-4 of the *Steel Vessel Rules* contains additional criteria to address such items, and to expand the criteria themselves by addressing numerous detailed considerations. Many of the enhanced criteria in Section 6-1-4 of the *Steel Vessel Rules* are retained requirements of the general ice class criteria that existed in the *Steel Vessel Rules* prior to the formal adoption of the Polar Class rules. When a vessel complies with the requirements of Section 6-1-4 of the *Steel Vessel Rules*, it can receive the Polar Class notation followed by **Enhanced**. A list of subjects addressed in the Enhanced requirements is provided in 3-2-A6/Table 3.

TABLE 3
List of Subjects Addressed in Enhanced Requirements *(1 July 2012)*

Ice breaker class*
Vessels intended to operate astern*
Local framing details
Peak frames
Double bottoms
Ice decks
Stem and stern frames
Towing arrangements
Addition machinery arrangement considerations
Power of propulsion machinery**
Flexible couplings
Bossings
Rudder, steering arrangements, and propeller nozzles

Notes:

* Indicates optional criteria

** Indicates recommendatory criteria

Section 6-1-4 of the *Steel Vessel Rules* provides optional criteria for an **Ice Breaker** notation which can be applied to Polar Classes (**PC1** to **PC6**). The intended application of the criteria given in structural requirements of the IACS Polar UR (Section 6-1-2 of the *Steel Vessel Rules*) is for ships navigating in ice-infested polar waters, except for ice breakers. Ice Breaking vessels are considered ships that have an operational profile to provide ice management functions and to be the lead vessel escorting another vessel navigating in ice. An **Ice Breaker** notation requires additional design considerations which will allow the ship to undertake aggressive operations in ice-covered waters. This includes increased stern ice belt and stern lower hull area factors to provide adequate structural redundancy. Due to aggressive maneuvering demands of OSVs, it is recommended to seek the optional ice breaker notation.

Additionally, comparable optional criteria are given for a ship intended to navigate in ice while travelling astern. If a vessel is intended to operate astern in ice regions, the aft section of the vessel is to be designed using the Bow and Bow Intermediate hull area requirements. Design guidance is provided to define the appropriate stern icebelt and stern intermediate regions and their associated hull area factors.

Powering requirements were excluded from the IACS Polar UR due to conflicting operational philosophies which exist for ice strengthened ships. However, recommended powering criteria are provided for Polar Class ships in Section 6-1-4 of the *Steel Vessel Rules*. The total ahead power delivered to the propellers is to be sufficient for the vessel to maintain its design service speed under the ice conditions associated with the selected Polar Class notation. Empirical formulations are provided to satisfy two different criteria. Suitable self-propelled ice model tests also provide acceptable means of demonstrating satisfactory power of propulsion machinery.

13 First Year Ice Classes *(2015)*

Ice classes applicable to vessels intending to navigate in first year ice are given in Section 6-1-5 of the *Steel Vessel Rules*. The structural design criteria for these classes reflect ice thicknesses, other ice properties, and the extent of ice cover expected to be experienced by the ship. Four first year ice classes are available (**A0**, **B0**, **C0**, **D0**, and **E0**). General guidance is provided for the selection of the most suitable first year ice class. 3-2-A6/Table 4, reproduced from Section 6-1-5 of the *Steel Vessel Rules*, identifies recommended ice classes with respect to anticipated operational philosophy (independent or escorted) and ice conditions.

TABLE 4
First Year Ice Class Selection Guidance *(2015)*

Ice Class	*Navigating independently or when escorted by an ice-capable vessel of the following ice classes*	*Year around navigation in water with first-year ice with the ice conditions given in Table 5, below*
A0	Escorted by **PC4** or Higher Ice Class Vessel	Extreme
B0	Escorted by **PC3** or Higher Ice Class Vessel	Extreme
A0, B0, C0	Escorted by **PC5** or Higher Ice Class Vessel	Very Severe
A0	Independently	Severe
B0	Independently	Medium
C0	Independently	Light
D0	Independently	Very Light
E0	Independently	Very Light drift ice [in coastal areas]

TABLE 5
First Year Ice Conditions Severity Definitions *(1 July 2012)*

Thickness of First-Year Ice Cover in m (ft)	*Concentration of Ice* [1]			
	Very Close and Consolidated Ice, Fast Ice (from 10/10 to 9/10 or from 8/8 to 7/8)	*Close Ice (from 9/10 to 6/10 or from 7/8 to 5/8)*	*Open Ice (from 6/10 to 3/10 or from 5/8 to 2/8) and Fresh Channel*[2] *in Fast Ice (more than 6/10 or 5/8)*	*Very Open Ice (less than 3/10 or 2/8), Fresh Channel*[2] *in Fast Ice (6/10 or 5/8 and less) and Brash Ice*
1.0 (3.3) and above	Extreme	Extreme	Very severe	Severe
from 0.6 (2) to 1.0 (3.3)	Extreme	Very severe	Severe	Medium
from 0.3 (1) to 0.6 (2)	Very severe	Severe	Medium	Light
less than 0.3 (1)	Severe	Medium	Light	Very light

Notes:

1 These ratios of mean area density of Ice in a given area are from the — "World Meteorological Organization Sea Ice Nomenclature", Appendix B.7, and give the ratio of area of Ice concentration to the total area of sea surface within some large geographic locales.

2 Provided the channel is wider than the ship

15 Baltic Ice Classes

The ice class notations and ice strengthening requirements in Section 6-1-6 of the *Steel Vessel Rules*, Baltic Ice Class are in accordance with the *Finnish-Swedish Ice Class Rules (FSICR) 2010* developed for vessels navigating in the Baltic Sea area in winter, or in other sea areas in similar ice conditions. The administrations of Sweden (Swedish Transport Agency, STA) and Finland (Finnish Transport Safety Agency, TraFi) provide icebreaker assistance to vessels bound for their ports in winter. Depending on the ice conditions, restrictions by the administrations may apply to the size and ice class of the vessel.

Four Baltic Ice Class notations are available as follows:

- **Ice Class I AA**; vessels with such structure, engine output and other properties that they are normally capable of navigating in difficult ice conditions without the assistance of icebreakers (equivalent to FSICR Ice Class 1A Super)
- **Ice Class I A**; vessels with such structure, engine output and other properties that they are capable of navigating in difficult ice conditions, with the assistance of icebreakers when necessary (equivalent to FSICR Ice Class 1A)

- **Ice Class I B**; vessels with such structure, engine output and other properties that they are capable of navigating in moderate ice conditions, with the assistance of icebreakers when necessary (equivalent to FSICR Ice Class 1B)
- **Ice Class I C**; vessels with such structure, engine output and other properties that they are capable of navigating in light ice conditions, with the assistance of icebreakers when necessary (equivalent to FSICR Ice Class 1C)

TraFi and the STA maintain the *Guidelines for the Application of the Finnish-Swedish Ice Class Rules* which provide background information concerning the implementation of the Baltic rules and the history of their development. The application of the rules and design philosophies of the engine power regulations, hull structural design, and machinery requirements are described. For additional guidance on the Baltic rules, reference can be made to these guidelines.

17 Winterization

Vessels operating in the low temperature environments are faced with additional challenges related to outfitting and equipment as well as issues pertaining to the ability of the crew to function in a difficult environment. The ABS *Guide for Vessels Operating in Low Temperature Environments* provides guidance for winterization related issues beyond the basic hull strengthening and machinery requirements in the ice class rules.

The *LTE Guide* specifies ABS requirements and criteria for obtaining the optional notations Cold Climate Operation (**CCO(T_{DST}, T_{MAT})**), Cold Climate Operation-Polar (**CCO-POLAR(T_{DST}, T_{MAT})**), Cold Climate Operation Plus (**CCO(T_{DST}, T_{MAT})+**), Cold Climate Operation-Polar Plus (**CCO-POLAR(T_{DST}, T_{MAT})+**), and **DE-ICE**. The **CCO** notation identifies the basic level of the prescriptive criteria contained in the Guide related to the design, construction, operation and survey of the vessel. For the **CCO-POLAR** notation, the Guide provides criteria for vessels that intend to operate in Polar Regions on a continuous basis. **DE-ICE** is a notation available for vessels occasionally operating in low temperatures subject to ice accretion. The appended Plus (**+**) notation indicates the placement of additional equipment onboard for the crew and recognizes specific low temperature training for the crew.

The *LTE Guide* also contains a series of Appendices that provide supporting information relative to the requirements. Additional Appendices cover climatic conditions, notes on specific vessel requirements, other reference sources, a list of administration contacts associated with navigation in Baltic, Arctic, and Antarctic areas, and a list of meteorological organization contacts.

19 Direct Calculation

While direct calculations are not permitted in the IACS Polar UR as an alternative to the prescribed procedures, prudent shipbuilders and operators may seek alternative methods to check the strength of structural systems subject to specialized operational scenarios or service missions. Direct design is an attractive option to complement the ice class rules and can address the added structural risks from adverse environmental and operational conditions. A revision of the ABS *Guidance Notes on Ice Class* is anticipated for publication in 2012 and includes guidance on developing supplementary loading conditions and structural analysis procedures which may be used to assess the adequacy of the structural design for additional ice/ship interactions. In addition the Guidance Notes describe plastic grillage analysis methods to determine the limit load of hull structure grillages subject to ice pressure.

21 Ice Load Monitoring System

The ABS *Guide for Ice Load Monitoring Systems* provides requirements for the installation of, and the information to be provided by ice load monitoring systems fitted on ice-classed ABS vessels. These systems are intended as an aid to the Master and navigating officers when a vessel is operating in ice infested waters so that appropriate action can be taken to minimize the likelihood of the vessel sustaining structural damage from interaction with the ice. The Guide specifies ice load monitoring systems extending from basic monitoring systems to sophisticated, integrated systems, the selection of which is left to the Owner. The information provided in the Guide is intended to assist the Owner in selecting the most appropriate system for a vessel based on the vessel's probable operating parameters.

It can be beneficial for the Owner of an ABS ice-classed vessel having recorded in-service data from an ice loads monitoring system to make that data available to ABS. This will permit correlation with survey results which will validate design requirements and help to refine the monitoring criteria, themselves.

PART
3

CHAPTER 3 Subdivision and Stability

CONTENTS

SECTION 1 General Requirements 321

1 General 321
3 Criteria 321
3.1 Intact Stability 321
3.3 Subdivision and Damage Stability 321
3.5 Carriage of Hazardous and Noxious Liquid Substances 321
3.7 Intact Stability for Anchor Handling/Towing Vessels 322
3.9 Intact Stability for Vessels Equipped with Lifting Appliances 322
5 Review Procedures 322
5.1 Administration Review 322
5.3 ABS Review 322
7 Onboard Computers for Stability Calculations 322

APPENDIX 1 Intact Stability Requirements for Offshore Support Vessels 323

1 General 323
3 Criteria 323
3.1 General Criteria 323
3.3 Severe Wind and Rolling Criterion 323
3.5 Alternative Criteria for Offshore Support Vessels 323
5 Lightship Determination 324
7 Standard Loading Conditions 325
9 Free Surface 326
11 Carriage of Pipe as Deck Cargo 326
13 Icing 327
15 Trim and Stability Booklet 327
17 Submission of Plans 328

APPENDIX 2 Damage Stability Requirements for Offshore Supply Vessels 329

1 General 329
3 Damage Assumptions 329
5 Criteria 330
7 Permeability 331
9 Free Surface 331
11 Subdivision 331

APPENDIX 3 Computer Software for Onboard Stability Calculations 332

1 General 332
1.1 Scope 332
1.3 Design 332
3 Calculation Systems 332
5 Types of Stability Software 332
7 Functional Requirements 333
7.1 Calculation Program 333
7.3 Direct Damage Stability Calculations 333
7.5 Warning 333
7.7 Data Printout 333
7.9 Date and Time 333
7.11 Information of Program 334
7.13 Units 334
7.15 Computer Model 334
7.17 Further Requirements for Type 4 Stability Software 334
9 Acceptable Tolerances 336
9.1 Calculation Program of the Approved Stability Information 337
9.3 Independent Program for Assessment of Stability 337
11 Approval Procedure 338
11.1 Conditions of Approval of the Onboard Software for Stability Calculations 338
11.3 General Approval (optional) 338
11.5 Specific Approval 339
13 Operation Manual 340
15 Installation Testing 340
17 Periodical Testing 340
19 Other Requirements 341

TABLE 1 Acceptable Tolerances 337

PART
3

CHAPTER 3 Subdivision and Stability

SECTION 1 General Requirements

1 General

An offshore support vessel is typically designed with accommodations and bridge erections in the forward part of the vessel and an exposed cargo deck in the after part for handling cargo at sea. Offshore support vessels, are to have subdivision and stability in accordance with the criteria listed in this Section.

In case the criteria listed in this Section are not applicable to a particular vessel, the intact and damage stability will be reviewed by ABS in accordance with other recognized criteria appropriate to the vessel's type, size and intended service.

Offshore support vessels that are configured as mobile offshore units are to comply with the subdivision and stability requirements of the ABS *Rules for Building and Classing Mobile Offshore Drilling Units (MODU Rules)*.

3 Criteria

3.1 Intact Stability

The criteria in Appendix 3-3-A1 "Intact Stability Requirements for Offshore Support Vessels" may be used for classification purposes.

3.3 Subdivision and Damage Stability

Vessels of applicable size, type and service are to have subdivision and damage stability as follows:

• Offshore supply vessel	Appendix 3-3-A2 "Damage Stability Requirements for Offshore Supply Vessels"
• All other offshore support vessel of 80 m (262 ft) or more in subdivision length	Chapter II-1, Regulation 4 through 7-3 of SOLAS 74, as amended
• Vessels carrying more than twelve Special Personnel (see 5-1-2/3.5)	5-1-2/5.3 Subdivision and Damage Stability – Special Purpose Ships

3.5 Carriage of Hazardous and Noxious Liquid Substances *(1 July 2012)*

Where it is intended to carry limited amounts (the lesser of 800 m^3 or a volume in cubic meters equal to 40% of the vessel's deadweight calculated at a cargo density of 1.0) of hazardous and noxious liquid substances in bulk on offshore support vessels, the arrangement is to comply with IMO Resolution A.673 (16), "Guidelines for the Transport and Handling of Limited Amounts of Hazardous and Noxious Liquid Substances in Bulk in Offshore Support Vessels" as amended by IMO Resolutions MSC.236(82) and MEPC.158(55).

Where the amount of hazardous and noxious liquid substances carried is greater than the lesser of 800 m^3 or a volume in cubic meters equal to 40% of the vessel's deadweight calculated at a cargo density of 1.0, the vessel shall comply with the survival capability requirements of Chapter 2 of the International Bulk Chemical Code or the International Gas Carrier Code.

Consideration will be given to the arrangement which complies with the published requirements of the flag Administration.

3.7 Intact Stability for Anchor Handling/Towing Vessels

Each vessel receiving a towing notation is to comply with the additional intact stability criteria in Appendix 5-3-A3.

3.9 Intact Stability for Vessels Equipped with Lifting Appliances

Each vessel equipped to lift loads is to comply with the additional intact stability criteria in Appendix 5-9-A1.

5 Review Procedures

5.1 Administration Review

When the vessel is issued a SOLAS 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 may 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 one or more of the above Certificates, the acceptance of subdivision and stability by the Administration will be required before the certificate is issued.

5.3 ABS Review

In all other cases, the information and calculations for subdivision and stability are to be submitted to ABS for review.

7 Onboard Computers for Stability Calculations

The use of onboard computers for stability calculations is not a requirement of class. However, if stability software is installed onboard offshore support 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-A3, “Onboard Computers for Stability Calculations”.

PART
3

CHAPTER 3 Subdivision and Stability

APPENDIX 1 Intact Stability Requirements for Offshore Support Vessels

1 General

For every loading condition, which is to be shown in the Trim and Stability Booklet, the righting arm curve (GZ curve) is to be plotted using the VCG corrected for the free surface effects of liquid in tanks.

3 Criteria

3.1 General Criteria

The following stability criteria are to be complied with:

i) The area under the righting lever curve (GZ curve) should not be less than 0.055 meter-radians (10.3 ft-degrees) up to θ = 30° angle of heel and not less than 0.09 meter-radians (16.9 ft-degrees) up to θ = 40° or the angle of flooding, if this angle is less than 40°. Additionally, the area under the righting lever curve (GZ curve) between the angles of heel of 30° and 40° or between 30° and θ_f*, if this angle (θ_f) is less than 40°, is not to be less than 0.03 meter-radians (5.6 ft-degrees).

ii) The righting lever GZ is to be at least 0.20 m (0.66 ft) at an angle of heel equal to or greater than 30°.

iii) The maximum righting arm is to occur at an angle of heel not less than 25°.

iv) The initial metacentric height, GM_0, is not to be less than 0.15 m (0.49 ft).

3.3 Severe Wind and Rolling Criterion

In addition to 3-3-A1/3.1, The Severe Wind and Rolling Criterion in Part A, Section 2.3 of the 2008 Intact Stability Code is to be complied with. Where the vessel's characteristics render compliance with this criteria impracticable, consideration will be given for compliance with another published weather criteria.

3.5 Alternative Criteria for Offshore Support Vessels *(2018)*

For vessels of 24 m (79 ft) in length and over but not more than 100 m (328 ft) in length where the vessel's characteristics render compliance with 3-3-A1/3.1 impracticable, the following alternative criteria are to be complied with. For vessels greater than 100 m (328 ft) in length where the vessel's characteristics render compliance with 3-3-A1/3.1 impracticable, consideration will be given for compliance with the following alternative criteria. The alternative criteria are not applicable to Special Purpose Ships greater than 100 m (328 ft) in length.

i) The area under the curve of righting levers (GZ curve) is not to be less than 0.070 meter-radians (13.2 ft-degrees) up to an angle of 15° when the maximum righting lever (GZ) occurs at 15° and 0.055 meter-radians (10.3 ft-degrees) up to an angle of 30° when the maximum righting lever (GZ) occurs at 30° or above. Where the maximum righting lever (GZ) occurs at angles of between 15° and 30°, the corresponding area under the righting lever curve is to be:

$0.055 + 0.001\ (30° - \theta_{max}^{**})$ meter-radians

$10.3 + 0.187\ (30° - \theta_{max}^{**})$ feet-degrees

ii) The area under the righting lever curve (GZ curve) between the angles of heel of 30° and 40°, or between 30° and θ_f, if this angle (θ_f) is less than 40°, is not to be less than 0.03 meter-radians (5.6 ft-degrees).

iii) The righting lever (GZ) is to be at least 0.20 m (0.66 ft) at an angle of heel equal to or greater than 30°.

iv) The maximum righting lever (GZ) is to occur at an angle of heel not less than 15°.

v) The initial transverse metacentric height (GM_0) is not to be less than 0.15 m (0.49 ft).

* θ_f is the angle of heel in degrees at which openings in the hull, superstructure or deckhouses which cannot be closed weathertight immerse. In applying this criterion, small openings through which progressive flooding cannot take place need not be considered as open.

** θ_{max} is the angle of heel in degrees at which the righting lever curve reaches its maximum.

5 Lightship Determination

5.1

Upon completion, each vessel is to undergo an inclining experiment to determine the actual displacement and position of the center of gravity for the lightship condition. The inclining experiment is to be conducted in accordance with Part B Chapter 8 and Annex 1 of the 2008 Intact Stability Code and ASTM Standard F-1321-14, *"Standard Guide for Conducting a Stability Test (Lightweight Survey and Inclining Experiment) to Determine the Light Ship Displacement and Centers of Gravity of a Vessel"*

5.3

If the inclining experiment results on the initial vessel in a series have been approved, the inclining experiment required by 3-3-A1-5.1 may be waived provided that, for each sister vessel (built to the same plans), the weights and centers of any known differences are documented and a lightweight survey is conducted to confirm the effects of the differences on the lightship characteristics.

5.5

If it can be demonstrated that the performance of an inclining experiment is not practicable or safe or yields inaccurate results due to the specific proportions, arrangements, strength or hull of a ship, the vessel's lightship characteristics may be determined by a detailed weight estimate confirmed by a lightweight survey. A formal request for an inclining experiment waiver shall be made to ABS technical office and shall include the technical justification for the request.

5.7

Prior to the performance of each inclining experiment or lightweight survey, a test procedure shall be submitted for approval. The procedure shall include the following data, as applicable:

- Identification of the vessel to be inclined.
- Date and location of the experiment.
- Inclining weight data.
- Pendulum locations and lengths. Alternate measuring devices may be proposed for use.
- Approximate draft and trim of the vessel, including location of draft and freeboard readings.
- Condition of each tank.
- Estimated items to be installed, removed, or relocated after the experiment, including the weight and location of each item.
- Schedule of events.
- Details of weight movements
- Person or persons responsible for conducting the experiment.

5.9

Each inclining experiment and lightweight survey must be performed in the presence of an ABS Surveyor and in accordance with the approved experiment procedure.

5.11

For vessels undergoing modifications, the lightship values may be approved without conducting a lightweight survey or inclining experiment if the submitted detailed weight calculation shows a change in both lightship weight and LCG of less than shown below.

i) Lightship LCG, relative to the most recent approved lightship data, is not to exceed 0.5% of L_s***, and

Lightship displacement, corrected for any known differences relative to the inclined vessel, is not to exceed:

- For L_s < 50 m — 2% of the lightship displacement from the most recent approved lightship data
- For L_s > 160 m — 1% of the lightship displacement from the most recent approved lightship data
- For intermediate length — By linear interpolation.

ii) Where a ship is within these limits, the calculated values of lightweight, lightship LCG and lightship VCG should be used in all subsequent stability information supplied to the Master.

iii) Where a ship is outside of either of these limits, an inclining experiment is to be performed to determine the new lightship values that will be used in all subsequent stability information supplied to the Master.

*** L_s is the greatest projected molded length of that part of the ship at or below decks limiting the vertical extent of flooding with the ship at the deepest subdivision draft.

7 Standard Loading Conditions *(1 July 2012)*

The following conditions of loading are to be examined in the Trim and Stability Booklet:

i) Vessel at the maximum Load Line draft, with full stores and fuel and fully loaded with all liquid and dry cargo distributed below deck and with remaining deadweight distributed as above deck cargo (specified by weight, LCG, VCG and total height above deck) corresponding to the worst service departure condition in which all the relevant stability criteria are met.

ii) Vessel with 10% stores and fuel and fully loaded cargoes of *i)* above, arrival condition.

iii) Vessel with full stores and fuel and loaded with the maximum design deck cargo (specified by weight, LCG, VCG and total height above deck) and with remaining deadweight distributed below deck in liquid and dry cargo spaces corresponding to the worst service departure condition in which all the relevant stability criteria are met.

iv) Vessel with 10% stores and fuel and fully loaded cargoes of *iii)* above, arrival condition.

v) Vessel with full stores and fuel in ballast departure condition.

vi) Vessel with 10% stores and fuel in ballast arrival condition.

vii) Vessel in the worst anticipated operating condition (i.e., arrival condition with deck cargo only – 100% deck cargo with 10% stores and fuel).

On a case-by-case basis, specific loading conditions may be excluded if it can be shown that the conditions are not applicable to a specific vessel type and/or operation.

9 Free Surface

For all loading conditions, the initial metacentric height and the righting arm curve should be corrected for the effect of free surfaces of liquids in tanks.

9.1

In determining the correction to initial metacentric height, the transverse moments of inertia of the tanks should be calculated at 0° angle of heel according to the categories indicated in 3-3-A1/9.5 *i)* and *ii)* below.

9.3

The righting arm curve may be corrected by any of the following methods:

- Correction based on the actual moment of fluid transfer for each angle of heel calculated; or
- Correction based on the moment of inertia, calculated at 0° angle of heel, modified at each angle of heel calculated.

9.5

Free surface shall be included as follows:

i) For slack, non-consumable tanks (e.g., liquid cargo, water ballast) with filling levels that do not change during the voyage, the free surface correction should be defined for the actual filling level of each tank.

ii) For tanks with variable filling levels (e.g., consumable liquids such as fuel oil, diesel oil and fresh water, and also liquid cargo and water ballast during liquid transfer operations), the free surface correction, except as permitted in *iv)* and *v)*, should be the maximum value attainable between the filing limits envisaged for each tank, consistent with any operating instructions.

iii) For each type of consumable liquid, the maximum free surface of at least one transverse pair of tanks or a single centerline tank shall be included. The tank or tanks to be taken into account should be those where the effect of free surface is the greatest.

iv) Where water ballast tanks, including roll reduction and anti-heeling tanks, are to be filled and discharged during the course of the voyage, the free surface effects should be calculated to take account of the most onerous transitory stage relating to such operations.

v) During liquid transfer operations, the free surface effects should be calculated to take account of the most onerous transitory stage relating to such operations.

11 Carriage of Pipe as Deck Cargo *(1 July 2012)*

Where pipes are carried on deck, a quantity of trapped water equal to a certain percentage of the net volume of the pipe deck cargo should be assumed in and around the pipes. The net volume is to be taken as the internal volume of the pipes, plus the volume between the pipes. This percentage is to be 30% if the freeboard amidships is equal to or less than 0.015L and 10% if the free board amidships is equal to or greater than 0.03L. For intermediate values of the freeboard amidships, the percentage is to be obtained by linear interpolation. In assessing the quantity of trapped water, the positive or negative sheer aft, actual trim and area of operation may be taken into account.

Where pipe is stored on decks located above the freeboard deck, the distance from the freeboard deck to the storage deck is to be added to the freeboard in the above calculation to determine the amount of trapped water.

13 Icing

For vessels operating in areas where ice accretion is likely to occur, icing allowances should be included in the analysis of conditions of loading. The following guidance may be used:

i) The vessel's stability is to be investigated in the worst conditions of loading.

ii) In the absence of area specific ice accretion data, the following ice accretion may be applied:

- The weight of ice on all horizontal surfaces is to be at least 30 kg/m^2 (6.14 lbs/ft^2).
- The weight of ice of the projected vertical area above the waterline is to be at least 15 kg/m^2 (3.07 lbs/ft^2). This accounts for 7.5 kg/m^2 (1.54 lbs/ft^2) on both the port and starboard vertical surfaces.
- Plans showing projected horizontal and vertical areas are to be submitted.

iii) The height of the center of gravity of the accumulated ice is to be located according to the position of the corresponding horizontal surfaces (decks and gangways) and other continuous surfaces on which ice can reasonably be expected to accumulate. The projected lateral area of small discontinuous surfaces such as rails, spars, and rigging with no sails can be accounted for by increasing the calculated area by 5 percent and the static moments of the area by 10 percent.

iv) The icing accretion assumptions, along with guidance for the avoidance of icing conditions, reduction and removal of ice and other actions to ensure the safety of the vessel during icing conditions are to be included in the Trim and Stability Booklet. Section 3 of Annex 2 of the IMO Code on Intact Stability contains operational guidance for fishing vessels during ice accretion and may be used as a reference.

15 Trim and Stability Booklet

15.1

Operating guidance for the Master is to be provided in a Trim and Stability Booklet.

15.3

Each trim and stability book is to contain sufficient information to enable the Master to operate the vessel in compliance with the applicable intact and damage stability requirements in Section 3-3-1. Information on loading restrictions used to determine compliance with applicable intact and damage stability criteria is to encompass the entire range of operating drafts and the entire range of the operating trims.

15.5

The format of the trim and stability booklet and the information included will vary dependent on the vessel type and operation. Units of measure used in the trim and stability booklet are to agree with the units of measure of the draft markings.

15.7

In developing the trim and stability booklet, consideration is to be given to including the following information:

- A table of contents and index for the booklet. All pages are to be numbered.
- A general description of the vessel, including identification, lightship data, amount and location of fixed ballast, vessel principal dimensions, Load Line draft, freeboard and allowances, maximum displacement and deadweight, etc.
- A brief description of the stability criteria satisfied including assumptions made in the calculations.
- Instructions on the use of the booklet.
- General arrangement plans showing watertight compartments, closures, vents, down-flooding angles, and allowable deck loadings.

- Hydrostatic curves or tables.
- Cross Curves of stability
- Capacity plan showing capacities and vertical, longitudinal, and transverse centers of gravity of stowage spaces and tanks.
- Tank sounding/ullage tables showing capacities, vertical centers of gravity, longitudinal centers of gravity and free surface data in graduated intervals for each tank. This may be submitted as a separate document.
- Information on loading restrictions, such as a maximum KG or minimum GM curve that can be used to determine compliance with applicable intact and damage stability criteria.
- In addition to the standard loading conditions in 3-3-A1/7, loading conditions showing vessel specific operations (lifting, towing, etc.) also are to be included.
- A rapid and simple means for evaluating the trim and stability of other loading conditions. This should include clear, step by step instructions for the calculation and evaluation of the loading condition, blank loading forms, and a worked example.
- General precautions for preventing unintentional flooding.
- References to the Damage Control Booklet and/or Cargo Securing Manual, as applicable.
- Any other necessary guidance for the safe operation of the vessel under normal and emergency conditions (i.e., required liquid ballast, fuel burn-off sequence, maximum cargo height, crane loads, etc.).
- The inclining experiment report may be included as an appendix.

15.9

Intact and damage stability calculations supporting the maximum KG or minimum GM curve should be contained in a separate document and not included in the trim and stability booklet.

17 Submission of Plans

The following drawings are to be submitted with the Trim and Stability Booklet for ABS review:

i) General arrangement plan, with outboard profile

ii) Capacity plan or table with centers of gravity and free surface values

iii) Lines plan

iv) Tank Sounding Tables, if not included in the Trim and Stability Booklet.

v) Cross curves of stability, if not included in the Trim and Stability Booklet.

vi) List of down-flooding points, including their transverse, longitudinal and vertical locations, used in the calculation of the intact and damage stability criteria.

vii) Draft Marks Drawing showing the draft mark details, longitudinal locations of marks fore and aft referenced to the forward and after perpendiculars or to the nearest frames and vertical reference points. Navigational draft marks should be based on the vessel's lowest vertical projection.

viii) Intact and damage stability calculations supporting the maximum KG or minimum GM curve

PART
3

CHAPTER 3 Subdivision and Stability

APPENDIX 2 Damage Stability Requirements for Offshore Supply Vessels

1 General

Taking into account, as initial conditions before flooding, all of the standard loading conditions as referred to in 3-3-A1/7 and the damage assumptions in 3-3-A2/3, the vessel is to comply with the damage stability criteria as specified in 3-3-A2/5.

3 Damage Assumptions *(1 July 2013)*

The following damage assumptions are to be applied:

i) Damage is to be assumed to occur anywhere in the vessel's length between transverse watertight bulkheads. The longitudinal extent of damage is:

a) For a vessel the keel of which is laid or which is at a similar stage of construction* before 22 November 2012:

with length (L_f**) not greater than 43 m (141 ft): 10% of L_f; and

with length (L_f) greater than 43 m (141 ft): 3 m (10 ft) plus 3% of L_f;

b) For a vessel the keel of which is laid or which is at a similar stage of construction on or after 22 November 2012:

with length (L_f) not greater than 43 m (141 ft): 10% of L_f;

with length (L_f) greater than 43 m (141 ft) and less than 80 m (262.5 ft): 3 m (10 ft) plus 3% of L_f; and

with length (L_f) from 80 m (262.5 ft) to 100 m (328 ft): $1/3L_f^{2/3}$;

* A similar stage of construction means the stage at which:

1 construction identifiable with a specific ship begins; and

2 assembly of that ship has commenced comprising at least 50 tonnes (49 Long tons) or one per cent of the estimated mass of all structural material, whichever is less.

** L_f is the freeboard length, as defined in 3-1-1/3.3.

ii) The vertical extent of damage is to be assumed from the underside of the cargo deck, or the continuation thereof, for the full depth of the vessel.

iii) The transverse extent of damage is:

a) For a vessel the keel of which is laid or which is at a similar stage of construction before 22 November 2012:

760 mm (30 in.) measured inboard from the side of the vessel perpendicularly to the centerline at the level of the summer load waterline;

b) For a vessel the keel of which is laid or which is at a similar stage of construction on or after 22 November 2012:

with length (L_f) less than 80 m (262.5 ft): 760 mm (30 in.); and

with length (L_f) from 80 m to 100 m (262.5 ft to 328 ft): B/20, but not less than 760 mm (30 in.);

Notes: 1 *(1 July 2013)* For a vessel the keel of which is laid or which is at a similar stage of construction:

1.1 Before 22 November 2012:

A transverse watertight bulkhead extending from the vessel's side to a distance inboard of 760 mm (30 in.) or more at the level of the summer load line joining longitudinal watertight bulkheads is to be considered as a transverse watertight bulkhead for the purpose of the damage calculations.

1.2 On or after 22 November 2012:

For a vessel with length (L_f) less than 80 m (262.5 ft), a transverse watertight bulkhead extending from the vessel's side to a distance inboard of 760 mm (30 in.) or more at the level of the summer load line joining longitudinal watertight bulkheads is to be considered as a transverse watertight bulkhead for the purpose of the damage calculations. For a vessel with length (L_f) from 80 m to 100 m (262.5 ft to 328 ft), a transverse watertight bulkhead extending from the vessel's side to a distance inboard of B/20 or more but not less than 760 mm (30 in.) at the level of the summer load line joining longitudinal watertight bulkheads is to be considered as a transverse watertight bulkhead for the purpose of the damage calculations.

2 If pipes, ducts or tunnels are situated within the assumed extent of damage, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed to be floodable for each case of damage.

3 If damage of a lesser extent than that specified in 3-3-A2/3i), 3-3-A2/3ii), and 3-3-A2/3iii) results in a more severe condition, such lesser extent is to be assumed.

4 Where a transverse watertight bulkhead is located within the transverse extent of assumed damage and is stepped in way of a double bottom or side tank by more than 3.05 m (10 ft), the double bottom or side tanks adjacent to the stepped portion of the transverse watertight bulkhead is to be considered as flooded simultaneously.

5 If the distance between adjacent transverse watertight bulkheads or the distance between the transverse planes passing through the nearest stepped portions of the bulkheads is less than the longitudinal extent of damage given in *i)*, only one of these bulkheads should be regarded as effective.

6 The forecastle space need not be assumed damaged if the continuation of the cargo deck forward is capable of being secured watertight.

7 For a vessel operating in well stimulation service, the assumed damage occurs anywhere in the vessel's length at any transverse watertight bulkhead.

5 Criteria

The following damage stability criteria are to be satisfied:

i) The final waterline, taking into account sinkage, heel and trim, is to be below the lower edge of any opening through which progressive flooding may take place. Such openings are to include air pipes and those openings which are capable of being closed by means of weather-tight doors or hatch covers and exclude those openings closed by means of watertight manhole covers and flush scuttles, small watertight cargo tank hatch covers which maintain the high integrity of the deck, remotely operated watertight sliding doors, and side scuttles of the non-opening type.

ii) In the final stage of flooding, the angle of heel due to unsymmetrical flooding is not to exceed 15°. This angle may be increased up to 17° if no deck immersion occurs.

iii) The stability in the final stage of flooding is to be investigated and may be regarded as sufficient if the righting lever curve has a positive range of at least 20° beyond the position of equilibrium in association with a maximum residual righting lever of at least 100 mm (3.9 in.) within this range. Unprotected openings are not to become immersed at an angle of heel within the prescribed minimum range of residual stability unless the space in question has been included as a floodable space in calculations for damage stability. Within this range, immersion of any of the openings referred to in 3-3-A2/5i) and any other openings capable of being closed weather-tight may be authorized.

iv) The vessel shall maintain sufficient stability during intermediate stages of flooding.

7 Permeability

The permeability** of compartments assumed to be damaged is to be as follows:

Spaces	*Permeability*
Appropriated to stores	0.60
Occupied by accommodation	0.95
Occupied by machinery	0.85
Void spaces	0.95
Intended for dry cargo	0.95

The permeability of tanks is to be consistent with the amount of liquid carried, as shown in the loading conditions specified in 3-3-A2/1. The permeability of empty tanks is to be assumed to be not less than 0.95.

** Permeability of a space means the ratio of the volume within that space, which should be assumed to be occupied by water to the total volume of that space. The total volume should be calculated to the molded lines and no reduction in total volume should be taken into account due to structural members (i.e., stiffeners, etc.).

9 Free Surface

The free surface effects are to be calculated in accordance with 3-3-A1/9. Additionally, the free surface effect of a damaged non-consumable tank may be omitted from the damage stability calculations.

11 Subdivision

The machinery spaces, working, cargo and accommodation spaces in the hull are to be separated by bulkheads made watertight up to the freeboard deck.

A collision bulkhead is to be fitted forward, complying with the relevant provisions of 3-2-9/3.1 applicable to cargo ships. In vessels having a long superstructure at the fore end, the collision bulkhead is to extend weather-tight up to the superstructure deck.

An aft peak bulkhead is to be fitted and made watertight up to the freeboard deck. The aft peak bulkhead may be stepped below the freeboard deck provided the degree of safety of the vessel with regard to subdivision is not diminished.

Arrangements made to maintain the watertight integrity of the watertight subdivisions in way of openings therein are to comply with the relevant provisions of Section 3-2-9 applicable to cargo ships.

PART
3

CHAPTER 3 Subdivision and Stability

APPENDIX 3 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.

The approved stability software is not a substitute for the approved stability information, and is used as a supplement to the approved stability information to facilitate stability calculations.

1.3 Design

The input/output information is to be easily comparable with the approved stability information so as to avoid confusion and possible misinterpretation by the operator relative to the approved stability information.

An operation manual is to be provided for the onboard computer stability software.

The language in which the stability information is displayed and printed out, and in which the operation manual is written is to be the same as used in the vessel's approved stability information. The primary language is to be English.

The onboard computer for stability calculations is to be vessel specific equipment and the results of the calculations are to be 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 submitted for re-approval.

3 Calculation Systems

This Appendix covers either system, a passive system that requires manual data entry or an active system, which replaces the manual with the automatic entry with sensors reading and entering the contents of tanks, etc., provided the active system is in the off-line operation mode. However, an integrated system, which controls or initiates actions based on the sensor-supplied inputs is not within the scope of this Appendix.

5 Types of Stability Software *(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
- 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 requirements 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-A3/9.1 or 3-3-A3/9.3. 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-A3/9.1 or 3-3-A3/9.3, 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-A3/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-A3/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-A3/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-A3/11.5),
- 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-A3/7.

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-A3/15). 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 lightship weight and center of gravity derived from the most recently approved inclining experiment or lightweight 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), and 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 *(2018)*

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 is to 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 load condition. The results are to be verified as identical to the results in the approved copy of the test conditions.

17 Periodical Testing *(2018)*

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-A3/15.

19 Other Requirements *(2018)*

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 Fire Protection, Detection, and Extinction 343

1 General 343
- 1.1 SOLAS Application 343
- 1.3 Regulation 343
- 1.5 Definitions 343
- 1.7 Materials Containing Asbestos 343

3 Offshore Support Vessels 343

5 Review Procedures 343
- 5.1 Administration Review 343
- 5.3 ABS Review 343

7 Fiber Reinforced Plastic (FRP) Gratings 344

APPENDIX 1 Fiber Reinforced Plastic (FRP) Gratings 345

1 General 345

3 FRP Grating Material Systems 345

5 Fire Test Requirements 345
- 5.1 Structural Fire Integrity 345
- 5.3 Flame Spread 346
- 5.5 Smoke Generation 346

7 Structural Fire Integrity Test Procedures 346

9 Structural Fire Integrity Matrix 346

11 Other Authorized Uses 347

TABLE 1 Structural Fire Integrity Matrix 346

PART
3

CHAPTER 4 Fire Safety Measures

SECTION 1 Fire Protection, Detection, and Extinction

1 General

1.1 SOLAS Application

For classification purposes, the fire safety measures contained in the International Convention for the Safety of Life at Sea, 1974 (1974 SOLAS) as amended, are applicable to vessels of type, size and service coming under that Convention.

This Chapter does not relax the requirements in other Chapters of these Rules.

1.3 Regulation

Regulation means the regulation contained in 1974 SOLAS, as amended. An abbreviated notation is used, e.g., Regulation II-2/5.2 means Regulation 5.2 of Chapter II-2.

1.5 Definitions

See Regulation II-2/3.

1.7 Materials Containing Asbestos

Installation of materials which contain asbestos is prohibited.

3 Offshore Support Vessels

For offshore support vessels that can be considered as cargo vessels as defined in Regulation II-2/3.7, the relevant requirements in Regulations 4 to 11; Regulation 13; and Regulations 19 and 20, Chapter II-2 of 1974 SOLAS, as amended, are applicable.

Vessels intended to carry hazardous and noxious liquid substances in bulk are to comply with the IMO Resolution A.673(16) as amended by MSC.236(82) requirements *Guidelines for the Transport and Handling of Limited Amounts of Hazardous and Noxious Liquid Substances in Bulk on Offshore Support Vessels* and the governing Administrative Regulations.

5 Review Procedures

5.1 Administration Review

When the vessel is issued a Cargo Ship Safety Equipment Certificate or Cargo Ship Safety 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.

5.3 ABS Review

In all other cases, the required information and plans are to be submitted to ABS for review.

7 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 4-7-1/11.15.

2 If the machinery space does not contain any internal combustion machinery, other oil-burning, oil-heating, or oil-pumping units, fuel oil filling stations, or other potential hydrocarbon fire sources, and has not more than 2.5 kg/m^2 (0.51 lb/ft^2) of combustible storage, gratings of L3 integrity may be used in lieu of L1.

3 If these spaces are normally entered when underway, gratings of L1 integrity are to be required.

4 If these spaces are normally entered when underway, gratings of L3 integrity shall be required.

5 *(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 349

1 General 349
3 Equipment Mass and Size 349
5 Tests 351
7 Anchor Types 351
9 Mooring and Towing Equipment 352
9.1 All Vessels 352
9.3 Mooring Lines 352
9.5 Tow Line 355
9.7 Mooring and Tow Line Construction 355
9.9 Mooring Winches 355
9.11 Mooring and Towing Arrangement 355
11 Windlass Support Structure and Chain Stopper 356
11.1 Support Structure 356
11.3 Trial 358
12 Hawse Pipes 360
13 Securing of the Inboard Ends of Chain Cables 360
14 Securing of Stowed Anchors 360
15 Bollard, Fairlead and Chocks 360
15.1 Shipboard Fittings 360
15.3 Safe Working Load (SWL) and Towing Load (TOW) 361
15.5 Towing and Mooring Arrangements Plan 362
17 Offshore Mooring Chain for Station Keeping 362
17.1 Qualification of Manufacturers 362
17.3 Materials 362
17.5 Design, Manufacture, Testing and Certification of Chain 363

TABLE 1 Equipment for Self-propelled Ocean-going Vessels 364
TABLE 2 Mooring Lines for Self-propelled Ocean-going Vessels with $EN \leq 2000$ 368
TABLE 3 Tow Lines for Self-propelled Ocean-going Vessels 369

FIGURE 1 Effective Heights of Deck Houses 351
FIGURE 2 Direction of Forces and Weight 359
FIGURE 3 Sign Convention 359

PART
3

CHAPTER 5 Equipment

SECTION 1 Anchoring, Mooring and Towing Equipment

1 General *(1 July 2018)*

All vessels are to have a complete equipment of anchors and chains. The symbol Ⓔ placed after the symbols of classification in the *Record*, thus: ✠ **A1** Ⓔ, will signify that the equipment of the vessel is in compliance with the requirements of these Rules, or with requirements corresponding to the service limitation noted in the vessel's classification, which have been specially approved for the particular service. The mass per anchor of bower anchors, given in 3-5-1/Table 1, is for anchors of equal mass. The mass of individual anchors may vary 7% plus or minus from the tabular mass, provided that the combined mass of all anchors is not less than that required for anchors of equal mass.

Cables which are intended to form part of the equipment are not to be used as check chains when the vessel is launched. The inboard ends of the cables of the bower anchors are to be secured to the vessel's structure such, as to be able to be released in the case of distress or emergency (see 3-5-1/13). Two bower anchors and their cables are to be connected and positioned, ready for use. Means are to be provided for stopping each cable as it is paid out, and the windlass should be capable of heaving in either cable. The length of chain cable required by 3-5-1/Table 1 can be equally distributed between the two bower anchors connected and ready for use. Where the chain is arranged such, that one anchor has a longer length for mooring, it is to be verified that the windlass has sufficient capability for heaving in the longer length of chain. Arrangements are to be provided for securing the anchors and stowing the cables. See 3-5-1/14.

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 strength of supporting hull structures in way of shipboard fittings used for mooring operations and towing operations as well as supporting hull structures of winches and capstans at the bow, sides, and stern are to comply with the requirements of 3-2-7/4.

3 Equipment Mass and Size *(1 July 2018)*

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 "Equipment Number" equation is based on an assumed maximum current speed of 2.5 m/s (8.2 ft/s), a maximum wind speed of 25 m/s (49 knots) and a minimum scope of 6, the scope being the ratio of length of chain paid out to the water depth. For vessels with a Rule length greater than 135 m (443 ft), alternatively the required anchoring equipment can be considered applicable to a maximum current speed of 1.54 m/s (4.9 ft/s), a maximum wind speed of 11 m/s (21 knots) and waves with maximum significant height of 2 m (6.6 ft). Anchors and chains are to be in accordance with 3-5-1/Table 1 and the numbers, mass and sizes of these are to be regulated by the equipment number (*EN*) obtained from the following equation:

$$\text{Equipment Number} = k\Delta^{2/3} + mBh + nA$$

where

k = 1.0 (1.0, 1.012)

m = 2 (2, 0.186)

n = 0.1 (0.1, 0.00929)

Δ = molded displacement, as defined in 3-1-1/13.1

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 centerline 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. The height of the hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining h and A except as specified in 3-5-1/9.3 for mooring lines. 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.

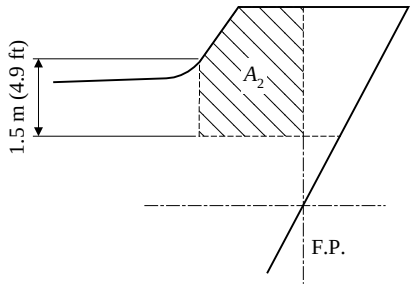
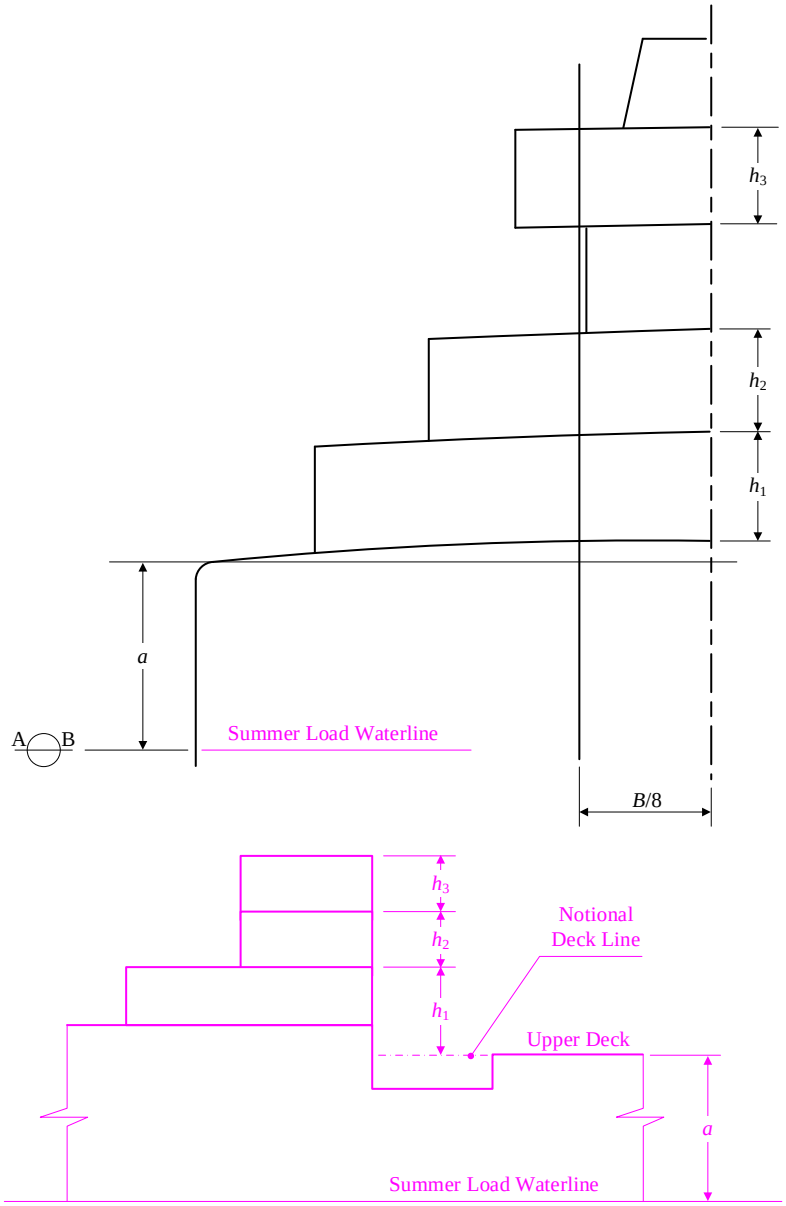


FIGURE 1
Effective Heights of Deck Houses *(1 July 2018)*



5 Tests

Tests 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.

7 Anchor Types

Anchors are to be of the stockless type. The mass of the head of a stockless anchor, including pins and fittings, is not to be less than three-fifths of the total mass of the anchor. Where specifically requested by the Owners, ABS is prepared to consider the use of special types of anchors, which are of proven superior holding capacity. This may result in a mass reduction of up to a maximum of 25% from the mass specified in 3-5-1/Table 1. In such cases, the notation **RW** (reduced weight) will be made in the *Record*.

9 Mooring and Towing Equipment *(1 July 2018)*

9.1 All Vessels

Except as indicated in 3-5-1/15.5, hawsers, towlines, and requirements for associated equipment and arrangements as described in in 3-5-1/9.9 and 3-5-1/9.11 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.

9.3 Mooring Lines

The mooring lines for vessels with Equipment Number EN of less than or equal to 2000 are given in 3-5-1/9.3.1. For other vessels, the mooring lines are given in 3-5-1/9.3.2.

The Equipment Number EN is to be calculated in compliance with 3-5-1/3. Deck cargo as given by the loading manual should be included for the determination of side-projected area *A*.

9.3.1 Mooring Lines for Vessels with EN ≤ 2000

The minimum mooring lines for vessels having an Equipment Number EN of less than or equal to 2000 are given in 3-5-1/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

9.3.2 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 3-5-1/9.3.2(a) and 3-5-1/9.3.2(b), respectively, and is intended as a guide. The length of mooring lines is given by 3-5-1/9.3.3.

The 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):

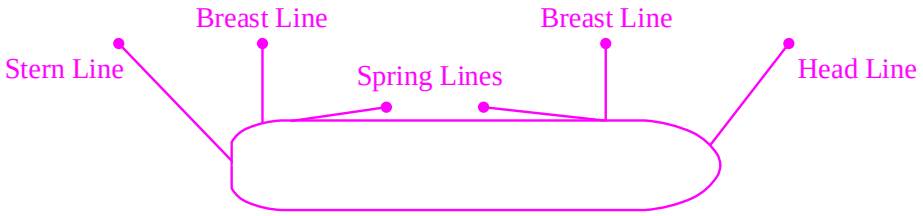
v_w	=	$25.0 - 0.002\,(A_1 - 2000)$ m/s	for passenger vessels, ferries, and car carriers with 2000 $m^2 < A_1 \le 4000\ m^2$
	=	21.0 m/s	for passenger vessels, ferries, and car carriers with $A_1 > 4000\ m^2$
	=	25.0 m/s	for other vessels
	=	$82.0 - 0.00061\,(A_1 - 21528)$ ft/s	for passenger vessels, ferries, and car carriers with 21528 $ft^2 < A_1 \le 43056\ ft^2$
	=	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.



9.3.2(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 3-5-1/9.3.2. 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 3-5-1/9.3.2

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 3-5-1/9.3.2, the minimum breaking strength should be taken as:

$$MBL^* = \left(\frac{v_w^*}{v_w}\right)^2 \cdot MBL$$

9.3.2(b) Number of Mooring Lines. The total number of head, stern, and breast lines (see Note in 3-5-1/9.3.2) should be taken as:

$n = 8.3 \cdot 10^{-4} \cdot A_1 + 6$ for A_1 in m^2

$n = 7.71 \cdot 10^{-5} \cdot A_1 + 6$ for A_1 in ft^2

For oil tankers, chemical tankers, bulk carriers, and ore carriers the total number of head, stern, and breast lines 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 3-5-1/9.3.2) 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.

9.3.3 Length of Mooring Lines

The length of mooring lines for vessels with *EN* of less than or equal to 2000 may be taken from 3-5-1/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.

9.5 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.

9.7 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 3-5-1/9.3 and 3-5-1/9.5, no fiber rope is to be less than 20 mm (0.79 in) in diameter. For polyamide ropes, the 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.

9.9 Mooring Winches

9.9.1

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.

9.9.2

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.

9.9.3

For powered winches on automatic control, the rendering tension that the winch can exert on the mooring line (the reeled first layer) is not to exceed 1.5 times, nor be less than 1.05 times the hauling tension for that particular power setting of the winch. The winch is to be marked with the range of rope strength for which it is designed.

9.11 Mooring and Towing Arrangement

9.11.1 Mooring Arrangement

Mooring lines in the same service (e.g. breast lines, see Note in 3-5-1/9.3.2) should be of the same characteristic in terms of strength and elasticity.

As far as possible, a sufficient number of mooring winches are to be fitted to allow for all mooring lines to be belayed on winches. This allows for an efficient distribution of the load to all mooring lines in the same service and for the mooring lines to shed load before they break. If the mooring arrangement is designed such that mooring lines are partly to be belayed on bitts or bollards, these lines are considered to be not as effective as the mooring lines belayed on winches.

Mooring lines are to have a lead as straight as is practicable from the mooring drum to the fairlead.

At points of change in direction, sufficiently large radii of the contact surface of a rope on a fitting are to be provided to minimize the wear experienced by mooring lines and as recommended by the rope manufacturer for the rope type intended to be used.

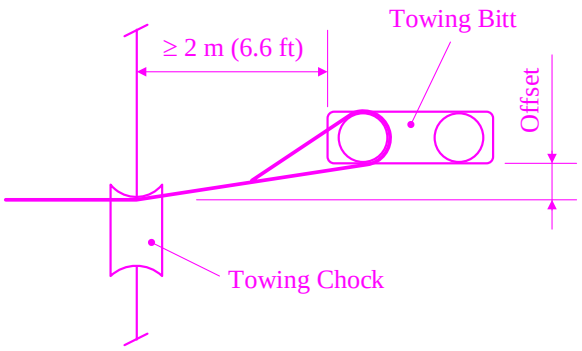
9.11.2 Towing Arrangement

Towing lines, in general, should be led through a closed chock. The use of open fairleads with rollers or closed roller fairleads is to be avoided.

For towing purposes, at least one chock is to be provided close to centerline of the vessel forward and aft. It is also beneficial to provide additional chocks on port and starboard side at the transom and at the bow.

Towing lines are to have a straight lead from the towing bitt or bollard to the chock.

For the purpose of towing, bitts or bollards serving a chock are to be located slightly offset and, as far as practicable, a distance of at least 2 m (6.6 ft) away from the chock, see figure below:



As far as practicable, warping drums are to be positioned not more than 20 m (65.6 ft) away from the chock, measured along the path of the line.

Attention is to be given to the arrangement of the equipment for towing and mooring operations in order to prevent interference of mooring and towing lines as far as practicable. It is beneficial to provide dedicated towing arrangements separate from the mooring equipment.

11 Windlass Support Structure and Chain Stopper

(2014) Construction and installation of all windlasses used for anchoring are to be carried out in accordance with 4-1-1/5 and Section 4-5-1. Where fitted, an independent chain stopper and its components are to be adequate for the load imposed. The arrangements and details of the chain stopper are to be submitted for review.

11.1 Support Structure

The windlass is to be bolted down to a foundation, which is to meet the following load cases and associated criteria.

11.1.1 Operating Loads

11.1.1(a) Load on Windlass Support Structure. The following load is to be applied in the direction of the chain.

With chain stopper not attached to windlass:	0.45 BS
With chain stopper attached to windlass:	0.8 BS
Without chain stopper:	0.8 BS

BS = 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)*.

11.1.1(b) Load on Chain Stopper and Support Structure. A load of 0.8 BS is to be applied in the direction of the chain.

11.1.1(c) Allowable Stress (1 July 2018). The allowable stresses for the structures supporting the windlass and cable 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

11.1.1(d) The net minimum scantlings of the supporting hull structure are to comply with the requirements given in 3-5-1/11.1.1(c). The required gross scantlings are determined according to 3-2-7/4.7.

11.1.2 Sea Loads *(2014)*

For vessels with length, L (as defined in 3-1-1/3), over 80 meters (263 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.

11.1.2(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. Where the cable is stored on the windlass drum, the drum's flange projected area is to be accounted for.
- 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.

11.1.2(b) Forces. Forces in the bolts, chocks and stoppers securing the windlass to the deck are to be calculated. The windlass is supported by N groups of bolts, each containing one or more bolts, see 3-5-1/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, Ltf), acting normal to the shaft axis

P_y = force, kN (tf, Ltf), acting parallel to the shaft axis, either inboard or outboard, whichever gives the greater force in bolt group i

h = shaft height above the windlass mounting, cm (in.)

x_i, y_i = x and y coordinates of bolt group i from the centroid of all N bolt groups, positive in the direction opposite to that of the applied force, cm (in.)

A_i = cross-sectional area of all bolts in group i, cm^2 (in^2)

I_x = $A_i x_i^2$ for N bolt groups

I_y = $A_i y_i^2$ for N bolt groups

R_{si} = static reaction at bolt group i, due to weight of windlass.

ii) *Shear forces.* Aggregated shear forces, F_{xi}, F_{yi}, applied to the respective bolt group, i, of bolts, and the resultant combined force, F_i, may be calculated from:

$$F_{xi} = (P_x - \alpha g M)/N$$

$$F_{yi} = (P_y - \alpha g M)/N$$

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/s^2 (32.2 ft/sec^2)

N = number of groups of bolts

The axial tensile/compressive and lateral forces from the above equations are also to be considered in the design of the supporting structure.

11.1.2(c) Stresses in Bolts. Tensile axial stresses in the individual bolts in each group of bolts i are to be calculated. The horizontal forces, F_{xi} and F_{yi}, are normally to be reacted by shear chocks. Where "fitted" bolts are designed to support these shear forces in one or both directions, the von Misses equivalent stresses in the individual "fitted" bolts are to be calculated and compared to the stress under proof load. Where pourable resins are incorporated in the holding down arrangements, due account is to be taken in the calculations.

11.1.2(d) Allowable 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 for the above deck framing and the hull structure supporting the windlass and chain stopper are as follows:

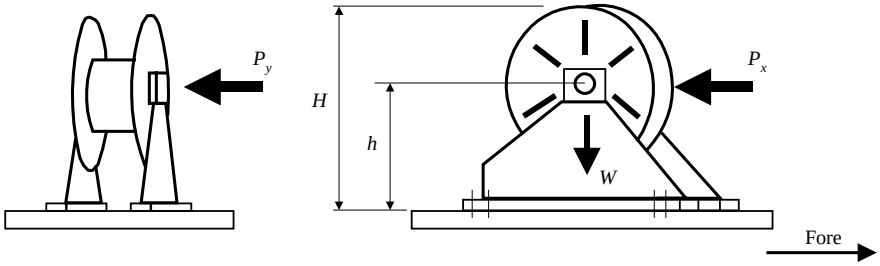
- Normal stress: 100% of the specified minimum yield stress of the material
- Shear stress: 60% of the specified minimum yield stress of the material

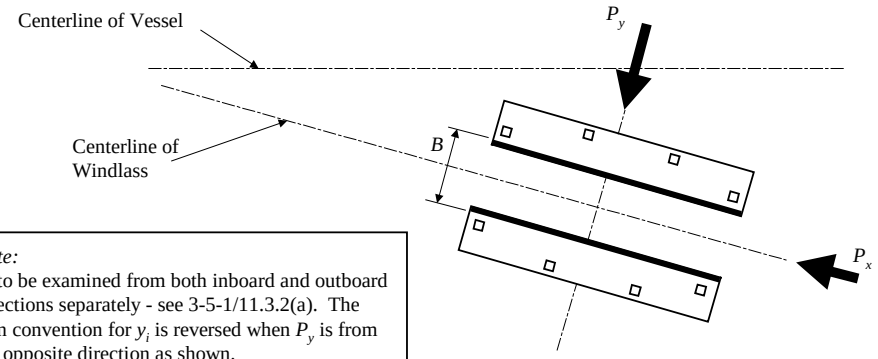
iii) The net minimum scantlings of the supporting hull structure are to comply with the requirements given in 3-5-1/11.1.2(d)ii). The required gross scantlings are determined according to 3-2-7/4.7.

11.3 Trial

See 3-7-2/1.

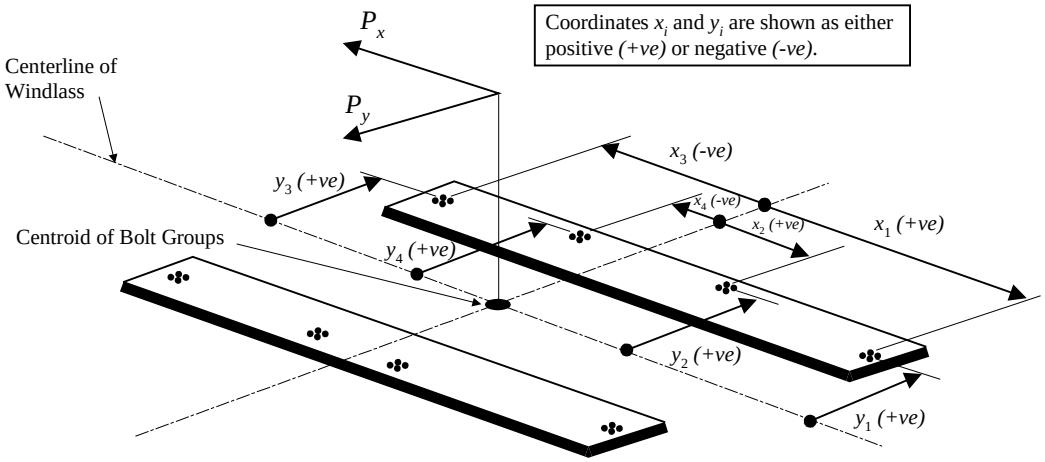
FIGURE 2
Direction of Forces and Weight





Note:
P_y to be examined from both inboard and outboard directions separately - see 3-5-1/11.3.2(a). The sign convention for y_i is reversed when P_y is from the opposite direction as shown.

FIGURE 3
Sign Convention



12 Hawse Pipes

Hawse pipes are to have full rounded flanges and the least possible lead, in order to minimize the nip on the cables. They are to be attached to thick insert plates by continuous welds the size of which are to be in accordance with Section 3-2-19 for the plating thickness and type of joint selected. They are to be hose tested in position for water-tightness with the water pressure of not less than 2.0 bar (2.0 kgf/cm^2, 30 psi). Hawse pipes for stockless anchors are to provide enough clearances to preclude the anchor jamming. The anchors are to be let go aweigh and heaved up to the satisfaction of the Surveyor, proving the smooth setting, flukes' adherence to the pocket surface and no jamming occurrence. Care is to be taken to ensure a fair lead for the chain from the windlass to the hawse pipes and down to the chain pipes of the chain lockers.

13 Securing of the Inboard Ends of Chain Cables *(1 July 2018)*

Arrangements are to be provided for securing the inboard ends of the bower anchor chain cables. The chain cables are to be secured to structures by a fastening able to withstand a force not less than 15% nor more than 30% of the breaking load of the chain cable. The fastening is to be provided with a mean suitable to permit, in case of emergency, an easy slipping of the chain cables to sea, operable from an accessible position outside the chain locker.

14 Securing of Stowed Anchors *(1 July 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.

15 Bollard, Fairlead and Chocks *(1 July 2018)*

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 fittings are specified in 3-2-7/4.

15.1 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 3-5-1/15.1.1 and 3-5-1/15.1.2. For shipboard fittings not in accordance with recognized standard the corrosion addition, t_c, and the wear allowance, t_c, given in 3-2-7/4.7, 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 3-2-7/4.

15.1.1 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 3-2-7/4.3.1).

Mooring bitts (double bollards) are to be chosen for the mooring line attached in figure-of-eight fashion if the industry standard distinguishes between different methods to attach the line (i.e., figure-of-eight or eye splice attachment).

When the shipboard fitting is not selected from an accepted industry standard, the strength of the fitting and of its attachment to the vessel is to be in accordance with requirements related to mooring in 3-2-7/4.3 and 3-2-7/4.5. Mooring bitts (double bollards) are required to resist the loads caused by the mooring line attached in figure-of-eight fashion, see Note. For strength assessment beam theory or finite element analysis using net scantlings is to be applied, as appropriate. Corrosion additions are to be as defined in 3-2-7/4.7.2. A wear down allowance is to be included as defined in 3-2-7/4.7.3. Consideration may be given to accepting load tests as alternative to strength assessment by calculations.

Note: With the line attached to a mooring bitt in the usual way (figure-of-eight fashion), either of the two posts of the mooring bitt can be subjected to a force twice as large as that acting on the mooring line. Disregarding this effect, depending on the applied industry standard and fitting size, overload may occur.

15.1.2 Towing Operations

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 3-2-7/4.3.2(b)],

iii) For fittings intended to be used for, both, normal and other towing operations, the greater of the loads according to *i)* and *ii)*.

Towing bitts (double bollards) may be chosen for the towing line attached with eye splice if the industry standard distinguishes between different methods to attach the line (i.e., figure-of-eight or eye splice attachment).

When the shipboard fitting is not selected from an accepted industry standard, the strength of the fitting and of its attachment to the vessel is to be in accordance with requirements related to towing in 3-2-7/4.3 and 3-2-7/4.5. Towing bitts (double bollards) are required to resist the loads caused by the towing line attached with eye splice. For strength assessment beam theory or finite element analysis using net scantlings is to be applied, as appropriate. Corrosion additions are to be as defined in 3-2-7/4.7.2. A wear down allowance is to be included as defined in 3-2-7/4.7.3. Consideration may be given to accepting load tests as alternative to strength assessment by calculations.

15.3 Safe Working Load (SWL) and Towing Load (TOW)

The requirements on SWL apply for a single post basis (no more than one turn of one cable).

15.3.1 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 3-2-7/4.3.3, the SWL is not to exceed the minimum breaking strength of the mooring line according to 3-5-1/Table 2, see Notes in 3-2-7/4.3.1.

iii) The SWL, in tonnes, of each shipboard fitting is to be marked (by weld bead or equivalent) on the fittings used for mooring. For fittings intended to be used for both, mooring and towing, TOW, in tonnes, according to 3-5-1/15.3.2 is to be marked in addition to SWL.

iv) The above requirements on SWL apply for the use with no more than one mooring line.

v) The towing and mooring arrangements plan mentioned in 3-5-1/15.5 is to define the method of use of mooring lines.

15.3.2 Towing Operations

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 3-2-7/4.3.2(a).

iii) TOW used for other towing operations is not to exceed 80% of the design load according to 3-2-7/4.3.2(b).

iv) For fittings used for both normal and other towing operations, the greater of the safe towing loads according to *ii)* and *iii)* is to be used.

v) For fittings intended to be used for both towing and mooring, the requirements in 3-2-7/4 and 3-5-1/15 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 3-5-1/15.3.1 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 3-5-1/15.5is to define the method of use of towing lines.

15.3.3 Marking and Plan

15.3.3(a) Marking. The SWL of each shipboard fitting is to be permanently marked (by weld bead or equivalent, but not painting alone) on the fittings used for towing/mooring.

15.3.3(b) Plan. The towing and mooring arrangements plan mentioned in 3-5-1/15.5 is to define the method and purpose of use of mooring lines and/or towing lines.

15.5 Towing and Mooring Arrangements Plan

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 3-5-1/9.3.2 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 3-5-1/9.3.2)
  - Maximum current speed acting on bow or stern (±10°)

17 Offshore Mooring Chain for Station Keeping

17.1 Qualification of Manufacturers

Offshore mooring chain is to be manufactured by works approved by ABS, in accordance with 2-2-2/7.1 of the ABS *Rules for Materials and Welding (Part 2)* or in accordance with the ABS *Guide for Certification of Offshore Mooring Chain*.

17.3 Materials

Materials used for the manufacture of offshore mooring chain are to meet the requirements of 2-2-2/7.1 of the ABS *Rules for Materials and Welding (Part 2)* or in accordance with the ABS *Guide for Certification of Offshore Mooring Chain*.

17.5 Design, Manufacture, Testing and Certification of Chain

Offshore mooring chain is to be designed, manufactured, tested and certified in accordance with the requirements of Section 2-2-2 of the ABS *Rules for Materials and Welding (Part 2)* or in accordance with the ABS *Guide for Certification of Offshore Mooring Chain*.

The common link is to be of stud link type grade 2a, 2b or 3a, 3b Anchor Chain, or grade RQ3, RQ3S, RQ4 Mooring Chain.

TABLE 1
Equipment for Self-propelled Ocean-going Vessels *(1 July 2018)*

For intermediate values of equipment number, use equipment complement in sizes and weights given for the lower equipment number in the table.

SI, MKS Units

		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)
Equipment for Self-propelled Ocean-going Vessels *(1 July 2018)*

SI, MKS Units

Equipment Numeral	*Equipment Number**	*Stockless Bower Anchors*		*Chain Cable Stud Link Bower Chain*			
		Number	*Mass per Anchor, kg*	*Length, m*	*Diameter*		
					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	660	102	90	78
U43	3600	2	11100	687.5	105	92	81
U44	3800	2	11700	687.5	107	95	84
U45	4000	2	12300	687.5	111	97	87
U46	4200	2	12900	715	114	100	87
U47	4400	2	13500	715	117	102	90
U48	4600	2	14100	715	120	105	92
U49	4800	2	14700	742.5	122	107	95
U50	5000	2	15400	742.5	124	111	97
U51	5200	2	16100	742.5	127	111	97
U52	5500	2	16900	742.5	130	114	100
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

TABLE 1
Equipment for Self-propelled Ocean-going Vessels *(1 July 2018)*

For intermediate values of equipment number, use equipment complement in sizes and weights given for the lower equipment number in the table.

US Units

		Stockless Bower Anchors		*Chain Cable Stud Link Bower Chain*			
					Diameter		
Equipment Numeral	*Equipment Number**	*Number*	*Mass per Anchor, pounds*	*Length, fathoms*	*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)
Equipment for Self-propelled Ocean-going Vessels *(1 July 2018)*

US Units

Equipment Numeral	*Equipment Number**	*Stockless Bower Anchors*		*Chain Cable Stud Link Bower Chain*			
		Number	*Mass per Anchor, pounds*	*Length, fathoms*	*Diameter*		
					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

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

* 3-5-1/9.3.3 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)	*(ft)*	*(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 371

1 Navigation Bridge Visibility 371

1.1 Field of Vision 371

1.3 Front Windows Arrangements 374

1.5 Unconventional Design 375

3 Offshore Operations Bridge Visibility 375

3.1 Field of Vision 375

3.3 Aft Windows Arrangements 375

5 Side Windows Arrangement 376

FIGURE 1 371

FIGURE 2 372

FIGURE 3 373

FIGURE 4 373

FIGURE 5 373

FIGURE 6 373

FIGURE 7 374

PART
3

CHAPTER 6 Navigation

SECTION 1 Visibility

1 Navigation Bridge Visibility

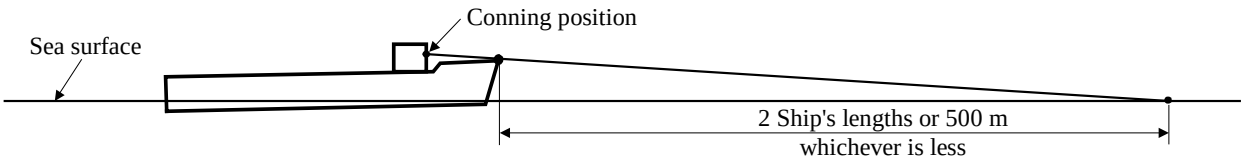
Vessels of not less than 55 m (180 ft) in length overall having the keel laid or in similar stage of construction on or after 1 July 1998, are to meet the following requirements with regard to the visibility from the navigation bridge. unless they are navigating solely the Great Lakes of North America and their connecting and tributary waters as far east as the lower exit of the St. Lambert Lock at Montreal in the Province of Quebec, Canada. Special consideration will be given to vessels that operate only on domestic or on short, limited, international voyages.

1.1 Field of Vision

1.1.1 Conning Position

1.1.1(a) The view of the sea surface from the conning position is not to be obscured by more than $2L_{OA}$ (Length Overall) or 500 m (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



Notes:

1 A conning position is a place on the bridge with a commanding view and which is used by navigators when commanding, maneuvering and controlling a vessel.

2 Attention is to be paid to the flag Administrations requiring the sea surface view lengths of less than $2L_{OA}$.

1.1.1(b) No blind sector caused by cargo, cargo gear, specialist equipment, support for helicopter deck or other obstructions outside of the wheelhouse forward of the beam which obstructs the view of the sea surface as seen from the conning position is to exceed 10°. The total arc of blind sectors is not to exceed 20°. The clear sectors between blind sectors are to be at least 5°. However, in the view described in 3-6-1/1.1.1(a), each individual blind sector is not to exceed 5°.

1.1.1(c) The horizontal field of vision from the conning position is to extend over an arc of not less than 225°, that is, from right ahead to not less than 22.5° abaft the beam on either side of the vessel. See 3-6-1/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) The vessel's side is to be visible from the bridge wing.

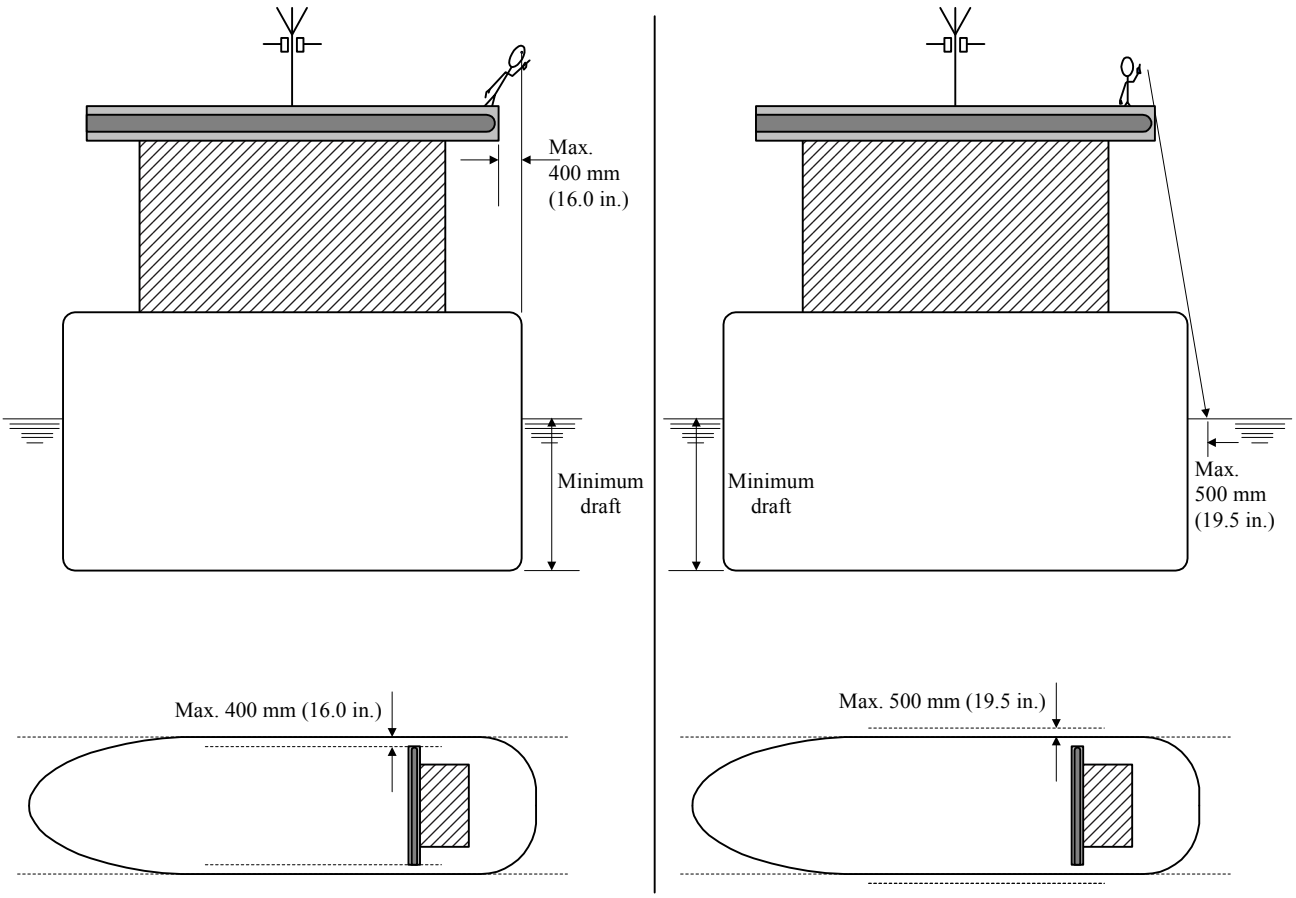
i) The requirements of 3-6-1/1.1.2(b) are accomplished when:

- 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



1.1.3 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 *(2018)*

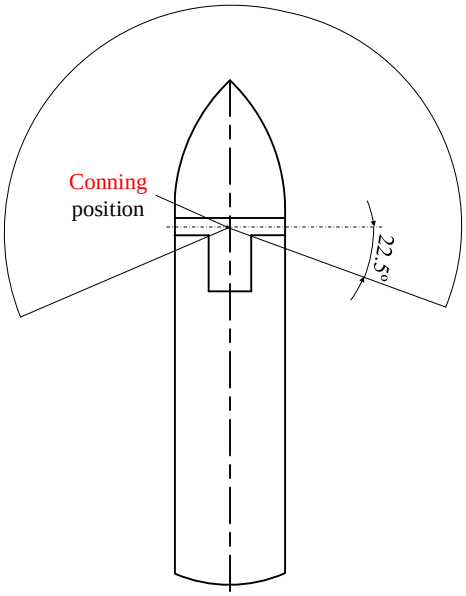


FIGURE 4

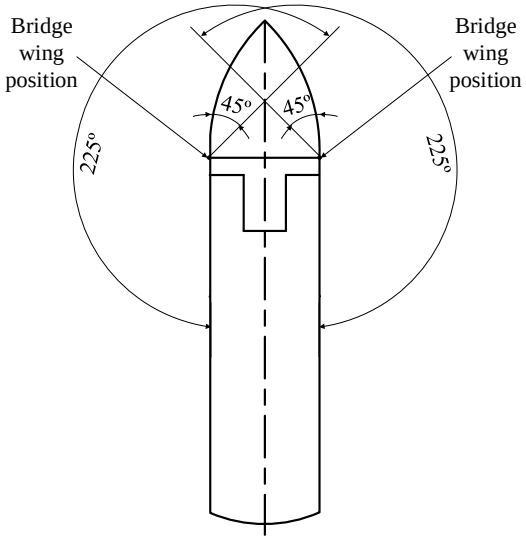


FIGURE 5 *(2018)*

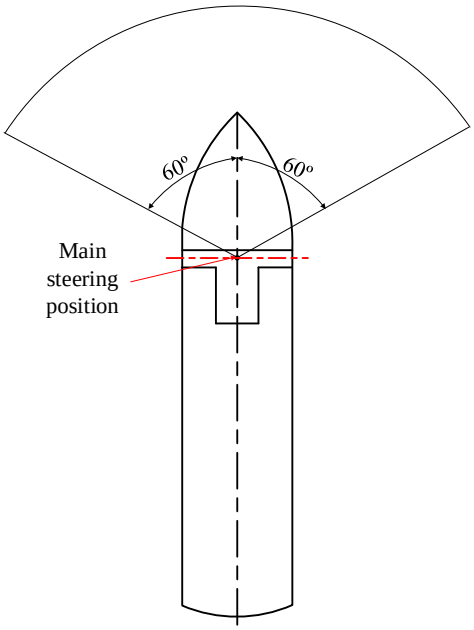
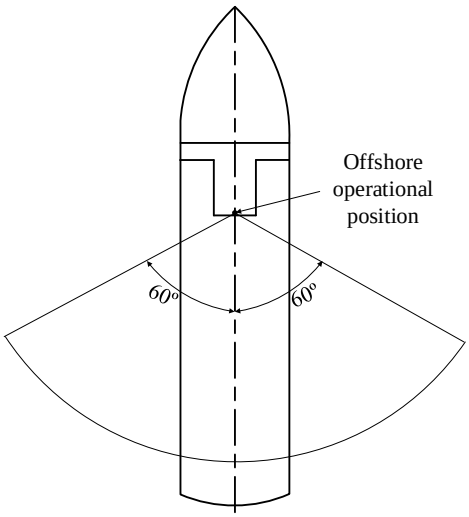


FIGURE 6



1.3 Front Windows Arrangements

Front windows and their arrangements are to meet the following requirements:

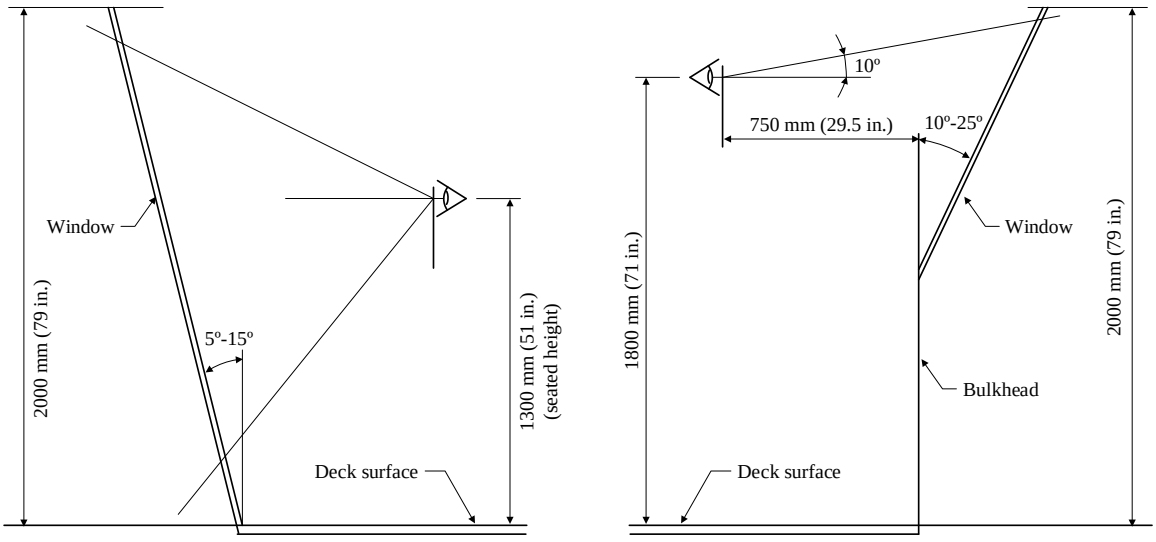
1.3.1 Framing

Framing between navigation bridge front 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 7.

FIGURE 7



Aft Window

Forward Window

1.3.3 Glass

Polarized and tinted windows are not to be fitted.

1.3.4 Clear View

At all times, regardless of the weather conditions, at least two of the navigation bridge front windows are to provide a clear view, and in addition, depending on the bridge configuration, an additional number of windows are to provide a clear view. To this end, the following, or equivalent, is to be provided:

1.3.4(a) Sun Screens. Sunscreens with minimum color distortion. These sunscreens are to be readily removable and not permanently installed.

1.3.4(b) Wipers and Fresh Water Wash Systems. Heavy-duty wipers, preferably provided with an interval function, and fresh water wash systems. These wipers are to be capable of operating independently of each other.

1.3.4(c) De-icing and De-misting Systems. De-icing and de-misting systems to be provided.

1.3.4(d) Fixed Catwalk. A fixed catwalk with guardrails, fitted forward of the bridge windows, to enable manual cleaning of windows in the event of failure of the above systems.

1.3.5 Lower Edge

The height of the lower edge of the navigation bridge front windows above the bridge deck is to be kept as low as possible. In no case is the lower edge to present an obstruction to the forward view as described in this Section.

1.3.6 Upper Edge

The upper edge of the navigation bridge front windows is to allow a forward view of the horizon, for a person with a height of eye of 1800 mm (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 7.

1.5 Unconventional Design

For vessels of unconventional design which cannot comply with the above requirements, arrangements are to be provided to the satisfaction of ABS achieve a level of visibility that is as near as practical to those prescribed in this Section.

3 Offshore Operations Bridge Visibility

All offshore support vessels are to be provided with an unobstructed as possible and practical view abaft from the Offshore Operations Control Area towards the cargo or work decks and machinery or specialist equipment. On supply vessels it is necessary to control both, the station keeping as well as cargo loading/unloading operations. On anchor handling/towing vessels it is necessary to control the heading, position, speed as well as deck machinery engaged for towing and/or anchor handling operations. On other types of offshore support vessels it may be necessary to control the station keeping as well as the specific service equipment installed on work deck. Where direct visual observation of machinery and equipment is unavoidably obstructed, a CCTV system suitable for use in the marine environment would be considered acceptable

3.1 Field of Vision

The view of the cargo or work deck area, including loading/unloading ports on supply vessels, as well as view of the sea surface in close vicinity of the vessel shall not be obstructed. From the Offshore Operations Control Area the horizontal field of vision should extend over an arc from right astern to at least 60° on each side of the vessel see 3-6-1/Figure 6.

3.3 Aft Windows Arrangements

Aft windows and their arrangements are to meet the following requirements:

3.3.1 Framing

Framing between navigation bridge aft windows is to be kept to a minimum to meet the structural strength and stiffness requirements, and is not to be installed immediately in front of any main commanding/maneuvering and controlling positions.

3.3.2 Inclination Angle

The bridge aft windows are to be inclined from a vertical plane top out, at an angle of not less than 5° and not more than 15°, see 3-6-1/Figure 7.

3.3.3 Glass

Polarized and tinted windows are not to be fitted.

3.3.4 Clear View

At all times, regardless of the weather conditions, at least two of the above aft windows are to provide a clear view, as described above. The following, or equivalent, is to be provided as well:

3.3.4(a) Sun Screens. Sunscreens are to be with minimum color distortion; are to be readily removable and are not to be permanently installed.

3.3.4(b) Wipers and Fresh Water Wash Systems. Heavy-duty wipers provided with an interval function and fresh water wash systems, being capable of operating independently of each other.

3.3.4(c) De-icing and De-misting Systems. De-icing and de-misting systems are to be provided.

3.3.4(d) Fixed Catwalk. A fixed catwalk with guardrails, fitted aft of the bridge windows is to be provided, enabling manual cleaning of windows in the event of failure of the above systems.

3.3.5 Impact Protection for Windows

Suitable protection of the aft windows against impact from any cargo being lifted onboard the vessel is recommended.

3.3.6 Lower and Upper Edge

The lower edge of the navigation bridge aft windows is to be kept as close to the bridge deck as practical. The upper edge of the navigation bridge aft windows is to be kept as close to the overhead deck as practical.

5 Side Windows Arrangement

Side windows shall be arranged so, as to minimize blind sectors such as funnels etc. which unavoidably restricts a 360° view of the sea surface from the wheelhouse.

Where windows are installed on bridge wings aligned with ship sides they are to provide the horizontal field of vision as well as visibility of vessel's sides as required in 3-6-1/1.1.2 above, see 3-6-1/Figure 4. Where windows are installed on bridge wings not aligned with ship sides then a fixed catwalk with guardrails is to be installed to enable fulfilling this requirement.

PART
3

CHAPTER 7 Testing, Trials and Surveys During Construction – Hull

CONTENTS

SECTION 1 Tank, Bulkhead, and Rudder Tightness Testing 378

1 General 378

3 Testing Requirements for Ships Built in Compliance with SOLAS 1974 as Amended 378

3.1 Application 378

3.3 Test Types and Definitions 379

3.5 Test Procedures 380

5 Testing Requirements for Ships Not Built in Compliance with SOLAS 1974 as Amended 386

TABLE 1 Testing Requirements for Tanks and Boundaries 383

TABLE 2 Additional Testing Requirements for Tanks of Special Service 385

TABLE 3 Application of Leak Testing, Coating and Provision of Safe Access for Type of Welded Joints 385

SECTION 2 Trials 387

1 Anchor Windlass Trials 387

3 Bilge System Trials 387

5 Steering Trials 387

SECTION 3 Surveys 388

1 Construction Welding and Fabrication 388

3 Hull Castings and Forgings 388

5 Hull Piping 388

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.

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 - 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 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	
22	Azimuthing Pod	Leak	See 3-7-1/3.5.4(c) through 3-7-1/3.5.4(f), as applicable	

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 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 the Tank Holding Spaces	Leak & Structural	The greater of - the top of overflow, or - to 2.4 m (8 ft) above top of tank (2)	Gas such as liquefied Nitrogen. 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.
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	Chemicals such as: Hydrochloric, Hydrofluoric and Acetic Acid, etc. 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 hawse pipe and the chain pipe, and effecting proper stowage of the chain and the anchor. It is to be confirmed that anchors properly seat in the stored position and that chain stoppers function as designed, if fitted. The mean hoisting speed, as specified in 4-5-1/5.1.4, is to be measured and verified, with each anchor and at least 82.5 m (44.5 fathoms) length of chain submerged and hanging free. The braking capacity is to be tested by intermittently paying out and holding the chain cable by means of the application of the brake. Where the available water depth is insufficient, the proposed test method will be specially considered.

3 Bilge System Trials

All elements of the bilge system are to be tested to demonstrate satisfactory pumping operation, including emergency suctions and all controls. Upon completion of the trials, the bilge strainers are to be opened, cleaned and closed up in good order.

5 Steering Trials

Refer to 4-3-4/21.7, as applicable, for technical details of the steering trials.

PART
3

CHAPTER 7 Testing, Trials, and Surveys During Construction – Hull

SECTION 3 Surveys

1 Construction Welding and Fabrication

For surveys of hull construction, refer to the ABS *Guide for Hull Survey for New Construction*.

For surveys of hull construction welding and fabrication, refer to Chapter 4 of the ABS *Rules for Materials and Welding (Part 2)* and the ABS *Guide for Nondestructive Inspection 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 Hull Piping

For surveys in connection with the manufacture and testing of hull piping, refer to Section 4-6-1.