



RULES FOR BUILDING AND CLASSING

STEEL VESSELS 2018

PART 6 SPECIALIZED ITEMS AND SYSTEMS

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

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Rule Change Notice (2018)

The effective date of each technical change since 1993 is shown in parenthesis 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)

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
Part 6	Specialized Items and Systems	To clarify that the requirements in Part 6 are not optional if the items or systems are to be classed. (Incorporates Notice No. 1)
6-1-1/Table 1	Ice Class Notations	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-1/1.1	Application – Polar Class	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-1/5.3	Upper and Lower Ice Waterlines	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/3.1vii) (New)	<No Title>	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/5.1	General	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/5.3	Glancing Impact Load Characteristics	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/Table 1	Class Factors to be Used in 6-1-2/5.5iii)	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/Table 2 (New)	Class Factors to be Used in 6-1-2/5.5iv)	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/5.5iii)	<No Title>	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/5.5iv) (New)	<No Title>	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/5.5.6 (New)	Shape Coefficient	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/5.5.7 (New)	Force	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/5.5.8 (New)	Line Load	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/5.5.9 (New)	Pressure	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/Table 3	Peak Pressure Factors	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
6-1-2/5.13	Hull Area Factors	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/Table 4	Hull Area Factors (AF) for Vessels Intended to Operate Ahead Only	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/Table 5 (New)	Hull Area Factors (AF) for Vessels Intended to Operate Ahead and Astern	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/Table 6 (New)	Hull Area Factors (AF) for Vessels with Additional Notation Ice Breaker and Intended to Operate Ahead Only	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/Table 7 (New)	Hull Area Factors (AF) for Vessels with Additional Notation Ice Breaker and Intended to Operate Ahead and Astern	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/7.3	Shell Plate Thickness to Resist Ice Load	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/9.9	Framing Span	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/9.13	Net Effective Shear Area	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/9.15	Net Effective Plastic Section Modulus	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/11	Framing – Local Frames in Bottom Structures and Transverse Local Frames in Side Structures	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/13	Framing – Longitudinal Local Frames in Side Structures	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/13.1	Plastic Strength	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/13.3	Required Shear Area	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/15.3	Application	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/15.7 (Deleted)	Actual Net Effective Shear Area and Plastic Section Modulus	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/15.9 (Deleted)	Scantling Requirement for Transversely-framed Side Structures	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/15.11 (Deleted)	Scantling Requirement for Large Members of Longitudinally-framed Structures	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/21.3	Corrosion/Abrasion Additions for Shell Plating	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/Table 8	Corrosion/Abrasion Additions for Shell Plating for Vessels Intended to Operate Ahead Only	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/Table 9 (New)	Corrosion/Abrasion Additions for Shell Plating for Vessels Intended to Operate Ahead and Astern	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/23.1	General	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/23.11 (Deleted)	Steel Grades for Inboard Framing Members	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
6-1-2/Table 7 (Deleted)	Steel Grades for Inboard Framing Members Attached to Weather Exposed Plating	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/25.1	Application	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/Table 12	Longitudinal Strength Criteria	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-2/33	Direct Calculations	To align the requirements with IACS UR I1 (Rev. 2 Apr 2016) and IACS UR I2 (Rev. 3 Apr 2016). (Incorporates Notice No. 1)
6-1-4/3 (Deleted)	Ice Breaker Class	To align the requirements with the revisions to Sections 6-1-1 and 6-1-2. (Incorporates Notice No. 1)
6-1-4/Table 1 (Deleted)	Hull Area Factors (AF) for Vessels with Ice Breaker Class Notation	To align the requirements with the revisions to Sections 6-1-1 and 6-1-2. (Incorporates Notice No. 1)
6-1-4/5 (Deleted)	Vessels Intended to Operate Astern	To align the requirements with the revisions to Sections 6-1-1 and 6-1-2. (Incorporates Notice No. 1)
6-1-4/Table 2 (Deleted)	Hull Area Factors (AF) for Vessels Intended to Operate Astern	To align the requirements with the revisions to Sections 6-1-1 and 6-1-2. (Incorporates Notice No. 1)
6-1-4/3.5.2v)	<No Title>	To align the requirements with the revisions to Sections 6-1-1 and 6-1-2. (Incorporates Notice No. 1)
6-1-4/5.1	Struts	To align the requirements with the revisions to Sections 6-1-1 and 6-1-2. (Incorporates Notice No. 1)
6-1-4/11.3	Deck Plating	To align the requirements with the revisions to Sections 6-1-1 and 6-1-2. (Incorporates Notice No. 1)
6-1-4/11.5.3	Scantlings	To align the requirements with the revisions to Sections 6-1-1 and 6-1-2. (Incorporates Notice No. 1)
6-1-4/11.7	Decks with Wide Openings	To align the requirements with the revisions to Sections 6-1-1 and 6-1-2. (Incorporates Notice No. 1)
6-1-4/13.3	Scantlings	To align the requirements with the revisions to Sections 6-1-1 and 6-1-2. (Incorporates Notice No. 1)

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

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
6-1-5/47	Materials for Propellers and Propulsion Shafting	To clarify the requirement in line with ABS practice.
6-1-5/51.3.1	Width and Thickness	To clarify that the calculation result of WT^2 by using the actual designed W and T should not be less than the required WT^2 .
6-1-5/53	Propulsion Shafting Diameters	To clarify that the WT^2 in 6-1-5/53 are the actual designed values.
6-1-5/59 (New)	Tunnel Thrusters	To provide requirements for tunnel thrusters.
6-1-6/28 (New)	Tunnel Thrusters	To provide requirements for tunnel thrusters.

PART 6

Specialized Items and Systems (1 July 2017)

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PART

6

CHAPTER 1 Strengthening for Navigation in Ice

Foreword (2012)

This Chapter provides requirements for optional ice strengthening classes. Sections 6-1-1 through 6-1-3 contain Polar Class ice strengthening requirements, based on IACS UR I1, I2, and I3, for vessels intended for operation in ice-covered Polar waters. Section 6-1-4 contains requirements for Enhanced Polar Class notation. Section 6-1-5 contains general ice strengthening requirements for vessels intended for navigation in first-year ice. Section 6-1-6 represents *1985 Finnish Swedish Ice Class Rules*, as amended.

The requirements in this Section are applicable to vessels of any length and are in addition to those in other Sections of these Rules or *Rules for Building and Classing Steel Vessels Under 90 Meters (295 Feet) in Length*, as appropriate.

Vessels intended for navigation in the Canadian Arctic are to comply with the requirements of the *Canadian Arctic Shipping Pollution Prevention Regulations*. ABS can issue an Arctic Pollution Prevention Certificate when authorized by the Canadian flag administration.

It is the responsibility of the owner to determine which ice class is most suitable for the intended service.

With publication of this edition of the Rules, the IACS Unified Requirements for Polar Class Ships (April 2016) are incorporated into Sections 6-1-1 through 6-1-3, replacing the requirements of the previous ABS general ice classes: **A5** through **A1**. Where the IACS requirements do not have a requirement comparable to an existing ABS requirement, the ABS requirement has been retained in Section 6-1-4 for an optional **Enhanced** notation.

With these changes, the ice strengthening requirements for general ice classes **A0**, **B0**, **C0**, **D0**, and **E0** and for non-self-propelled vessels have been retained in Section 6-1-5.

The attention of designers, owners and operators is directed to the optional *ABS Guide for Vessels Operating in Low Temperature Environments* for considerations not covered in this Chapter. Further, IMO statutory instruments having requirements specific to cold regions operations also is to be considered.

PART

6

CHAPTER 1 Strengthening for Navigation in Ice

SECTION 1 Introduction (2012)

1 General

The ice classes are as follows in 6-1-1/Table 1.

TABLE 1
Ice Class Notations⁽²⁾ (1 July 2017)

<i>Polar Class</i> (6-1-1, 6-1-2, 6-1-3)	<i>Polar Class</i> (6-1-1, 6-1-2, 6-1-3)	<i>Polar Class, Enhanced</i> (6-1-4)	<i>First-year Ice Class</i> (6-1-5)	<i>Baltic Class</i> (6-1-6)
PC1	Ice Breaker, PC1	PC1, Enhanced		
PC2	Ice Breaker, PC2	PC2, Enhanced		
PC3	Ice Breaker, PC3	PC3, Enhanced		
PC4	Ice Breaker, PC4	PC4, Enhanced		
PC5	Ice Breaker, PC5	PC5, Enhanced		
PC6	Ice Breaker, PC6	PC6, Enhanced		I AA
PC7	Ice Breaker, PC7	PC7, Enhanced	A0	I A
			B0	I B
			C0	I C
			D0	
			E0	

Notes:

- 1 The shaded ice classes are eligible for **Ice Breaker** class notation.
- 2 (1 July 2017) This table shows the approximate correspondence between different ABS ice class notations. It is not to be interpreted to imply direct equivalencies between ice classes.

1.1 Application – Polar Class (1 July 2017)

- i) The requirements for Polar Class Vessels apply to vessels constructed of steel and intended for independent navigation in ice-infested polar waters.
- ii) Vessels that comply with the requirements of this Section, 6-1-1 and 6-1-2 can be considered for a Polar Class notation as listed in 6-1-1/Table 2. The requirements of these Sections are in addition to the open water requirements of the Rules. If the hull and machinery are constructed such as to comply with the requirements of different Polar Classes, then both the hull and machinery are to be assigned the lower of these classes in the Certificate of Classification. Compliance of the hull or machinery with the requirements of a higher Polar Class is also to be indicated in the Certificate of Classification.
- iii) Vessels requiring ice breaker assistance are to comply with the additional requirements in 6-1-4/17.1.
- iv) Provided all Polar Class Vessel requirements as specified in this Chapter are met, the vessels will be distinguished in the Record by **Ice Class** followed by ice class **PC 7** through **PC 1**, as applicable.

- v) Vessels which are assigned a Polar Class notation and complying with the relevant requirements of Sections 6-1-1, 6-1-2 and 6-1-3 may be given the additional notation **Ice Breaker**. **Ice Breaker** refers to any vessel having an operational profile that includes escort or ice management functions, having powering and dimensions that allow it to undertake aggressive operations in ice-covered waters. These vessels are to be distinguished in the *Record* by the notation **Ice Breaker** followed by an appropriate Ice Class notation in 6-1-1/3.1 (e.g., **A1, Ice Breaker, Ice Class PC3**)
- vi) For vessels which are assigned a Polar Class notation, the hull form and propulsion power are to be such that the ship can operate independently and at continuous speed in a representative ice condition, as defined in 6-1-1/Table 2 for the corresponding Polar Class. For vessels and vessel-shaped units which are intentionally not designed to operate independently in ice, such operational intent or limitations are to be explicitly stated in the Certificate of Classification.
- vii) For vessels which are assigned a Polar Class notation **PC1** through **PC5**, bows with vertical sides, and bulbous bows are generally to be avoided. Bow angles should in general be within the range specified in 6-1-2/5.1v).
- viii) For vessels which are assigned a Polar Class notation **PC6** and **PC7**, and are designed with a bow with vertical sides or bulbous bows, operational limitations (restricted from intentional ramming) in design conditions are to be stated in the Certificate of Classification.

3 Description of Polar Class

3.1 Selection of Polar Classes

The Polar Class (PC) notations and descriptions are given in 6-1-1/Table 2. It is the responsibility of the Owner to select an appropriate Polar Class. The descriptions in 6-1-1/Table 2 are intended to guide owners, designers and administrations in selecting an appropriate Polar Class to match the requirements for the vessel with its intended voyage or service.

The Polar Class notations are used throughout this Chapter to convey the differences between classes with respect to operational capability and strength.

TABLE 2
Polar Class Descriptions (2012)

<i>Polar Class</i>	<i>Ice Description (based on WMO Sea Ice Nomenclature)</i>
PC1	Year-round operation in all Polar waters
PC2	Year-round operation in moderate multi-year ice conditions
PC3	Year-round operation in second-year ice which may include multi-year ice inclusions.
PC4	Year-round operation in thick first-year ice which may include old ice* inclusions
PC5	Year-round operation in medium first-year ice which may include old ice* inclusions
PC6	Summer/autumn operation 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

* Note: "Old ice" means 2nd year ice or multi-year ice.

5 Definitions

5.1 Ice Belt

The ice belt is that reinforced portion of the shell and hull appendages that overlaps the upper and lower ice waterlines and is subject to the design ice loads. The required ice belt overlap extends from 1.5 m below the lower ice waterline to 1.0 m or 1.5 m above the upper ice waterline, depending upon Polar Class. In the bow area, the overlap increases linearly to 2.0 m above the upper ice waterline at the stem. See 6-1-2/Figure 1.

5.3 Upper and Lower Ice Waterlines (*1 July 2017*)

The upper and lower ice waterlines upon which the design of the vessel has been based are to be indicated on the Certificate of Classification. The upper ice waterline (UIWL) is to be defined by the maximum drafts fore, amidships and aft. The lower ice waterline (LIWL) is to be defined by the minimum drafts fore, amidships and aft.

The lower ice waterline is to be determined with due regard to the vessel's ice-going capability in the ballast loading conditions. The propeller is to be fully submerged at the lower ice waterline.

5.5 Displacement

The displacement, D , is the molded displacement in metric tons (long tons) at the upper ice waterline.

5.7 Length

The vessel's length, L , is as defined in 3-1-1/3.1, but measured on the upper ice waterline, in m (ft).

PART

6

CHAPTER 1 Strengthening for Navigation in Ice

SECTION 2 Structural Requirements for Polar Class Vessels (2012)

1 Application

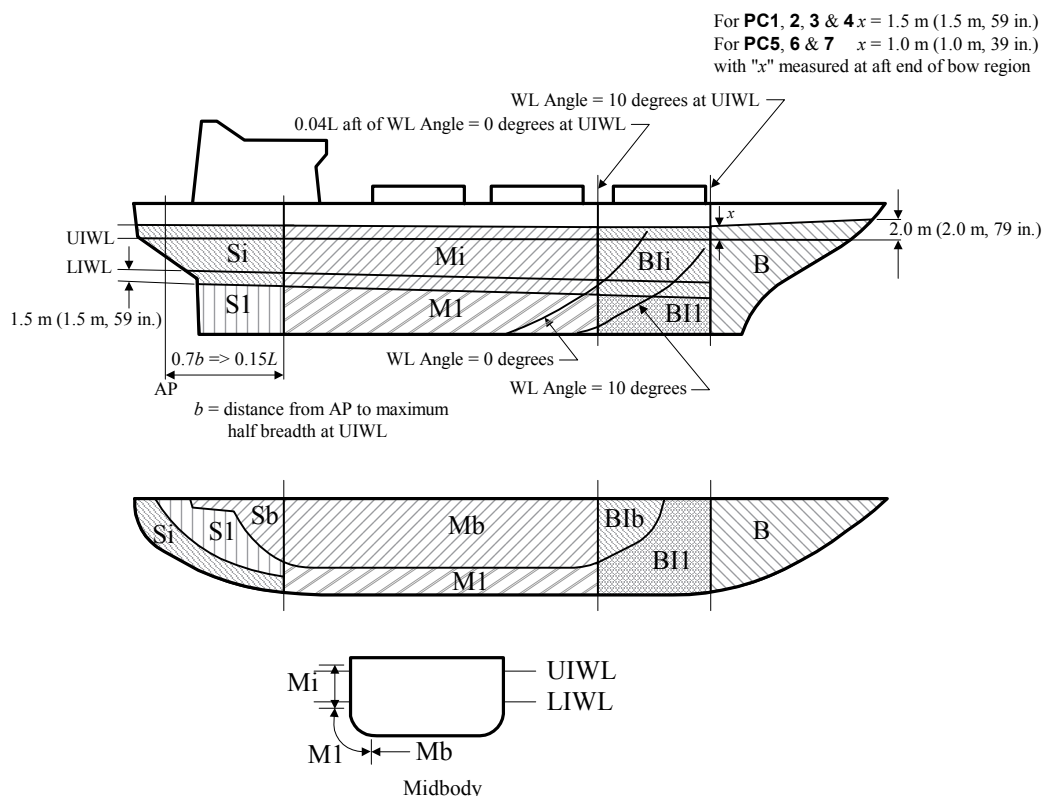
These requirements apply to Polar Class vessels according to 6-1-1/1.1.

3 Hull Areas

3.1 General

- i) The hull of all Polar Class vessels is divided into areas reflecting the magnitude of the loads that are expected to act upon them. In the longitudinal direction, there are four regions: Bow, Bow Intermediate, Midbody and Stern. The Bow Intermediate, Midbody and Stern regions are further divided in the vertical direction into the Bottom, Lower and Icebelt regions. The extent of each Hull Area is illustrated in 6-1-2/Figure 1.
- ii) The upper ice waterline (UIWL) and lower ice waterline (LIWL) are as defined in 6-1-1/5.3.
- iii) 6-1-2/Figure 1 notwithstanding, at no time is the boundary between the Bow and Bow Intermediate regions to be forward of the intersection point of the line of the stem and the vessel baseline.
- iv) 6-1-2/Figure 1 notwithstanding, the aft boundary of the Bow region need not be more than $0.45L$ aft of the forward perpendicular (FP).
- v) The boundary between the bottom and lower regions is to be taken at the point where the shell tangent is inclined 7 degrees from horizontal.
- vi) 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 as prescribed in 6-1-2/3.1vii).
- vii) (1 July 2017) 6-1-2/Figure 1 notwithstanding, if the vessel is assigned the additional notation **Ice Breaker**, the forward boundary of the stern region is to be at least $0.04L$ forward of the section where the parallel ship side at the upper ice waterline (UIWL) ends.

FIGURE 1
Hull Area Extents (2012)



5 Design Ice Loads

5.1 General (1 July 2017)

- A glancing impact on the bow is the design scenario for determining the scantlings required to resist ice loads.
- The design ice load is characterized by an average pressure (P_{avg}) uniformly distributed over a rectangular load patch of height (b) and width (w).
- Within the Bow area of all Polar Class vessels, and within the Bow Intermediate Icebelt area of Polar Class **PC6** and **PC7**, the ice load parameters are functions of the actual bow shape. To determine the ice load parameters (P_{avg} , b and w), it is required to calculate the following ice load characteristics for sub-regions of the bow area; shape coefficient (f_{a_i}), total glancing impact force (F_i), line load (Q_i) and pressure (P_i).
- In other ice-strengthened areas, the ice load parameters (P_{avg} , b_{NonBow} and w_{NonBow}) are determined independently of the hull shape and based on a fixed load patch aspect ratio, $AR = 3.6$.
- Design ice forces calculated according to 6-1-2/5.5iii) are applicable for bow forms where the buttock angle γ at the stem is positive and less than 80° , and the normal frame angle β' at the center of the foremost sub-region, as defined in 6-1-2/5.5i), is greater than 10° .
- Design ice forces calculated according to 6-1-2/5.5iv) are applicable for ships which are assigned the Polar Class **PC6** or **PC7** and have a bow form with vertical sides. This includes bows where the normal frame angles β' at the considered sub-regions, as defined in 6-1-2/5.5i), are between 0° and 10° .
- For ships which are assigned the Polar Class **PC6** or **PC7**, and equipped with bulbous bows, the design ice forces on the bow are to be determined according to 6-1-2/5.5iv). In addition, the design forces are not to be taken less than those given in 6-1-2/5.5iii), assuming $f_a = 0.6$ and $AR = 1.3$.

- viii) For ships with bow forms other than those defined in 6-1-2/5.1v) to 6-1-2/5.1vii), design forces are to be specially considered.
- ix) Vessel structures that are not directly subjected to ice loads may still experience inertial loads of stowed cargo and equipment resulting from ship/ice interaction. These inertial loads, based on the maximum accelerations as given in 6-1-3/13, are to be considered in the design of these structures.

5.3 Glancing Impact Load Characteristics (1 July 2017)

The parameters defining the glancing impact load characteristics are reflected in the Class Factors listed in 6-1-2/Table 1 and 6-1-2/Table 2.

TABLE 1
Class Factors to be Used in 6-1-2/5.5iii) (1 July 2017)

Polar Class	Crushing Failure Class Factor (CF_C)	Flexural Failure Class Factor (CF_F)	Load Patch Dimensions Class Factor (CF_D)	Displacement Class Factor (CF_{DIS})	Longitudinal Strength Class Factor (CF_L)
PC1	17.69 (1804, 1794)	68.60 (6995, 6885)	2.01 (0.122, 0.308)	250 (250, 246)	7.46 (753, 473)
PC2	9.89 (1009, 1003)	46.80 (4772, 4697)	1.75 (0.1062, 0.268)	210 (210, 207)	5.46 (551, 346)
PC3	6.06 (618, 614)	21.17 (2159, 2125)	1.53 (0.093, 0.234)	180 (180, 177)	4.17 (421, 264)
PC4	4.50 (459, 456)	13.48 (1375, 1353)	1.42 (0.086, 0.218)	130 (130, 128)	3.15 (318, 200)
PC5	3.10 (316, 314)	9.00 (918, 903)	1.31 (0.080, 0.201)	70 (70, 69)	2.50 (252, 158)
PC6	2.40 (245, 243)	5.49 (560, 551)	1.17 (0.071, 0.179)	40 (40, 39)	2.37 (239, 150)
PC7	1.80 (184, 183)	4.06 (414, 407)	1.11 (0.0673, 0.170)	22 (22, 22)	1.81 (183, 115)

Note on Units: There are 3 system of units employed in this document. The first is SI, as is used in the IACS Unified Requirement. The second is the MKS system, and the third is the US customary units. In the document units and constants will be shown as SI (MKS, US), as for example: MPa (kgf/mm², psi). In many cases the SI and MKS values are the same, but 3 values are always given for complete clarity.

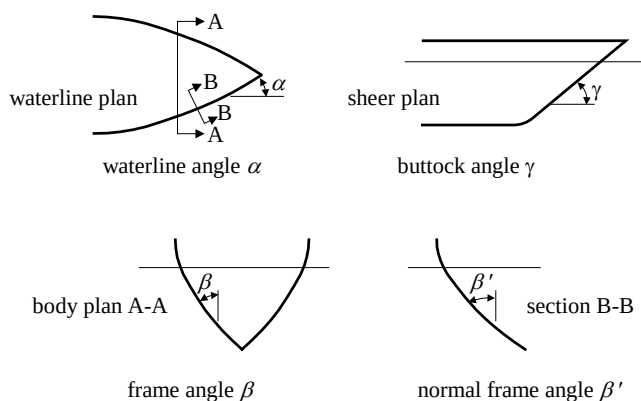
TABLE 2
Class Factors to be Used in 6-1-2/5.5iv) (1 July 2017)

Polar Class	Crushing Failure Class Factor (CF_{CV})	Line Load Class Factor (CF_{QV})	Pressure Class Factor (CF_{PV})
PC6	3.43 (350, 347)	2.82 (1.039, 2.608)	0.65 (0.00497, 7.137)
PC7	2.60 (265, 263)	2.33 (0.859, 2.155)	0.65 (0.00497, 7.137)

5.5 Bow Area

- i) In the Bow area, the force (F), line load (Q), pressure (P) and load patch aspect ratio (AR) associated with the glancing impact load scenario are functions of the hull angles measured at the upper ice waterline (UIWL). The influence of the hull angles is captured through calculation of a bow shape coefficient (f_a). The hull angles are defined in 6-1-2/Figure 2.
- ii) The waterline length of the bow region is generally to be divided into four sub-regions of equal length. The force (F), line load (Q), pressure (P) and load patch aspect ratio (AR) are to be calculated with respect to the mid-length position of each sub-region (each maximum of F , Q and P is to be used in the calculation of the ice load parameters P_{avg} , b and w).
- iii) (1 July 2017) The Bow area load characteristics for bow forms defined in 6-1-2/5.1v) are determined as follows:

FIGURE 2
Definition of Hull Angles (2012)



Note: β' = normal frame angle at upper ice waterline, degrees
 α = upper ice waterline angle, degrees
 γ = buttock angle at upper ice waterline (angle of buttock line measured from horizontal), degrees
 $\tan(\beta) = \tan(\alpha)/\tan(\gamma)$
 $\tan(\beta') = \tan(\beta) \cos(\alpha)$

a) **Shape Coefficient.** Shape coefficient, fa_i , is to be taken as:

$$fa_i = \text{minimum}(fa_{i,1}; fa_{i,2}; fa_{i,3})$$

where

$$fa_{i,1} = [0.097 - 0.68 (x/L - 0.15)^2] \cdot \alpha_i / (\beta'_i)^{0.5}$$

$$fa_{i,2} = 1.2 \cdot CF_F / (\sin(\beta'_i) \cdot CF_C \cdot D^{0.64})$$

$$fa_{i,3} = 0.60$$

i = sub-region considered

L = vessel length as defined in 6-1-1/5.7, in m (m, ft)

x = distance from the forward perpendicular (FP) to station under consideration, in m (m, ft)

α = waterline angle, in degrees, see 6-1-2/Figure. 2

β = normal frame angle, in degrees, see 6-1-2/Figure 2

D = vessel displacement, in kt (kt, kLt), not to be taken less than 5 kt (5 kt, 5 kLt) See 6-1-1/5.5

CF_C = Crushing Failure Class Factor from 6-1-2/Table 1

CF_F = Flexural Failure Class Factor from 6-1-2/Table 1

b) **Force.** Force, F , in MN (tf, Ltf) is to be taken as:

$$F_i = fa_i \cdot CF_C \cdot D^{0.64}$$

where

i = sub-region considered

fa_i = shape coefficient of sub-region i

CF_C = Crushing Failure Class Factor from 6-1-2/Table 1

D = vessel displacement, in kt (kt, kLt), not to be taken less than 5 kt (5 kt, 4.9 kLt)

- c) *Load Patch Aspect Ratio.* Load patch aspect ratio, AR , is to be taken as:

$$AR_i = 7.46 \cdot \sin(\beta'_i) \geq 1.3$$

where

i = sub-region considered

β'_i = normal frame angle of sub-region i , in degrees

- d) *Line Load.* Line load, Q , in MN/m (tf/cm, Ltf/in) is to be taken as:

$$Q_i = F_i^{0.61} \cdot CF_D / AR_i^{0.35}$$

where

i = sub-region considered

F_i = force of sub-region i , in MN (tf, Ltf)

CF_D = Load Patch Dimensions Class Factor from 6-1-2/Table 1

AR_i = load patch aspect ratio of sub-region i

- e) *Pressure.* Pressure, P , in MPa (kgf/mm², psi) is to be taken as:

$$P_i = c_1 \cdot F_i^{0.22} \cdot CF_D^2 \cdot AR_i^{0.3}$$

where

i = sub-region considered

F_i = force of sub-region i , in MN (tf, Ltf)

CF_D = Load Patch Dimensions Class Factor from 6-1-2/Table 1

AR_i = load patch aspect ratio of sub-region i

c_1 = 1 (10, 2240)

- iv) (1 July 2017) The Bow area load characteristics for bow forms defined in 6-1-2/5.1vi) are determined as follows:

- a) *Shape Coefficient*

$$fa_i = \alpha_i / 30$$

where

i = sub-region considered

α_i = waterline angle, in degrees, see 6-1-2/Figure 2

- b) *Force.* Force, F , in MN (tf, Ltf) is to be taken as:

$$F_i = fa_i \cdot CF_{CV} \cdot D^{0.47}$$

where

i = sub-region considered

fa_i = shape coefficient of sub-region i

CF_{CV} = Crushing Failure Class Factor from 6-1-2/Table 2

D = vessel displacement, in kt (kt, kLt), not to be taken less than 5 kt (5 kt, 4.9 kLt)

c) *Line Load.* Line load, Q , in MN/m (tf/cm, Ltf/in) is to be taken as:

$$Q_i = F_i^{0.22} \cdot CF_{QV}$$

where

i = sub-region considered

F_i = force of sub-region i , in MN (tf, Ltf)

CF_{QV} = Load Patch Dimensions Class Factor from 6-1-2/Table 2

d) *Pressure.* Pressure, P , in MPa (kgf/mm², psi) is to be taken as:

$$P_i = F_i^{0.56} \cdot CF_{PV}$$

where

i = sub-region considered

F_i = force of sub-region i , in MN (tf, Ltf)

CF_{PV} = Pressure Class Factor from 6-1-2/Table 2

5.7 Hull Areas Other Than the Bow

In the hull areas other than the bow, the force (F_{NonBow}) and line load (Q_{NonBow}) used in the determination of the load patch dimensions (b_{NonBow} , w_{NonBow}) and design pressure (P_{avg}) are determined as follows:

5.7.1 Force

Force, F_{NonBow} , in MN (tf, Ltf) is to be taken as:

$$F_{NonBow} = 0.36 \cdot CF_C \cdot DF$$

where

CF_C = Crushing Force Class Factor from 6-1-2/Table 1

DF = vessel displacement factor

$$= D^{0.64} \quad \text{if } D \leq CF_{DIS}$$

$$= CF_{DIS}^{0.64} + 0.10 (D - CF_{DIS}) \quad \text{if } D > CF_{DIS}$$

D = vessel displacement, in kt (kt, kLt), not to be taken less than 10 kt (10 kt, 9.8 kLt). See 6-1-1/5.5

CF_{DIS} = Displacement Class Factor from 6-1-2/Table 1

5.7.2 Line Load

Line Load, Q_{NonBow} , in MN/m (tf/cm, Ltf/in) is to be taken as:

$$Q_{NonBow} = 0.639 \cdot F_{NonBow}^{0.61} \cdot CF_D$$

where

F_{NonBow} = force from 6-1-2/5.7.1, in MN (tf, Ltf)

CF_D = Load Patch Dimensions Class Factor from 6-1-2/Table 1

5.9 Design Load Patch

5.9.1 Bow Area

In the Bow area, and the Bow Intermediate Ice belt area for vessels with class notation **PC6** and **PC7**, the design load patch has dimensions of width, w_{Bow} , and height, b_{Bow} , expressed in m (cm, in.) and defined as follows:

$$i) \quad w_{Bow} = F_{Bow} / Q_{Bow}$$

$$ii) \quad b_{Bow} = c_1 Q_{Bow} / P_{Bow}$$

where

$$F_{Bow} = \text{maximum } F_i \text{ in the Bow area, in MN (tf, Ltf)}$$

$$Q_{Bow} = \text{maximum } Q_i \text{ in the Bow area, in MN/m (tf/cm, Ltf/in)}$$

$$P_{Bow} = \text{maximum } P_i \text{ in the Bow area, in MPa (kgf/mm}^2\text{, psi)}$$

$$c_1 = 1 \text{ (10, 2240)}$$

5.9.2 Other Hull Areas

In hull areas other than those covered by 6-1-2/5.9.1, the design load patch has dimensions of width, w_{NonBow} , and height, b_{NonBow} , expressed in m (cm, in.) and defined as follows:

$$i) \quad w_{NonBow} = F_{NonBow} / Q_{NonBow}$$

$$ii) \quad b_{NonBow} = w_{NonBow} / 3.6$$

where

$$F_{NonBow} = \text{force determined using 6-1-2/5.7.1, in MN (tf, Ltf)}$$

$$Q_{NonBow} = \text{line load determined using 6-1-2/5.7.2, in MN/m (tf/cm, Ltf/in)}$$

5.11 Pressure within the Design Load Patch

5.11.1 Average Pressure

The average pressure, P_{avg} , in MPa (kgf/mm², psi) within a design load patch is determined as follows:

$$P_{avg} = c_1 F / (b \cdot w)$$

where

$$F = F_{Bow} \text{ or } F_{NonBow} \text{ as appropriate for the hull area under consideration, in MN (tf, Ltf)}$$

$$b = b_{Bow} \text{ or } b_{NonBow} \text{ as appropriate for the hull area under consideration, in m (cm, in.)}$$

$$w = w_{Bow} \text{ or } w_{NonBow} \text{ as appropriate for the hull area under consideration, in m (cm, in.)}$$

$$c_1 = 1 \text{ (10, 2240)}$$

5.11.2 Areas of Higher, Concentrated Pressure

Areas of higher, concentrated pressure exist within the load patch. In general, smaller areas have higher local pressures. Accordingly, the peak pressure factors listed in 6-1-2/Table 3 are used to account for the pressure concentration on localized structural members.

TABLE 3
Peak Pressure Factors (1 July 2017)

Structural Member		Peak Pressure Factor (PPF _i)
Plating	Transversely Framed	$PPF_p = (1.8 - s/c_2) \geq 1.2$
	Longitudinally Framed	$PPF_p = (2.2 - 1.2 \cdot s/c_2) \geq 1.5$
Frames in Transverse Framing Systems	With Load Distributing Stringers	$PPF_t = (1.6 - s/c_2) \geq 1.0$
	With No Load Distributing Stringers	$PPF_t = (1.8 - s/c_2) \geq 1.2$
Frames in bottom structures		$PPF_s = 1.0$
Load Carrying Stringers Side and Bottom Longitudinals Web Frames		$PPF_s = 1.0$, if $S_w \geq 0.5 \cdot w$ $PPF_s = 2.0 - 2.0 \cdot S_w/w$, if $S_w < (0.5 \cdot w)$
where s = frame or longitudinal spacing, in m (m, in.) c_2 = 1 (1, 39.4) S_w = web frame spacing, in m (cm, in.) w = ice load patch width, in m (cm, in.)		

5.13 Hull Area Factors (1 July 2017)

- Associated with each hull area is an Area Factor that reflects the relative magnitude of the load expected in that area. The Area Factors (AF) for each hull area for Polar Class vessels are listed in 6-1-2/Table 4 and 6-1-2/Table 5. For ships assigned the additional notation, **Ice Breaker**, the Area Factors (AF) for each hull area are listed in 6-1-2/Table 6 and 6-1-2/Table 7.
- In the event that a structural member spans across the boundary of a hull area, the largest hull area factor is to be used in the scantling determination of the member.
- Due to their increased maneuverability, vessels having propulsion arrangements with azimuth thruster(s) or "podded" propellers are to have specially considered Stern Icebelt (S_i) and Stern Lower (S_l) hull area factors. The adjusted hull area factors are listed in 6-1-2/Table 5 and 6-1-2/Table 7 for Polar Class vessels and ships assigned with the additional notation **Ice Breaker**, respectively.

TABLE 4
Hull Area Factors (AF) for Vessels Intended to Operate Ahead Only (1 July 2017)

Hull Area		Area	Polar Class						
			PC1	PC2	PC3	PC4	PC5	PC6	PC7
Bow (B)	All	B	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bow Intermediate (BI)	Icebelt	BI _i	0.90	0.85	0.85	0.80	0.80	1.00*	1.00*
	Lower	BI _l	0.70	0.65	0.65	0.60	0.55	0.55	0.50
	Bottom	BI _b	0.55	0.50	0.45	0.40	0.35	0.30	0.25
Midbody (M)	Icebelt	M _i	0.70	0.65	0.55	0.55	0.50	0.45	0.45
	Lower	M _l	0.50	0.45	0.40	0.35	0.30	0.25	0.25
	Bottom	M _b	0.30	0.30	0.25	**	**	**	**
Stern (S)	Icebelt	S _i	0.75	0.70	0.65	0.60	0.50	0.40	0.35
	Lower	S _l	0.45	0.40	0.35	0.30	0.25	0.25	0.25
	Bottom	S _b	0.35	0.30	0.30	0.25	0.15	**	**

Notes:

* See 6-1-2/5.5iii).

** Indicates that strengthening for ice loads is not necessary.

TABLE 5
Hull Area Factors (AF) for Vessels Intended
to Operate Ahead and Astern (1 July 2017)

Hull Area		Area	Polar Class						
			PC1	PC2	PC3	PC4	PC5	PC6	PC7
Bow (B)	All	B	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bow Intermediate (BI)	Icebelt	BI _i	0.90	0.85	0.85	0.80	0.80	1.00*	1.00*
	Lower	BI _ℓ	0.70	0.65	0.65	0.60	0.55	0.55	0.50
	Bottom	BI _b	0.55	0.50	0.45	0.40	0.35	0.30	0.25
Midbody (M)	Icebelt	M _i	0.70	0.65	0.55	0.55	0.50	0.45	0.45
	Lower	M _ℓ	0.50	0.45	0.40	0.35	0.30	0.25	0.25
	Bottom	M _b	0.30	0.30	0.25	**	**	**	**
Stern Intermediate (SI)	Icebelt	SI _i	0.90	0.85	0.85	0.80	0.80	1.00*	1.00*
	Lower	SI _ℓ	0.70	0.65	0.65	0.60	0.55	0.55	0.50
	Bottom	SI _b	0.55	0.50	0.45	0.40	0.35	0.30	0.25
Stern (S)	All	S	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Notes:

* See 6-1-2/5.5iii).

** Indicates that strengthening for ice loads is not necessary.

TABLE 6
Hull Area Factors (AF) for Vessels with Additional Notation Ice Breaker
and Intended to Operate Ahead Only (1 July 2017)

Hull Area		Area	Polar Class						
			PC1	PC2	PC3	PC4	PC5	PC6	PC7
Bow (B)	All	B	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bow Intermediate (BI)	Icebelt	BI _i	0.90	0.85	0.85	0.85	0.85	1.00	1.00
	Lower	BI _ℓ	0.70	0.65	0.65	0.65	0.65	0.65	0.65
	Bottom	BI _b	0.55	0.50	0.45	0.45	0.45	0.45	0.45
Midbody (M)	Icebelt	M _i	0.70	0.65	0.55	0.55	0.55	0.55	0.55
	Lower	M _ℓ	0.50	0.45	0.40	0.40	0.40	0.40	0.40
	Bottom	M _b	0.30	0.30	0.25	0.25	0.25	0.25	0.25
Stern (S)	Icebelt	S _i	0.95	0.90	0.80	0.80	0.80	0.80	0.80
	Lower	S _ℓ	0.55	0.50	0.45	0.45	0.45	0.45	0.45
	Bottom	S _b	0.35	0.30	0.30	0.30	0.30	0.30	0.30

TABLE 7
Hull Area Factors (AF) for Vessels with Additional Notation Ice Breaker
and Intended to Operate Ahead and Astern (1 July 2017)

Hull Area		Area	Polar Class						
			PC1	PC2	PC3	PC4	PC5	PC6	PC7
Bow (B)	All	B	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bow Intermediate (BI)	Icebelt	BI _i	0.90	0.85	0.85	0.85	0.85	1.00	1.00
	Lower	BI _l	0.70	0.65	0.65	0.65	0.65	0.65	0.65
	Bottom	BI _b	0.55	0.50	0.45	0.45	0.45	0.45	0.45
Midbody (M)	Icebelt	M _i	0.70	0.65	0.55	0.55	0.55	0.55	0.55
	Lower	M _l	0.50	0.45	0.40	0.40	0.40	0.40	0.40
	Bottom	M _b	0.30	0.30	0.25	0.25	0.25	0.25	0.25
Stern Intermediate (SI)	Icebelt	SI _i	0.90	0.85	0.85	0.85	0.85	1.00	1.00
	Lower	SI _l	0.70	0.65	0.65	0.65	0.65	0.65	0.65
	Bottom	SI _b	0.55	0.50	0.45	0.45	0.45	0.45	0.45
Stern (S)	All	S	1.00	1.00	1.00	1.00	1.00	1.00	1.00

7 Shell Plate Requirements

7.1 Required Minimum Shell Plate Thickness

The required minimum shell plate thickness, t , expressed in mm (mm, in.), is given by:

$$t = t_{net} + t_s$$

where

t_{net} = plate thickness required to resist ice loads according to 6-1-2/7.3

t_s = corrosion and abrasion allowance according to 6-1-2/21

7.3 Shell Plate Thickness to Resist Ice Load (1 July 2017)

The thickness of shell plating required to resist the design ice load, t_{net} , expressed in mm (mm, in.), depends on the orientation of the framing.

- i) In the case of transversely-framed plating ($\Omega \geq 70$ degrees), including all bottom plating (i.e., plating in hull areas BI_b, M_b and S_b), the net thickness is given by:

$$t_{net} = n_0 \cdot s \cdot [(AF \cdot PPF_p \cdot P_{avg})/\sigma_y]^{0.5} / [1 + c_3 s / (2 \cdot b)]$$

- ii) In the case of longitudinally-framed plating ($\Omega \leq 20$ degrees), when $b \geq s$, the net thickness is given by:

$$t_{net} = n_0 \cdot s \cdot [(AF \cdot PPF_p \cdot P_{avg})/\sigma_y]^{0.5} / [1 + s / (2 \cdot \ell)]$$

- iii) In the case of longitudinally-framed plating ($\Omega \leq 20$ degrees), when $b < s$, the net thickness is given by:

$$t_{net} = n_0 \cdot s \cdot [(AF \cdot PPF_p \cdot P_{avg})/\sigma_y]^{0.5} \cdot [2 \cdot b / (c_3 s) - (b / (c_3 s))^2]^{0.5} / [1 + s / (2 \cdot \ell)]$$

- iv) In the case of obliquely-framed plating ($70 \text{ deg} > \Omega > 20$ degrees), linear interpolation is to be used.

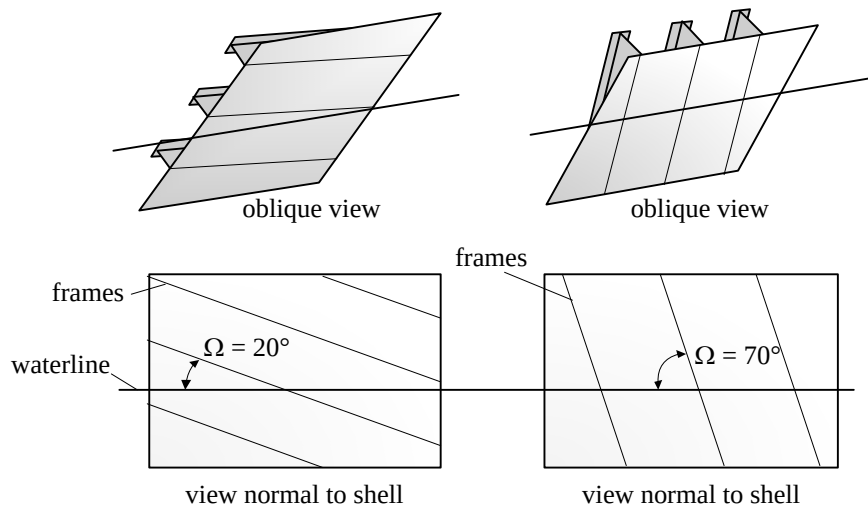
where

$$c_3 = 1 \text{ (100, 1)}$$

$$n_0 = 500 \text{ (500, 0.5)}$$

- Ω = smallest angle between the chord of the waterline and the line of the first level framing as illustrated in 6-1-2/Figure 3, in degrees
- s = transverse frame spacing in transversely-framed vessels or longitudinal frame spacing in longitudinally-framed vessels, in m (m, in.)
- AF = Hull Area Factor from 6-1-2/Table 4, 6-1-2/Table 5, 6-1-2/Table 6, or 6-1-2/Table 7
- PPF_p = Peak Pressure Factor from 6-1-2/Table 3
- P_{avg} = average patch pressure determined by 6-1-2/5.11.1, in MPa (kgf/mm², psi)
- σ_y = minimum upper yield stress of the material, in N/mm² (kgf/mm², psi), but not greater than the lesser of 0.70 of minimum UTS or 450 N/mm² (45.9 kgf/mm², 65880 psi)
- b = height of design load patch, in m (cm, in.), where b is to be taken not greater than $(\ell - s/4)/c_3$ in the case of determination of the net thickness for transversely framed plating, 6-1-2/7.3i)
- ℓ = distance between frame supports in m (m, in.) (i.e., equal to the frame span as given in 6-1-2/9.9), but not reduced for any fitted end brackets, in m (m, in.). When a load-distributing stringer is fitted, the length ℓ need not be taken greater than the distance from the stringer to the most distant frame support.

FIGURE 3
Shell Framing Angle Ω (2012)



7.5 Changes in Plating Thickness

Changes in plating thickness in the transverse direction from the ice belt to the bottom and in the longitudinal direction within the ice belt are to be gradually tapered.

9 Framing – General

9.1 General

Framing members of Polar Class vessels are to be designed to withstand the ice loads defined in 6-1-2/5.

9.3 Application (2014)

The term “framing member” refers to transverse and longitudinal local frames, load-carrying stringers and load-carrying web frames in the areas of the hull exposed to ice pressure, see 6-1-2/Figure 1.

9.5 Fixity

The strength of a framing member is dependent upon the fixity that is provided at its supports. Fixity can be assumed where framing members are either continuous through the support or attached to a supporting section with a connection bracket. In other cases, simple support is to be assumed unless the connection can be demonstrated to provide significant rotational restraint. Fixity is to be ensured at the support of any framing which terminates within an ice-strengthened area.

9.7 Details

The details of framing member intersection with other framing members, including plated structures, as well as the details for securing the ends of framing members at supporting sections, are to be prepared and submitted for review.

9.9 Framing Span (1 July 2017)

The effective span of a framing member is to be determined on the basis of its molded length. If brackets are fitted, the effective span may be reduced provided the bracket is in accordance with 3-2-9/Table 1 and rigidity of the supporting member where the bracket being attached is adequate. Brackets are to be configured to ensure stability in the elastic and post-yield response regions.

9.11 Scantlings

When calculating the section modulus and shear area of a framing member, net thicknesses of the web, flange (if fitted) and attached shell plating are to be used. The shear area of a framing member may include that material contained over the full depth of the member (i.e., web area including portion of flange, if fitted), but excluding attached shell plating.

9.13 Net Effective Shear Area (1 July 2017)

The actual net effective shear area, A_w , in cm^2 (cm^2 , in^2) of a transverse or longitudinal local frame is given by:

$$A_w = h \cdot t_{wn} \cdot \sin \varphi_w / c_4^2$$

where

$$c_4 = 10 \text{ (10, 1)}$$

$$h = \text{height of stiffener, in mm (mm, in.), see 6-1-2/Figure 4}$$

$$t_{wn} = \text{net web thickness, in mm (mm, in.)}$$

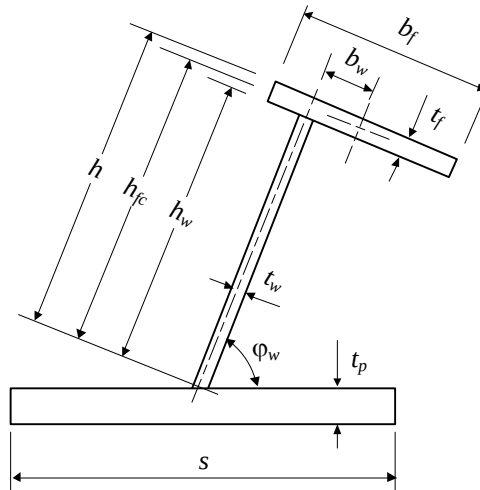
$$= t_w - t_c$$

$$t_w = \text{as-built web thickness, in mm (mm, in.), see 6-1-2/Figure 4}$$

$$t_c = \text{corrosion deduction, in mm (mm, in.), to be subtracted from the web and flange thickness (but not less than } t_s \text{ as required by 6-1-2/21.5)}$$

$$\varphi_w = \text{smallest angle between shell plate and stiffener web, measured at the midspan of the stiffener, see 6-1-2/Figure 4. The angle } \varphi_w \text{ may be taken as 90 degrees provided the smallest angle is not less than 75 degrees.}$$

FIGURE 4
Stiffener Geometry (2014)



9.15 Net Effective Plastic Section Modulus (1 July 2017)

When the net cross-sectional area of the attached plate flange, A_{pn} , exceeds the net cross-sectional area of the frame, A_{fn} , to which the shell plate flange is attached, the actual net effective plastic section modulus, Z_p , in cm^3 (cm^3 , in^3), of a transverse or longitudinal frame is given by:

$$Z_p = A_{fn} t_{pn} / (2 c_4) + \frac{h_w^2 t_{wn} \sin \varphi_w}{2 \cdot c_4^3} + A_{fn} (h_{fc} \sin \varphi_w - b_w \cos \varphi_w) / c_4$$

where

$$\begin{aligned} A_{pn} &= \text{net cross-sectional area of the attached plate flange, in cm}^2 \text{ (cm}^2 \text{, in}^2\text{)} \\ &= \frac{t_{pn} s}{c_4^2} \end{aligned}$$

$$\begin{aligned} A_{fn} &= \text{net cross-sectional area of the local frame, in cm}^2 \text{ (cm}^2 \text{, in}^2\text{)} \\ &= \frac{h_w t_{wn} + b_f t_{fn}}{c_4^2} \end{aligned}$$

$$t_{pn} = \text{fitted net shell plate thickness, in mm (mm, in.), (is to comply with } t_{net} \text{ as required by 6-1-2/7.3)}$$

$$h_w = \text{height of local frame web, in mm (mm, in.), see 6-1-2/Figure 4}$$

$$b_f = \text{width of local frame flange, in mm (mm, in.), see 6-1-2/Figure 4}$$

$$t_{fn} = \text{net thickness of local frame flange, in mm (mm, in.), see 6-1-2/Figure 4}$$

$$\begin{aligned} A_{fn} &= \text{net cross-sectional area of local frame flange, in cm}^2 \text{ (cm}^2 \text{, in}^2\text{)} \\ &= \frac{b_f t_{fn}}{c_4^2} \end{aligned}$$

$$h_{fc} = \text{height of local frame measured to center of the flange area, mm (mm, in.), see 6-1-2/Figure 4}$$

$$= h_w + \frac{t_{fn}}{2}$$

b_w = distance from mid thickness plane of local frame web to the center of the flange area, in mm (mm, in.), see 6-1-2/Figure 4

c_4 , h , t_{wn} , t_c and φ_w are as given in 6-1-2/9.13 and s is as given in 6-1-2/7.3.

When the net cross-sectional area of the local frame, A_{fn} , exceeds the net cross-sectional area of the attached plate flange, A_{pn} , the plastic neutral axis is located a distance z_{na} , in mm (mm, in.), above the attached shell plate, given by:

$$z_{na} = (c_4^2 A_{fn} + h_w t_{wn} - c_4^3 t_{pn} s) / (2 t_{wn})$$

and the net effective plastic section modulus, Z_p , in cm^3 (cm^3 , in^3), of a transverse or longitudinal frame is given by:

$$Z_p = t_{pn} s (z_{na} + t_{pn}/2) \sin \varphi_w + \left[\frac{[(h_w - z_{na})^2 + z_{na}^2] t_{wn} \sin \varphi_w}{2 \cdot c_4^3} + A_{fn} [(h_{fc} - z_{na}) \sin \varphi_w - b_w \cos \varphi_w] / c_4 \right]$$

9.17 Oblique Framing

In the case of oblique framing arrangement ($70 \text{ degrees} > \Omega > 20 \text{ degrees}$, where Ω is defined as given in 6-1-2/7.3), linear interpolation is to be used.

11 Framing – Local Frames in Bottom Structures and Transverse Local Frames in Side Structures (1 July 2017)

11.1 Plastic Strength

The local frames in bottom structures (i.e., hull areas BI_b , M_b and S_b) and transverse local frames in side structures are to be dimensioned such that the combined effects of shear and bending do not exceed the plastic strength of the member. The plastic strength is defined by the magnitude of midspan load that causes the development of a plastic collapse mechanism. For bottom structure the patch load shall be applied with the dimension b parallel with the frame direction.

11.3 Required Shear Area

The actual net effective shear area of the frame, A_w , as defined in 6-1-2/9.13, is to comply with the following condition: $A_w \geq A_t$ in cm^2 (cm^2 , in^2) where:

$$A_t = 100^{n_1} \cdot 0.5 \cdot LL \cdot s \cdot (AF \cdot PPF \cdot P_{avg}) / (0.577 \cdot \sigma_y)$$

where

$$n_1 = 2 \text{ (1, 0)}$$

$$LL = \text{length of loaded portion of span, the lesser of } a \text{ and } b, \text{ in m (cm, in.)}$$

$$a = \text{local frame span as defined in 6-1-2/9.9, in m (cm, in.)}$$

$$b = \text{height of design ice load patch according to 6-1-2/5.9.1ii) or 6-1-2/5.9.2ii), in m (cm, in.)}$$

$$s = \text{spacing of local frame, in m (m, in.)}$$

$$AF = \text{Hull Area Factor from 6-1-2/Table 4 and 6-1-2/Table 5, 6-1-2/Table 6, or 6-1-2/Table 7}$$

$$PPF = \text{Peak Pressure Factor, } PPF_t \text{ or } PPF_s, \text{ as appropriate from 6-1-2/Table 3}$$

$$P_{avg} = \text{average pressure within load patch according to 6-1-2/5.11.1, in MPa (kgf/mm}^2\text{, psi)}$$

$$\sigma_y = \text{minimum upper yield stress of the material, in N/mm}^2\text{ (kgf/mm}^2\text{, psi), but not greater than the lesser of 0.70 of minimum UTS or 450 N/mm}^2\text{ (45.9 kgf/mm}^2\text{, 65880 psi)}$$

11.5 Required Plastic Section Modulus

The actual net effective plastic section modulus of the plate/stiffener combination, Z_p , as defined in 6-1-2/9.15, is to comply with the following condition: $Z_p \geq Z_{pt}$, in cm^3 (cm^3 , in^3) where Z_{pt} is to be the greater calculated on the basis of two load conditions:

- i) Ice load acting at the midspan of the local frame, and
- ii) The ice load acting near a support.

The A_1 parameter, in the equation below, reflects these two conditions.

$$Z_{pt} = 100^{n_2} \cdot LL \cdot Y \cdot s \cdot (AF \cdot PPF \cdot P_{avg}) \cdot a \cdot A_1 / (4 \cdot \sigma_y)$$

where

$$\begin{aligned} n_2 &= 3 \text{ (1, 0)} \\ Y &= 1 - 0.5 \cdot (LL/a) \\ A_1 &= \text{maximum of:} \\ A_{1A} &= 1/(1 + j/2 + k_w \cdot j/2 \cdot [(1 - a_1^2)^{0.5} - 1]) \\ A_{1B} &= [1 - 1/(2 \cdot a_1 \cdot Y)] / (0.275 + 1.44 \cdot k_z^{0.7}) \\ j &= 1 \quad \text{for a local frame with one simple support outside the ice-strengthened areas} \\ &= 2 \quad \text{for a local frame without any simple supports} \\ a_1 &= A_t/A_w \\ A_t &= \text{minimum shear area of the local frame as given in 6-1-2/11.3, in cm}^2 \text{ (cm}^2 \text{, in}^2\text{)} \\ A_w &= \text{net effective shear area of the local frame (calculated according to 6-1-2/9.13), in cm}^2 \text{ (cm}^2 \text{, in}^2\text{)} \\ k_w &= 1/(1 + 2 \cdot A_{fn}/A_w) \text{ with } A_{fn} \text{ as given in 6-1-2/9.15} \\ k_z &= z_p/Z_p \quad \text{in general} \\ &= 0.0 \quad \text{when the frame is arranged with end bracket} \\ z_p &= \text{sum of individual plastic section moduli of flange and shell plate as fitted, in cm}^3 \text{ (cm}^3 \text{, in}^3\text{)} \\ &= (b_f \cdot t_{fn}^2/4 + b_{eff} \cdot t_{pn}^2/4)/c_5 \\ c_5 &= 1000 \text{ (1000, 1)} \\ b_f &= \text{flange breadth, in mm (mm, in.), see 6-1-2/Figure 4} \\ t_{fn} &= \text{net flange thickness, in mm (mm, in.)} \\ &= t_f - t_c \text{ (} t_c \text{ as given in 6-1-2/9.13)} \\ t_f &= \text{as-built flange thickness, in mm (mm, in.), see 6-1-2/Figure 4} \\ t_{pn} &= \text{fitted net shell plate thickness, in mm (mm, in.) (not to be less than } t_{net} \text{ as given in 6-1-2/7)} \\ b_{eff} &= \text{effective width of shell plate flange, in mm (mm, in.)} \\ &= 0.5 c_5 \cdot s \\ Z_p &= \text{net effective plastic section modulus of the local frame (calculated according to 6-1-2/9.15), in cm}^3 \text{ (cm}^3 \text{, in}^3\text{)} \end{aligned}$$

AF , PPF , P_{avg} , LL , b , s , a and σ_y are as given in 6-1-2/11.3.

11.7 Structural Stability

The scantlings of the local frame are to meet the structural stability requirements of 6-1-2/17.

13 Framing – Longitudinal Local Frames in Side Structures (1 July 2017)

13.1 Plastic Strength (1 July 2017)

Longitudinal local frames in side structures are to be dimensioned such that the combined effects of shear and bending do not exceed the plastic strength of the member. The plastic strength is defined by the magnitude of midspan load that causes the development of a plastic collapse mechanism.

13.3 Required Shear Area (1 July 2017)

The actual net effective shear area of the frame, A_w , as defined in 6-1-2/9.13, is to comply with the following condition: $A_w \geq A_L$, in cm^2 (cm^2 , in^2) where:

$$A_L = 100^{n_3} \cdot (AF \cdot PPF_s \cdot P_{avg}) \cdot 0.5 \cdot b_1 \cdot a / (0.577 \cdot \sigma_y)$$

where

n_3	=	2 (0, 0)
AF	=	Hull Area Factor from 6-1-2/Table 4, 6-1-2/Table 5, 6-1-2/Table 6, or 6-1-2/Table 7
PPF_s	=	Peak Pressure Factor from 6-1-2/Table 3
P_{avg}	=	average pressure within load patch according to 6-1-2/5.11.1, in MPa (kgf/mm ² , psi)
b_1	=	$k_o \cdot b_2$, in m (cm, in.)
k_o	=	$1 - 0.3/b'$
b'	=	$b/(s \cdot c_6)$
c_6	=	1 (100, 1)
b	=	height of design ice load patch from 6-1-2/5.9.1ii) or 6-1-2/5.9.2.ii), in m (cm, in.)
s	=	spacing of longitudinal frames, in m (m, in.)
b_2	=	$b(1 - 0.25 \cdot b')$, in m (cm, in.) if $b' < 2$
	=	$s \cdot c_6$, in m (cm, in.) if $b' \geq 2$
a	=	effective span of longitudinal local frame as given in 6-1-2/9.9, in m (cm, in.)
σ_y	=	minimum upper yield stress of the material, in N/mm ² (kgf/mm ² , psi), but not greater than the lesser of 0.70 of minimum UTS or 450 N/mm ² (45.9 kgf/mm ² , 65880 psi)

13.5 Required Plastic Section Modulus

The actual net effective plastic section modulus of the plate/stiffener combination, Z_p , as defined in 6-1-2/9.15, is to comply with the following condition: $Z_p \geq Z_{pL}$ in cm^3 (cm^3 , in^3) where:

$$Z_{pL} = 100^{n_4} \cdot (AF \cdot PPF_s \cdot P_{avg}) \cdot b_1 \cdot a^2 \cdot A_4 / (8 \cdot \sigma_y)$$

where

n_4	=	3 (0, 0)
A_4	=	$1/(2 + k_{wl} \cdot [(1 - a_4^2)^{0.5} - 1])$
a_4	=	A_L/A_w
A_L	=	minimum shear area for longitudinal as given in 6-1-2/13.3, in cm^2 (cm^2 , in^2)
A_w	=	net effective shear area of longitudinal (calculated according to 6-1-2/9.13), in cm^2 (cm^2 , in^2)
k_{wl}	=	$1/(1 + 2 \cdot A_{fn}/A_w)$ with A_{fn} as given in 6-1-2/9.15

AF , PPF_s , P_{avg} , b_1 , a and σ_y are as given in 6-1-2/13.3.

13.7 Structural Stability

The scantlings of the longitudinals are to meet the structural stability requirements of 6-1-2/17.

15 Framing – Web Frames and Load-carrying Stringers (1 July 2017)

15.1 General

Web frames and load-carrying stringers are to be designed to withstand the ice load patch as defined in 6-1-2/5. The load patch is to be applied at locations where the capacity of these members under the combined effects of bending and shear is minimized.

15.3 Application (1 July 2017)

- i) Web frames and load-carrying stringers are to be dimensioned so that the combined stresses of shear and bending are to be maintained within the acceptable limit. Where these members form part of a structural grillage system, appropriate methods of analysis are to be used. Where the structural configuration is such that members do not form part of a grillage system, the appropriate peak pressure factor (PPF) from 6-1-2/Table 3 is to be used. Special attention is to be paid to the shear capacity in way of lightening holes and cut-outs in way of intersecting members.
- ii) For determination of scantlings of load carrying stringers, web frames supporting local frames, or web frames supporting load carrying stringers forming part of a structural grillage system, the method outlined in 6-1-2/33 is to be used, in general.

15.5 Structural Stability

The scantlings of web frames and load-carrying stringers are to meet the structural stability requirements of 6-1-2/17.

17 Framing – Structural Stability

17.1 Framing Members (2014)

To prevent local buckling in the web, the ratio of web height (h_w) to net web thickness (t_{wn}) of any framing member is not to exceed:

- For flat bar sections: $h_w/t_{wn} \leq c_7/(\sigma_y)^{0.5}$
- For bulb, tee and angle sections: $h_w/t_{wn} \leq c_8/(\sigma_y)^{0.5}$

where

$$c_7 = 282 \text{ (90, 3396)}$$

$$c_8 = 805 \text{ (257, 9695)}$$

$$h_w = \text{web height in mm (mm, in.)}$$

$$t_{wn} = \text{net web thickness in mm (mm, in.)}$$

$$\sigma_y = \text{minimum upper yield stress of the material, in N/mm}^2 \text{ (kgf/mm}^2 \text{, psi), but not greater than the lesser of 0.70 of minimum UTS or 450 N/mm}^2 \text{ (45.9 kgf/mm}^2 \text{, 65880 psi)}$$

17.3 Web Stiffening (2014)

Framing members for which it is not practicable to meet the requirements of 6-1-2/17.1 (e.g., load-carrying stringers or deep web frames) are required to have their webs effectively stiffened. The scantlings of the web stiffeners are to ensure the structural stability of the framing member. The minimum net web thickness, t_{wn} , in mm (mm, in.), for these framing members is given by:

$$t_{wn} = 2.63 \cdot 10^{-3} \cdot h_u \cdot [\sigma_y / (c_{11} + c_{12} \cdot (h_u/L_w)^2)]^{0.5}$$

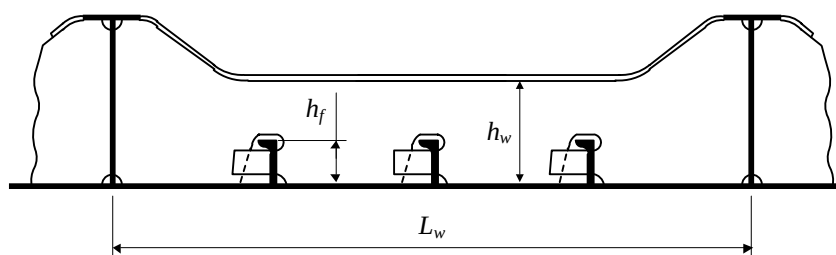
where

$$h_u = h_w - 0.8h_f \text{ mm (mm, in.)}$$

$$h_w = \text{web height of stringer/web frame, in mm (mm, in.) (see 6-1-2/Figure 5)}$$

- h_f = height of framing member penetrating the member under consideration (0 if no such framing member), in mm (mm, in.) (see 6-1-2/Figure 5)
- L_w = spacing between supporting structure oriented perpendicular to the member under consideration, in mm (mm, in.) (see 6-1-2/Figure 5)
- c_{11} = 5.34 (0.545, 775)
- c_{12} = 4 (0.41, 580)
- σ_y = minimum upper yield stress of the material, in N/mm² (kgf/mm², psi), but not greater than the lesser of 0.70 of minimum UTS or 450 N/mm² (45.9 kgf/mm², 65880 psi)

FIGURE 5
Parameter Definition for Web Stiffening (2014)



17.5 Web Thickness

In addition, the following is to be satisfied:

$$t_{wn} \geq 0.35 \cdot t_{pn} \cdot (\sigma_y/c_{13})^{0.5}$$

where

- σ_y = minimum upper yield stress of the shell plate in way of the framing member, in N/mm² (kgf/mm², psi)
- c_{13} = 235 (24, 34083)
- t_{wn} = net thickness of the web, in mm (mm, in.)
- t_{pn} = net thickness of the shell plate in way of the framing member, in mm (mm, in.)

17.7 Flange Width and Outstand (2014)

To prevent local flange buckling of welded profiles, the following are to be satisfied:

- The flange width, b_f is not to be less than five times the net thickness of the web, t_{wn} .
- The flange outstand, b_{out} , in mm (mm, in.), is to meet the following requirement:

$$b_{out}/t_{fn} \leq c_{14}/(\sigma_y)^{0.5}$$

where

- c_{14} = 155 (49.5, 1867)
- t_{fn} = net thickness of flange, in mm (mm, in.)
- σ_y = minimum upper yield stress of the material, in N/mm² (kgf/mm², psi), but not greater than the lesser of 0.70 of minimum UTS or 450 N/mm² (45.9 kgf/mm², 65880 psi)

19 Plated Structures

19.1 General

Plated structures are those stiffened plate elements in contact with the hull and subject to ice loads. These requirements are applicable to an inboard extent which is the lesser of:

- i) Web height of adjacent parallel web frame or stringer; or
- ii) 2.5 times the depth of framing that intersects the plated structure

19.3 End Fixity

The thickness of the plating and the scantlings of attached stiffeners are to be such that the degree of end fixity necessary for the shell framing is ensured.

19.5 Stability

The stability of the plated structure is to adequately withstand the ice loads defined in 6-1-2/5.

21 Corrosion/Abrasion Additions and Steel Renewal

21.1 General

Effective protection against corrosion and ice-induced abrasion is recommended for all external surfaces of the shell plating for all Polar Class vessels.

21.3 Corrosion/Abrasion Additions for Shell Plating (1 July 2017)

The values of corrosion/abrasion additions, t_s , in mm (mm, in.) to be used in determining the shell plate thickness are listed in 6-1-2/Table 8 and 6-1-2/Table 9.

21.5 Corrosion/Abrasion Additions for Internal Structures

Polar Class vessels are to have a minimum corrosion/abrasion addition of $t_s = 1.0$ mm (1.0 mm, 0.0394 in.) applied to all internal structures within the ice-strengthened hull areas, including plated members adjacent to the shell, as well as stiffener webs and flanges.

21.7 Steel Renewal

Steel renewal for ice strengthened structures is required when the gauged thickness is less than $t_{net} + 0.5$ mm (0.5 mm, 0.02 in.).

TABLE 8
Corrosion/Abrasion Additions for Shell Plating for Vessels
Intended to Operate Ahead Only (1 July 2017)

Hull Area	t_s , mm (mm, in.)					
	With Effective Protection			Without Effective Protection		
	PC1 - PC3	PC4 & PC5	PC6 & PC7	PC1 - PC3	PC4 & PC5	PC6 & PC7
Bow; Bow Intermediate Icebelt	3.5 (3.5, 0.138)	2.5 (2.5, 0.098)	2.0 (2.0, 0.079)	7.0 (7.0, 0.276)	5.0 (5.0, 0.197)	4.0 (4.0, 0.158)
Bow Intermediate Lower; Midbody & Stern Icebelt	2.5 (2.5, 0.098)	2.0 (2.0, 0.079)	2.0 (2.0, 0.079)	5.0 (5.0, 0.197)	4.0 (4.0, 0.158)	3.0 (3.0, 0.118)
Midbody & Stern Lower; Bottom	2.0 (2.0, 0.079)	2.0 (2.0, 0.079)	2.0 (2.0, 0.079)	4.0 (4.0, 0.158)	3.0 (3.0, 0.118)	2.5 (2.5, 0.098)

TABLE 9
Corrosion/Abrasion Additions for Shell Plating for Vessels
Intended to Operate Ahead and Astern (1 July 2017)

Hull Area	<i>t_s, mm (mm, in.)</i>					
	<i>With Effective Protection</i>			<i>Without Effective Protection</i>		
	PC1 - PC3	PC4 & PC5	PC6 & PC7	PC1 - PC3	PC4 & PC5	PC6 & PC7
Bow; Bow Intermediate Icebelt; Stern; Stern Intermediate Icebelt	3.5 (3.5, 0.138)	2.5 (2.5, 0.098)	2.0 (2.0, 0.079)	7.0 (7.0, 0.276)	5.0 (5.0, 0.197)	4.0 (4.0, 0.158)
Bow Intermediate Lower; Midbody Icebelt & Stern Intermediate Lower	2.5 (2.5, 0.098)	2.0 (2.0, 0.079)	2.0 (2.0, 0.079)	5.0 (5.0, 0.197)	4.0 (4.0, 0.158)	3.0 (3.0, 0.118)
Midbody Lower; Bottom	2.0 (2.0, 0.079)	2.0 (2.0, 0.079)	2.0 (2.0, 0.079)	4.0 (4.0, 0.158)	3.0 (3.0, 0.118)	2.5 (2.5, 0.098)

23 Materials (1 July 2017)

All hull structural materials are to be in accordance with the requirements of Part 2, Chapter 1 and the following paragraphs.

23.1 General (1 July 2017)

Steel grades of plating for hull structures are to be not less than those given in 6-1-2/Table 11 based on the as-built thickness, the Polar Class and the Material Class of structural members according to 6-1-2/23.3.

23.3 Material Classes

Material classes specified in 3-1-2/Table 2 are applicable to Polar Class vessels regardless of the vessel's length. In addition, material classes for weather and sea exposed structural members and for members attached to the weather and sea exposed plating of polar vessels are given in 6-1-2/Table 10. Where the material classes in 6-1-2/Table 10 and those in 3-1-2/Table 2 differ, the higher material class is to be applied.

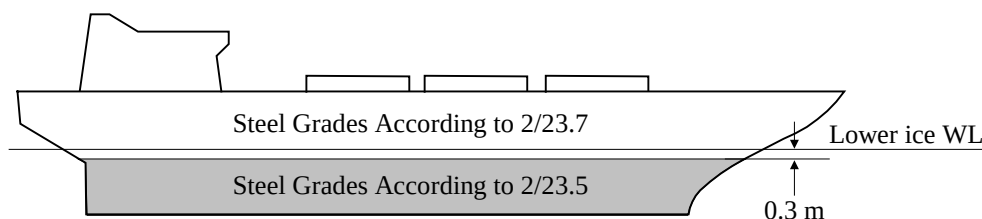
TABLE 10
Material Classes for Structural Members of Polar Class Vessels (2012)

<i>Structural Members</i>	<i>Material Class</i>
Shell plating within the bow and bow intermediate icebelt hull areas (B, BI)	II
All weather and sea exposed SECONDARY and PRIMARY, as defined in 3-1-2/Table 2, structural members outside 0.4L amidships	I
Plating materials for stem and stern frames, rudder horn, rudder, propeller nozzle, shaft brackets, ice skeg, ice knife and other appendages subject to ice impact loads	II
All inboard framing members attached to the weather and sea-exposed plating including any contiguous inboard member within 600 mm (600 mm, 23.6 in.) of the plating	I
Weather-exposed plating and attached framing in cargo holds of vessels which by nature of their trade have their cargo hold hatches open during cold weather operations	I
All weather and sea exposed SPECIAL, as defined in 3-1-2/Table 2, structural members within 0.2L from FP	II

23.5 Steel Grades

Steel grades for all plating and attached framing of hull structures and appendages situated below the level of 0.3 m (0.3 m, 12 in.) below the lower waterline, as shown in 6-1-2/Figure 6, are to be obtained from 3-1-2/Table 1 based on the Material Class for Structural Members in 6-1-2/Table 10 above, regardless of Polar Class.

FIGURE 6
Steel Grade Requirements for Submerged
and Weather Exposed Shell Plating (2012)



23.7 Steel Grades for Weather Exposed Plating

Steel grades for all weather exposed plating of hull structures and appendages situated above the level of 0.3 m (0.3 m, 12 in.) below the lower ice waterline, as shown in 6-1-2/Figure 6, are to be not less than given in 6-1-2/Table 11.

TABLE 11
Steel Grades for Weather Exposed Plating (2012)

Thickness, <i>t</i> mm (in.)	Material Class I				Material Class II				Material Class III					
	PC1-5		PC6 & 7		PC1-5		PC6 & 7		PC1-3		PC4 & 5		PC6 & 7	
	MS	HT	MS	HT	MS	HT	MS	HT	MS	HT	MS	HT	MS	HT
$t \leq 10$ $t \leq 0.394$	B	AH	B	AH	B	AH	B	AH	E	EH	E	EH	B	AH
$10 < t \leq 15$ $0.394 < t \leq 0.591$	B	AH	B	AH	D	DH	B	AH	E	EH	E	EH	D	DH
$15 < t \leq 20$ $0.591 < t \leq 0.787$	D	DH	B	AH	D	DH	B	AH	E	EH	E	EH	D	DH
$20 < t \leq 25$ $0.787 < t \leq 0.984$	D	DH	B	AH	D	DH	B	AH	E	EH	E	EH	D	DH
$25 < t \leq 30$ $0.984 < t \leq 1.18$	D	DH	B	AH	E	EH2	D	DH	E	EH	E	EH	E	EH
$30 < t \leq 35$ $1.18 < t \leq 1.38$	D	DH	B	AH	E	EH	D	DH	E	EH	E	EH	E	EH
$35 < t \leq 40$ $1.38 < t \leq 1.58$	D	DH	D	DH	E	EH	D	DH	F	FH	E	EH	E	EH
$40 < t \leq 45$ $1.58 < t \leq 1.77$	E	EH	D	DH	E	EH	D	DH	F	FH	E	EH	E	EH
$45 < t \leq 50$ $1.77 < t \leq 1.97$	E	EH	D	DH	E	EH	D	DH	F	FH	F	FH	E	EH

Notes:

- Includes weather-exposed plating of hull structures and appendages, as well as their outboard framing members, situated above a level of 0.3 m (0.3 m, 12 in.) below the lowest ice waterline.
- Grades D, DH are allowed for a single strake of side shell plating not more than 1.8 m (1.8 m, 70.9 in.) wide from 0.3 m (0.3 m, 12 in.) below the lowest ice waterline.

23.9 Castings

Castings are to have specified properties consistent with the expected service temperature for the cast component.

25 Longitudinal Strength

25.1 Application (1 July 2017)

- i) A ramming impact on the bow is the design scenario for the evaluation of the longitudinal strength of the hull.
- ii) Intentional ramming is not considered as a design scenario for ships which are designed with vertical or bulbous bows, see 6-1-1/1.1viii) Hence the longitudinal strength requirements given in this section are not to be considered for ships with stem angle γ_{stem} equal to or larger than 80° .
- iii) Ice loads are only to be combined with still water loads. The combined stresses are to be compared against permissible bending and shear stresses at different locations along the vessel's length. In addition, sufficient local buckling strength is also to be maintained.

25.3 Design Vertical Ice Force at the Bow

The design vertical ice force at the bow, F_{IB} , in MN (tf, Ltf) is to be taken as:

$$F_{IB} = \text{minimum } (F_{IB,1}; F_{IB,2})$$

where

$$F_{IB,1} = 0.534 \cdot K_I^{0.15} \cdot \sin^{0.2}(\gamma_{stem}) \cdot (D \cdot K_h)^{0.5} \cdot CF_L$$

$$F_{IB,2} = 1.20 \cdot CF_F$$

$$K_I = \text{indentation parameter} = K_f/K_h$$

a) For the case of a blunt bow form:

$$K_f = c_{15} [2 \cdot C \cdot (B/c_{16})^{1-e_b}/(1+e_b)]^{0.9} \cdot \tan(\gamma_{stem})^{-0.9(1+e_b)} \quad \text{MN/m (tf/cm, Ltf/in)}$$

$$c_{15} = 1 \quad (1.02, 2.54)$$

$$c_{16} = 1 \quad (1, 3.28)$$

b) For the case of wedge bow form ($\alpha_{stem} < 80 \text{ deg}$), $e_b = 1$ and the above simplifies to:

$$K_f = [\tan(\alpha_{stem})/\tan^2(\gamma_{stem})]^{0.9} \quad \text{MN/m (tf/cm, Ltf/in)}$$

$$K_h = c_{17} A_{wp} \quad \text{MN/m (tf/cm, Ltf/in)}$$

$$c_{17} = 0.01 \quad (0.01, 0.00237) \quad \text{MN/m}^3 [\text{tf}/(\text{m}^2\text{-cm}), \text{Ltf}/(\text{ft}^2\text{-in})]$$

$$CF_L = \text{Longitudinal Strength Class Factor from 6-1-2/Table 1}$$

$$e_b = \text{bow shape exponent which best describes the waterplane (see 6-1-2/Figures 7 and 8)}$$

$$= 1.0 \quad \text{for a simple wedge bow form}$$

$$= 0.4 \text{ to } 0.6 \quad \text{for a spoon bow form}$$

$$= 0 \quad \text{for a landing craft bow form}$$

An approximate e_b determined by a simple fit is acceptable

$$\gamma_{stem} = \text{stem angle to be measured between the horizontal axis and the stem tangent at the upper ice waterline, in degrees (buttock angle as per 6-1-2/Figure 2 measured on the centerline)}$$

$$\alpha_{stem} = \text{waterline angle measured in way of the stem at the upper ice waterline (UIWL), in degrees (see 6-1-2/Figure 7)}$$

- $C = 1/[2 \cdot (L_B/B)^{e_b}]$
- B = vessel molded breadth, in m (m, ft)
- L_B = bow length used in the equation $y = B/2 \cdot (x/L_B)^{e_b}$, in m (m, ft) (see 6-1-2/Figure 7 and 6-1-2/Figure 8)
- D = vessel displacement, in kt (kt, kLt), not to be taken less than 10 kt (10 kt, 9.8 kLt)
- A_{wp} = vessel waterplane area, in m² (m², ft²)
- CF_F = Flexural Failure Class Factor from 6-1-2/Table 1

Where applicable, draft dependent quantities are to be determined at the waterline corresponding to the loading condition under consideration.

FIGURE 7
Bow Shape Definition (2012)

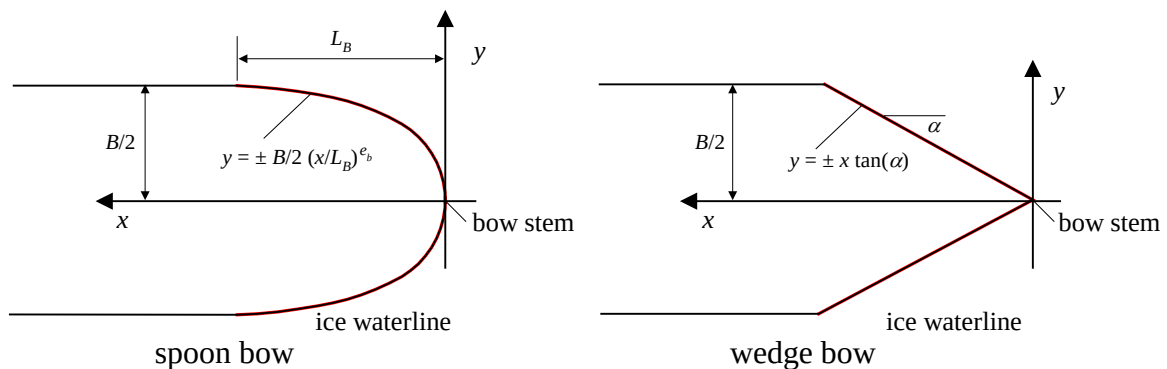
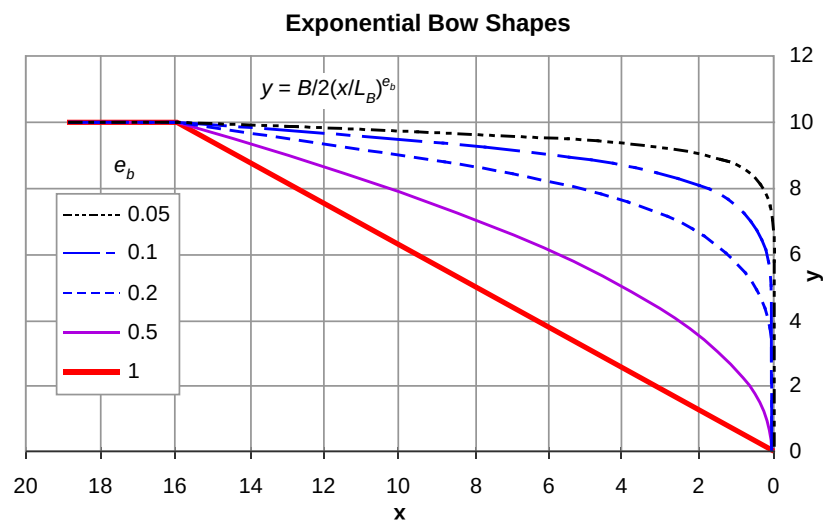


FIGURE 8
Illustration of e_b Effect on the Bow Shape for $B = 20$ and $L_B = 16$ (2012)



25.5 Design Vertical Shear Force

25.5.1

The design vertical ice shear force, F_p , in MN (tf, Ltf) along the hull girder is to be taken as:

$$F_I = C_f \cdot F_{IB}$$

where

C_f = longitudinal distribution factor to be taken as follows:

i) *Positive shear force*

C_f = 0.0 between the aft end of L and $0.6L$ from aft
= 1.0 between $0.9L$ from aft and the forward end of L

ii) *Negative shear force*

C_f = 0.0 at the aft end of L
= -0.5 between $0.2L$ and $0.6L$ from aft
= 0.0 between $0.8L$ from aft and the forward end of L

Intermediate values are to be determined by linear interpolation

25.5.2

The applied vertical shear stress, τ_a , is to be determined along the hull girder in a similar manner as in 3-2-1/3.9 by substituting the design vertical ice shear force for the design vertical wave shear force.

25.7 Design Vertical Ice Bending Moment

25.7.1

The design vertical ice bending moment, M_p , in MN-m (tf-m, Ltf-ft) along the hull girder is to be taken as:

$$M_I = 0.1 \cdot C_m \cdot L \cdot \sin^{0.2}(\gamma_{stem}) \cdot F_{IB}$$

where

L = vessel length as defined in 6-1-1/5.7, in m (m, ft)

γ_{stem} = as given in 6-1-2/25.3

F_{IB} = design vertical ice force at the bow, in MN (tf, Ltf)

C_m = longitudinal distribution factor for design vertical ice bending moment to be taken as follows:

= 0.0 at the aft end of L
= 1.0 between $0.5L$ and $0.7L$ from aft
= 0.3 at $0.95L$ from aft
= 0.0 at the forward end of L

Intermediate values are to be determined by linear interpolation

Where applicable, draft dependent quantities are to be determined at the waterline corresponding to the loading condition under consideration.

25.7.2

The applied vertical bending stress, σ_a , is to be determined along the hull girder in a similar manner as in 3-2-1/3.7 by substituting the design vertical ice bending moment for the design vertical wave bending moment. The vessel still water bending moment is to be taken as the maximum sagging moment.

25.9 Longitudinal Strength Criteria (2014)

The strength criteria provided in 6-1-2/Table 12 are to be satisfied. The design stress is not to exceed the permissible stress.

TABLE 12
Longitudinal Strength Criteria (1 July 2017)

Failure Mode	Applied Stress	Permissible Stress when $\sigma_y/\sigma_u \leq 0.7$	Permissible Stress when $\sigma_y/\sigma_u > 0.7$
Tension	σ_a	$\eta \cdot \sigma_y$	$\eta \cdot 0.41(\sigma_u + \sigma_y)$
Shear	τ_a	$\eta \cdot \sigma_y/(3)^{0.5}$	$\eta \cdot 0.41(\sigma_u + \sigma_y)/(3)^{0.5}$
Buckling	σ_a	σ_c for plating and for web plating of stiffeners $\sigma_c/1.1$ for stiffeners	
	τ_a	τ_c	

where

- σ_a = applied vertical bending stress, in N/mm² (kgf/mm², psi)
- τ_a = applied vertical shear stress, in N/mm² (kgf/mm², psi)
- σ_y = minimum upper yield stress of the material, in N/mm² (kgf/mm², psi), but not greater than the lesser of 0.70 of minimum UTS or 450 N/mm² (45.9 kgf/mm², 65880 psi)
- σ_u = ultimate tensile strength of material, in N/mm² (kgf/mm², psi)
- σ_c = critical buckling stress in compression, according to Appendix 3-2-A4, in N/mm² (kgf/mm², psi)
- τ_c = critical buckling stress in shear, according to Appendix 3-2-A4, in N/mm² (kgf/mm², psi)
- η = 0.6 for ships which are assigned the additional notation **Ice Breaker**
= 0.8 otherwise

27 Stem and Stern Frames

For Polar Class **PC6** and **PC7** vessels requiring Baltic Ice Class **IAA** or **IA** equivalency of Section 6-1-6, the stem and stern requirements of the Finnish-Swedish Ice Class Rules may need to be additionally considered.

29 Appendages

29.1 General

All appendages are to be designed to withstand forces appropriate for the location of their attachment to the hull structure or their position within a hull area.

29.3 Load Definition and Response Criteria

Load definition and response criteria are to be determined on a case-by-case basis.

31 Local Details

31.1 General

For the purpose of transferring ice-induced loads to supporting structure (bending moments and shear forces), local design details are to be prepared and submitted for review.

31.3 Cut-outs

The loads carried by a member in way of cut-outs are not to cause instability. Where necessary, the structure is to be stiffened.

33 Direct Calculations (1 July 2017)

33.1 General

- i) Direct calculations are not to be utilized as an alternative to the analytical procedures prescribed for the shell plating and local frame requirements given in 6-1-2/7, 6-1-2/11 and 6-1-2/13.
- ii) Direct calculations are to be used for load carrying stringers and web frames forming part of a grillage system.

33.3 Load Patch

Where direct calculation is used to check the strength of structural systems, the load patch specified in 6-1-2/5 is to be applied, without being combined with any other loads. The load patch is to be applied at locations where the capacity of these members under the combined effects of bending and shear is minimized. Special attention is to be paid to the shear capacity in way of lightening holes and cut-outs in way of intersecting members.

33.5 Strength Evaluation

The strength evaluation of web frames and stringers may be performed based on linear or non-linear analysis. Recognized structural idealization and calculation methods are to be applied, with detailed requirements agreed upon with ABS. In the strength evaluation, the guidance given in 6-1-2/33.7 and 6-1-2/33.9 may generally be considered.

33.7 Acceptance Criteria – Linear Analysis Methods

If the structure is evaluated based on linear calculation methods, the following are to be considered:

- i) Web plates and flange elements in compression and shear to fulfill relevant buckling criteria
- ii) Nominal shear stresses in member web plates to be less than $\sigma_y/\sqrt{3}$
- iii) Nominal von Mises stresses in member flanges to be less than $1.15\sigma_y$

33.9 Acceptance Criteria – Non-linear Analysis Methods

If the structure is evaluated based on non-linear calculation methods, the following are to be considered:

- i) The analysis is to reliably capture buckling and plastic deformation of the structure.
- ii) The acceptance criteria are to ensure a suitable margin against fracture and major buckling and yielding that causes significant loss of stiffness.
- iii) Permanent lateral and out-of plane deformation of considered member are to be minor relative to the relevant structural dimensions.
- iv) Detailed acceptance criteria are to be decided by ABS.

35 Welding

35.1 General

Hull construction welding design is to comply with Section 3-2-19. All welding within ice-strengthened areas is to be of the double continuous type.

35.3 Continuity of Strength

Continuity of strength is to be ensured at all structural connections.

35.5 Filler Metals

When the ABS ordinary and higher strength hull steels of 2-1-2/Table 5 or 2-1-3/Table 5 are applied in accordance with 6-1-2/Table 11, approved filler metals appropriate to the grades shown in Part 2, Appendix 3 may be used.

35.7 Hull Steels Other than the ABS Grades

For the welding of hull steels other than the ABS grades in 6-1-2/Table 11, weld metal is to exhibit a Charpy V-Notch toughness value at least equivalent to the transverse base metal requirements ($\frac{2}{3}$ of longitudinal base metal requirements).

PART

6

CHAPTER 1 Strengthening for Navigation in Ice

SECTION 3 Machinery Requirements for Polar Class Vessels (2012)

1 Application

The contents of Section 6-1-3 apply to main propulsion, steering gear, emergency and essential auxiliary systems essential for the safety of the vessel and the survivability of the crew.

The vessel operating conditions are defined in Section 6-1-1.

The requirements herein are additional to those applicable for the basic class.

3 Drawings and Particulars to be Submitted

3.1 Environmental Conditions

Details of the environmental conditions and the required ice class for the machinery, if different from vessel's ice class.

3.3 Drawings

Detailed drawings of the main propulsion machinery, description of the main propulsion, steering, emergency and essential auxiliaries are to include operational limitations. Information on essential main propulsion load control functions.

3.5 Description Detailing

Description detailing how main, emergency and auxiliary systems are located and protected to prevent problems from freezing, ice and snow and evidence of their capability to operate in intended environmental conditions.

3.7 Calculations and Documentation

Calculations and documentation indicating compliance with the requirements of Section 6-1-3.

5 System Design

5.1 General

All machinery is to be suitable for operation under the environmental conditions to which it will be exposed in service and is to include all necessary special provisions for that purpose.

5.3 Governmental Authority

Attention is directed to the appropriate governmental authorities in the intended regions of operation for additional requirements in consideration of operation in ice such as fuel capacity, refueling capability, water capacity, radio communications requirements, etc.

5.5 Damage by Freezing

Systems, subject to damage by freezing, are to be drainable.