RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

Part I Polar Class Ships and Ice Class Ships

RULES

2016 AMENDMENT NO.1

Rule No.82 27th December 2016
Resolved by Technical Committee on 27th July 2016
Approved by Board of Directors on 20th September 2016

An asterisk (*) after the title of a requirement indicates that there is also relevant information in the corresponding Guidance.

Rule No.82 27th December 2016
AMENDMENT TO THE RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

"Rules for the survey and construction of steel ships" has been partly amended as follows:

Part I POLAR CLASS SHIPS AND ICE CLASS SHIPS

Chapter 1 GENERAL

Section 1.1 has been amended as follows.

1.1 General

1.1.1 Application*

1 The requirements in this Part apply to ships intended for navigation in polar waters or ice-infested waters.

2 ~~Where a ship is intended to be registered as a polar class vessel (hereinafter referred to as "polar class ship" in this Part) complying with *IMO Resolution MSC/Circ.1056* and *MEPC/Circ.399* "*Guideline for ships operating in Arctic ice-covered waters*",~~The materials, hull structures, equipment, ~~and~~ machinery, etc. of ships operating in polar waters are to be in accordance with the requirements in **Chapter 1** to **Chapter** ~~**4**~~**7** of this Part in addition to those in other Parts as well as the **Rules for Marine Pollution Prevention Systems**, **Rules for Safety Equipment** and **Rules for Radio Installations** relevant to such ships.

3 Notwithstanding the provision in **-2** above, ships corresponding to following **(1)** or **(2)** need not comply with the requirements in **Chapter 1** and **Chapter 7** of this Part.

(1) Ships not subject to the *SOLAS* convention in accordance with *SOLAS Chapter I*; and

(2) Ships owned or operated by the flag administration and used for non-commercial purposes.

4 Ships intended to be registered as polar class vessels (hereinafter referred to as "polar class ship" in this Part), as defined in **1.2.1(20)**, are to comply with **Annex 1** "**Special Requirements for the Materials, Hull Structures, Equipment and Machinery of Polar Class Ships**".

~~**3**~~**5** Where a ship is intended to be registered as an ice class vessel (hereinafter referred to as "ice class ship" in this Part) for navigation of the Northern Baltic complying with the *Finnish-Swedish Ice Class Rules 2010* or in the Canadian Arctic complying with the *Arctic Shipping Pollution Prevention Regulations*, the materials, hull structures, equipment and machinery of the ship are to be in accordance with the requirements in **Chapter 1** except for **1.3** to **1.5** and **Chapter** ~~**5**~~**8** of this Part in addition to those in other Parts.

1.1.2 Documentation*

1 The polar class defined in **1.2.1(20)**~~**2**~~ or the ice class defined in **1.2.2(1)**~~**3**~~ is to be indicated in the general arrangement, midship section, arrangements to resist panting in both peaks and their vicinity, shell expansion and plan of propeller specified in **2.1.2**, **Part B**.

2 For polar class ships, the upper ice waterline specified in **1.2.1(23)**~~**4-1**~~, the lower ice waterline specified in **1.2.1(24)**~~**4-2**~~ and hull area specified in **1.2.3**~~**5-1**~~ of **Annex 1** "**Special Requirements for**

the Materials, Hull Structures, Equipment and Machinery of Polar Class Ships" are to be indicated in the shell expansion specified in **2.1.2, Part B**. The corrosion/abrasion additions specified in **2.3** of **Annex 1** "**Special Requirements for the Materials, Hull Structures, Equipment and Machinery of Polar Class Ships**" are to be indicated in the midship section, arrangements of both peaks and shell expansion.

3 For ice class ships, the upper ice water line specified in **1.2.1(23)~~4-1~~**, the lower ice waterline specified in **1.2.1(24)~~4-2~~** and hull area specified in **1.2.2(2)~~5-2~~** are to be indicated in the shell expansion specified in **2.1.2, Part B**. The engine output defined in **~~5.4.1~~ 8.4.2**, the displacement defined in **~~5~~8.1.2-6** and the dimensions necessary for the engine output calculation required in **~~5.4.1~~ 8.4.2** are to be indicated in the general arrangement specified in **2.1.2, Part B**.

1.1.3 Precautions Regarding Low Temperatures

The low temperature of the ship's ambience is to be considered for designing structures, equipment and arrangements essential for the safety and operation of the ship, *e.g.* the functioning of hydraulic systems, hazard of freezing of water piping and tanks, starting of emergency diesels, etc.

1.1.4 Equivalency

1 Alternative hull construction, equipment, etc. which does not fall under the provisions of **Chapters 3**, **6** and **7** of this Part ~~machinery and their arrangements~~ will be accepted by the Society, provided that ~~the Society is satisfied that~~ such construction, equipment, etc. ~~machinery and their arrangements and scantlings are~~ is considered to be equivalent to ~~those~~ that required ~~in~~ by this Part in accordance with *SOLAS Chapter XIV Regulation 4*.

2 Alternative hull construction, equipment, etc. which does not fall under the provisions of **Chapter 8** of this Part will be accepted by the Society, provided that the Society is satisfied that such construction, equipment, etc. is considered to be equivalent to that required by **Chapter 8** of this Part

1.2 Definitions

Paragraph 1.2.1 has been amended as follows.

1.2.1 ~~Application~~Terms*

The definitions of terms ~~and symbols~~ which appear in this Part are to be as specified in the following **(1)** to **(27)** ~~hear in 1.2~~, unless specified elsewhere.

(1) "Category *A* ship" is a ship designed for operation in polar waters in at least medium first-year ice, which may include old ice inclusions.

(2) "Category *B* ship" is a ship designed for operation in polar waters in at least thin first-year ice, which may include old ice inclusions.

(3) "Category *C* ship" is a ship designed to operate in open water or in ice conditions less severe than those included in categories *A* and *B*.

(4) "First-year ice" is sea ice of not more than one winter growth developing from young ice with thickness from 0.3 *m* to 2.0 *m*.

(5) "Ice free waters" is no ice present. If ice of any kind is present this term is not to be used.

(6) "Ice of land origin" is ice formed on land or in an ice shelf, found floating in water.

(7) "Medium first-year ice" is first-year ice of 70 *cm* to 120 *cm* thickness.

(8) "Old ice" is sea ice which has survived at least one summer's melt; typical thickness up to 3

m or more. It is subdivided into residual first-year ice, second-year ice and multi-year ice.

(9) "Open water" is a large area of freely navigable water in which sea ice is present in concentrations less than 1/10. No ice of land origin is present.

(10) "Sea ice" is any form of ice found at sea which has originated from the freezing of sea water.

(11) "Thin first-year ice" is first-year ice 30 *cm* to 70 *cm* thick.

(12) "Bergy waters" is an area of freely navigable water in which ice of land origin is present in concentrations less than 1/10. There may be sea ice present, although the total concentration of all ice is not to exceed 1/10.

(13) "Escort ship" is any ship with superior ice capability in transit with another ship.

(14) "Escorted operation" is any operation in which a ship's movement is facilitated through the intervention of an escort.

(15) "Habitable environment" is a ventilated environment that will protect against hypothermia.

(16) "Icebreaker" is any ship whose operational profile may include escort or ice management functions, whose powering and dimensions allow it to undertake aggressive operations in ice-covered waters.

(17) "Maximum expected time of rescue" is the time adopted for the design of equipment and system that provide survival support. It is never to be less than 5 days.

(18) "Machinery Installations" are equipment and machinery and its associated piping and cabling, which is necessary for the safe operation of the ship.

(19) "Mean Daily Low Temperature" (*MDLT*) is the mean value of the daily low temperature for each day of the year over a minimum 10 year period. A data set acceptable to the Society may be used if 10 years of data is not available.

(20) "Polar Class" (*PC*) is class notation for the ship designed to operate in ice-infested waters in accordance with **Annex 1** "**Special Requirements for the Materials, Hull Structures, Equipment and Machinery of Polar Class Ships**".

(21) "Polar Service Temperature" (*PST*) is a temperature specified for a ship which is intended to operate in low air temperature, which is to be set at least 10ºC below the lowest *MDLT* for the intended area and season of operation in polar waters.

(22) "Ship intended to operate in low air temperature" is a ship which is intended to undertake voyages to or through areas where the lowest *MDLT* is below -10ºC.

(23) "Upper ice waterline" (*UIWL*) is defined by the maximum draughts fore, amidships and aft when sailing in ice covered waters.

(24) "Lower ice waterline" (*LIWL*) is defined by the minimum draughts fore, amidships and aft when sailing in ice covered waters. The *LIWL* is determined with due regard to the vessel's ice-going capability in ballast loading conditions (*e.g.* propeller submergence).

(25) "Polar waters" is Arctic waters and/or the Antarctic area.

(26) "Antarctic area" is the sea area south of latitude 60º S. (see **Fig. I1.1**)

(27) "Arctic waters" is those waters which are located north of a line from the latitude 58º00′.0 N and longitude 042º00′.0 W to latitude 64º37′.0 N, longitude 035º27′.0 W and thence by a rhumb line to latitude 67º03′.9 N, longitude 026º33′.4 W and thence by a rhumb line to the latitude 70º49′.56 N and longitude 008º59′.61 W (Sørkapp, Jan Mayen) and by the southern shore of Jan Mayen to 73º31'.6 N and 019º01'.0 E by the Island of Bjørnøya, and thence by a great circle line to the latitude 68º38′.29 N and longitude 043º23′.08 E (Cap Kanin Nos) and hence by the northern shore of the Asian Continent eastward to the Bering Strait and thence from the Bering Strait westward to latitude 60º N as far as Il'pyrskiy and following the 60th North parallel eastward as far as and including Etolin Strait and thence by the northern shore of the North American continent as far south as latitude 60º N and thence eastward along

parallel of latitude 60º N, to longitude 056º37′.1 W and thence to the latitude 58º00′.0 N, longitude 042°00′.0 W. (see **Fig. I1.2**)

Paragraphs 1.2.2 to 1.2.7 have been deleted.

~~1.2.2 Polar Classes*~~

~~Polar Class is classified into the seven classes given in **Table I1.1**. It is the responsibility of the Owner to determine which class in **Table I1.1** is most suitable for his requirement.~~

~~Table I1.1 Polar Classes~~

~~Polar Class~~	~~Symbol~~	~~Ice description~~
~~Polar Class 1~~	~~*PC1*~~	~~Year-round operation in all Polar waters~~
~~Polar Class 2~~	~~*PC2*~~	~~Year-round operation in moderate multi-year ice condition~~
~~Polar Class 3~~	~~*PC3*~~	~~Year-round operation in second-year ice which may include multi-year ice inclusion~~
~~Polar Class 4~~	~~*PC4*~~	~~Year-round operation in thick first-year ice which may include multi-year and/or second-year ice inclusion~~
~~Polar Class 5~~	~~*PC5*~~	~~Year-round operation in medium first-year ice which may include multi-year and/or second-year ice inclusion~~
~~Polar Class 6~~	~~*PC6*~~	~~Summer/autumn operation in medium first-year ice which may include multi-year and/or second-year ice inclusions~~
~~Polar Class 7~~	~~*PC7*~~	~~Summer/autumn operation in thin first-year ice which may include multi-year and/or second-year ice inclusions~~

~~Notes:~~

~~Multi-year ice, second-year ice and first-year ice are based on WMO (World Meteorological Organization) Sea Ice Nomenclature.~~
~~Multi-year ice : old ice which has survived at least two summer's melt~~
~~Second-year ice : Sea ice which has survived only one summer's melt~~
~~First-year ice : Sea ice of not more than one winter's growth, developing from young ice~~

~~1.2.3 Ice Class*~~

~~Ice Class is classified into the following five classes. It is the responsibility of the Owner to determine which class is most suitable for his requirements.~~

~~(1) I*A Super*~~
~~(2) I*A*~~
~~(3) I*B*~~
~~(4) I*C*~~
~~(5) I*D*~~

~~1.2.4 Ice Waterlines~~

~~**1** The upper ice waterline (*UIWL*) is to be defined by the maximum draughts fore, amidships and aft when sailing in ice covered waters.~~
~~**2** The lower ice waterline (*LIWL*) is to be defined by the minimum draughts fore, amidships and aft when sailing in ice covered waters. The *LIWL* is to be determined with due regard to the vessel's ice-going capability in ballast loading conditions (*e.g.* propeller submergence).~~

~~1.2.5 Hull Areas*~~

~~**1** The hull areas are defined as areas reflecting the magnitude of the loads that are expected to act upon them, and divided into the following (see **Fig. I1.1**). If a ship with special ice breaking aft construction and propulsion system is intended to operate astern in ice-infested water, the hull areas~~

~~of the aft structures are to be deemed appropriate by the Society.~~

~~(1) Bow area~~

~~(a) Bow area of *PC*1, *PC*2, *PC*3 and *PC*4 polar class ships~~

~~"Bow area" is defined as the hull area which is located forward of the intersection point of the *UIWL* and the line with a waterline angle (as defined in **1.2.6**) of 10 degrees at the *UIWL* (hereinafter referred to as "the aft boundary of the Bow area"), and below the line connecting the point 1.5 *m* above the *UIWL* at the aft boundary of the Bow area and the point 2.0 *m* above the *UIWL* at the stem.~~

~~(b) Bow area of *PC*5, *PC*6 and *PC*7 polar class ships~~

~~"Bow area" is defined as the hull area which is located forward of the intersection point of the *UIWL* and the line with a waterline angle (as defined in **1.2.6**) of 10 degrees at the *UIWL*, and below the line connecting the point 1.0*m* above the *UIWL* at the aft boundary of the Bow area and the point 2.0*m* above the *UIWL* at the stem.~~

~~Notwithstanding the provision in (a) and (b), the aft boundary of the Bow area is not to be forward of the intersection point of the extended line of the stem frame and the baseline of the ship. In addition, the aft boundary of the Bow area need not be more than 0.45 *times* L_{UIWL} (length of the ship at the *UIWL*) aft of the *F.P.*~~

~~(2) Bow Intermediate area~~

~~(a) Bow Intermediate area of *PC*1, *PC*2, *PC*3 and *PC*4 polar class ships with~~

~~"Bow Intermediate area" is defined as the hull area which is located aft of the aft boundary of the Bow area, and forward of the vertical line 0.04L_{UIWL} aft of the point on the *UIWL* where the waterline angle is 0 degrees (hereinafter referred to as "the aft boundary of the Bow Intermediate area"), and below the line 1.5*m* above the *UIWL*.~~

~~(b) Bow Intermediate area of *PC*5, *PC*6 and *PC*7 polar class ships with~~

~~"Bow Intermediate area" is defined as the hull area which is located aft of the aft boundary of the Bow area, and forward of the vertical line 0.04L_{UIWL} aft of the point on the *UIWL* where the waterline angle is 0 degrees, and below the line 1.0*m* above the *UIWL*.~~

~~(3) Stern area~~

~~(a) Stern area of *PC*1, *PC*2, *PC*3 and *PC*4 polar class ships with~~

~~"Stern area" is defined as the hull area aft of the *A.P.* to the vertical line located 70% of the distance from the *A.P.* forward the maximum breadth point at the *UIWL* (hereinafter referred to as "the fore boundary of the Stern area"), and below the line 1.5*m* above the *UIWL*.~~

~~(b) Stern area of *PC*5, *PC*6 and *PC*7 polar class ships~~

~~"Stern area" is defined as the hull area aft of the *A.P.* to the vertical line located 70% of the distance from the *A.P.* forward the maximum breadth point at the *UIWL*, and below the line 1.0*m* above the *UIWL*.~~

~~However, the distance from the *A.P.* to the fore boundary of the Stern area is not to be less than 0.15 times L_{UIWL}.~~

~~(4) Midbody area~~

~~(a) Midbody area of *PC*1, *PC*2, *PC*3 and *PC*4 polar class ships with~~

~~"Midbody area" is defined as the hull area which is located aft of the aft boundary of the Bow Intermediate area, and forward of the fore boundary of the Stern area, and below the line 1.5*m* above the *UIWL*.~~

~~(b) Midbody area of *PC*5, *PC*6 and *PC*7 polar class ships~~

~~"Midbody area" is defined as the hull area which is located aft of the aft boundary of the~~

Bow Intermediate area, and forward of the fore boundary of the Stern area, and below the line 1.0*m* above the *UIWL*.

(5) Bottom area

"Bottom area" is defined as the hull area which is located inside the line circumscribed by the points where the bottom shell is inclined 7 degrees from horizontal (hereinafter referred to as "the upper boundary of the Bottom area") in the Bow Intermediate area, the Midbody area and the Stern area.

(6) Lower area

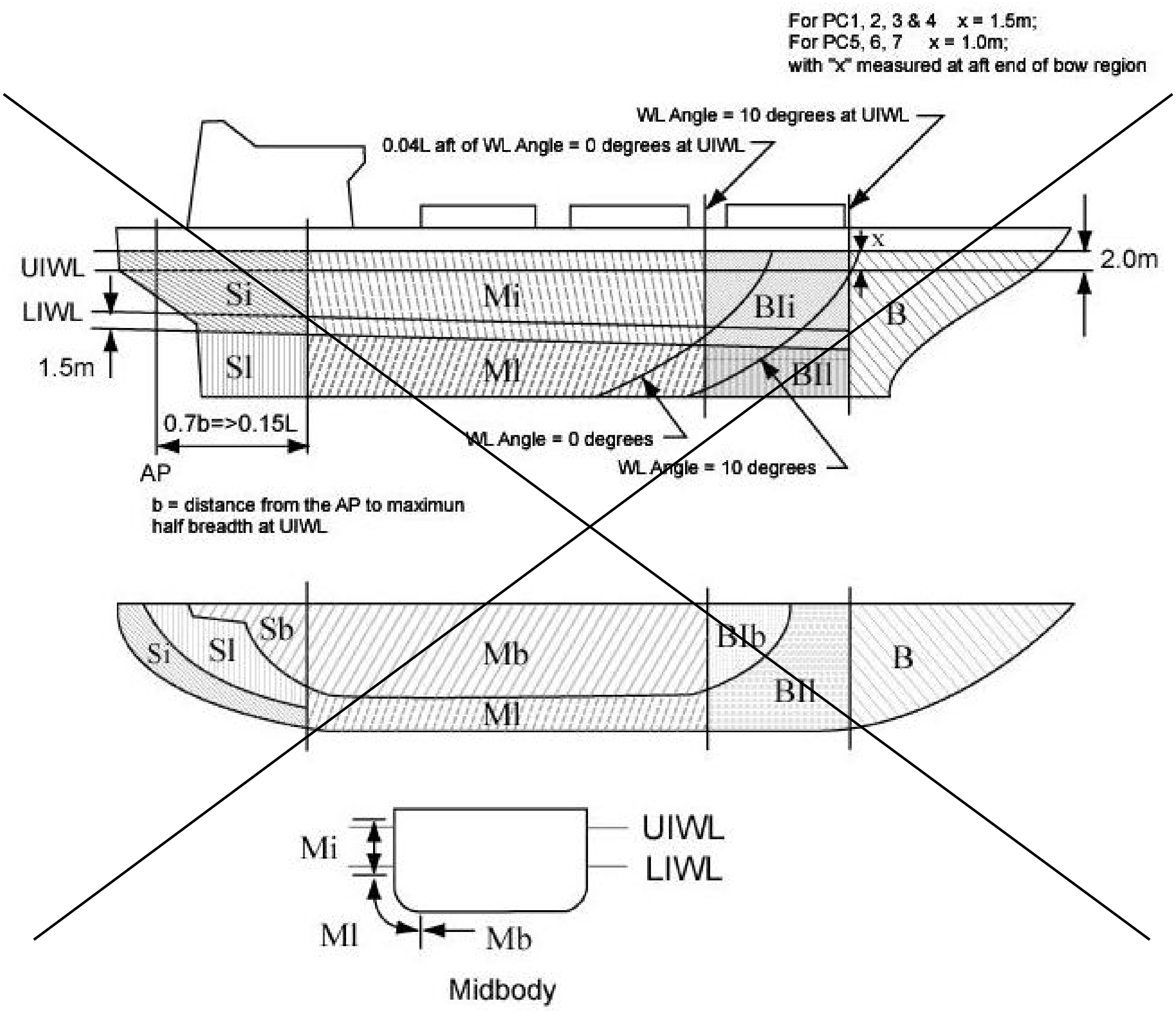
"Lower area" is defined as the hull area which is located upside of the upper boundary of the Bottom area, and below the line 1.5*m* below the *LIWL* (hereinafter referred to as "the upper boundary of the Lower area") in the Bow Intermediate area, the Midbody area and the Stern area.

(7) Icebelt area

For *PC*1, *PC*2, *PC*3 and *PC*4 polar class ships, "Icebelt area" is defined as the hull area which is located upside of the upper boundary of the Lower area, and below the line 1.5*m* above the *LIWL* in the Bow Intermediate area, the Midbody area and the Stern area.

For *PC*5, *PC*6 and *PC*7 polar class ships, "Icebelt area" is defined as the hull area which is located upside of the upper boundary of the Lower area, and below the line 1.0*m* above the *LIWL* in the Bow Intermediate area, the Midbody area and the Stern area.

Fig. I1.1 Hull Areas



Notes:

Notation in the figure are as follows:

B : Bow area

BIi : Bow Intermediate Icebelt area

BIl : Bow Intermediate Lower area

BIb : Bow Intermediate Bottom area

Mi : Midbody Icebelt area

Ml : Midbody Lower area

Mb : Midbody Bottom area

Si : Stern Icebelt area

Sl : Stern Lower area

Sb : Stern Bottom area

2 The bow, midbody and stern regions in way of hull part are defined for I*A Super*, I*A*, I*B* and I*C* ice class ships and the bow region is defined for I*D* ice class ships as follows:

(1) Bow region

From the stem to a line parallel to and 0.04*L* aft of the forward border line of the part of the hull where the waterlines run parallel to the centerline. For I*A Super* and I*A* ice class ships the overlap over the border line need not exceed 6 *metres*, and for I*B*, I*C* and I*D* ice class ships this overlap need not exceed 5 *metres*.

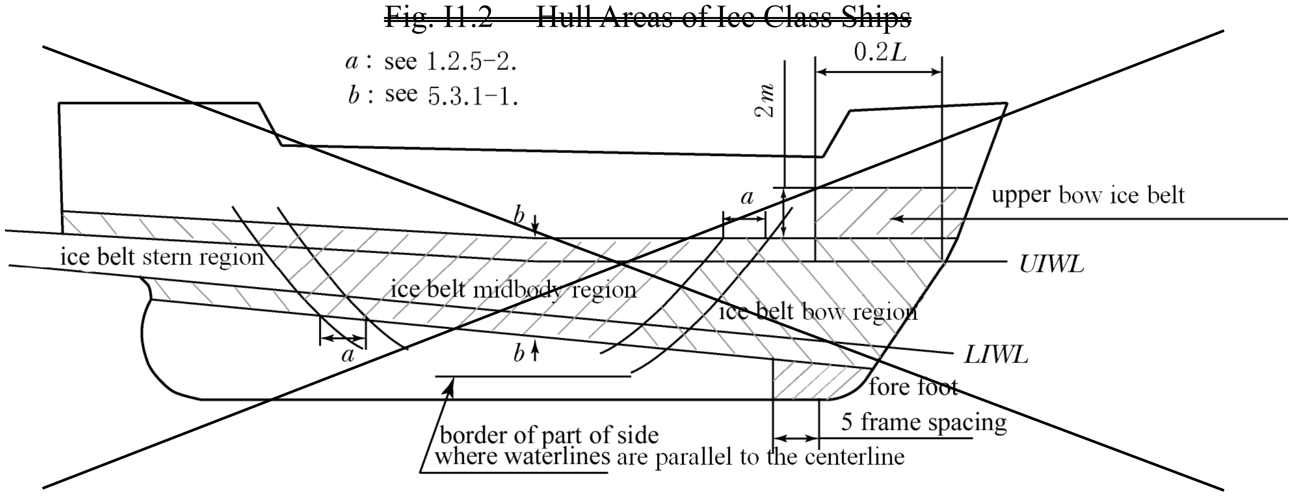
(2) Midbody region

From the aft boundary of the bow region to a line parallel to and 0.04*L* aft of the aft borderline of the part of the hull where the waterlines run parallel to the centreline. For *I*A *Super* and *I*A ice class ships the overlap over the borderline need not exceed 6 *metres*, and for *I*B and *I*C ice class ships this overlap need not exceed 5 *metres*.

(3) Stern region

From the aft boundary of the midbody region to the stern

Fig. I1.2 Hull Areas of Ice Class Ships



1.2.6 Waterline Angle

Waterline angle is defined as the angle between the tangential line of side shell and the line of longitudinal direction of a ship at water line. (See **Fig. I1.3**)

1.2.7 Engine Output

The engine output (*H*) is the Maximum Continuous output of the engine. If the output of the propulsion machinery is restricted by technical means or by any regulations applicable to the ship, *H* is to be taken as the restricted output.

Fig. I1.3 Waterline Angle α

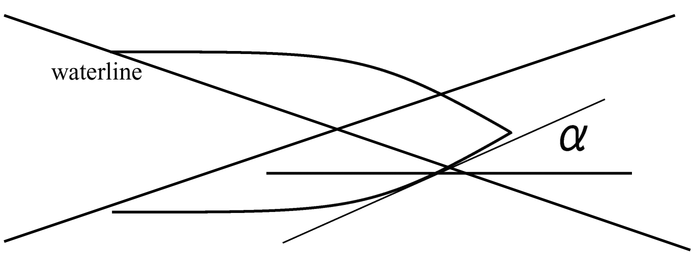
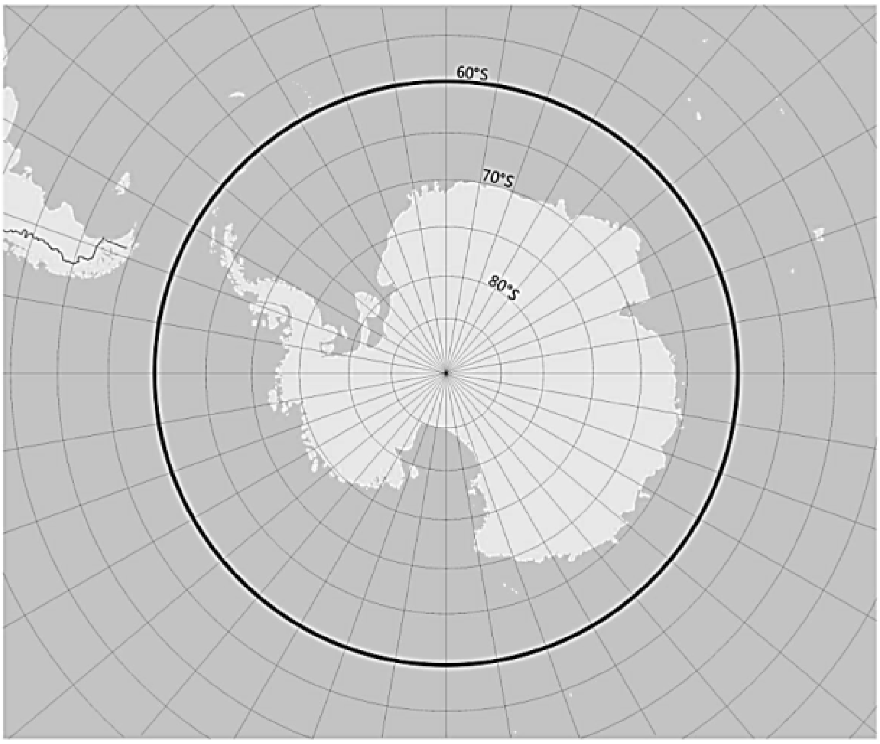
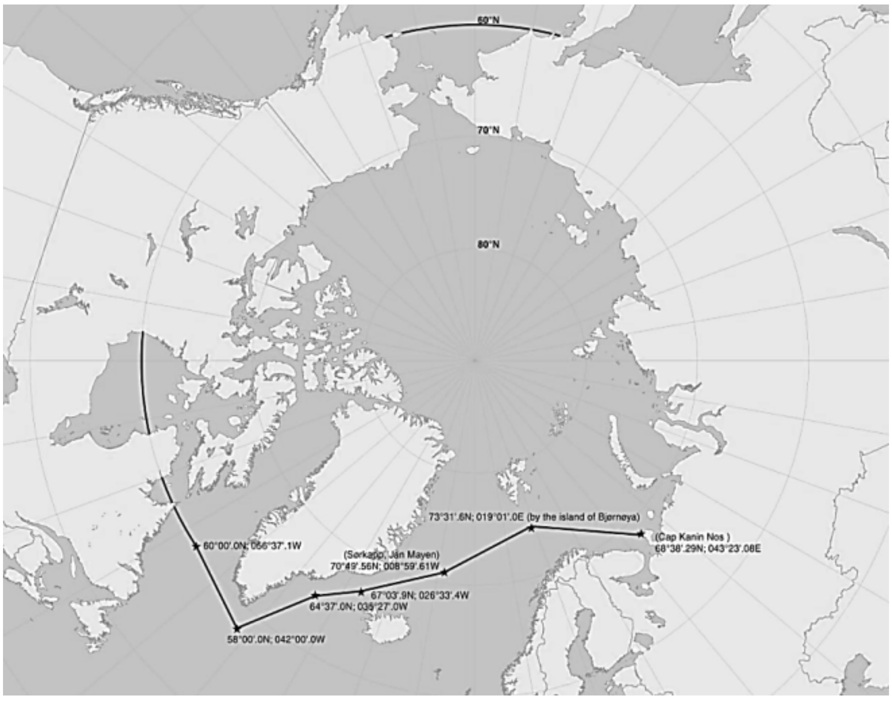


Fig. I1.1 and Fig. I1.2 have been added as follows.

<u>Fig. I1.1 Maximum extent of Antarctic area application</u>



<u>Fig. I1.2 Maximum extent of Arctic waters application</u>



Paragraph 1.2.2 has been added as follows.

1.2.2 Ice Class Ships*

When the requirements in **Chapter 8** of this Part are applied, the definitions of terms and symbols which appear in this Part are to be as specified in the following **(1)** to **(3)**, unless specified elsewhere.

(1) Ice Class

Ice Class is classified into the following five classes. It is the responsibility of the Owner to determine which class is most suitable for his requirements.

(a) I*A Super*

(b) I*A*

(c) I*B*

(d) I*C*

(e) I*D*

(2) Hull areas

The bow, midbody and stern regions in way of hull part are defined for I*A Super*, I*A*, I*B* and I*C* ice class ships and the bow region is defined for I*D* ice class ships as follows:

(a) Bow region

From the stem to a line parallel to and 0.04*L* aft of the forward border line of the part of the hull where the waterlines run parallel to the centerline. For I*A Super* and I*A* ice class ships the overlap over the border line need not exceed 6 *metres*, and for I*B*, I*C* and I*D* ice class ships this overlap need not exceed 5 *metres*.

(b) Midbody region

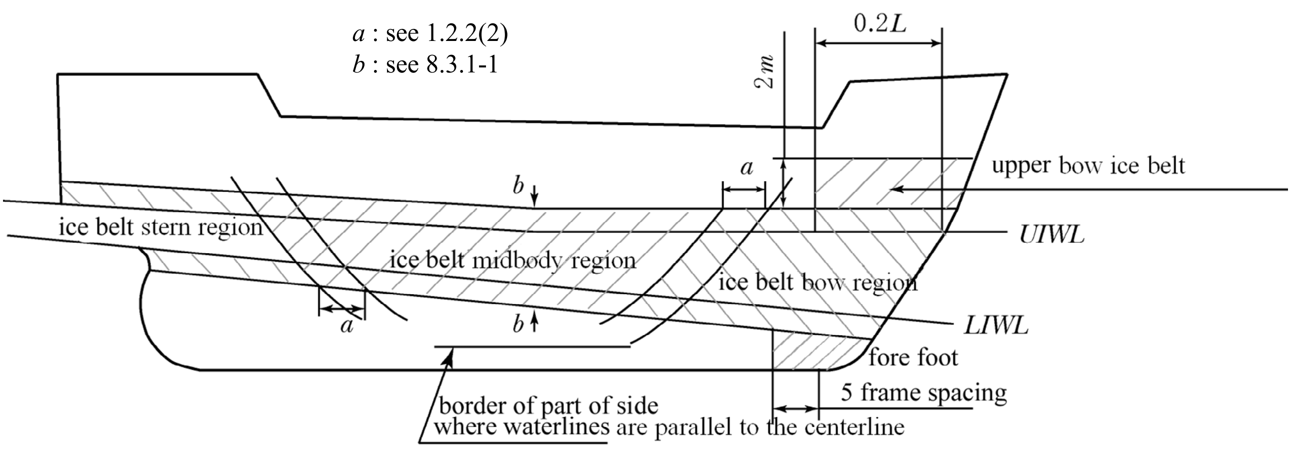
From the aft boundary of the bow region to a line parallel to and 0.04*L* aft of the aft borderline of the part of the hull where the waterlines run parallel to the centreline. For I*A Super* and I*A* ice class ships the overlap over the borderline need not exceed 6 *metres*, and for I*B* and I*C* ice class ships this overlap need not exceed 5 *metres*.

(c) Stern region

From the aft boundary of the midbody region to the stern

(3) The engine output (*H*) is the Maximum Continuous output of the engine. If the output of the propulsion machinery is restricted by technical means or by any regulations applicable to the ship, *H* is to be taken as the restricted output.

Fig. I1.3 Hull Areas of Ice Class Ships



Sections 1.3 to 1.5 have been added as follows.

1.3 Performance Standards (*Polar Code*, Part I-A, 1.4)

1.3.1 General*

Unless expressly provided otherwise, ship systems and equipment addressed in **Chapter 2** to **Chapter 7** of this Part, **Rules for Safety Equipment** and **Rules for Radio Installations** are to satisfy at least the same performance standards referred to **Rules for the Survey and Construction of Steel Ships**, **Rules for Safety Equipment** and **Rules for Radio Installations**.

1.3.2 Ships Operating in Low Air Temperature

1 For ships operating in low air temperature, a polar service temperature (*PST*) is to be specified. *PST* is to be at least 10*C* below the lowest *MDLT* for the intended area and season of operation in polar waters. Systems and equipment required by **Chapter 2** to **Chapter 7** of this Part, **Rules for Safety Equipment** and **Rules for Radio Installations** are to be fully functional at the polar service temperature.

2 For ships operating in low air temperature, survival systems and equipment required by **Part 6 of Rules for Safety Equipment** are to be fully operational at the polar service temperature during the maximum expected rescue time.

1.4 Sources of Hazards (with reference to *Polar Code*, INTRODUCTION, 3)

1.4.1 Sources of Hazards

1 The provision of **Chapter 2** to **Chapter 7** of this Part, **Rules for Marine Pollution Prevention Systems**, **Rules for Safety Equipment** and **Rules for Radio Installations** considers hazards specified in the following **(1)** to **(10)** which may lead to elevated levels of risk due to increased probability of occurrence, more severe consequences, or both:

(1) Ice, as it may affect hull structure, stability characteristics, machinery systems, navigation, the outdoor working environment, maintenance and emergency preparedness tasks and malfunction of safety equipment and systems;

(2) experiencing topside icing, with potential reduction of stability and equipment functionality;

(3) low temperature, as it affects the working environment and human performance, maintenance and emergency preparedness tasks, material properties and equipment efficiency, survival time and performance of safety equipment and systems;

(4) extended periods of darkness or daylight as it may affect navigation and human performance;

(5) high latitude, as it affects navigation systems, communication systems and the quality of ice imagery information;

(6) remoteness and possible lack of accurate and complete hydrographic data and information, reduced availability of navigational aids and seamarks with increased potential for groundings compounded by remoteness, limited readily deployable SAR facilities, delays in emergency response and limited communications capability, with the potential to affect incident response;

(7) potential lack of ship crew experience in polar operations, with potential for human error;

(8) potential lack of suitable emergency response equipment, with the potential for limiting the effectiveness of mitigation measures;

(9) rapidly changing and severe weather conditions, with the potential for escalation of incidents;

and

(10) the environment with respect to sensitivity to harmful substances and other environmental impacts and its need for longer restoration.

2 The risk level within polar waters may differ depending on the geographical location, time of the year with respect to daylight, ice-coverage, etc. Thus, the mitigating measures required to address the hazards specified in **-1(1)** to **(10)** above may vary within polar waters and may be different in Arctic and Antarctic waters.

1.5 Operational Assessment (*Polar Code*, Part I-A, 1.5)

1.5.1 Operational Assessment*

In order to establish procedures or operational limitations, an assessment of the ship and its equipment is to be carried out, taking into consideration the following **(1)** to **(3)**. The Society may require submission of data regarding the assessment.

(1) The anticipated range of operating and environmental conditions, such as following **(a)** to **(d)**.
   (a) Operation in low air temperature
   (b) Operation in ice
   (c) Operation in high latitude
   (d) Potential for abandonment onto ice or land

(2) Hazards, as listed in **1.4.1**, as applicable

(3) Additional hazards, if identified

Chapter 2 to Chapter 4 have been deleted, Chapter 5 has been renumbered to Chapter 8, and Chapter 2 to Chapter 7 have been added as follows.

Chapter 2 POLAR WATER OPERATIONAL MANUAL (PWOM)

2.1 Goal (*Polar Code*, Part I-A, 2.1)

The goal of this chapter is to provide the owner, operator, master and crew with sufficient information regarding the ship's operational capabilities and limitations in order to support their decision-making process.

2.2 Functional Requirements (*Polar Code*, Part I-A, 2.2)

2.2.1 Functional Requirements

In order to achieve the goal set out in **2.1** above, the following functional requirements are embodied in the regulations of this chapter.

(1) The Manual is to include information on the ship-specific capabilities and limitations in relation to the assessment required under **1.5**.

(2) The Manual is to include or refer to specific procedures to be followed in normal operations and in order to avoid encountering conditions that exceed the ship's capabilities.

(3) The Manual is to include or refer to specific procedures to be followed in the event of incidents in polar waters.

(4) The Manual is to include or refer to specific procedures to be followed in the event that conditions are encountered which exceed the ship's specific capabilities and limitations in **(1)**.

(5) The Manual is to include or refer to procedures to be followed when using icebreaker assistance, as applicable.

2.3 Regulations (*Polar Code*, Part I-A, 2.3)

2.3.1 Polar Water Operational Manual*

In order to comply with the functional requirements of **2.2.1**, the Manual is to be carried on board.

2.3.2 Operational Assessment

In order to comply with the functional requirements of **2.2.1(1)**, the Manual is to contain, where applicable, the methodology used to determine capabilities and limitations in ice.

2.3.3 Procedures for Normal Operations

In order to comply with the functional requirements of **2.2.1(2)**, the Manual is to include risk-based procedures for the following:

(1) voyage planning to avoid ice and/or temperatures that exceed the ship's design capabilities or limitations;

(2) arrangements for receiving forecasts of the environmental conditions;

(3) means of addressing any limitations of the hydrographic, meteorological and navigational

information available;

(4) operation of equipment required under other chapters of this Code; and

(5) implementation of special measures to maintain equipment and system functionality under low temperatures, topside icing and the presence of sea ice, as applicable.

2.3.4 Procedures for Incidents in Polar Waters*

In order to comply with the functional requirements of **2.2.1(3)**, the Manual is to include risk-based procedures to be followed for:

(1) contacting emergency response providers for salvage, search and rescue (*SAR*), spill response, etc., as applicable; and

(2) in the case of ships ice strengthened in accordance with **Chapter 3**, procedures for maintaining life support and ship integrity in the event of prolonged entrapment by ice.

2.3.5 Procedures for Conditions Exceeding Ship Design Capabilities and Limitations

In order to comply with the functional requirements of **2.2.1(4)**, the Manual is to include risk-based procedures to be followed for measures to be taken in the event of encountering ice and/or temperatures which exceed the ship's design capabilities or limitations.

2.3.6 Procedures for Icebreaker Assistance*

In order to comply with the functional requirements of **2.2.1(5)**, the Manual is to include risk-based procedures for monitoring and maintaining safety during operations in ice, as applicable, including any requirements for escort operations or icebreaker assistance. Different operational limitations may apply depending on whether the ship is operating independently or with icebreaker escort. Where appropriate, the *PWOM* is to specify both options.

Chapter 3 SHIP STRUCTURE

3.1 Goal (*Polar Code*, Part I-A, 3.1)

The goal of this chapter is to provide that the material and scantlings of the structure retain their structural integrity based on global and local response due to environmental loads and conditions.

3.2 Functional Requirements (*Polar Code*, Part I-A, 3.2)

3.2.1 Functional Requirements

In order to achieve the goal set out in **3.1** above, the following functional requirements are embodied in the regulations of this chapter:

(1) for ships intended to operate in low air temperature, materials used are to be suitable for operation at the ships polar service temperature; and

(2) in ice strengthened ships, the structure of the ship is to be designed to resist both global and local structural loads anticipated under the foreseen ice conditions.

3.3 Regulations (*Polar Code*, Part I-A, 3.3)

3.3.1 Materials of Structures*

In order to comply with the functional requirements of **3.2.1(1)** above, materials of exposed structures in ships are to be approved by the Society taking into account **Annex 1** "**Special Requirements for the Materials, Hull Structures, Equipment and Machinery of Polar Class Ships**", **1.1.12 of Part C** or other standards offering an equivalent level of safety based on the polar service temperature.

3.3.2 Hull Structures*

In order to comply with the functional requirements of **3.2.1(2)** above, the following apply:

(1) Scantlings of category *A* ships are to comply with the following **(a)** or **(b)**.
   - (a) The scantlings are to comply with the requirements regarding to hull structures for any polar class *PC1* to *PC5* and be approved by the Society.
   - (b) The scantlings are to comply with other standards offering an equivalent level of safety and be approved by the Society.

(2) Scantlings of category *B* ships are to comply with the following **(a)** or **(b)**.
   - (a) The scantlings are to comply with the requirements regarding to hull structures for polar class *PC6* or *PC7* and be approved by the Society.
   - (b) The scantlings are to comply with other standards offering an equivalent level of safety and be approved by the Society.

(3) Scantlings of ice strengthened category *C* ships are to be approved by the Society, taking into account acceptable standards adequate for the ice types and concentrations encountered in the area of operation; and

(4) A category *C* ship need not be ice strengthened if, in the opinion of the Society, the ship's structure is adequate for its intended operation.

Chapter 4 SUBDIVISION AND STABILITY

4.1 Goal (*Polar Code*, Part I-A, 4.1)

The goal of this chapter is to ensure adequate subdivision and stability in both intact and damaged conditions.

4.2 Functional Requirements (*Polar Code*, Part I-A, 4.2)

4.2.1 Functional Requirements

In order to achieve the goal set out in **4.1** above, the following functional requirements are embodied in the regulations of this chapter:

(1) Ships are to have sufficient stability in intact conditions when subject to ice accretion; and

(2) Ships of category *A* and *B*, constructed on or after 1 January 2017, are to have sufficient residual stability to sustain ice-related damages.

4.3 Regulations (*Polar Code*, Part I-A, 4.3)

4.3.1 Stability in Intact Conditions

In order to comply with the functional requirement of **4.2.1(1)**, the following apply.

(1) For ships operating in areas and during periods where ice accretion is likely to occur, the following icing allowance is to be made in the stability calculations:

  (a) 30 kg/m^2 on exposed weather decks and gangways;

  (b) 7.5 kg/m^2 for the projected lateral area of each side of the ship above the water plane; and the projected lateral area of discontinuous surfaces of rail, sundry booms, spars (except masts) and rigging of ships having no sails and the projected lateral area of other small objects is to be computed by increasing the total projected area of continuous surfaces by 5*%* and the static moments of this area by 10*%*.

(2) Ships operating in areas and during periods where ice accretion is likely to occur are to be:

  (a) designed to minimize the accretion of ice; and

  (b) equipped with such means for removing ice as the Society may require; for example, electrical and pneumatic devices, and/or special tools such as axes or wooden clubs for removing ice from bulwarks, rails and erections.

(3) Information on the icing allowance included in the stability calculations is to be given in the *PWOM*.

(4) Ice accretion is to be monitored and appropriate measures taken to ensure that the ice accretion does not exceed the values given in the *PWOM*.

4.3.2 Stability in Damaged Conditions

In order to comply with the functional requirements of **4.2.1(2)**, ships of categories *A* and *B*, constructed on or after 1 January 2017, are to be able to withstand flooding resulting from hull penetration due to ice impact, of which the damage extent is to be in accordance with the following **(1)** to **(3)**. The residual stability following ice damage is to be such that the factor s_i, as defined in **4.2.3-1**, **Part C** or **4.2.3-1**, **Part CS**, is equal to one for all loading conditions used to calculate the attained subdivision index *A* in **4.2.1-2**, **Part C** or **4.2.1-2**, **Part CS**. However, for cargo ships that comply with subdivision and damage stability regulations, the residual stability criteria of that instrument is to be met for each loading condition.

(1) the longitudinal extent is 0.045 times the upper ice waterline length if centred forward of the maximum breadth on the upper ice waterline, and 0.015 times the upper ice waterline length otherwise, and are to be assumed at any longitudinal position along the ship's length;

(2) the transverse penetration extent is 760 *mm*, measured normal to the shell over the full extent of the damage; and

(3) the vertical extent is the lesser of 0.2 times the upper ice waterline draught or the longitudinal extent, and is to be assumed at any vertical position between the keel and 1.2 times the upper ice waterline draught.

Chapter 5 WATERTIGHT AND WEATHERTIGHT INTEGRITY

5.1 Goal (*Polar Code*, Part I-A, 5.1)

The goal of this chapter is to provide measures to maintain watertight and weathertight integrity.

5.2 Functional Requirements (*Polar Code*, Part I-A, 5.2)

5.2.1 Functional Requirements

In order to achieve the goal set out in **5.1** above, all closing appliances and doors relevant to watertight and weathertight integrity of the ship is to be operable.

5.3 Regulations (*Polar Code*, Part I-A, 5.3)

5.3.1 General

In order to comply with the functional requirements of **5.2.1** above, the following apply:

(1) for ships operating in areas and during periods where ice accretion is likely to occur, means are to be provided to remove or prevent ice and snow accretion around hatches and doors; and

(2) in addition to **(1)** above, for ships intended to operate in low air temperature the following apply:

- (a) if the hatches or doors are hydraulically operated, means are to be provided to prevent freezing or excessive viscosity of liquids; and
- (b) watertight and weathertight doors, hatches and closing devices which are not within an habitable environment and require access while at sea are to be designed to be operated by personnel wearing heavy winter clothing including thick mittens.

Chapter 6 MACHINERY INSTALLATIONS

6.1 Goal (*Polar Code*, Part I-A, 6.1)

The goal of this chapter is to ensure that, machinery installations are capable of delivering the required functionality necessary for safe operation of ships.

6.2 Functional Requirements (*Polar Code*, Part I-A, 6.2)

6.2.1 Functional Requirements

In order to achieve the goal set out in **6.1**, the following **(1)** to **(3)** are to be complied with.

(1) Machinery installations are to provide functionality under the anticipated environmental conditions, taking into account the following **(a)** to **(e)**:
  - (a) Ice accretion and/or snow accumulation;
  - (b) Ice ingestion from seawater;
  - (c) Freezing and increased viscosity of liquids;
  - (d) Seawater intake temperature; and
  - (e) Snow ingestion.

(2) In addition to **(1)** above, for ships intended to operate in low air temperatures the following **(a)** and **(b)** are to be complied with.
  - (a) Machinery installations are to provide functionality under the anticipated environmental conditions, also taking into account the following **i)** and **ii)**:
    - i) cold and dense inlet air; and
    - ii) loss of performance of battery or other stored energy device.
  - (b) Materials used are to be suitable for operation at the ships polar service temperature.

(3) In addition to **(1)** and **(2)** above, for ships ice strengthened in accordance with **Chapter 3** of this Part, machinery installations are to provide functionality under the anticipated environmental conditions, taking into account loads imposed directly by ice interaction.

6.3 Regulations (*Polar Code*, Part I-A, 6.3)

6.3.1 General*

In order to comply with the functional requirement of **6.2.1(1)**, taking into account the anticipated environmental conditions, the following **(1)** to **(3)** are to apply.

(1) Machinery installations and associated equipment are to be protected against the effect of ice accretion and/or snow accumulation, ice ingestion from sea water, freezing and increased viscosity of liquids, seawater intake temperature and snow ingestion.

(2) Working liquids are to be maintained in a viscosity range that ensures operation of the machinery.

(3) Seawater supplies for machinery systems are to be designed to prevent ingestion of ice or otherwise arranged to ensure functionality.

6.3.2 Ships intended to Operate in Low Air Temperatures*

In addition to **6.3.1**, for ships intended to operate in low air temperatures, the following **(1)** to

(3) are to apply:

(1) In order to comply with **6.2.1(2)**, exposed machinery and electrical installation and appliances are to function at the polar service temperature;

(2) In order to comply with **6.2.1(2)(a)**, means are to be provided to ensure that combustion air for internal combustion engines driving essential machinery is maintained at a temperature in compliance with the criteria provided by the engine manufacturer; and

(3) In order to comply with **6.2.1(2)(b)**, materials of exposed machinery and foundations are to be either of the following **(a)** or **(b)**:

  (a) Those complying the requirements specified in **Annex 1** "**Special Requirements for the Materials, Hull Structures, Equipment and Machinery of Polar Class Ships**" appicable to materials of machinery installations and approved by the Society; or

  (b) Those complying with other standards offering an equivalent level of safety based on the polar service temperature and approved by the Administration.

6.3.3 Ice Strengthened Ships*

In addition to **6.3.1** and **6.3.2**, for ships ice strengthened in accordance with **Chapter 3** of this Part, in order to comply with **6.2.1(3)**, the following **(1)** to **(3)** are to apply.

(1) Scantlings of propeller blades, propulsion line, steering equipment and other appendages of category *A* ships are to be either of the following **(a)** or **(b)**:

  (a) Those complying with the requirements specified in **Annex 1** "**Special Requirements for the Materials, Hull Structures, Equipment and Machinery of Polar Class Ships**" applicable to scantlings of propeller blades, propulsion line, steering equipment and other appendages and approved by the Society; or

  (b) Those complying with other standards offering an equivalent level of safety and approved by the Administration.

(2) Scantlings of propeller blades, propulsion line, steering equipment and other appendages of category *B* ships are to be either of the following **(a)** or **(b)**:

  (a) Those complying with the requirements specified in **Annex 1** "**Special Requirements for the Materials, Hull Structures, Equipment and Machinery of Polar Class Ships**" applicable to scantlings of propeller blades, propulsion line, steering equipment and other appendages and approved by the Society; or

  (b) Those complying with other standards offering an equivalent level of safety and approved by the Administration.

(3) Scantlings of propeller blades, propulsion line, steering equipment and other appendages of ice-strengthened category *C* ships are to be approved by the Administration or Society taking into account acceptable standards adequate with the ice types and concentration encountered in the area of operation.

Chapter 7 FIRE SAFETY/PROTECTION

7.1 Goal (*Polar Code*, Part I-A, 7.1)

The goal of this chapter is to ensure that fire safety systems and appliances are effective and operable, and that means of escape remain available so that persons on board can safely and swiftly escape to the lifeboat and liferaft embarkation deck under the expected environmental conditions.

7.2 Functional Requirements (*Polar Code*, Part I-A, 7.2)

7.2.1 Functional Requirements

In order to achieve the goal set out in **7.1**, the following **(1)** to **(5)** are to be complied with:

(1) All components of fire safety systems and appliances if installed in exposed positions are to be protected from ice accretion and snow accumulation;

(2) Local equipment and machinery controls are to be arranged so as to avoid freezing, snow accumulation and ice accretion and their location to remain accessible at all time;

(3) The design of fire safety systems and appliances are to take into consideration the need for persons to wear bulky and cumbersome cold weather gear, where appropriate;

(4) Means are to be provided to remove or prevent ice and snow accretion from accesses; and

(5) Extinguishing media are to be suitable for intended operation.

7.2.2 Ships intended to Operate in Low Air Temperature

In addition to **7.2.1**, for ships intended to operate in low air temperature, the following **(1)** and **(2)** are to be complied with:

(1) All components of fire safety systems and appliances are to be designed to ensure availability and effectiveness under the polar service temperature; and

(2) Materials used in exposed fire safety systems are to be suitable for operation at the polar service temperature.

7.3 Regulations (*Polar Code*, Part I-A, 7.3)

7.3.1 Fire Safety Systems and Appliances Installed in Exposed Positions

In order to comply with the requirement of **7.2.1(1)**, the following **(1)** and **(2)** are to apply:

(1) Isolating and pressure/vacuum valves in exposed locations are to be protected from ice accretion and remain accessible at all time; and

(2) All two-way portable radio communication equipment is to be operable at the polar service temperature.

7.3.2 Local Equipment and Machinery Controls

In order to comply with the requirement of **7.2.1(2)**, the following **(1)** to **(4)** are to apply:

(1) Fire pumps including emergency fire pumps, water mist and water spray pumps are to be located in compartments maintained above freezing;

(2) The fire main is to be arranged so that exposed sections can be isolated and means of draining of exposed sections are to be provided. Fire hoses and nozzles need not be connected to the

fire main at all times, and may be stored in protected locations near the hydrants;

(3) Firefighter's outfits are to be stored in warm locations on the ship; and

(4) Where fixed water-based firefighting systems are located in a space separate from the main fire pumps and use their own independent sea suction, this sea suction is to be also capable of being cleared of ice accumulation.

7.3.3 Ships Intended to Operate in Low Air Temperatures*

In addition to **7.3.1** and **7.3.2**, for ships intended to operate in low air temperature, the following **(1)** and **(2)** are to apply:

(1) In order to comply with the requirement of **7.2.2(1)**, portable and semi-portable extinguishers are to be located in positions protected from freezing temperatures, as far as practical. Locations subject to freezing are to be provided with extinguishers capable of operation under the polar service temperature.

(2) In order to comply with the functional requirements of **7.2.2(2)**, materials of exposed fire safety systems are to be acceptable to the Society.

Chapter 8 has been amended as follows.

Chapter ~~5~~8 ICE CLASS SHIPS

~~5~~8.1 General

~~5~~8.1.1 Application*

1 The requirements in this Chapter apply to hull structure, equipment and machinery, etc. of ice class ships.

2 The requirements in this Chapter are framed for the ice strengthening of ships which are intended to navigate in the Northern Baltic complying with the *Finnish-Swedish Ice Class Rules 2010* or in the Canadian Arctic complying with the *Arctic Shipping Pollution Prevention Regulations*.

~~5~~8.1.2 Maximum and Minimum Draught

1 The maximum and minimum ice draughts at fore and aft perpendicular are to be determined in accordance with the upper and lower ice waterlines.

2 Restrictions on draughts when operating in ice are to be documented and kept on board readily available to the master.

3 If the summer load line in fresh water is anywhere located at a higher level than the *UIWL*, the ship's side is to be provided with a warning triangle and with an ice class draught mark at the maximum permissible ice class draught amidships. (see **Fig. I~~5~~8.1**)

4 Any ballast tank, situated above the *LIWL* and needed to load down the ship to this water line is to be equipped with proper devices to prevent the water from freezing.

5 The propeller is to be fully submerged, if possible entirely below the ice.

6 The minimum forward draught is not to be less than that obtained from the following formula.

$(2.0 + 0.00025\,\Delta)h_0\,(m)$ but need not exceed $4h_0$

where

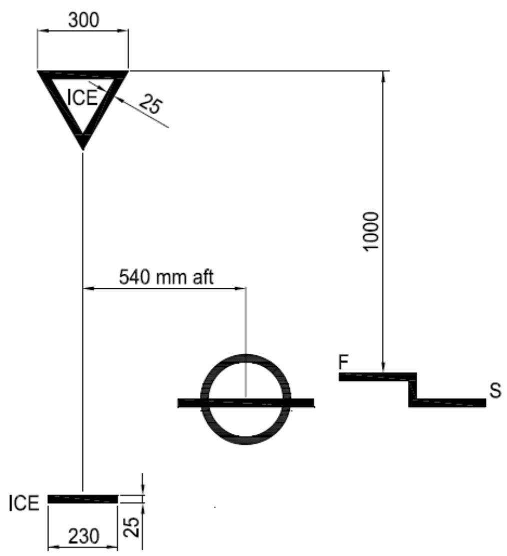
Δ : The displacement of the ship at the maximum draught amidships on the *UIWL*.

h_0 : Constant given in **Table I~~5~~8.1** according to the respective ice class

Table I~~5~~8.1 Value of Constant h_0

Ice Class	h_0
I*A Super*	1.0
I*A*	0.8
I*B*	0.6
I*C*	0.4
I*D*	0.4

Fig. I~~5~~8.1 Ice Class Draught Marking



Notes:

1. The upper edge of the warning triangle is to be located vertically above the Ice mark, 1,000 *mm* higher than the Summer Load Line in fresh water but in no case higher than the deck line. The sides of the triangle are to be 300 *mm* in length.
2. The ice class draught mark is to be located 540 *mm* abaft the centre of the load line ring or 540 *mm* abaft the vertical line of the timber load line mark, if applicable.
3. The marks and figures are to be cut out of 5 *mm* – 8 *mm* plate and then welded to the ship's side. The marks and figures are to be painted in a red or yellow reflecting colour in order to make the marks and figures plainly visible even in ice conditions.
4. The dimensions of all figures are to be the same as those used in the load line mark.

~~5~~8.2 Design Ice Pressures

~~5~~8.2.1 Design Ice Pressures

1 Design ice pressure (P) is not to be less than that obtained from the following formula:

$C_d\ C_p\ C_a\ p_0\ (MPa)$

where

C_d: As given by the following formula. However, C_d needs not to exceed 1.0.

$$C_d = \frac{ak+b}{1000}$$

$$k = \frac{\sqrt{\Delta H}}{1000}$$

Δ : Displacement (t) of the ship on the maximum draught specified in **~~5~~8.1.2-6**

H : Engine output (kW)

a and b : As given in **Table I~~5~~8.2** according to the region under consideration and the value of k.

C_p : As given in **Table I~~5~~8.3** according to the ice class and the region under consideration.

p_0 : The nominal ice pressure; the value 5.6 MPa is to be used.

C_a : As given by the following formula. However, C_a is not to be less than 0.35 but need not to exceed 1.0.

$$\sqrt{\frac{0.6}{l_a}}$$

l_a : To be taken as specified in **Table I~~5~~8.4** according to the structural member under consideration.

Table I~~5~~8.2 Value of a and b

	Bow region		Midbody & Stern regions	
	$k \le 12$	$k > 12$	$k \le 12$	$k > 12$
a	30	6	8	2
b	230	518	214	286

Table I~~5~~8.3 Coefficient C_p

Ice Class	Bow region	Midbody region	Stern region
I*A Super*	1.00	1.00	0.75
I*A*	1.00	0.85	0.65
I*B*	1.00	0.70	0.45
I*C*	1.00	0.50	0.25
I*D*	1.00	-	-

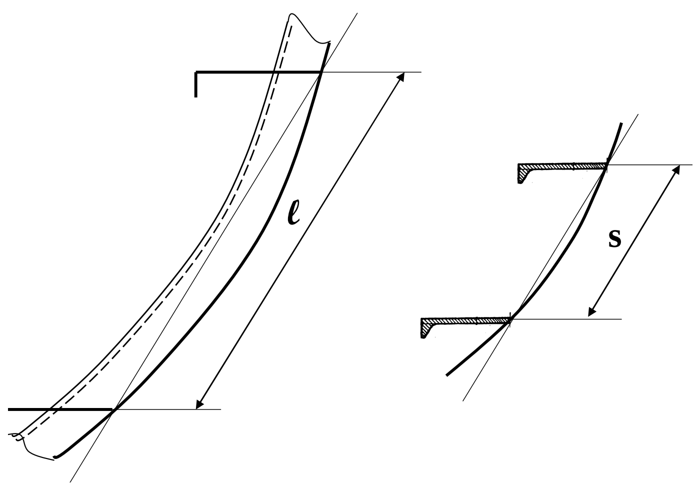
Table I~~5~~8.4 Value of l_a

Structural member	Type of framing	l_a (m)
Shell	Transverse	Frame spacing
	Longitudinal	1.7-spacing of frame
Frames	Transverse	Frame spacing
	Longitudinal	Span of frame
Ice stringer	-	Span of stringer
Web frame	-	2-spacing of web frame

Note:

The frame spacing and spans are normally assumed to be measured along the plate and perpendicular to the axis of the stiffener for plates, along the flange for members with a flange, and along the free edge for flat bar stiffeners. For curved members, the span or spacing is defined as the chord length between the span or spacing points. The span points are defined by the intersection between the flange or upper edge of the member and the supporting structural element. (See **Fig. I~~5~~8.2**)

Fig. I~~5~~8.2 Definition of the Frame Span l and Frame Spacing s for Curved Members



2 *h* is the height of the area under the ice pressure (*P*) specified in **-1**. and is to be as given in **Table I~~5~~8.5** according to the ice class.

Table I~~5~~8.5 Value of *h*

Ice Class	*h* (*m*)
I*A Super*	0.35
I*A*	0.30
I*B*	0.25
I*C*	0.22
I*D*	0.22

~~5~~8.3 Hull Structures and Equipment

~~5~~8.3.1 Shell Plating

1 The vertical extension of the ice belt is to be as given in **Table I~~5~~8.6** according to the ice class and is to comply with the following requirements.

(1) Fore foot
For I*A Super* ice class ships with the shell plating below the ice belt from the stem to a position five main frame spaces abaft the point where the bow profile departs from the keel line is to have at least the thickness required in the ice belt in the midbody region.

(2) Upper bow ice belt
For I*A Super* and I*A* ice class ships with an open water service speed equal to or exceeding 18 *knots*, the shell plate from the upper limit of the ice belt to 2 *m* above it and from the stem to a position at least 0.2*L* abaft the forward perpendicular, is to have at least the thickness required in the ice belt in the midbody region. A similar strengthening of the bow region is to apply to a ship with lower service speed, when it is, *e.g.* on the basis of the model tests, evident that the ship will have a high bow wave.

(3) Side scuttles are not to be situated in the ice belt.

(4) If the weather deck in any part of the ship is situated below the upper limit of the ice belt, the bulwark and the construction of the freeing ports are to be given at least the same strength as is required for the shell in the ice belt.

Table I~~5~~8.6 Vertical Extension of the Ice Belt

Ice Class	Hull region	Above the *UIWL*	Below the *LIWL*
I*A Super*	Bow	0.6 *m*	1.2 *m*
	Midbody		
	Stern		1.0 *m*
I*A*	Bow	0.5 *m*	0.9 *m*
	Midbody		0.75 *m*
	Stern		
I*B* I*C*	Bow	0.4 *m*	0.7 *m*
	Midbody		0.6 *m*
	Stern		
I*D*	Bow	0.4 *m*	0.7 *m*

2 The thickness of shell plating in the ice belt is not to be less than that obtained from the following formula according to the type of framing.

For the transverse framing: $667s\sqrt{\frac{f_1 p_{PL}}{\sigma_y}}+t_c \quad (mm)$

For the longitudinal framing: $667s\sqrt{\frac{p}{f_2\sigma_y}}+t_C \quad (mm)$

where

s : Frame spacing (m)

p_{PL} : $0.75p$ (MPa)

p : As specified in **~~5~~8.2.1-1**

f_1 : As given in the following formula. Where, however, f_1 is greater than 1.0, f_1 is to be taken as 1.0.

$$1.3-\frac{4.2}{(h/s+1.8)^2}$$

f_2 : As given in the following formula depending on the value of h/s

where $h/s<1.0$: $0.6+\frac{0.4}{h/s}$

where $1.0\le h/s<1.8$: $1.4-0.4\,(h/s)$

h : As specified in **~~5~~8.2.1-2**

σ_y : Yield stress of the materials (N/mm^2), for which the following values are to be used
235 N/mm^2 for normal-strength hull structural steel
315 N/mm^2 for high-strength hull structural steel
However, if steels with different yield stresses than those given above are used, the value is to be at the discretion of the Society.

t_c : 2mm: If special surface coating, by experience shown capable to withstand the abrasion of ice, is applied and maintained, lower values may be approved.

~~5~~8.3.2 General Requirements for Frames*

1 The vertical extension of the ice strengthening of the framing is to be at least as given in **Table I~~5~~8.7** according to the respective ice classes and regions. Where an upper bow ice belt is required in **~~5~~8.3.1-1**, the ice strengthening part of the framing is to be extended at least to the top of this ice belt. Where the ice strengthening would go beyond a deck or a tank top by no more than 250 mm, it can be terminated at that deck or tank top.

2 Within the ice strengthening area all frames are to be effectively attached to all the supporting structures. A longitudinal frame is to be attached to all the supporting web frames and bulkheads by brackets at both ends. When a transverse frame terminates at a stringer or deck, a bracket or similar construction is to be fitted. When a frame is running through the supporting structure, both sides of the web plate of the frame are to be connected to the structure by direct welding, collar plate or lug. When a bracket is installed, it is to have at least the same thickness as the web plate of the frame and the edge is to be appropriately stiffened against buckling.

3 In all regions for I*A Super* ice class ships, in the bow and midbody regions for I*A* ice class ships and in the bow regions for I*B*, I*C* and I*D* ice class ships, the following are to apply in the ice strengthening area:

(1) The frames are to be attached to the shell by double continuous welds. No scalloping is allowed except when crossing shell plate butts.

(2) The web thickness of the frames is not to be less than the greatest of the following **(a)** to **(d)**.

(a) $\dfrac{h_w\sqrt{\sigma_y}}{C}$

h_w: web height (*mm*)
C: 805 for profiles
282 for flat bars
σ_y: As specified in **~~5~~8.3.1-2**

(b) 2.5% of the frame spacing for transverse frames

(c) Half of the net thickness of the shell plating $t - t_c$. For the purpose of calculating the web thickness of frames, the required thickness of the shell plating is to be calculated according to **~~5~~8.3.1-2** using the yield strength σ_y of the frames

(d) 9 *mm*

(3) Where there is a deck, tank top or bulkhead in lieu of a frame, the plate thickness of this is to be as per the preceding **(2)**, to a depth corresponding to the height of adjacent frames.

(4) Frames that are not normal to the plating or the profile is unsymmetrical, and the span exceeds 4.0 *m,* are to be supported against tripping by brackets, intercostals, stringers or similar at a distance not exceeding 1.3 *m*. If the span is less than 4.0 *m*, the supports against tripping are required for unsymmetrical profiles and stiffeners for webs which are not normal to plating.

Table I~~5~~8.7 Vertical Extension of the Ice Strengthening of Framing

Ice Class	Hull region	Above the *UIWL*	Below the *LIWL*
I*A Super*	Bow	1.2 *m*	Down to double bottom or below top of the floors
	Midbody		2.0 *m*
	Stern		1.6 *m*
I*A* I*B* I*C*	Bow	1.0 *m*	1.6 *m*
	Midbody		1.3 *m*
	Stern		1.0 *m*
I*D*	Bow	1.0 *m*	1.6 *m*

~~5~~8.3.3 Transverse Frames

1 The section modulus and the effective shear area of a main or intermediate transverse frame specified in **~~5~~8.3.2-1** are to be not less than that obtained from the following formula:

Section modulus: $\dfrac{pshl}{m_t\sigma_y}\times 10^6 \quad (cm^3)$

Effective shear area: $\dfrac{\sqrt{3}f_3phs}{2\sigma_y}\times 10^4 \quad (cm^2)$

where

p : As specified in **~~5~~8.2.1-1**

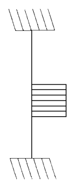
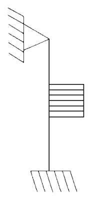
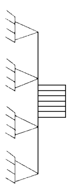
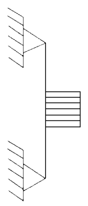
s : Frame spacing (*m*) (See the note to **Table I~~5~~8.4**)

h : As specified in **~~5~~8.2.1-2**
l : Span of the frame (m) (See the note to **Table I~~5~~8.4**)
m_t : As given by the following formula

$$\frac{7m_0}{7-5h/l}$$

m_0 : As specified in **Table I~~5~~8.8**
f_3 : Factor which takes into account the maximum shear force versus the load location and the shear stress distribution, taken as 1.2
σ_y : As specified in **~~5~~8.3.1-2**.

Table I~~5~~8.8 Value of m_0

Boundary condition	m_0	Example
	7.0	Frames in a bulk carrier with top side tanks
	6.0	Frames extending from the tank top to a single deck
	5.7	Continuous frames between Several decks or stringers
	5.0	Frames extending between two decks only

Note:
The boundary conditions are those for the main and intermediate frames. Load is applied at mid span.

2 Notwithstanding the **-1** above, where less than 15% of the span, l, of the frame is situated within the ice strengthening zone for frames, ordinary frame scantlings may be used.
3 The upper end of the strengthening part of a main frame and of an intermediate frame are to be attached to a deck or an ice stringer as specified in **~~5~~8.3.5**. Where a frame terminates above a deck or a stringer (hereinafter, referred to as the lower deck in this section) which is situated at or above the upper limit of the ice belt, the part of the frame above the lower deck is to be in accordance with the followings:

(1) the part of the main frame and the intermediate frame may have the scantlings required by the ordinary frame; and

(2) the upper end of the main frame and the intermediate frame is to be connected to a deck which situated above the lower deck (hereinafter, referred to as the higher deck in this section). However, the upper end of the intermediate frame may be connected to the adjacent main frames by a horizontal stiffener having the same scantlings as the main frame.

4 The lower end of the strengthened part of a main frame and of an intermediate ice frame is to be attached to a deck, tank top or ice stringer specified in **~~5~~8.3.5**. Where an intermediate frame terminates below a deck, tank top or ice stringer which is situated at or below the lower limit of the ice belt, the lower end may be connected to the adjacent main frames by a horizontal member of the same scantlings as the frames.

~~5~~8.3.4 Longitudinal Frames*

1 The section modulus and effective shear area of a longitudinal frame in the extension specified in **~~5~~8.3.2-1** are not to be less than those obtained by the following formulae. However, in calculating the actual shear area of the frames, the area of the brackets is not to be taken into account:

Section modulus : $\dfrac{f_4 p h l^2}{m\sigma_y}\times 10^6 \quad (cm^3)$

Effective shear area : $\dfrac{\sqrt{3} f_4 f_5 p h l}{2\sigma_y}\times 10^4 \quad (cm^2)$

f_4 : Factor which takes account of the load distribution to adjacent frames as given by the following formula.
$(1-0.2h/s)$

f_5: Factor which takes into account the pressure definition and maximum shear force versus load location and also the shear stress distribution, taken as 2.16

h : As specified in **~~5~~8.2.1-2**

s : Frame spacing (m) (See the note to **Table I~~5~~8.4**)

p : As specified in **~~5~~8.2.1-1**

l : Span of the longitudinal frame (m) (See the note to **Table I~~5~~8.4**)

m : Boundary condition factor is to be taken as 13.3. Where the boundary conditions deviate significantly from those of a continuous beam, a smaller boundary factor is to be adapted. For frames without brackets, the boundary condition factor is to be taken as 11.0.

σ_y : As specified in **~~5~~8.3.1-2**

~~5~~8.3.5 Ice Stringers*

1 The section modulus and effective shear area of a stringer situated within the ice belt are not to be less than those obtained by the following formulae:

Section modulus: $\dfrac{f_6 f_7 p h l^2}{m\ \sigma_y}\times 10^6 \quad (cm^3)$

Effective shear area: $\dfrac{\sqrt{3} f_6 f_7 f_8 p h l}{2\sigma_y}\times 10^4 \quad (cm^2)$

f_6 : Factor which takes account of the distribution of load to the transverse frames is to be taken as 0.9.

f_7: Safety factor of stringers is to be taken as 1.8.

f_8: Factor which takes into account the maximum shear force versus load location and the shear stress distribution, taken as 1.2.

p : As specified in **~~5~~8.2.1-1**

h : As specified in **~~5~~8.2.1-2**

However, the product of p and h is not to be taken as less than 0.15

l : Span of the stringer (m)

m : Boundary condition factor as defined in **~~5~~8.3.4-1**

σ_y : As specified in **~~5~~8.3.1-2**

2 The section modulus and effective shear area of a stringer situated outside the ice belt but supporting ice strengthened frames are not to be less than those obtained by the following formulae:

Section modulus: $\dfrac{f_9 f_{10} phl^2}{m\ \sigma_y}(1-h_s/l_s)\times 10^6 \quad (cm^3)$

Effective shear area: $\dfrac{\sqrt{3} f_9 f_{10} f_{11} phl}{2\sigma_y}(1-h_s/l_s)\times 10^4 \quad (cm^2)$

f_9: Factor which takes account of load to the transverse frames is to be taken as 0.8.

f_{10}: Safety factor of stringers is to be taken as 1.8.

f_{11}: Factor which takes into account the maximum shear force versus load location and the shear stress distribution, taken as 1.2.

p: As specified in **~~5~~8.2.1-1**

h: As specified in **~~5~~8.2.1-2**

However, the product of p and h is not to be taken as less than 0.15

l: Span (m) of the stringer

h_s: The distance to the ice belt

l_s: The distance (m) to the adjacent ice stringer (m)

m: Boundary condition factor as defined in **~~5~~8.3.4-1**

σ_y : As specified in **~~5~~8.3.1-2**

3 Narrow deck strips abreast of hatches and serving as ice stringers are to comply with the section modulus and shear area requirements in the preceding **-1** and **-2** respectively. In the case of very long hatches, the product p and h may be taken as less than 0.15 but in no case less than 0.10. Regard is to be paid to the deflection of the ship's sides due to ice pressure in way of very long hatch openings, when designing weather deck, hatch covers and their fittings.

~~5~~8.3.6 Web Frames

1 The load F transferred to a web frame from an ice stringer or from longitudinal framing is not to be less than that obtained by the following formula:

$f_{12}phS$ (MN)

f_{12}: Safety factor of web frames is to be taken as 1.8.

p: Ice pressure (MPa) as specified in **~~5~~8.2.1-1**, in calculating C_a however, l_a is to be taken as $2S$.

h: As specified in **~~5~~8.2.1-2**

However, the product of p and h is not to be taken as less than 0.15

S: Distance (m) between web frames

2 Notwithstanding the provisions specified in **-1** above, in case the supported stringer is outside the ice belt, the force F may be reduced to that obtained by the following formula:

$$f_{12}\, phS\left(1 - h_s / l_s\right) \quad (MN)$$

h_s and l_s: As specified in **~~5~~8.3.5-2**

3 The section modulus and effective shear area are to be calculated by the following formulae:

Effective shear area: $$\frac{\sqrt{3}\alpha f_{13} Q}{\sigma_y} \times 10^4 \quad (cm^2)$$

Section modulus: $$\frac{M}{\sigma_y}\sqrt{\frac{1}{1-\left(\gamma A/A_a\right)^2}} \times 10^6 \quad (cm^3)$$

f_{13}: Factor which takes into account the shear force distribution is to be taken as 1.1.

Q: Maximum calculated shear force under the load F transferred to a web frame from an ice stringer or from longitudinal framing as specified in **-1** or **-2**, as given in the following formula:
$Q = F$

M: Maximum calculated bending moment under the load F transferred to a web frame from an ice stringer or from longitudinal framing as specified in **-1** or **-2**, as given in the following formula:
$M = 0.193Fl$

l: Span (m) of the web frame

α and γ: As given in **Table I~~5~~8.9**. For intermediate values of A_f / A_w is to be obtained by linear interpolation.

A: Required shear area (cm^2)

A_a: Actual cross sectional area (cm^2) of the web frame, as given in the following formula:
$A_a = A_f + A_w$

A_f: Actual cross sectional area (cm^2) of free flange

A_w: Actual effective cross sectional area (cm^2) of web plate

σ_y: As specified in **~~5~~8.3.1-2**

Table I~~5~~8.9 Value of α and γ

A_f / A_w	0.00	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00
α	1.50	1.23	1.16	1.11	1.09	1.07	1.06	1.05	1.05	1.04	1.04
γ	0.00	0.44	0.62	0.71	0.76	0.80	0.83	0.85	0.87	0.88	0.89

4 The scantlings of web frames may be calculated by direct analysis where deemed appropriate by the Society. In this case, the following are to be complied with:

(1) The pressure to be used is $1.8p$ (MPa) where p is determined according to **~~5~~8.2.1-1,** and the load patch is to be applied at locations where the capacity of the structure under the combined effects of bending and shear are minimized.

(2) The structure is to be checked with load centred at the *UIWL*, 0.5 h_0 (m) below the *LIWL*, and positioned several vertical locations in between. Several horizontal locations which are the locations centred at the mid-span or spacing are to be checked. If the load length l_a cannot be determined directly from the arrangement of the structure, several values of l_a may be checked using corresponding values for C_a.

(3) Acceptance criterion for designs is that the combined stresses from bending and shear, using the von Mises yield criterion, is to be lower than the σ_y as specified in **~~5~~8.3.1-2**. When the direct analysis is using beam theory, the allowable shear stress is not to be greater than $0.9\tau_y$, where $\tau_y = \sigma_y / \sqrt{3}$

~~5~~8.3.7 Stem

1 A stem is recommended to be similar to the structure shown in **Fig. I~~5~~8.3**.

2 The plate thickness of a shaped plate stem and in the case of a blunt bow, any part of the shell where angle α and ψ as specified in **~~5~~8.4.2-1** are respectively not less than 30 *degrees* and 75 *degrees*, is to be obtained from the formula in **~~5~~8.3.1-2**

where

s: Spacing (m) of elements supporting the plate

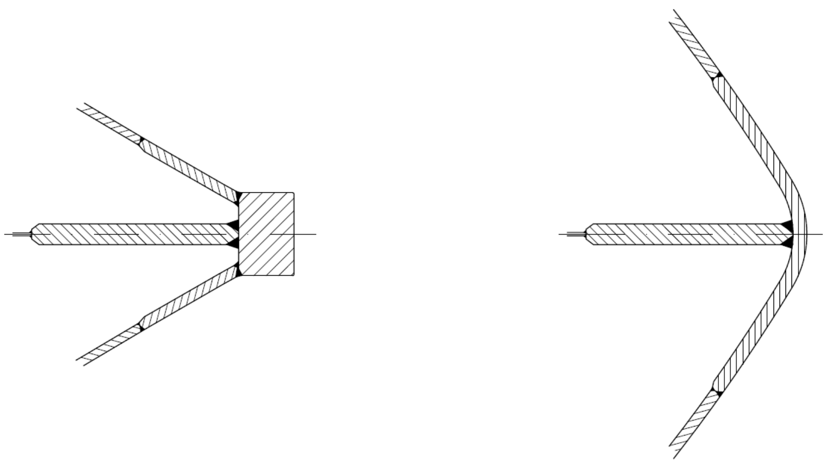
p_{PL}: Ice pressure (MPa) as specified in **~~5~~8.2.1-1**

l_a: Spacing (m) of vertical supporting elements

3 The stem and the part of a blunt bow specified in the preceding **-2** is to be supported by floors or brackets spaced not more than 0.6m apart and having a thickness of at least half the plate thickness.

4 The reinforcement of the stem is to be extended from the keel to a point 0.75 m above *ULWL* or, in case an upper bow ice belt is required in **~~5~~8.3.1-1** to the upper limit of this.

Fig. I~~5~~8.3 Examples of Suitable Stems



~~5~~8.3.8 Arrangements for Towing*

Special consideration is to be given to the strength and installation of towing arrangements.

~~5~~8.3.9 Stern*

1 The clearance between the propeller blade tip and hull, including the stern frame, is not to be less than h_0 as specified in **~~5~~8.1.2-6** to prevent from occurring high loads on the blade tip.

2 On twin and triple screw ships, the ice strengthening of the shell and framing are to be extended to the double bottom for 1.5 *metres* forward and aft of the side propellers.

3 On twin and triple screw ships, the shafting and stern tubes of side propellers are to be normally enclosed within plated bossings. If detached struts are used, their design, strength and attachment to the hull is to be duly considered.

4 The introduction of new propulsion arrangements with azimuthing thrusters or podded propellers, which provide an improved maneuverability, will result in increased ice loading of the stern region and the stern area. This fact is to be considered in the design of the aft/stern structure.

~~5~~8.3.10 Bilge Keel*

Special consideration is to be given to the design of bilge keels.

~~5~~8.4 Fundamental Requirements of Machinery

~~5~~8.4.1 Materials

1 Materials for Machinery Parts exposed to Seawater

Materials exposed to seawater, such as propeller blades, propeller hub and blade bolts are to have an elongation of not less than 15% for the *U*14*A* test specimens given in **Part K**. Materials other than bronze and austenitic steel are to have an average impact energy value of 20 *J* at -10°C for the *U*4 test specimens given in **Part K**.

2 Materials for Machinery Parts exposed to Seawater Temperatures

Materials exposed to seawater temperatures are to be of steel or other ductile material approved by the Society. The materials are to have an average impact energy value of 20 *J* at -10°C for the U4 test specimens given in **Part K**.

~~5~~8.4.2 Engine Output

1 The engine output (*H*) is not to be less than the greater of two outputs determined by the following formula for the maximum draught amidships referred to as the *UIWL* and the minimum draught referred to as the *LIWL*, and in no case less than 1,000*kW* for ice class ships with I*A*, I*B*, I*C* and I*D*, and not less than 2,800*kW* for ice class ships with I*A Super*.

$$H = K_e \frac{(R_{CH}/1000)^{3/2}}{D_P}$$

H : Engine output (*kW*)

K_e : Constant given in **Table I~~5~~8.10**

D_p : Diameter (*m*) of the propeller

R_{CH} : The resistance (*N*) of the ship in a channel with brash ice and a consolidated layer

$$R_{CH} = C_1 + C_2 + C_3 C_\mu (H_F + H_M)^2 (B + C_\psi H_F) + C_4 L_{PAR} H_F^2 + C_5 (LT/B^2)^3 (A_{wf}/L)$$

L : Length (*m*) of the ship between the perpendiculars on the *UIWL*

B : Maximum breadth (*m*) of the ship on the *UIWL*

T : Actual ice class draughts (*m*) of the ship, in general being a draught amidships of length L_f corresponding to the *UIWL* according to **1.2.~~4-1~~1(23)** and a draught amidships of length L_f corresponding to the *LIWL* according to **1.2.~~4-2~~1(24)**.

In any case, $(LT/B^2)^3$ is not to be taken as less than 5 and not to be taken as more than 20.

L_{PAR} : Length (*m*) of the parallel midship body, measured horizontally between the fore and aft ends of the flat side on the waterline at the actual ice class draught, see **Fig. I~~5~~8.4**

L_{BOW} : Length (*m*) of the bow, measured horizontally between the fore end of the flat side on the waterline at the actual ice class draught and the fore perpendicular at the *UIWL*, *s*ee **Fig. I~~5~~8.4.**

A_{wf}: Area (m^2) of the waterline of the bow at the actual ice class draught, see **Fig. I~~5~~8.4.**

$\psi = \arctan(\tan\varphi_2 / \sin\alpha)$ (deg)

φ_1, φ_2, α : The angle (*deg*) between the ship and the water plane at the actual ice class draught, see **Fig. I~~5~~8.4**. If the ship has a bulbous bow then φ_1 is taken as 90 *degrees*.

C_1 and C_2 : Coefficient taken into account a consolidated upper layer of the brash ice and are to be taken as the followings.

(1) For I*A Super* ice class ships

$$C_1 = f_1 BL_{PAR} / (2T/B+1) + (1+0.021\varphi_1)(f_2 B + f_3 L_{BOW} + f_4 BL_{BOW})$$

$$C_2 = (1+0.063\varphi_1)(g_1 + g_2 B) + g_3(1+1.2T/B)B^2/\sqrt{L}$$

(2) For I*A*, I*B*, I*C* and I*D* ice class ships

$C_1 = 0$

$C_2 = 0$

C_3, C_4 and C_5 : Value given in **Table I~~5~~8.11**

C_μ : Value given by the following formula, but in no case less than 0.45

$$C_\mu = 0.15\cos\varphi_2 + \sin\psi\sin\alpha$$

C_ψ : Value given by the following formula, but taken as 0 where $\psi \le 45°$

$$C_\psi = 0.047\psi - 2.115$$

f_1, f_2, f_3, f_4, g_1, g_2 and g_3 : Value given in **Table I~~5~~8.11**

H_M : Thickness (*m*) of the brash ice in a channel as given by the followings.

(1) For I*A Super* and I*A* ice class ships $H_M = 1.0$

(2) For I*B* ice class ships $H_M = 0.8$

(3) For I*C* ice class ships $H_M = 0.6$

(4) For I*D* ice class ships $H_M = 0.5$

H_F : Thickness (*m*) of the brash ice layer displaced by the bow as given by the following formula.

$$H_F = 0.26 + (H_M B)^{0.5}$$

Fig. I~~5~~8.4 Dimensions

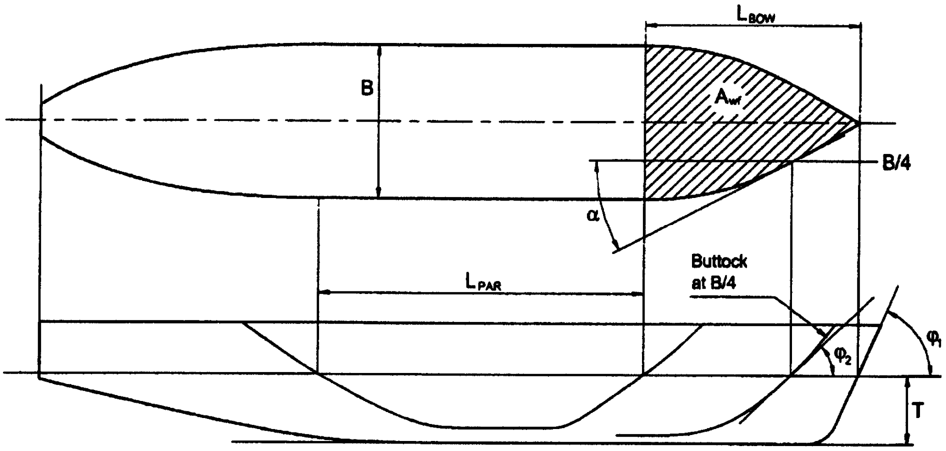


Table I~~5~~8.10 Value of Constant K_e

Propeller type or machinery	CPP or Electric or Hydraulic propulsion machinery	FPP
1 Propeller	2.03	2.26
2 Propellers	1.44	1.60
3 Propellers	1.18	1.31

Table I~~5~~8.11 Value of $f_1, f_2, f_3, f_4, g_1, g_2, g_3, C_3, C_4, C_5$

f_1:	23.0 (N/m^2)	g_1:	1,530 (N)	C_3:	845 (N/m^3)
f_2:	45.8 (N/m)	g_2:	170 (N/m)	C_4:	42 (N/m^3)
f_3:	14.7 (N/m)	g_3:	400 ($N/m^{1.5}$)	C_5:	825 (N/m)
f_4:	29.0 (N/m^2)				

2 Special Requirements for Existing Ships

For I*A Super* and I*A* ice class ships which are at beginning stage of construction before 1 September 2003, the engine output (H) is to comply with the requirements specified in **-1** above or equivalent requirements by 1 January in the year when 20 *years* have elapsed since the year the ship was delivered. When, for an existing ship, values for some of the hull form parameters required for the calculation method specified in **-1** above are difficult to obtain, the following alternative formulae may be used. The dimensions of the ship, defined below, are measured on the *UIWL* as defined in **1.2.~~4-1~~1(23)**.

$$H = K_e \frac{(R_{CH}/1000)^{3/2}}{D_P}$$

H : Engine output (kW)

K_e : Constant given in **Table I~~5~~8.10**

D_P : Diameter of the propeller (m)

R_{CH} : The resistance of the ship in a channel with brash ice and a consolidated layer (N)

$$R_{CH} = C_1 + C_2 + C_3(H_F + H_M)^2(B + 0.658H_F) + C_4 LH_F^2 + C_5(LT/B^2)^3(B/4)$$

L : Length (m) of the ship between the perpendiculars

B : Maximum breadth (m) of the ship

T : Actual ice class draught (m) of the ship

However, $(LT/B^2)^3$ is not to be taken as less than 5 and not to be taken as more than 20.

C_1 and C_2 : Coefficient taken into account a consolidated upper layer of the brash ice and are to be taken as the followings.

(1) For I*A Super* ice class ships and ice class ships with a bulbous bow

$$C_1 = f_1 BL/(2T/B + 1) + 2.89(f_2 B + f_3 L + f_4 BL)$$

$$C_2 = 6.67(g_1 + g_2 B) + g_3(1 + 1.2T/B)B^2/\sqrt{L}$$

(2) For I*A Super* ice class ships and ice class ships without a bulbous bow

$$C_1 = f_1 BL/(2T/B + 1) + 1.84(f_2 B + f_3 L + f_4 BL)$$

$$C_2 = 3.52(g_1 + g_2 B) + g_3(1 + 1.2T/B)B^2/\sqrt{L}$$

(3) For I*A* ice class ships

$C_1 = 0$ and $C_2 = 0$

$f_1, f_2, f_3, f_4, g_1, g_2, g_3, C_3, C_4$, and C_5 : Value given in **Table I~~5~~8.12**

H_M : Thickness (m) of the brash ice in a channel as given by the followings.

$H_M = 1.0$

H_F : Thickness (m) of the brash ice layer displaced by the bow as given by the following formula.

$H_F = 0.26 + (H_M B)^{0.5}$

Table I~~5~~8.12 Value of $f_1, f_2, f_3, f_4, g_1, g_2, g_3, C_3, C_4, C_5$

f_1:	10.3 (N/m^2)	g_1:	1,530 (N)	C_3:	460 (N/m^3)
f_2:	45.8 (N/m)	g_2:	170 (N/m)	C_4:	18.7 (N/m^3)
f_3:	2.94 (N/m)	g_3:	400 ($N/m^{1.5}$)	C_5:	825 (N/m)
f_4:	5.8 (N/m^2)				

3 For ships having features of which, there is ground to assume that they will improve the performance of the ship when navigation in ice or ships parameter values of which defined in **-1** above are beyond the range given in **Table I~~5~~8.13**, an engine output less than that required in **-1** may be approved, provided that it gives a minimum speed of 5 *knots* in the following brash ice channels.

(1) For I*A Super* ice class ships: 1.0m of the brash ice and a 0.1m thick consolidated layer of ice

(2) For I*A* ice class ships: 1.0m of the brash ice

(3) For I*B* ice class ships: 0.8m of the brash ice

(4) For I*C* ice class ships: 0.6m of the brash ice

(5) For I*D* ice class ships: 0.5m of the brash ice

Table I~~5~~8.13 The Range of Parameters

Parameter	Minimum	Maximum
α (deg)	15	55
φ_1 (deg)	25	90
φ_2 (deg)	10	90
L (m)	65.0	250.0
B (m)	11.0	40.0
T (m)	4.0	15.0
L_{BOW} / L	0.15	0.40
L_{PAR} / L	0.25	0.75
D_P / T	0.45	0.75
$A_{wf} / (LB)$	0.09	0.27

~~5~~8.4.3 Rudders and Steering Arrangements*

1 The rudder scantlings of rudder post, rudder stock, pintles, steering gear etc. are to comply with requirements in **Chapter 3** of **Part C** and **Chapter 15, Part D**. In this case, the maximum service speed of the ship to be used in these calculations is not to be taken less than that given in the **Table I~~5~~8.14**.

2 The local scantlings of rudders are to be determined assuming that the whole rudder belongs to the ice belt. The rudder plating and frames are to be designed using the ice pressure for the plating and frames in the midbody region.

3 For I*A Super* and I*A* ice class ships, the rudder stock and the upper part of the rudder are to be protected from direct contact with intact ice by either an ice knife that extends blew the *LIWL* or by equivalent means. Special consideration is to be given to the design of the rudder and the ice knife for ships with flap-type rudders.

4 For I*A Super* and I*A* ice class ships, the rudders and steering arrangements are to be designed as follows to endure the loads that work on the rudders by the ice when backing into an ice ridge.

(1) Relief valves for hydraulic pressure are to be installed.

(2) The components of the steering gear are to be dimensioned to stand the yield torque of the rudder stock.

(3) Suitable arrangements such as rudder stoppers are to be installed.

Table I~~5~~8.14 Minimum Speed

Class	Speed (*kt*)
I*A Super*	20
I*A*	18
I*B*	16
I*C*	14
I*D*	14

~~5~~8.5 Design Loads of Propulsion Units

~~5~~8.5.1 General

1 In the design of the propeller, propulsion shafting system and power transmission system, the following are to be taken into account.

(1) Maximum backward blade force

(2) Maximum forward blade force

(3) Maximum blade spindle torque

(4) Maximum propeller ice torque

(5) Maximum propeller ice thrust

(6) Design torque on propulsion shafting system

(7) Maximum thrust on propulsion shafting system

(8) Blade failure load

2 The loads specified in **-1** above are to comply with the following:

(1) The ice loads cover open and ducted-type propellers situated at the stern of ships having controllable pitch or fixed pitch blades. Ice loads on bow propellers and pulling type propellers are to receive special consideration and ice loads due to ice impact on the bodies of azimuthing thrusters are not covered by this Chapter.

(2) The given loads in this chapter are expected, single occurrence, maximum values for the whole ships service life for normal operation conditions. The loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice.

(3) The loads are total loads (unless otherwise stated) during interaction and are to be applied separately (unless otherwise stated) and are intended for component strength calculations only.

3 Design Loads of Propellers

(1) The loads given are intended for component strength calculations only and are total loads including ice-induced loads and hydrodynamic loads during propeller/ice interaction.

(2) The F_b and F_f specified in **~~5~~8.5.2** and **~~5~~8.5.3** originate from different propeller/ice interaction phenomena, and do not occur simultaneously. Hence, they are to be applied separately to one blade.

(3) If the propeller is not fully submerged when the ship is in the ballast condition, the propulsion

system is to be designed according to Ice Class I*A* for Ice Classes I*B* and I*C*.

~~5~~8.5.2 Maximum Backward Blade Force

1 The maximum backward blade force which bends a propeller blade backwards when a propeller mills an ice block while rotating ahead is to be given by the following formulae:

(1) For open propellers:

when $D \le D_{limit} = 0.85(H_{ice})^{1.4}\ (m)$

$$F_b = 27\left(\frac{n}{60}D\right)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} D^2 \quad (kN)$$

when $D > D_{\mathrm{limit}} = 0.85(H_{ice})^{1.4}\ (m)$

$$F_b = 23(H_{ice})^{1.4}\left(\frac{n}{60}D\right)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} D \quad (kN)$$

(2) For ducted propellers:

when $D \le D_{\mathrm{limit}} = 4H_{ice}\ (m)$

$$F_b = 9.5\left(\frac{n}{60}D\right)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} D^2 \quad (kN)$$

when $D > D_{\mathrm{limit}} = 4H_{ice}\ (m)$

$$F_b = 66(H_{ice})^{1.4}\left(\frac{n}{60}D\right)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} D^{0.6} \quad (kN)$$

where

F_b: Maximum backward blade force for the ship's service life (kN)
Direction of the backward blade force resultant taken perpendicular to chord line at radius $0.7R$. (See Fig. **I~~5~~8.5**)

H_{ice}: Ice thickness (m) specified in **Table I~~5~~8.15**.

D : Propeller diameter (m)

EAR : Expanded blade area ratio

d : external diameter of propeller hub (at propeller plane) (m)

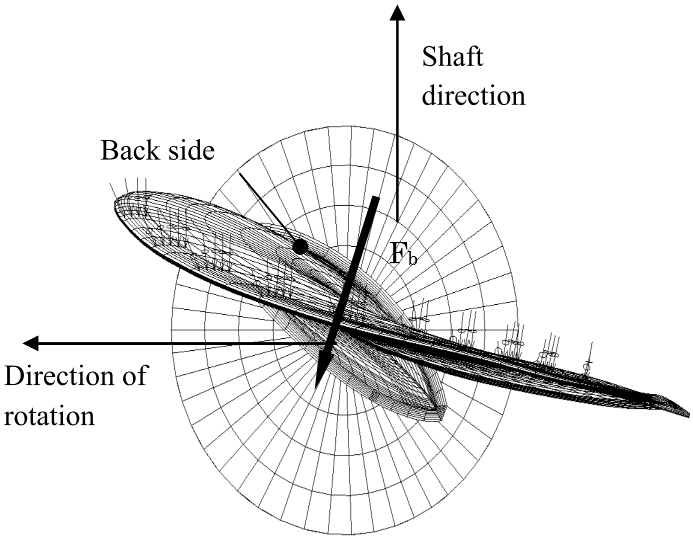
Z : number of propeller blades

n : Nominal rotational propeller speed (rpm) at maximum continuous revolutions in free running condition for controllable pitch propellers and 85% of the nominal rotational propeller speed at maximum continuous revolutions in free running condition for fixed pitch propellers

Table I~~5~~8.15 The Thickness of the Ice Block H_{ice}

	I*A Super*	I*A*	I*B*	I*C*
Thickness of the design maximum ice block entering the propeller H_{ice} (m)	1.75	1.5	1.2	1.0

Fig.I~~5~~8.5 Direction of the Force Acting on Propeller Blades



2 The maximum backward blade force F_b is to be applied as a uniform pressure distribution to an area of the blade for the following load cases:

(1) In the case of open propellers:

(a) The F_b specified in **-1(1)** above is to be applied to an area from 0.6*R* to the tip and from the blade leading edge to a value 0.2 of the chord length. (See Load Case 1 in **Table ~~I~~4.2.2-2 of Chapter 4** of **Annex 1 "Special Requirements for the Materials, Hull Structures, Equipment and Machinery of Polar Class Ships"**)

(b) A load equal to 50% of the F_b specified in **-1(1)** above is to be applied to the propeller tip area outside of 0.9*R*. (See Load Case 2 in **Table ~~I~~4.2.2-2** of **Chapter 4** of **Annex 1 "Special Requirements for the Materials, Hull Structures, Equipment and Machinery of Polar Class Ships"**)

(c) In the case of reversible propellers, a load equal to 60% of the F_b specified in **-1(1)** above is to be applied to an area from 0.6*R* to the tip and from the blade trailing edge to a value 0.2 of the chord length. (See load case 5 in **Table ~~I~~4.2.2-2** of **Chapter 4** of **Annex 1 "Special Requirements for the Materials, Hull Structures, Equipment and Machinery of Polar Class Ships"**)

(2) In the case of ducted propellers:

(a) The F_b specified in **-1(2)** above is to be applied to an area from 0.6*R* to the tip and from the blade leading edge to a value 0.2 of the chord length. (See Load Case 1 in **Table ~~I~~4.2.2-3** of **Chapter 4** of **Annex 1 "Special Requirements for the Materials, Hull Structures, Equipment and Machinery of Polar Class Ships"**)

(b) In the case of reversible propellers, a load equal to 60% of the F_b specified in **-1(2)** above is to be applied to an area from 0.6*R* to the tip and from the blade trailing edge to a value 0.2 of the chord length. (See load case 5 in **Table ~~I~~4.2.2-3** of **Chapter 4** of **Annex 1 "Special Requirements for the Materials, Hull Structures, Equipment and Machinery of Polar Class Ships"**)

~~5~~8.5.3 Maximum Forward Blade Force

1 The maximum forward blade force which bends a propeller blade forwards when a propeller interacts with an ice block while rotating ahead is to be given by the following formulae:

(1) For open propellers:

when $D \le D_{\text{limit}} = \dfrac{2}{(1-d/D)} H_{ice} \quad (m)$

$$F_f = 250\left(\frac{EAR}{Z}\right)D^2 \quad (kN)$$

when $D > D_{\text{limit}} = \dfrac{2}{(1-d/D)} H_{ice} \quad (m)$

$$F_f = 500 H_{ice}\left(\frac{EAR}{Z}\right)\left(\frac{1}{1-d/D}\right)D \quad (kN)$$

(2) For ducted propellers:

when $D \le D_{\text{limit}} = \dfrac{2}{(1-d/D)} H_{ice} \quad (m)$

$$F_f = 250\left(\frac{EAR}{Z}\right)D^2 \quad (kN)$$

when $D > D_{\text{limit}} = \dfrac{2}{(1-d/D)} H_{ice} \quad (m)$

$$F_f = 500 H_{ice}\left(\frac{EAR}{Z}\right)\left(\frac{1}{1-d/D}\right)D \quad (kN)$$

where

F_f: The maximum forward blade force for the ship's service life (kN)
Direction of the forward blade force resultant taken perpendicular to chord line at radius $0.7R$.

H_{ice}, D, EAR, d and Z : As specified in **~~5~~8.5.2**

2 The maximum forward blade force F_f is to be applied as a uniform pressure distribution to an area of the blade for the following load cases:

(1) In the case of open propellers:

(a) The F_f specified in **-1(1)** above is to be applied to an area from $0.6R$ to the tip and from the blade leading edge to a value 0.2 of the chord length. (See Load Case 3 in **Table ~~1~~4.2.2-2** of **Chapter 4** of **Annex 1** "**Special Requirements for the Materials, Hull Structures, Equipment and Machinery of Polar Class Ships**")

(b) A load equal to 50% of the F_f specified in **-1(1)** above is to be applied to the propeller tip area outside of $0.9R$. (See Load Case 4 in **Table ~~1~~4.2.2-2** of **Chapter 4** of **Annex 1** "**Special Requirements for the Materials, Hull Structures, Equipment and Machinery of Polar Class Ships**")

(c) In the case of reversible propellers, a load equal to 60% of the F_f specified in **-1(1)** above is to be applied to an area from $0.6R$ to the tip and from the blade trailing edge to a value 0.2 of the chord length. (See Load Case 5 in **Table ~~1~~4.2.2-2** of **Chapter 4** of **Annex 1** "**Special Requirements for the Materials, Hull Structures, Equipment and**

Machinery of Polar Class Ships”)

(2) In the case of ducted propellers:

(a) The F_f specified in **-1(2)** above is to be applied to an area from 0.6R to the tip and from the blade leading edge to a value 0.5 of the chord length. (See Load Case 3 in **Table ~~I~~4.2.2-3** of **Chapter 4** of **Annex 1** “**Special Requirements for the Materials, Hull Structures, Equipment and Machinery of Polar Class Ships**”)

(b) In the case of reversible propellers, a load equal to 60% of the F_f specified in **-1(2)** above is to be applied to an area from 0.6R to the tip and from the blade trailing edge to a value 0.2 of the chord length. (See Load Case 5 in **Table ~~I~~4.2.2-3** of **Chapter 4** of **Annex 1** “**Special Requirements for the Materials, Hull Structures, Equipment and Machinery of Polar Class Ships**”)

~~5~~8.5.4 Maximum Blade Spindle Torque

The spindle torque around the spindle axis of the blade fitting is to be calculated both for the load cases specified in **~~5~~8.5.2** and **~~5~~8.5.3** for F_b and F_f. In cases where these spindle torque values are less than the default value obtained from the following formula, the default value is to be used.

$$Q_{s\max} = 0.25FC_{0.7} \quad (kNm)$$

where

$C_{0.7}$: Length (m) of the blade chord at radius 0.7R

F: Either F_b determined in **~~5~~8.5.2-1** or F_f determined in **~~5~~8.5.3-1,** whichever has the greater absolute value (kN).

~~5~~8.5.5 Frequent Distributions for Propellers Blade Loads

1 A Weibull-type distribution (probability that F_{ice} exceeds $(F_{ice})_{max}$), as given in **Fig. I~~5~~8.6**, is to be used for the fatigue design of blades.

$$P\left(\frac{F_{ice}}{(F_{ice})_{max}} \geq \frac{F}{(F_{ice})_{max}}\right) = e^{\left(-\left(\frac{F}{(F_{ice})_{max}}\right)^{k} \ln(N_{ice})\right)}$$

where

F_{ice}: Random variable for ice loads (kN) on the blade, and meet the requirements $0 \leq F_{ice} \leq (F_{ice})_{max}$

$(F_{ice})_{max}$: Maximum ice load for the ship’s service life (kN)

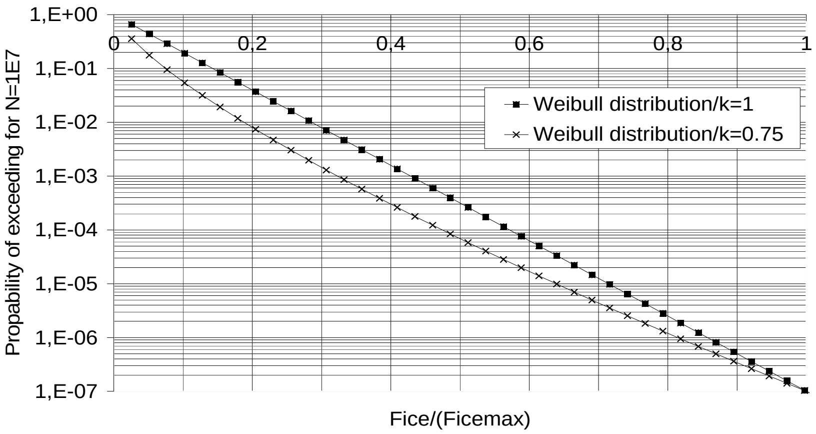
k: Shape parameter for Weibull-type distribution The following definitions apply:

Open propeller: k =0.75

Ducted propeller: k =1.0

N_{ice}: Total number of ice loads on a propeller blade for the ship’s service life

Fig.I~~5~~8.6 The Weibull-type Distribution (probability that F_{ice} exceeds $(F_{ice})_{max}$) that is Used for Fatigue Designs



2 Number of ice loads

(1) The number of load cycles per propeller blade in the load spectrum shall be determined according to the formula:

$$N_{ice} = k_1 k_2 k_3 k_4 N_{class} \frac{n}{60}$$

where

N_{class}: Reference number of loads for ice classes, as specified in **Table I~~5~~8.16**

k_1 : Propeller location factor, as specified in **Table I~~5~~8.17**

k_2 : Propeller type factor, as specified in **Table I~~5~~8.18**

k_3 : Propulsion type factor, as specified in **Table I~~5~~8.19**

Table I~~5~~8.16 Reference Number of Loads for Ice Classes N_{class}

Class	I*A Super*	I*A*	I*B*	I*C*
impacts in life / n	$9\cdot 10^6$	$6\cdot 10^6$	$3.4\cdot 10^6$	$2.1\cdot 10^6$

Table I~~5~~8.17 Propeller Location Factor k_1

factor	Centre propeller	Wing propeller
k_1	1	1.35

Table I~~5~~8.18 Propeller Type Factor k_2

factor	open propeller	ducted propeller
k_2	1	1.1

Table I~~5~~8.19 Propulsion Type Factor k_3

factor	fixed	azimuthing
k_3	1	1.2

k_4 : The submersion factor k_4 is determined from the equation.

$$k_4 = \begin{cases} 0.8 - f & : f < 0 \\ 0.8 - 0.4f & : 0 \le f \le 1 \\ 0.6 - 0.2f & : 1 < f \le 2.5 \\ 0.1 & : f > 2.5 \end{cases}$$

where

$$f = \frac{h_0 - H_{ice}}{D/2} - 1$$

h_0 : The depth of the propeller centreline at the lower ice waterline (*LIWL*) of the ship (*m*)

H_{ice} and D : As specified in **~~5~~8.5.2**

(2) In the case of components that are subject to loads resulting from propeller/ice interaction with all of the propeller blades, the number of load cycles (N_{ice}) is to be multiplied by the number of propeller blades (Z).

~~5~~8.5.6 Maximum Propeller Ice Thrust

The maximum propeller ice thrust applied to a propeller is to be given by the following formulae:

(1) Maximum backward propeller ice thrust

$T_b = 1.1\ F_b\ (kN)$

(2) Maximum forward propeller ice thrust

$T_f = 1.1\ F_f\ (kN)$

where

F_b : Maximum backward blade force for the ship’s service life, as specified in **~~5~~8.5.2-1**

F_f : Maximum forward blade force for the ship’s service life, as specified in **~~5~~8.5.3-1**

T_b : Maximum backward propeller ice thrust (*kN*)

T_f : Maximum forward propeller ice thrust (*kN*)

~~5~~8.5.7 Design Thrust along Propulsion Shaft Lines

The design thrust along the propeller shaft line is to be given by the following formulae:

(1) Maximum shaft thrust forwards:

$T_r = T + 2.2T_f\ \ (kN)$

(2) Maximum shaft thrust backwards:

$T_r = 1.5T_b\ \ (kN)$

where:

T_b and T_f : Maximum propeller ice thrust (*kN*) determined in **~~5~~8.5.6**

T: Propeller bollard thrust (*kN*). If not known, T is to be taken as specified in **Table I~~5~~8.20**

Table I~~5~~8.20 Value of T

Propeller type	T
Controllable pitch propellers (open)	$1.25\ T_n$
Controllable pitch propellers (ducted)	$1.1\ T_n$
Fixed pitch propellers driven by turbine or electric motor	T_n
Fixed pitch propellers driven by diesel engine (open)	$0.85\ T_n$
Fixed pitch propellers driven by diesel engine (ducted)	$0.75\ T_n$

Note:

T_n : Nominal propeller thrust (*kN*) at maximum continuous revolutions in free running open water conditions

~~5~~8.5.8 Maximum Propeller Ice Torque

The maximum propeller ice torque applied to the propeller is to be given by the following formulae:

(1) For open propellers:

when $D \le D_{\text{limit}} = 1.8H_{ice}$ (m)

$$Q_{max} = 10.9\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}\left(\frac{n}{60}D\right)^{0.17} D^3 \quad (kNm)$$

when $D > D_{\text{limit}} = 1.8H_{ice}$ (m)

$$Q_{max} = 20.7\left(H_{ice}\right)^{1.1}\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}\left(\frac{n}{60}D\right)^{0.17} D^{1.9} \quad (kNm)$$

(2) For ducted propellers:

when $D \le D_{\text{limit}} = 1.8H_{ice}$ (m)

$$Q_{max} = 7.7\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}\left(\frac{n}{60}D\right)^{0.17} D^3 \quad (kNm)$$

when $D > D_{\text{limit}} = 1.8H_{ice}$ (m)

$$Q_{max} = 14.6\left(H_{ice}\right)^{1.1}\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}\left(\frac{n}{60}D\right)^{0.17} D^{1.9} \quad (kNm)$$

where:

H_{ice}, D and d: As specified in **~~5~~8.5.2**

$P_{0.7}$: Propeller pitch (m) at $0.7R$

In the case of controllable pitch propellers, $P_{0.7}$ is to correspond to maximum continuous revolutions at the bollard condition. If not known, $P_{0.7}$ is to be taken as 0.7 $P_{0.7n}$, where $P_{0.7n}$ is the propeller pitch at maximum continuous revolutions at a free running condition.

n : Rotational propeller speed (rpm) at the bollard condition

If not known, n is to be taken as specified in **Table I~~5~~8.21**.

Table I~~5~~8.21 Rotational Propeller Speed n

Propeller type	n
Controllable pitch propellers	n_n
Fixed pitch propellers driven by turbine or electric motor	n_n
Fixed pitch propellers driven by diesel engine	$0.85n_n$

Note:

n_n: Nominal rotational speed (rpm) at maximum continuous revolutions at the free running condition

~~5~~8.5.9 Design Torque on Propulsion Shafting System

1 The propeller ice excitation torque for shaft line transient torsional vibration dynamic analysis is to comply with the following requirements:

(1) The excitation torque is to be described by a sequence of blade impacts which are of half sine shape and occur at the blade. The total ice torque is to be obtained by summing the torques of single ice blade ice impacts taking into account the phase shift. The single ice blade impact is given by the following formulae: (See **Fig. I~~5~~8.7**)

(a) when $0 \le \varphi \le \alpha_i$ (deg)

$$Q(\varphi) = C_q Q_{max} \sin(\varphi(180/\alpha_i))$$

(b) when $\alpha_i \le \varphi \le 360$ (deg)

$$Q(\varphi) = 0$$

where

Q_{max}: Maximum torque on the propeller as specified in **~~5~~8.5.8**

C_q: As specified in **Table I~~5~~8.22**

a_i: Duration of propeller blade/ice interaction expressed in rotation angle as specified in **Table I~~5~~8.22**

Table I~~5~~8.22 Values of C_q and a_i

Torque excitation	Propeller-ice interaction	C_q	a_i
Case 1	Single ice block	0.75	90
Case 2	Single ice block	1.0	135
Case 3	Two ice blocks (phase shift 360/2/Z deg.)	0.5	45

Note:

Total ice torque is obtained by summing the torque of single blades, taking into account the phase shift 360deg./Z. In addition, at the beginning and at the end of the milling sequence, a linear ramp functions for 270 degrees of rotation angle is to be used.

(2) The number of propeller revolutions and the number of impacts during the milling sequence are to be given by the following formulae. For bow propellers, the number of propeller revolutions and the number of impacts during the milling sequence are subject to special consideration.

(a) The number of propeller revolutions:

$$N_Q = 2H_{ice}$$

(b) The number of impacts:

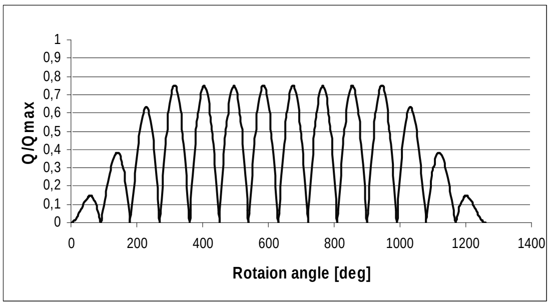
$$ZN_Q$$

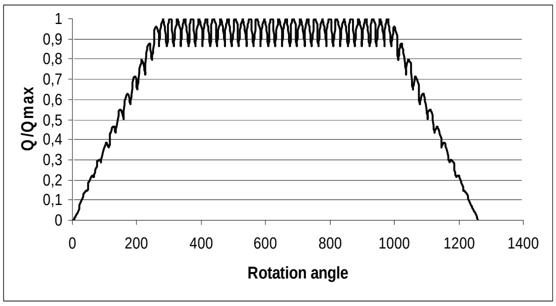
Where

H_{ice} : As specified in **Table I~~5~~8.15**

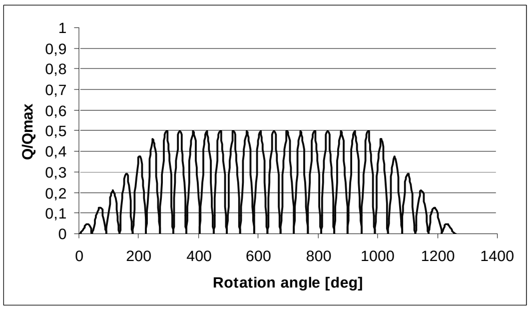
Z : Number of propeller blades

Fig.I~~5~~8.7 Example of the Shape of the Propeller Ice Torque Excitation (four bladed propeller)





(a) Case 1 Single blade impact($\alpha_i = 90°$) (b) Case 2 Single blade impact($\alpha_i = 135°$)



(c) Case 3 Double blade impact ($\alpha_i = 45°$)

2 Design torque along propeller shaft line

(1) If there is not a predominant torsional resonance within the designed operating rotational speed range extended 20% above the maximum and 20% below the minimum operating speeds, the following estimation of the maximum torque can be used:

$$Q_r = Q_{emax} + Q_{max}\frac{I}{I_t} \quad (kNm)$$

Q_{emax}: maximum engine torque (kNm)

If the maximum torque, Q_{emax}, is not known, it is to be taken as specified in **Table I~~5~~8.23**

I : equivalent mass moment of inertia of all parts on the engine side of the component under consideration (kgm^2)

I_t : equivalent mass moment of inertia of the whole propulsion system (kgm^2)

(2) If there is a first blade order torsional resonance within the designed operating rotational speed range extended 20% above the maximum and 20% below the minimum operating speeds, the design torque (Q_r) of the shaft component is to be determined by means of torsional vibration analysis of the propulsion line.

Table I~~5~~8.23 Maximum Engine Torque Q_{emax}

Propeller type	Q_{emax}
Propellers driven by electric motor	Q_{motor}
CP propellers not driven by electric motor	Q_n
FP propellers driven by turbine	Q_n
FP propellers driven by diesel engine	0.75 Q_n

Notes:

Q_{motor} : Electric motor peak torque (kNm)
Q_n : Nominal torque at MCR in free running condition (kNm)
Q_r : Maximum response torque along the propeller shaft line (kNm)

~~5~~8.5.10 Blade Failure Loads

1 The blade failure load is to be given by the following formula:

$$F_{ex} = \frac{300ct^2\sigma_{ref}}{0.8D - 2r} \quad (kN)$$

where

σ_{ref} : The reference stress is to be given by the following formula:

$$\sigma_{ref} = 0.6\sigma_{0.2} + 0.4\sigma_u \quad (MPa)$$

where

σ_u : Tensile stress of blade material (MPa)
$\sigma_{0.2}$: Yield stress or 0.2% proof strength of blade material (MPa)
c : Chord length of blade section (m)
F_{ex} : ultimate blade load resulting from blade loss through plastic bending (kN)
r : blade section radius (m)
t : Maximum blade section thickness (m)

2 The force specified in **-1.** above is to be acting at $0.8R$ in the weakest direction of the blade and at a spindle arm of 2/3 the distance of the axis of blade rotation of the leading or trailing edge, whichever is greater.

~~5~~8.6 Design of Propellers and Propulsion Shafting Systems

~~5~~8.6.1 General

With respect to the design of the propeller and the propulsion shafting system, the following are to be taken into account:

(1) Propeller and propulsion shafting systems are to have sufficient strength for the loads specified in **~~5~~8.5**.
(2) The blade failure load given in **~~5~~8.5.10** is not to damage the propulsion shafting system other than the propeller blade itself.
(3) Propeller and propulsion shafting systems are to have sufficient fatigue strength.

~~5~~8.6.2 Propeller Blade Stresses

1 Propeller blade stresses are to be calculated for the design loads given in **~~5~~8.5.2** and **~~5~~8.5.3** using Finite Element Analysis.

In the case of a relative radius $r/R < 0.5$, the blade stresses for all propellers at their root areas may be calculated by the formula given below. Root area dimensions based on this formula can be accepted even if FEM analysis shows greater stresses at the root area.

$$\sigma_{st} = C_1 \frac{M_{BL}}{100ct^2} \quad (MPa)$$

where

C_1 : $\dfrac{\text{stress obtained with FEM analysis result}}{\text{stress obtained with beam equation}}$

If the actual value is not available, C_1 should be taken as 1.6.

where

M_{BL}: Blade bending moment (kNm), in the case of a relative radius r/R <0.5, the following:

$$M_{BL} = (0.75 - r/R)RF$$

F: Maximum of F_b and F_f, whichever is greater.

2 The calculated blade stress σ_{st} specified in **-1** above is to comply with the following:

$$\frac{\sigma_{ref2}}{\sigma_{st}} \geq 1.5$$

where

σ_{st}: Maximum stress resulting from F_b or F_f (MPa)

σ_u: Tensile stress of blade material (MPa)

σ_{ref2}: Reference stress (MPa), whichever is less

$\sigma_{ref2} = 0.7\sigma_u$,or $\sigma_{ref2} = 0.6\sigma_{0.2}+0.4\sigma_u$

3 Fatigue design of propeller blades

(1) The fatigue design of a propeller blade is based on the estimated load distribution for the service life of the ship and the S-N curve for the blade material. An equivalent stress that produces the same fatigue damage as the expected load distribution is to be calculated and the acceptability criterion for fatigue is to be fulfilled as given in this section. The equivalent stress is normalized for 100 million cycles. If the following criterion is fulfilled, the fatigue calculations specified in this section are not required.

$$\sigma_{\exp} \geq B_1 \sigma_{ref2}{}^{B_2} \log(N_{ice})^{B_3}$$

where

The coefficients B_1, B_2 and B_3 are as given in the **Table I~~5~~8.24**.

Table I~~5~~8.24 The Coefficients B_1, B_2 and B_3

Coefficients	Open propeller	Ducted propeller
B_1	0.00270	0.00184
B_2	1.007	1.007
B_3	2.101	2.470

(2) For the calculation of equivalent stress, two types of S-N curves are to be used.

(a) Two-slope S-N curve (slopes 4.5 and 10), see **Fig. I~~5~~8.8**.

(b) One-slope S-N curve (the slope can be chosen), see **Fig. I~~5~~8.9**.

(3) The type of the S-N curve shall be selected to correspond to the material properties of the blade. If the S-N curve is not known, a two-slope S-N curve is to be used.

Fig.I~~5~~8.8 Two-slope S-N Curve

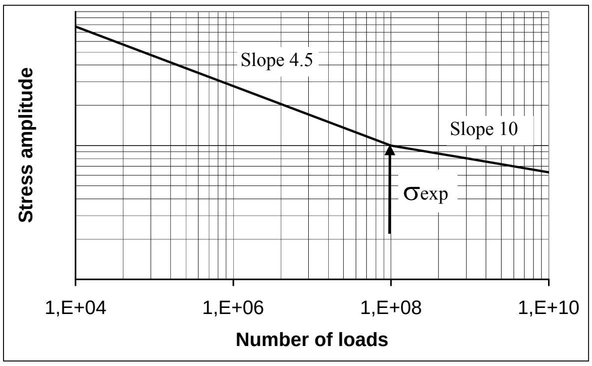
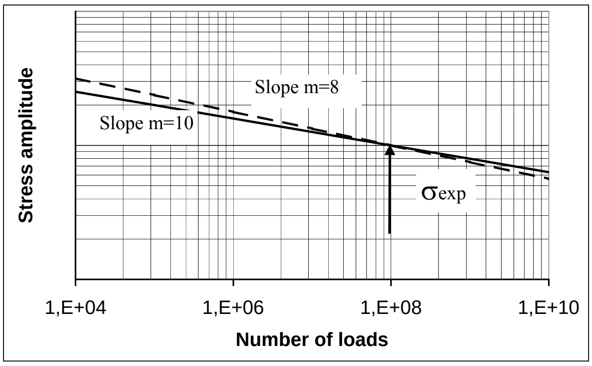


Fig.I~~5~~8.9 Constant-slope S-N Curve



(4) The equivalent fatigue stress for 100 million stress cycles which produces the same fatigue damage as the load distribution is:

$$\sigma_{fat} = \rho(\sigma_{ice})_{max}$$

where

ρ: Depending on the applicable S-N curve, ρ is to be given by either **(5)** or **(6)**.

$$(\sigma_{ice})_{max} = 0.5((\sigma_{ice})_{fmax} - (\sigma_{ice})_{bmax})$$

$(\sigma_{ice})_{max}$: The mean value of the principal stress amplitudes resulting from forward and backward blade forces at the location being studied.

$(\sigma_{ice})_{fmax}$: The principal stress resulting from forward load

$(\sigma_{ice})_{bmax}$: The principal stress resulting from backward load

(5) The calculation of the parameter ρ for a two-slope S-N curve is as follows:
Parameter ρ relates the maximum ice load to the distribution of ice loads according to the following regression formulae:

$$\rho = C_1(\sigma_{ice})_{max}^{C2}\sigma_{fl}^{C3}\lg(N_{ice})^{C4}$$

where

$$\sigma_{fl} = \gamma_\varepsilon\gamma_v\gamma_m\sigma_{exp}$$

σ_{fl}: Characteristic fatigue strength for blade material (MPa)

γ_ε : The reduction factor for scatter and test specimen size effect

γ_v : The reduction factor for variable amplitude loading

γ_m : The reduction factor for mean stress

$\sigma_{\exp}$: The mean fatigue strength of the blade material at 10^8 cycles to failure in seawater (MPa)

The following values are to be used as reduction factors if actual values are not available:

$\gamma_\varepsilon = 0.67$, $\gamma_v = 0.75$, $\gamma_m = 0.75$

The coefficients C_1, C_2, C_3, and C_4 are given in **Table I~~5~~8.25**.

Table I~~5~~8.25 The Coefficients C_1, C_2, C_3 and C_4

Coefficients	Open propeller	Ducted propeller
C_1	0.000711	0.000509
C_2	0.0645	0.0533
C_3	-0.0565	-0.0459
C_4	2.220	2.584

(6) The calculation of the parameter for a constant-slope S-N curve

In the case of materials with a constant-slope S-N curve - see **Fig. I~~5~~8.9** – the ρ factor is to be calculated using the following formula:

$$\rho = \left(G \frac{N_{ice}}{N_R} \right)^{1/m} \left(\ln \left(N_{ice} \right) \right)^{-1/k}$$

where

k is the shape parameter of the Weibull distribution, it is as follows:

(a) $k = 1.0$ for ducted propellers

(b) $k = 0.75$ for open propellers

N_R : The reference number of load cycles (= 10^8)

m : slope for S-N curve in log/log scale

G : Values for the parameter G are given in **Table I~~5~~8.26**. Linear interpolation may be used to calculate the G value for m/k ratios other than those given in **Table I~~5~~8.26**.

Table I~~5~~8.26 Value for the G Parameter for Different m/k Ratios

m/k	G	m/k	G	m/k	G
3	6	5.5	287.9	8	40320
3.5	11.6	6	720	8.5	119292
4	24	6.5	1871	9	362880
4.5	52.3	7	5040	9.5	1.133E6
5	120	7.5	14034	10	3.623E6

4 Acceptability criterion for fatigue

The equivalent fatigue stress at all locations on a blade has to fulfill the following acceptability criterion:

$$\frac{\sigma_{fl}}{\sigma_{fat}} \geq 1.5$$

~~5~~8.6.3 Propeller Bossing and CP Mechanism*

1 The blade bolts, the CP mechanism, the propeller boss, and the fitting of the propeller to the propeller shaft are to be designed to withstand maximum and fatigue design loads, as defined in

~~5~~8.5. The safety factor is as follows.

(1) The safety factor against yielding is to be greater than 1.3

(2) The safety factor against fatigue is to be greater than 1.5

2 The safety factor for loads resulting from loss of a propeller blade through plastic bending as defined in **~~5~~8.5.10** is to be greater than 1.0 against yielding.

~~5~~8.6.4 Propulsion Shaft Line

1 The shafts and shafting components, such as the thrust and stern tube bearings, couplings, flanges and sealings, shall be designed to withstand the propeller/ice interaction axial, bending and torsion loads. The safety factor is to be at least 1.3.

2 The ultimate load resulting from total blade failure as defined in Section **~~5~~8.5.10** is not to cause yielding in shafts and shaft components. The loading is to consist of the combined axial, bending, and torsion loads, wherever this is significant. The minimum safety factor against yielding is to be 1.0 for bending and torsional stresses.

~~5~~8.6.5 Azimuthing Main Propulsors

With respect to the design of azimuthing main propulsors, the following are to be taken into account in addition to the requirements specified in **~~5~~8.6.1**:

(1) Loading cases which are extraordinary for propulsion units are to be taken into account. The estimation of loading cases is to reflect the operational realities of the ship and the thrusters.

(2) The steering mechanism, the fitting of the unit and body of the thruster are to be designed to withstand the loss of a blade without damage.

(3) The plastic bending of a blade is to be considered in the propeller blade position, which causes the maximum load on the considered component.

(4) Azimuth thrusters are to be designed for the estimated loads specified in **3.5.10** of **Chapter 4** of **Annex 1** "**Special Requirements for the Materials, Hull Structures, Equipment and Machinery of Polar Class Ships**").

(5) The thickness of an ice sheet is to be taken as the thickness of the maximum ice block entering the propeller, as defined in **Table I~~5~~8.15**

~~5~~8.6.6 Vibrations

The propulsion system shall be designed in such a way that the complete dynamic system is free from dominant torsional, axial, and bending resonances within the designed running speed range, extended by 20% above and below the maximum and minimum operating rotational speeds. If this condition cannot be fulfilled, a detailed vibration analysis has to be carried out in order to determine that the acceptable strength of the components can be achieved.

~~5~~8.7 Alternative Design

~~5~~8.7.1 Alternative Design*

As an alternative to **~~5~~8.5** and **~~5~~8.6**, a comprehensive design study may be carried out.

~~5~~8.8 Miscellaneous Machinery Requirements

~~5~~8.8.1 Starting Arrangements

1 The capacity of air reservoirs is to be sufficient to provide, without reloading, not less than 12 consecutive starts of the propulsion engines if these have to be reversed for going astern, or 6 consecutive starts if such propulsion engines do not have to be reversed for going astern.

2 If the air reservoirs serve any other purposes than starting propulsion engines, they are to have additional capacity sufficient for such purposes.

3 The capacity of air compressors is to be sufficient for charging the air reservoirs from atmospheric to full pressure in one hour. In the case of I*A Super* ice class ships that require their propulsion engines to be reversed for going astern, the compressors are to be able to charge the air reservoirs in half an hour.

~~5~~8.8.2 Sea Inlet and Cooling Water Systems

1 Cooling water systems are to be designed to ensure a supply of cooling water when navigating in ice.

2 To satisfy **-1** above, at least one cooling sea water inlet chest is to be arranged as follows. However, I*D* ice class ships may not comply with the requirements given in **(2)**, **(3)** and **(5)**:

(1) Sea inlets are to be situated near the centre line of ships and well aft if possible.

(2) As guidance for design, the volume of sea chests is to be about $1m^3$ for every $750kW$ of engine output of ships including the output of auxiliary engines necessary for the ship service.

(3) Sea chests are to be sufficiently high to allow ice to accumulate above inlet pipes.

(4) Pipes for discharging cooling water, allowing full capacity discharge, are to be connected to sea chests.

(5) Areas through grating holes are not to be less than 4 *times* inlet pipe sectional areas.

3 In cases where more than two sea chests are arranged, it is not necessary to satisfy the requirements given in **-2(2)** and **(3)** above. In such cases, except for I*D* ice class ships, sea chests are to be arranged for alternating the intake and discharge of cooling water as well as complying with the requirements given **-2(1)**, **(4)** and **(5)** above.

4 Heating coils may be installed in the upper parts of sea chests.

5 Arrangements for using ballast water for cooling purposes may be useful as a reserve in the ballast condition, but cannot be accepted as a substitute for the sea inlet chests described above.

Annex 1 has been added as follows.

ANNEX 1 SPECIAL REQUIREMENTS FOR THE MATERIALS, HULL STRUCTURES, EQUIPMENT AND MACHINERY OF POLAR CLASS SHIPS

Chapter 1 GENERAL

1.1 General

1.1.1 Application

This Annex are to be applied to materials, constructions, equipment and machineries of polar class ships in accordance with **1.1.1-4**, **3.3**, **Part I of the Rules** and **I7.3.3**, **Part I of the Guidance**.

1.2 Definitions

1.2.1 Application

The definitions of terms and symbols which appear in this Annex are to be as specified in this section and **1.2.1**, **Part I of the Rules**, unless specified elsewhere.

1.2.2 Polar Classes

1 Polar Class is classified into the seven classes given in **Table 1.2.2-1**. It is the responsibility of the Owner to determine which class in **Table 1.2.2-1** is most suitable for his requirement.

2 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 classification certificate. Compliance of the hull or machinery with the requirements of a higher polar class is also to be indicated in the Classification Register.

Table 1.2.2-1 Polar Classes

Polar Class	Symbol	Ice description
Polar Class 1	*PC*1	Year-round operation in all Polar waters
Polar Class 2	*PC*2	Year-round operation in moderate multi-year ice condition
Polar Class 3	*PC*3	Year-round operation in second-year ice which may include multi-year ice inclusion
Polar Class 4	*PC*4	Year-round operation in thick first-year ice which may include multi-year and/or second-year ice inclusion
Polar Class 5	*PC*5	Year-round operation in medium first-year ice which may include multi-year and/or second-year ice inclusion
Polar Class 6	*PC*6	Summer/autumn operation in medium first-year ice which may include multi-year and/or second-year ice inclusions
Polar Class 7	*PC*7	Summer/autumn operation in thin first-year ice which may include multi-year and/or second-year ice inclusions

Notes:

Multi-year ice, second-year ice and first-year ice are based on WMO (World Meteorological Organization) Sea Ice Nomenclature.

Multi-year ice: old ice which has survived at least two summer's melt

Second-year ice: Sea ice which has survived only one summer's melt

First-year ice: Sea ice of not more than one winter's growth, developing from young ice

Thick first-year ice:	first-year ice of about 120-250 *cm* in thickness and which has a high strength. Only when strong pressure is received, this ice forms an ice hill of about 150-250 *cm* in height.
Medium first-year ice:	first-year ice of about 70-120 *cm* in thickness. In the ice water regions other than Polar Regions, this kind of one-year ice is a limit stage of growth, and it is formed in the severest winter. In this kind of ice, there might be a lot of intersecting ice hills, and the height of the ice hill reaches 170 *cm*. This kind of ice melts in summer and disappears almost completely.
Thin first-year ice:	first-year ice of about 30-70 *cm* in thickness. In this kind of ice, there might be straight ice hills, and the height of the ice hill reaches 30-75 *cm* on the average. Thin first-year ice may be subdivided to the thin fires-year in the first stage (30-50 *cm* in thickness) and second stages (50-70 *cm* in thickness).

1.2.3 Hull Areas

The hull areas are defined as areas reflecting the magnitude of the loads that are expected to act upon them, and divided into the following (see **Fig. 1.2.3-1**). If a ship with special ice breaking aft construction and propulsion system is intended to operate astern in ice-infested water, the hull areas of the aft structures are to be deemed appropriate by the Society. If a polar class ship that installed special icebreaking stern structure and propulsion unit intended to operate astern in ice regions, the hull area of the ship is to refer to **Fig. 1.2.3-2**.

(1) Bow area

(a) Bow area of *PC*1, *PC*2, *PC*3 and *PC*4 polar class ships

"Bow area" is defined as the hull area which is located forward of the intersection point of the *UIWL* and the line with a waterline angle (as defined in **1.2.4**) of 10 degrees at the *UIWL* (hereinafter referred to as "the aft boundary of the Bow area"), and below the line connecting the point 1.5 *m* above the *UIWL* at the aft boundary of the Bow area and the point 2.0 *m* above the *UIWL* at the stem.

(b) Bow area of *PC*5, *PC*6 and *PC*7 polar class ships

"Bow area" is defined as the hull area which is located forward of the intersection point of the *UIWL* and the line with a waterline angle (as defined in **1.2.4**) of 10 degrees at the *UIWL*, and below the line connecting the point 1.0*m* above the *UIWL* at the aft boundary of the Bow area and the point 2.0*m* above the *UIWL* at the stem.

Notwithstanding the provision in (a) and (b), the aft boundary of the Bow area is not to be forward of the intersection point of the extended line of the stem frame and the baseline of the ship. In addition, the aft boundary of the Bow area need not be more than 0.45 times L_{UIWL} (length of the ship at the *UIWL*) aft of the *F.P.*

(2) Bow Intermediate area

(a) Bow Intermediate area of *PC*1, *PC*2, *PC*3 and *PC*4 polar class ships with

"Bow Intermediate area" is defined as the hull area which is located aft of the aft boundary of the Bow area, and forward of the vertical line $0.04L_{UIWL}$ aft of the point on the *UIWL* where the waterline angle is 0 degrees (hereinafter referred to as "the aft boundary of the Bow Intermediate area"), and below the line 1.5 *m* above the *UIWL*.

(b) Bow Intermediate area of *PC*5, *PC*6 and *PC*7 polar class ships with

"Bow Intermediate area" is defined as the hull area which is located aft of the aft boundary of the Bow area, and forward of the vertical line $0.04L_{UIWL}$ aft of the point on the *UIWL* where the waterline angle is 0 degrees, and below the line 1.0 *m* above the *UIWL*.

(3) Stern area

(a) Stern area of *PC*1, *PC*2, *PC*3 and *PC*4 polar class ships with

"Stern area" is defined as the hull area aft of the *A.P.* to the vertical line located 70% of the distance from the *A.P.* forward the maximum breadth point at the *UIWL* (hereinafter referred to as "the fore boundary of the Stern area"), and below the line 1.5 *m* above the *UIWL*.

(b) Stern area of *PC*5, *PC*6 and *PC*7 polar class ships
"Stern area" is defined as the hull area aft of the *A.P.* to the vertical line located 70% of the distance from the *A.P.* forward the maximum breadth point at the *UIWL*, and below the line 1.0*m* above the *UIWL*.
However, the distance from the *A.P.* to the fore boundary of the Stern area is not to be less than 0.15 times L_{UIWL}.

(4) Midbody area

(a) Midbody area of *PC*1, *PC*2, *PC*3 and *PC*4 polar class ships with
"Midbody area" is defined as the hull area which is located aft of the aft boundary of the Bow Intermediate area, and forward of the fore boundary of the Stern area, and below the line 1.5 *m* above the *UIWL*.

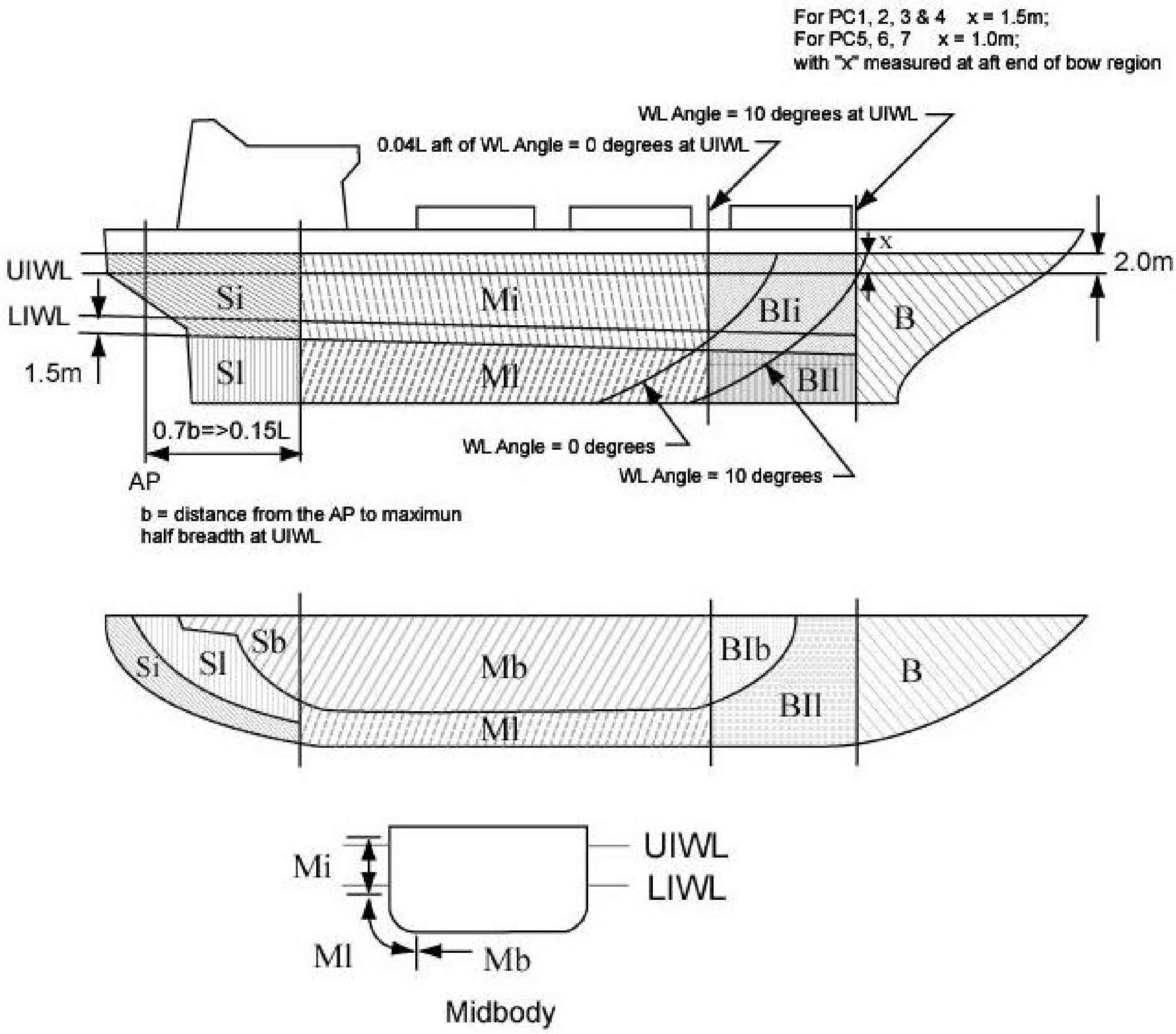
(b) Midbody area of *PC*5, *PC*6 and *PC*7 polar class ships
"Midbody area" is defined as the hull area which is located aft of the aft boundary of the Bow Intermediate area, and forward of the fore boundary of the Stern area, and below the line 1.0 *m* above the *UIWL*.

(5) Bottom area
"Bottom area" is defined as the hull area which is located inside the line circumscribed by the points where the bottom shell is inclined 7 degrees from horizontal (hereinafter referred to as "the upper boundary of the Bottom area") in the Bow Intermediate area, the Midbody area and the Stern area.

(6) Lower area
"Lower area" is defined as the hull area which is located upside of the upper boundary of the Bottom area, and below the line 1.5*m* below the *LIWL* (hereinafter referred to as "the upper boundary of the Lower area") in the Bow Intermediate area, the Midbody area and the Stern area.

(7) Icebelt area
For *PC*1, *PC*2, *PC*3 and *PC*4 polar class ships, "Icebelt area" is defined as the hull area which is located upside of the upper boundary of the Lower area, and below the line 1.5*m* above the *LIWL* in the Bow Intermediate area, the Midbody area and the Stern area.
For *PC*5, *PC*6 and *PC*7 polar class ships, "Icebelt area" is defined as the hull area which is located upside of the upper boundary of the Lower area, and below the line 1.0*m* above the *LIWL* in the Bow Intermediate area, the Midbody area and the Stern area.

Fig. 1.2.3-1 Hull Areas of Polar Class Ship



Notes:

Notation in the figure are as follows:

B: Bow area

BIi: Bow Intermediate Icebelt area

BIl: Bow Intermediate Lower area

Bib: Bow Intermediate Bottom area

Mi: Midbody Icebelt area

Ml: “Midbody Lower area

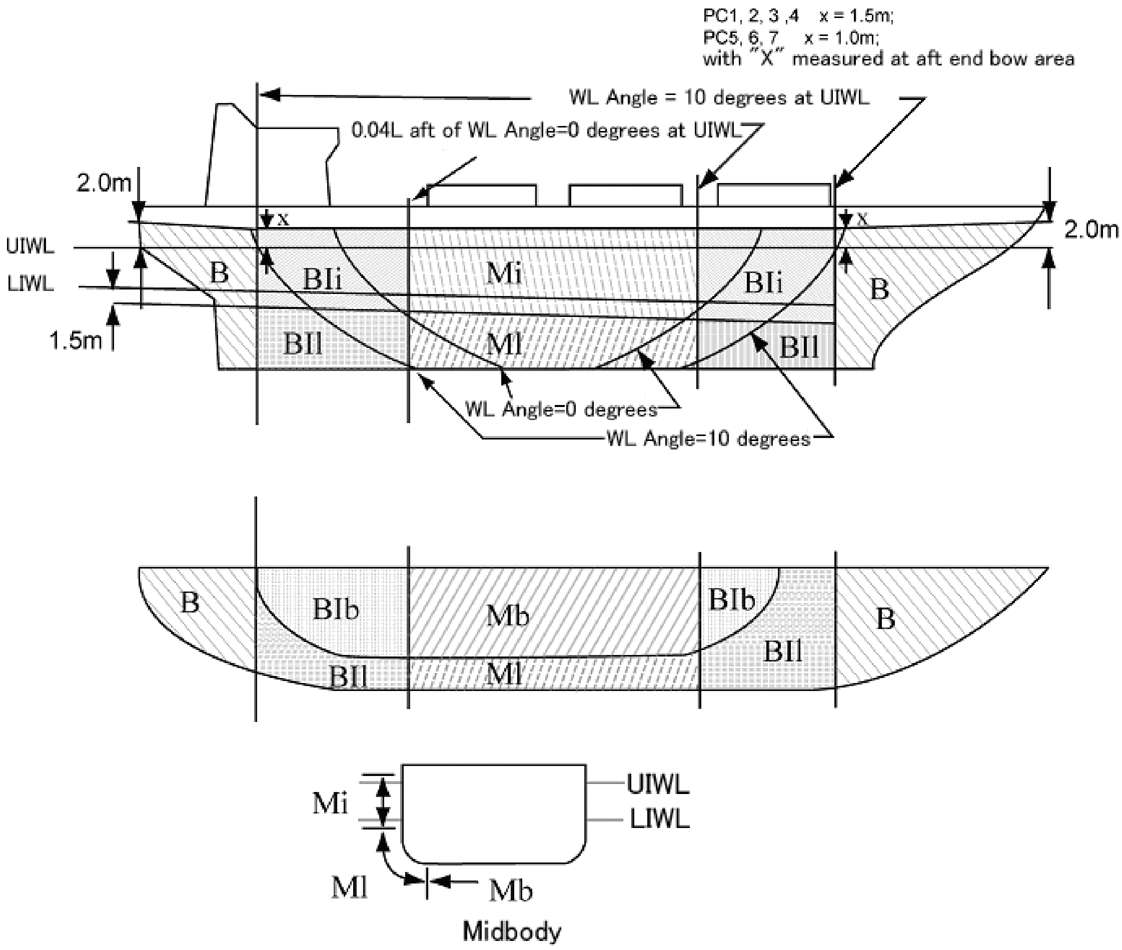
Mb: Midbody Bottom area

Si: Stern Icebelt area

Sl: Stern Lower area

Sb: Stern Bottom area

Fig. 1.2.3-2 Hull Area



Notes:

Symbols in the figure are as follows:

B: Bow Area

BIi: Bow Intermediate Icebelt Area

BIl: Bow Intermediate Lower Area

BIb: Bow Intermediate Bottom Area

Mi: Midbody Icebelt Area

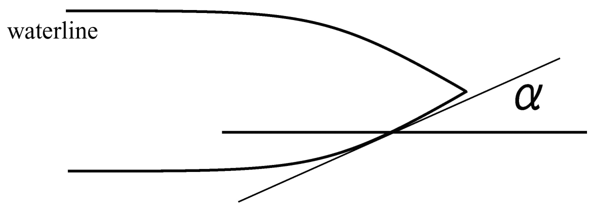
Ml: Midbody Lower Area

Mb: Midbody Bottom

1.2.4 Waterline Angle

Waterline angle is defined as the angle between the tangential line of side shell and the line of longitudinal direction of a ship at water line. (See **Fig. 1.2.4-1**)

Fig. 1.2.4-1 Waterline Angle α



Chapter 2 MATERIALS AND WELDING

2.1 Material

2.1.1 Materials for Hull Structures

Materials such as rolled steels, steel castings, steel forgings, etc. used for hull structures are to comply with the requirements of **Chapter 3**, **Part K of the Rules**.

2.1.2 Material Classes and Grades*

1 Material classes and grades used for the hull structure are given in **Table 2.1.2-1** to **Table 2.1.2-4**.

2 In addition, material classes for weather and sea exposed structural members and for members attached to the weather and sea exposed shell plating of polar class ships are given in **Table 2.1.2-5**.

3 For polar class ships designed base on a designated design temperature, the steels used for hull structures are to comply with the requirements in **1.1.12, Part C of the Rules**. However, regardless of the design temperature, the steel grades are not to be of lower than the steel grade provided in **Part I of the Rules**.

4 The steel grade of rolled steels with a thickness of 50 *mm* or more and/or a minimum upper yield stress of 390 N/mm^2 or more is deemed appropriate by the Society.

5 Where stainless clad steel is used for hull structure, **Table 2.1.3-1** to **Table 2.1.3-3** are to apply according to thickness of the base metal in lieu of thickness of the plates.

Table 2.1.2-1 Material Classes for Structural Members in general

Structural Member Category	Material Class/Grade
SECONDARY: A1. Longitudinal bulkhead strakes, other than that belonging to the Primary category A2. Deck plating exposed to weather, other than that belonging to the Primary or Special category A3. Side plating	-Class I within 0.4*L* amidships -Grade *A*/*AH* (2) outside 0.4*L* amidships
PRIMARY: B1. Bottom plating, including keel plate B2. Strength deck plating, excluding that belonging to the Special category B3. Continuous longitudinal members above strength deck, excluding hatch coamings B4. Uppermost strake in longitudinal bulkhead B5. Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank	-Class II within 0.4*L* amidships -Grade *A*/*AH* (2) outside 0.4*L* amidships
SPECIAL C1. Sheer strake at strength deck (1) C2. Stringer plate in strength deck (1) C3. Deck strake at longitudinal bulkhead, excluding deck plating in way of inner-skin bulkhead of double-hull ships(1)	-Class III within 0.4*L* amidships -Class II outside 0.4*L* amidships -Class I outside 0.6*L* amidships
C4. Strength deck plating at outboard corners of cargo hatch openings in container carriers and other ships with similar hatch opening configuration	-Class III within 0.4*L* amidships -Class II outside 0.4*L* amidships -Class I outside 0.6*L* amidships -Min. Class III within cargo region
C5. Strength deck plating at corners of cargo hatch openings in bulk carriers, ore carriers, combination carriers and other ships with similar hatch opening configuration	-Class III within 0.6*L* amidships -Class II within rest of cargo region
C6. Bilge strake in ships with double bottom over the full breadth and length less than 150 *m*(1)	-Class II within 0.6*L* amidships -Class I outside 0.6*L* amidships
C7. Bilge strake in other ships (1)	-Class III within 0.4*L* amidships -Class II outside 0.4*L* amidships -Class I outside 0.6*L* amidships
C8. Longitudinal hatch coamings of length greater than 0.15*L* C9. End brackets and deck house transition of longitudinal cargo hatch openings	-Class III within 0.4*L* amidships -Class II outside 0.4*L* amidships -Class I outside 0.6*L* amidships -Not to be less than Grade *D*/*DH* (3)

Notes:

(1) Single strakes required to be of class III within 0.4*L* amidships are to have breadths not less than 5*L*+800 *mm*, need not be greater than 1,800 *mm*, unless limited by the geometry of the ship's design.

(2) *A* means *KA*, *AH* means *KA*32 or *KA*36

(3) *D* means *KD*, *DH* means *KD*32 or *KD*36

Table 2.1.2-2 Minimum Material Grades for ships with length exceeding 150 *m* and single strength deck

Structural Member Category	Material Grade
Longitudinal strength members of strength deck plating	Grade *B*/*AH*(1) within 0.4*L* amidships
Continuous longituginal strength members above strength deck	Grade *B*/*AH*(1) within 0.4*L* amidships
Single side strakes for ships without inner continuous longituginal bulkhead(s) between bottom and the strength deck	Grade *B*/*AH*(1) within cargo region

Note:

(1) *B* means *KB*, *AH* means *KA*32 or *KA*36

Table 2.1.2-3 Minimum Material Grades for ships with length exceeding 250 *m*

Structural Member Category	Material Grade
Shear strake at strength deck(1)	Grade *E*/*EH*(2) within 0.4*L* amidships
Stringer plate in strength deck(1)	Grade *E*/*EH*(2) within 0.4*L* amidships
Bilge strake(1)	Grade *D*/*DH*(3) within 0.4*L* amidships

Notes:

(1) Single strakes required to be of Grade *E*/*EH* and within 0.4*L* amidships are to have breadths not less than 5*L*+800 *mm*, need not be greater than 1,800 *mm*, unless limited by the geometry of the ship's design.

(2) *E* means *KE*, *EH* means *KE*32 or *KE*36

(3) *D* means *KD*, *DH* means *KD*32 or *KD*36

Table 2.1.2-4 Minimum Material Grades for ships of *BC-A* and *BC-B*

Structural Member Category	Material Grade
Lower bracket of ordinary side frame(1)(2)	Grade *D*/*DH* (3)
Side shell strakes included totally or partially between the two points located to 0.125*l* above and below the intersection of side shell and bilge hopper sloping plate or inner bottom plate(2)	Grade *D*/*DH* (3)

Notes:

(1) The term "lower bracket" means webs of lower brackets and webs of the lower part of side frames up to the point of 0.125*l* above the intersection of side shell and bilge hopper sloping plate or inner bottom plate.

(2) The span of the side frame, *l*, is defined as the distance between the supporting structures.

(3) *D* means *KD*, *DH* means *KD*32 or *KD*36

Table 2.1.2-5 Material Classes for Structural Members of Polar Class Ships

Structural Members	Material Class
Shell plating within the Bow and Bow Intermediate Icebelt hull areas (B, B_{Ii})	II
All weather and sea exposed Secondary and Primary, as defined in **Table 2.1.2-1**, structural members outside 0.4 *L* amidships	I
Plating materials for stem and stern frames, rudder hone, 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* of the plating	I
Weather-exposed plating and attached framing in cargo holds of ships 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 **Table 2.1.2-1**, structural members within 0.2*L* from *FP*	II

2.1.3 Steel Grade

1 Steel grades for all plating and attached framing of hull structures and appendages situated below the level of 0.3 *m* below the *LIWL*, are to be obtained from **Table 2.1.3-1** based on the Material Classes for Structural members in **Table 2.1.2-1** to **Table 2.1.2-5** above, regardless of polar classes.

2 Steel grades for all weather exposed plating of hull structures and appendages situated above the level of 0.3 *m* below the *LIWL* are to be not less than that given in **Table 2.1.3-2** based on the Material Class for Structural Members in **Table 2.1.2-1** to **Table 2.1.2-5** above, regardless of polar class.

3 Steel grades for all inboard framing members attached to weather exposed plating are not to be less than that given in **Table 2.1.3-3**. This applies to all inboard framing members as well as to other contiguous inboard members (*e.g*. bulkheads, decks) within 600 *mm* of the exposed plating.

Table 2.1.3-1 Steel Grades for Plating and attached Framing below the Level of 0.3*m* below the *LIWL*

	Material Class I		Material Class II		Material Class III	
Thickness *t* (*mm*)	*MS*	*HT*	*MS*	*HT*	*MS*	*HT*
$t \le 15$	*A*	*AH*	*A*	*AH*	*A*	*AH*
$15 < t \le 20$	*A*	*AH*	*A*	*AH*	*B*	*AH*
$20 < t \le 25$	*A*	*AH*	*B*	*AH*	*D*	*DH*
$25 < t \le 30$	*A*	*AH*	*D*	*DH*	*D*	*DH*
$30 < t \le 35$	*B*	*AH*	*D*	*DH*	*E*	*EH*
$35 < t \le 40$	*B*	*AH*	*D*	*DH*	*E*	*EH*
$40 < t \le 50$	*D*	*DH*	*E*	*EH*	*E*	*EH*

Table 2.1.3-2 Steel Grades for Weather Exposed Plating

Thickness, *t* (*mm*)	Material Class I				Material Class II				Material Class III					
	*PC*1-5		*PC*6&7		*PC*1-5		*PC*6&7		*PC*1-3		*PC*4&5		*PC*6&7	
	MS	*HT*	*MS*	*HT*	*MS*	*HT*	*MS*	*HT*	*MS*	*HT*	*MS*	*HT*	*MS*	*HT*
$t \le 10$	*B*	*AH*	*B*	*AH*	*B*	*AH*	*B*	*AH*	*E*	*EH*	*E*	*EH*	*B*	*AH*
$10 < t \le 15$	*B*	*AH*	*B*	*AH*	*D*	*DH*	*B*	*AH*	*E*	*EH*	*E*	*EH*	*D*	*DH*
$15 < t \le 20$	*D*	*DH*	*B*	*AH*	*D*	*DH*	*B*	*AH*	*E*	*EH*	*E*	*EH*	*D*	*DH*
$20 < t \le 25$	*D*	*DH*	*B*	*AH*	*D*	*DH*	*B*	*AH*	*E*	*EH*	*E*	*EH*	*D*	*DH*
$25 < t \le 30$	*D*	*DH*	*B*	*AH*	*E*	*EH*	*D*	*DH*	*E*	*EH*	*E*	*EH*	*E*	*EH*
$30 < t \le 35$	*D*	*DH*	*B*	*AH*	*E*	*EH*	*D*	*DH*	*E*	*EH*	*E*	*EH*	*E*	*EH*
$35 < t \le 40$	*D*	*DH*	*D*	*DH*	*E*	*EH*	*D*	*DH*	-	*FH*	*E*	*EH*	*E*	*EH*
$40 < t \le 45$	*E*	*EH*	*D*	*DH*	*E*	*EH*	*D*	*DH*	-	*FH*	*E*	*EH*	*E*	*EH*
$45 < t \le 50$	*E*	*EH*	*D*	*DH*	*E*	*EH*	*D*	*DH*	-	*FH*	-	*FH*	*E*	*EH*

Note:

Grades *D*, *DH* are allowed for a single strake of side shell plating not more than 1.8 *m* wide from 0.3 *m* below the lowest ice waterline.

Table 2.1.3-3 Steel Grades for Inboard Framing Members Attached to Weather Exposed Plating

Thickness, *t* (*mm*)	*PC*1-5		*PC*6&7	
	MS	*HT*	*MS*	*HT*
$t \le 20$	*B*	*AH*	*B*	*AH*
$20 < t \le 35$	*D*	*DH*	*B*	*AH*
$35 < t \le 45$	*D*	*DH*	*D*	*DH*
$45 < t \le 50$	*E*	*EH*	*D*	*DH*

Note:

In **Table 2.1.3-1**, **Table 2.1.3-2** and **Table 2.1.3-3**, *MS* means mild steel, *HT* means high tensile steel, *A*, *B*, *D*, *E* and *AH*, *DH*, *EH*, *FH* mean the grades of steel as follows :

A : *KA*
B : *KB*
D : *KD*
E : *KE*
AH : *KA*32 and/or *KA*36
DH : *KD*32 and/or *KD*36
EH : *KE*32 and/or *KE*36
FH : *KF*32 and/or *KF*36

2.1.4 Materials other than Rolled Steel Plate

Materials other than rolled steel plate are to be of appropriate chemical composition for the expected service temperature.

2.1.5 Materials for Machinery Parts Exposed to Sea Water

Materials exposed to sea water, such as propeller blades, propeller hub and blade bolts are to have an elongation of not less than 15% for the *U*14*A* test specimen in **Part K of the Rules**. Materials other than bronze and austenitic steel are to have an average impact energy value of 20 *J* at -10°C for the *U*4 test specimen in **Part K of the Rules**.

2.1.6 Materials for Machinery Parts Exposed to Sea Water Temperatures

Materials exposed to sea water temperatures are to be of steel or other ductile material approved by the Society. The materials are to have an average impact energy value of 20 *J* at -10°C for the *U*4 test specimen in **Part K of the Rules**.

2.1.7 Materials for Machinery Parts Exposed to Low Air Temperatures

Materials of essential components exposed to low air temperatures are to be of steel or other ductile materials approved by the Society. The materials are to have an average impact energy value of 20 *J* obtained at 10°C below the lowest design temperature for the *U*4 test specimen in **Part K of the Rules**.

2.2 Welding

2.2.1 General

1 Welding is to comply with the requirements of **Part M of the Rules**.

2 All fillet welding within ice-strengthened areas are to be of the double continuous type and their sizes are to be of *F*2 or more as specified in **Table C1.4, Part C of the Rules**.

3 Continuity of strength is to be ensured at all structural connections, especially at the boundary between the ice-strengthened area and other areas.

2.3 Corrosion/Abrasion Additions

2.3.1 Protection of Shell Plating

Effective protection against corrosion and ice-induced abrasion is recommended for all external surfaces of the shell plating for all polar class ships.

2.3.2 Corrosion/Abrasion Additions

The values of corrosion/abrasion additions, t_s, to be used in determining the shell plate thickness for each Polar Class are listed in **Table 2.3.2-1**.

Table 2.3.2-1 Corrosion/Abrasion Additions for Shell Plating

Hull Area	Additional Thickness t_s (*mm*)					
	With Effective Protection[(1)]			Without Effective Protection		
	*PC*1-3	*PC*4&5	*PC*6&7	*PC*1-3	*PC*4&5	*PC*6&7
Bow area, Bow Intermediate Icebelt area	3.5	2.5	2.0	7.0	5.0	4.0
Bow Intermediate Lower area, Midbody Icebelt area, Stern Icebelt area	2.5	2.0	2.0	5.0	4.0	3.0
Midbody Lower area, Stern Lower area, Bottom area	2.0	2.0	2.0	4.0	3.0	2.5

Notes:

(1) "With Effective Protection" refers to coating the ship with paints such as ice strengthening paint that takes into account use in polar waters or equivalent measures which are deemed appropriate by the Society.

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

2.3.3 Corrosion/Abrasion addition of Internal Structures

Polar class ships are to have a minimum corrosion/abrasion addition of t_s = 1.0 *mm* 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.

Chapter 3 HULL STRUCTURE

3.1 Application

3.1.1 General

1 Design ice loads specified in this Chapter are applied to polar class ships with icebreaking forms.

2 Design ice loads for any other bow forms are to be specially considered at the Society's discretion.

3.1.2 Load Scenario

The design ice load provided in this Chapter is based on the collision load scenario, i.e., a glancing impact on the bow and determined in consideration of the following **(1)** to **(4)**.

(1) 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.

(2) Within the Bow area of all polar classes, and within the Bow Intermediate Icebelt area of *PC*6 and *PC*7 polar class ships, 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 fa_i, total glancing impact force F_i, line load Q_i and pressure P_i.

(3) In other ice-strengthened areas (within Midbody and Stern, Bow Intermediate Lower and Bow Intermediate Bottom areas of all polar classes, and within the Bow Intermediate Icebelt area of *PC*1, *PC*2, *PC*3, *PC*4 and *PC*5 polar class ships), 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, $AR = 3.6$.

(4) Ship 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 accelerations determined by each member society, are to be considered in the design of these structures.

3.2 Stability

3.2.1 Intact Stability*

1 Intact stability of all polar class ships is to meet the requirements in **Part U of the Rules**. In addition, stability calculation is to be carried out to demonstrate the following **(1)** and **(2)**. The effect of icing on the weather exposed area is to be taken into account in the stability calculation.

(1) During a disturbance causing roll, pitch, heave or heel due to turning or any other cause, sufficient positive stability is to be maintained.

(2) When riding up on ice and remaining momentarily poised at the lowest stem extremity, sufficient positive stability is to be maintained.

Sufficient positive stability means that the ship is in a positive state of equilibrium with a positive metacentric height of at least 150*mm*, and a line 150*mm* below the edge of the freeboard deck as defined in **Part V of the Rules**, is not submerged.

2 The stability in the state of riding up onto the ice is to be calculated by the procedure deemed appropriate by the Society.

3 For polar class ships without the capability of ride up on ice which is accepted by the Society, the stability calculation specified in **-1(2)** may be dispensed with taking into account the service features and hull forms, etc.

4 When the stability calculation of the polar class ship is performed, it is necessary to consider the influence due to icing up at least given in the following **(1)** and **(2)**.

(1) The icing up condition of $30kg/m^2$ or more is to be considered for the horizontal area on the weather exposed deck.

(2) The icing up condition of $7.5kg/m^2$ or more is to be considered for the vertical area of weather exposed deck.

5 In case where a more severe icing up is assumed, the designer is to decide the icing up condition used for the stability calculation.

3.2.2 Stability in Damaged Condition

1 All polar class ships are to have sufficient stability to withstand flooding resulting from hull penetration due to ice damage of the extent specified in the following **(1)** to **(4)**.

(1) Longitudinal extent 0.045 of the *UIWL* length, if centered forward of the point of maximum beam on the *UIWL*.

(2) Longitudinal extent 0.015 of the *UIWL* length, if centered backwards of the point of maximum beam on the *UIWL*.

(3) Vertical extent the lesser of 0.2 of deepest ice draught, or of longitudinal extent.

(4) Depth 760*mm* measured normal to the shell over the full extent of the damage.

2 The centre of the ice damage is to be assumed to be located at any point between the keel and 1.2 times the deepest ice draught.

3 For *PC*5, *PC*6 and *PC*7 polar class ships not carrying polluting or hazardous cargoes, damage may be assumed to be confined between watertight bulkheads, except where such bulkheads are spaced at less than the damage dimensions.

3.3 Subdivision

3.3.1 General

The subdivision of polar class ships is to be applied in **3.3**, in addition to complying with the requirements in other Parts and related Conventions.

3.3.2 Double Bottom

1 All polar class ships are to have double bottoms over the breadth and the length between forepeak and aft peak bulkheads.

2 All polar class ships with icebreaking bow forms and short forepeaks may dispense with double bottoms up to the forepeak bulkhead in the area of the inclined stem, provided that the watertight compartments between the forepeak bulkhead and the bulkhead at the junction between the stem and the keel are not used to carry pollutants.

3.3.3 Carriage of Pollutants

1 No polar class ship is to carry any pollutant directly against the outer shell.

2 Any pollutant is to be separated from the outer shell of the ship by double skin construction of at least 760*mm* in width.

3 Double bottoms in *PC*6 and *PC*7 polar class ships with may be used for the carriage of any working liquids where the tanks are aft of midship and within the flat of the bottom. However, it is not permitted when it is prohibited by the requirements in other Parts and related Conventions.

3.4 Design Ice Load

3.4.1 Glancing Impact Load Characteristics

The parameters defining the glancing impact load characteristics are reflected in the Class Factors listed in **Table 3.4.1-1**.

Table 3.4.1-1 Class Factors

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)
*PC*1	17.69	68.60	2.01	250	7.46
*PC*2	9.89	46.80	1.75	210	5.46
*PC*3	6.06	21.17	1.53	180	4.17
*PC*4	4.50	13.48	1.42	130	3.15
*PC*5	3.10	9.00	1.31	70	2.50
*PC*6	2.40	5.49	1.17	40	2.37
*PC*7	1.80	4.06	1.11	22	1.81

3.4.2 Bow Area

1 In the Bow area for all polar class ships and the Bow Intermediate Icebelt area for *PC*6 and *PC*7 polar class ships, 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 *UIWL*. The influence of the hull angles is captured through calculation of a bow shape coefficient f_a. The hull angles are defined in **Fig. 3.4.2-1**.

2 The waterline length of the bow region is generally to be divided into 4 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).

3 Shape coefficient fa_i is to be taken as the minimum value obtained from the following two formulas. However, when the shape coefficient fa_i is 0.6 or more, it is taken to be 0.6.

$$fa_{i,1} = \left\{0.097 - 0.68\left(\frac{x}{L'} - 0.15\right)^2\right\}\frac{\alpha_i}{\sqrt{\beta_i'}}$$

$$fa_{i,2} = \frac{1.2CF_F}{\sin(\beta_i')CF_C\left(\frac{\Delta_1}{1000}\right)^{0.64}}$$

where

i : sub-region considered

L' : ship length (m) measured on the *UIWL* from the forward side of the stem to the after side of the rudder post, or the centre of the rudder stock if there is no rudder post. L' is to be not less than 96% and need not exceed 97% of the extreme length on the *UIWL*.

x :distance (m) from the forward perpendicular to station under consideration

α :waterline angle (deg), see **Fig. 3.4.2-1**

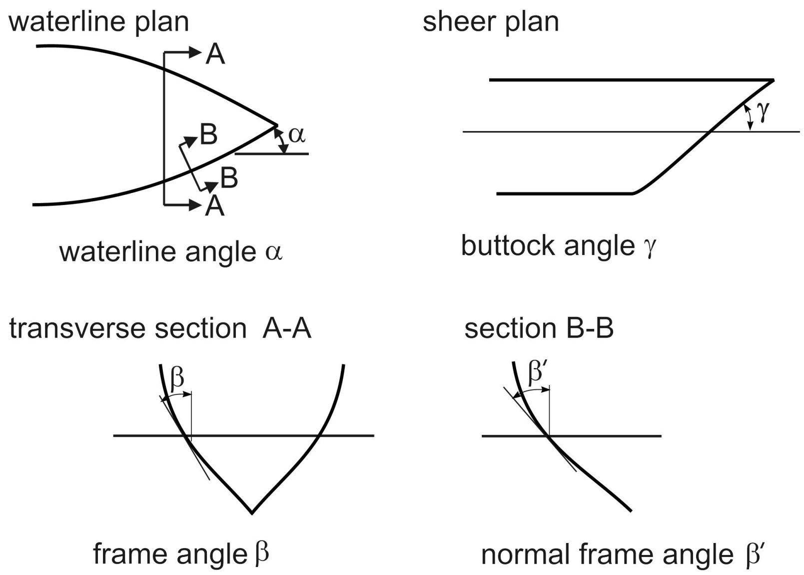
β' :normal frame angle (deg), see **Fig. 3.4.2-1**

Δ_1 :ship displacement (t) at the *UIWL*, not to be taken as less than 5,000t

CF_C :Crushing Failure Class Factor from **Table 3.4.1-1**

CF_F :Flexural Failure Class Factor from **Table 3.4.1-1**

Fig. 3.4.2-1 Definition of Hull Angles



Note :

β' : normal frame angle (deg) at the *UIWL*

α : upper ice waterline angle (deg)

γ : buttock angle (deg) at the *UIWL* (angle of buttock line measured from horizontal)

$\tan(\beta) = \tan(\alpha)/\tan(\gamma)$

$\tan(\beta') = \tan(\beta)\cos(\alpha)$

4 Force F is to be obtained from the following formula.

$$F_i = fa_i CF_C \left(\frac{\Delta_1}{1000} \right)^{0.64} \times 1000 \quad (kN)$$

where

i : sub-region considered

fa_i : shape coefficient of sub-region i, see **-3**

CF_C : Crushing Failure Class Factor from **Table 3.4.1-1**

Δ_1 : ship displacement (t), not to be taken as less than 5,000t

5 Load patch aspect ratio AR_i is to be obtained from the following formula, however, when load patch aspect ratio AR_i is less than 1.3, it is taken to be 1.3.

$AR_i = 7.46 \sin(\beta'_i)$

where

i : sub-region considered

β'_I : normal frame angle (deg) of sub-region i

6 Line load Q is to be obtained from the following formula.

$$Q_i = \left(\frac{F_i}{1000}\right)^{0.61} \frac{CF_D}{AR_i^{0.35}} \times 1000 \quad (kN/m)$$

where

i : sub-region considered

F_i and AR_i : the values specified in **-4** and **-5**, respectively

CF_D : Load Patch Dimensions Class Factor from **Table 3.4.1-1**

7 Pressure P is to be obtained from the following formula:

$$P_i = \left(\frac{F_i}{1000}\right)^{0.22} CF_D^{\,2} AR_i^{0.3} \times 1000 \quad (kN/m^2)$$

where

i : sub-region considered

CF_D : Load Patch Dimensions Class Factor from **Table 3.4.1-1**

F_i and AR_i : the values specified in **-4** and **-5**, respectively

8 In the Bow area, and the Bow Intermediate Icebelt area for $PC6$ and $PC7$polar class ships, the design load patch has dimensions of width, w_{Bow}, and height, b_{Bow}, defined as follows:

$w_{Bow} = F_{Bow} / Q_{Bow}$ (m)

$b_{Bow} = Q_{Bow} / P_{Bow}$ (m)

where

F_{Bow} : maximum force F_i (kN) in the Bow area from **-4**

Q_{Bow} : maximum line load Q_i (kN/m) in the Bow area from **-6**

P_{Bow} : maximum pressure P_i (kN/m^2) in the Bow area from **-7**

9 The average pressure, P_{avg}, within a design load patch is determined as follows:

$P_{avg} = F_{Bow} / (b_{Bow}\, w_{Bow})$ (kN/m^2)

3.4.3 Hull Areas other than the Bow

1 Midbody, Stern, Bow Intermediate Lower, Bow Intermediate Bottom Area and the Bow Intermediate Icebelt area for $PC1$, $PC2$, $PC3$, $PC4$ and $PC5$ polar class ships with, 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:

(a) Force, F_{NonBow}

$$F_{NonBow} = 0.36\, CF_C DF \times 1000 \quad (kN)$$

where

CF_C : Crushing Failure Class Factor from **Table 3.4.1-1**

DF : ship displacement factor, obtained from the following formula.

$$DF = \left(\frac{\Delta_2}{1000}\right)^{0.64} \quad \text{if} \quad \frac{\Delta_2}{1000} \le CF_{DIS}$$

$$DF = CF_{DIS}^{\,0.64} + 0.10\left(\frac{\Delta_2}{1000} - CF_{DIS}\right) \quad \text{if} \quad \frac{\Delta_2}{1000} > CF_{DIS}$$

where

Δ_2 : ship displacement (t) at the $UIWL$, not to be taken as less than 10,000t

CF_{DIS} : Displacement Class Factor from **Table 3.4.1-1**

(b) Line load Q_{NonBow}

$$Q_{NonBow} = 0.639\left(\frac{F_{NonBow}}{1000}\right)^{0.61} CF_D \times 1000 \quad (kN/m)$$

where

F_{NonBow} : the force (kN) obtained from **(a)**

CF_D : Load Patch Dimensions Class Factor from **Table 3.4.1-1**

2 In the Midbody area, the Stern area, and the Bow Intermediate Lower area, and the Bow Intermediate Bottom area for all polar class ships and the Bow Intermediate Icebelt area for *PC*6 and *PC*7 polar class ships, the design load patch has dimensions of width, w_{NonBow}, and height, b_{NonBow}, defined as follows:

$w_{NonBow} = F_{NonBow} / Q_{NonBow}$ (m)

$b_{NonBow} = w_{NonBow} / 3.6$ (m)

where

F_{NonBow} : force (kN) obtained from **3.4.3-1(a)**

Q_{NonBow} : line load (kN/m) obtained from **3.4.3-1(b)**

3 The average pressure, P_{avg}, within a design load patch is determined as follows:

$P_{avg} = F_{NonBow} / (b_{NonBow}\ w_{NonBow})$ (kN/m^2)

where

F_{NonBow}, b_{NonBow} and w_{NonBow} : the values specified in **-1** and **-2**, respectively.

3.4.4 Peak 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 **Table 3.4.4-1** are used to account for the pressure concentration on localized structural members.

Table 3.4.4-1 Peak Pressure Factors

Structural Member		Peak Pressure Factor (PPF_i)
Plating	Transversely-Framed	$PPF_p = (1.8 - s)$, not to be less than 1.2
	Longitudinally-Framed	$PPF_p = (2.2 - 1.2s)$, not to be less than 1.5
Frames in Transverse Framing Systems	With Load Distributing Stringers	$PPF_t = (1.6 - s)$, not to be less than 1.0
	With No Load Distributing Stringers	$PPF_t = (1.8 - s)$, not to be less than 1.2
Load Carrying Stringers Side and Bottom Longitudinals Web Frames		$PPF_s = 1.0$, if $S_w \geq 0.5w$ $PPF_s = 2.0 - 2.0S_w / w$, if $S_w < 0.5w$
where	s = frame or longitudinal (m) S_w = web frame spacing (m) w = ice load patch width (m)	

3.4.5 Hull Area Factors

1 Associated with each hull area is an Area Factor that reflects the relative magnitude of the load expected in that area. The Area Factor *AF* for each hull area is listed in **Table 3.4.5-1**.

2 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.

3 Due to their increased manoeuvrability, ships having propulsion arrangements with azimuthing thruster(s) or "podded" propellers are to have specially considered the Stern Icebelt S_i and the Stern Lower S_l hull area factors.

Table 3.4.5-1 Hull Area Factors *AF*

Hull Area		Area	Polar Class						
			*PC*1	*PC*2	*PC*3	*PC*4	*PC*5	*PC*6	*PC*7
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 **3.1.2(2)**

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

3.5 Local Strength

3.5.1 Shell Plate Requirements

1 The required minimum shell plate thickness, *t*, is given by:

$t = t_{net} + t_s$ (mm)

where

t_{net} : plate thickness (mm) required to resist ice loads according to **-2**

t_s : corrosion and abrasion allowance (mm) according to **2.3.2**

2 The thickness of shell plating required to resist the design ice load, t_{net}, depends on the orientation of the framing.

(1) In the case of transversely-framed plating ($\Omega \geq 70$ deg):

$$t_{net} = 500s \times \sqrt{\frac{AF \times PPF_P \left(\frac{P_{avg}}{1000}\right)}{\sigma_y}} \frac{1}{1+\frac{s}{2b}} \quad (mm)$$

(2) In the case of longitudinally-framed plating ($\Omega \leq 20$ deg) :

$$t_{net} = 500s \times \sqrt{\frac{AF \times PPF_P \left(\frac{P_{avg}}{1000}\right)}{\sigma_y}} \frac{1}{1+\frac{s}{2l}} \quad (mm), \text{ if } b \geq s$$

$$t_{net} = 500s \times \sqrt{\frac{AF \times PPF_P \left(\frac{P_{avg}}{1000}\right)}{\sigma_y}} \sqrt{\frac{2b}{s-\left(\frac{b}{s}\right)^2}} \frac{1}{1+\frac{s}{2l}} \quad (mm), \text{ if } b < s$$

where

Ω : smallest angle (deg) between the chord of the waterline and the line of the first level framing as illustrated in **Fig. 3.5.1-1**

s : transverse frame spacing (m) in transversely-framed ships or longitudinal frame spacing (m) in longitudinally-framed ships

AF : Hull Area Factor from **Table 3.4.5-1**

PPF_p : Peak Pressure Factor from **Table 3.4.4-1**

P_{avg} : average patch pressure (kN/m^2) according to **3.4.3-3**

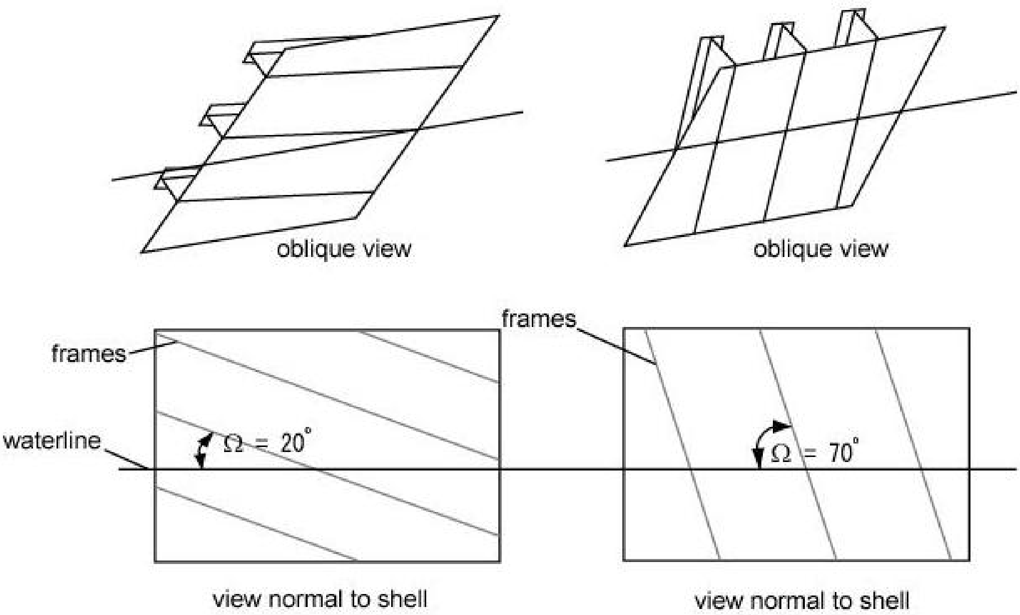
σ_y : minimum upper yield stress of the material (N/mm^2)

b : height (m) of design load patch, where $b \le (l - s/4)$ in the case of transversely-framed plating

l : distance (m) between frame supports, i.e. equal to the frame span, but not reduced for any fitted end brackets. When a load-distributing stringer is fitted, the length l need not be taken larger than the distance from the stringer to the most distant frame support.

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

Fig. 3.5.1-1 Shell Framing Angle Ω



3.5.2 Framing

1 Framing members of polar class ships are to be designed to withstand the ice loads defined in **3.4**.

2 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.

3 The actual net effective shear area, A_w, of a framing member is given by:

$$A_w = \frac{h t_{wn} \sin\varphi_w}{100} \quad (cm^2)$$

where

h : height of stiffener (mm), see **Fig. 3.5.2-1**

t_{wn} : net web thickness (mm), $t_{wn} = t_w - t_c$

t_w : as built web thickness (mm), see **Fig. 3.5.2-1**

t_c : corrosion deduction (mm) to be subtracted from the web and flange thickness (as specified by other Parts , but not less than t_s as required by **2.3.3**).

φ_w : smallest angle (deg) between shell plate and stiffener web, measured at the mid-span of the stiffener, see **Fig. 3.5.2-1**. The angle φ_w may be taken as 90 degrees provided the smallest angle is not less than 75 degrees.

(1) When the cross-sectional area of the attached plate flange exceeds the cross-sectional area of the local frame, the actual net effective plastic section modulus, Z_p, is given by:

$$Z_p = \frac{A_{pn} t_{pn}}{20} + \frac{h_w^2 t_{wn} \sin\varphi_w}{2000} + \frac{A_{fn}(h_{fc} \sin\varphi_w - b_w \cos\varphi_w)}{10} \quad (cm^3)$$

where

s : frame spacing (m)

A_{pn} : net cross-sectional area (cm^2) of the local frame

t_{pn} : fitted net shell plate thickness (mm) (is to comply with t_{net} as required by **3.5.1-2**)

h_w : height (mm) of local frame web, see **Fig. 3.5.2-1**

A_{fn} : net cross-sectional area (cm^2) of local frame flange

h_{fc} : height (mm) of local frame measured to centre of the flange area, see **Fig. 3.5.2-1**

b_w : distance (mm) from mid thickness plane of local frame web to the centre of the flange area, see **Fig. 3.5.2-1**

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

$$Z_{na} = \frac{100A_{fn} + h_w t_{wn} - 1000 t_{pn} s}{2t_{wn}} \quad (mm)$$

where

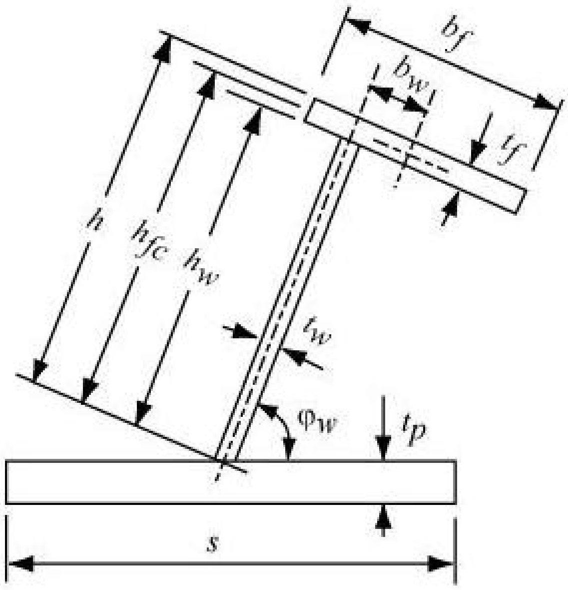
s : frame spacing (m)

The net effective plastic section modulus, Z_p, is given by:

$$Z_p = t_{pn} s\left(z_{na} + \frac{t_{pn}}{2}\right)\sin\varphi_w + \left(\frac{((h_w - z_{na})^2 + z_{na}^2)t_{wn}\sin\varphi_w}{2000} + \frac{A_{fn}\left((h_{fc} - z_{na})\sin\varphi_w - b_w\cos\varphi_w\right)}{10}\right)$$

(cm^3)

Fig. 3.5.2-1 Stiffener Geometry



3.5.3 Framing - Transversely-framed Side Structures and Bottom Structures

1 The local frames in transversely-framed side structures and in bottom structures (i.e. hull areas is the Bow Intermediate Bottom area, the Midbody Bottom area and the Stern Bottom area) 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 mid-span load that causes the development of a plastic collapse mechanism.

2 The actual net effective shear area of the frame, A_w, as defined in **3.5.2-3** is to be not less than A_t determined as follows:

$$A_t = \frac{100^2 \times 0.5 \times LLsAF \times PPF_t \dfrac{P_{avg}}{1000}}{0.577\sigma_y} \quad (cm^2)$$

where

LL : length of loaded portion of span (*m*), taken equal to lesser of *a* and *b*

a : frame span (*m*)

b : height (*m*) of design ice load patch according to **3.5.1-2**

s : transverse frame spacing (*m*)

AF : Hull Area Factor from **Table 3.4.5-1**

PPF_t : Peak Pressure Factor from **Table 3.4.4-1**

P_{avg} : Average pressure (kN/m^2) within load patch according to **3.4.3-3**

σ_y : Minimum upper yield stress of the material (N/mm^2)

3 The actual net effective plastic section modulus of the plate/stiffener combination Z_p as defined in **3.5.2-3** is to be not less than Z_{pt} determined as follows:

$$Z_{pt} = \frac{100^3 \times LL \times YsAF \times PPF_t \dfrac{P_{avg}}{1000} aA_1}{4\sigma_y} \quad (cm^3)$$

where

AF, PPF_t, P_{avg}, LL, b, s, a and σ_y are as given in **3.5.3-2.**

$Y = 1 - 0.5\ (LL / a)$

A_1 : taken equal to the greater of following **(a)** and **(b)**

(a) When ice load acting at the mid-span of the transverse frame

$$A_1 = \frac{1}{1 + \frac{j}{2} + \frac{k_w j}{2\left(\sqrt{1 - a_1^2} - 1\right)}}$$

(b) When ice load acting near a support

$$A_1 = \frac{1 - \frac{1}{2 a_1 Y}}{0.275 + 1.44 k_z^{0.7}}$$

$j = 1$ for framing with one simple support outside the ice-strengthened areas

$j = 2$ for framing without any simple supports

$a_1 = A_t / A_w$

A_t : Minimum shear area (cm^2) of transverse frame as given in **3.5.3-2**

A_w : Effective net shear area (cm^2) of transverse frame (calculated according to **3.5.2-3**)

$k_w = 1 / (1 + 2A_{fn} / A_w)$ with A_{fn} as given in **3.5.2-3(1)**

k_z : Section modulus ratio

$k_z = z_p / Z_p$ in general

$k_z = 0.0$ when the frame is arranged with end bracket

z_p : Sum of individual plastic section modulus (cm^3) of flange and shell plate as fitted

$z_p = (b_f\, t_{fn}^2 / 4 + b_{eff}\, t_{pn}^2 / 4) / 1000$

b_f : Flange breadth (mm), see **Fig. 3.5.2-1**

t_{fn} : net flange thickness (mm)

$t_{fn} = t_f - t_c$ (t_c as given in **3.5.2-3**)

t_f : As-built flange thickness (mm), see **Fig. 3.5.2-1**

t_{pn} : The fitted net shell plate thickness (mm), not to be less than t_{net} as given in **3.5.1**.

b_{eff} : Effective width (mm) of shell plate flange

$b_{eff} = 500\ s$

Z_p : Net effective plastic section modulus (cm^3) of transverse frame (calculated according to **3.5.2-3(1)** and **(2)**)

3.5.4 Framing - Side Longitudinals (longitudinally-framed ships)

1 Side longitudinals 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 mid-span load that causes the development of a plastic collapse mechanism.

2 The actual net effective shear area of the frame, A_w, as defined in **3.5.2-3** is to be not less than A_L determined as follows:

$$A_L = \frac{100^2\left(AF \times PPF_s \dfrac{P_{avg}}{1000}\right) \times 0.5 b_1 a}{0.577\varphi_y} \quad (cm^2)$$

where

AF : Hull Area Factor from **Table 3.4.5-1**

PPF_s : Peak Pressure Factor from **Table 3.4.4-1**

P_{avg} : Average pressure (kN/m^2) within load patch according to **3.4.3-3**

$b_1 = k_o\, b_2$ (m)

$k_o = 1 - 0.3 / b'$

$b' = b / s$

b : Height (m) of design ice load patch from **3.4.2-8** or **3.4.3-2**

s : Spacing (m) of longitudinal frames

b_2 : as given by

$b_2 = b\,(1 - 0.25\, b')$ (m), if $b' < 2$

$b_2 = s$ (m), if $b' \geq 2$

a : Longitudinal design span (m)

σ_y : Minimum upper yield stress of the material (N/mm^2)

3 The actual net effective plastic section modulus of the plate/stiffener combination Z_p as defined in **3.5.2-3(1)** is to be not less than Z_{pL} determined as follows:

$$Z_{pL} = \frac{100^3\left(AF \times PPF_s \dfrac{P_{avg}}{1000}\right) b_1 a^2 A_4}{8\sigma_y} \quad (cm^3)$$

where

AF, PPF_s, P_{avg}, b_1, a and σ_y are as given in **3.5.4-2.**

$$A_4 = \frac{1}{2 + k_{wl}\left(\sqrt{1 - a_4^{\,2}} - 1\right)}$$

$a_4 = A_L / A_w$

A_L : Minimum shear area (cm^2) for longitudinal as given in **3.5.4-2**

A_w : Net effective shear area (cm^2) of longitudinal (calculated according to **3.5.2-3**)

$k_{wl} = 1 / (1 + 2\, A_{fn} / A_w)$ with A_{fn} as given in **3.5.2-3(1)**

3.5.5 Web Frame and Load-carrying Stringers

1 Web frames and load-carrying stringers are to be designed to withstand the ice load patch as defined in **3.4**. The load patch is to be applied at locations where the capacity of these members under the combined effects of bending and shear is minimised.

2 Web frames and load-carrying stringers are to be dimensioned such that the combined effects of shear and bending do not exceed the plastic strength of the structural members. 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 **Table 3.4.4-1** is to be used, and the requirements specified in **3.5.2** to **3.5.4** are to be applied to the members.

3 Special attention is to be paid to the shear capacity in way of lightening holes and cut-outs in way of intersecting members.

3.5.6 Structural Stability

1 To prevent local buckling in the web, the ratio of web height h_w to net web thickness t_w of any framing member is not to exceed :

For flat bar sections : $\frac{h_w}{t_{wn}} \le \frac{282}{\sqrt{\sigma_y}}$

For bulb, tee and angle sections : $\frac{h_w}{t_{wn}} \le \frac{805}{\sqrt{\sigma_y}}$

where

h_w : web height (*mm*)

t_{wn} : net web thickness (*mm*)

σ_y : minimum upper yield stress of the material (N/mm^2)

2 Framing members for which it is not practicable to meet the requirements of **3.5.6-1** (*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 for these framing members is not to be less than of the maximum value obtained from following **(a)** and **(b)**:

(a) $t_{wn} = 2.63 \times 10^{-3} \times c_1 \sqrt{\frac{\sigma_y}{5.34 + 4(c_1 / c_2)^2}}$ (*mm*)

where

$c_1 = h_w - 0.8h$ (*mm*)

h_w : web height (*mm*) of stringer / web frame, see **Fig. 3.5.6-1**.

h : height (*mm*) of framing member penetrating the member under consideration, 0 if no such framing member, see **Fig. 3.5.6-1**.

c_2 : spacing (*mm*) between supporting structure oriented perpendicular to the member under consideration, see **Fig. 3.5.6-1**.

σ_y : minimum upper yield stress of the material (N/mm^2)

(b) $t_{wn} = 0.35 t_{pn} \sqrt{\frac{\sigma_y}{235}}$ (*mm*)

where

σ_y : minimum upper yield stress of the shell plate in way of the framing member (N/mm^2)

t_{wn} : net thickness (*mm*) of the web

t_{pn} : net thickness (*mm*) of the shell plate in way of the framing member

3 To prevent local flange buckling of welded profiles, the following **(1)** and **(2)** are to be satisfied:

(1) The flange width, b_f (*mm*) is not to be less than five times the net thickness of the web, t_{wn}.

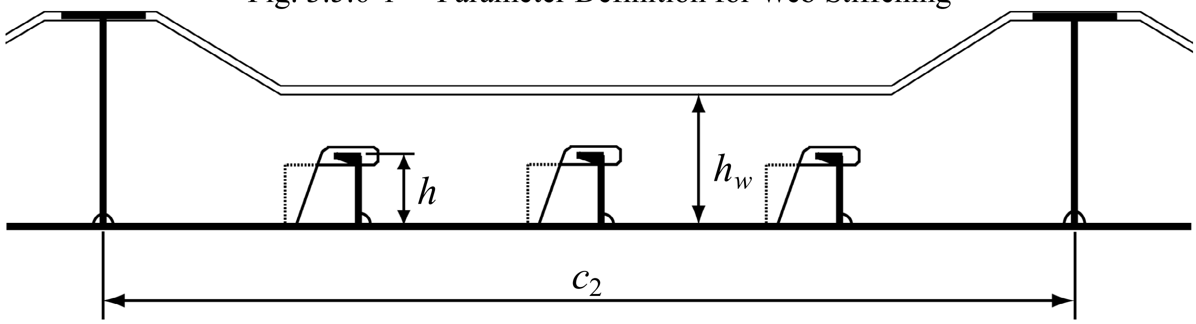
(2) The flange outstand, b_{out} (*mm*) is to meet the following requirement:

$$\frac{b_{out}}{t_{fn}} \le \frac{155}{\sqrt{\sigma_y}}$$

where

t_{fn} : net thickness (*mm*) of flange
σ_y : minimum upper yield stress of the material (N/mm^2)

Fig. 3.5.6-1 Parameter Definition for Web Stiffening



3.5.7 Plated Structures

1 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:

(1) web height of adjacent parallel web frame or stringer; or
(2) 2.5 times the depth of framing that intersects the plated structure

2 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.

3.5.8 Stem and Stern Frames

The stem and stern frame are to be designed according to the requirements deemed appropriate by the Society. For *PC*6 and *PC*7 polar class ships, the stem and stern requirements of **8.3.7** and **8.3.9**, **Part I of the Rules** may need to be additionally considered.

3.5.9 Bilge Keel

1 The connection of bilge keels to the hull is to be so designed, that the risk of the hull, in case a bilge keel is ripped off, is minimized.

2 It is recommended that bilge keels are cut up into several shorter independent lengths.

3.5.10 Appendages

1 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.

2 Load definition and response criteria are deemed appropriately by the Society.

3.5.11 Local Details

1 Local design details are to comply with the requirements deemed appropriate by the Society.

2 The collar plate is to be fitted in way of the cut-out for longitudinal penetration in the ice reinforcement region in principle.

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

3.5.12 Direct Calculations

1 Direct calculations are to not to be utilised as an alternative to the analytical procedures prescribed in this unified requirement.

2 Where direct calculation is used to check the strength of structural systems, the load patch specified in **3.4** is to be applied.

3.6 Longitudinal Strength

3.6.1 General

1 Ice loads for examination of longitudinal strength in navigating ice-infested polar waters need only be combined with still water loads.

2 The combined stresses are to be compared against permissible bending and shear stresses at different locations along the ship's length.

3 In addition, sufficient local buckling strength is also to be verified.

3.6.2 Design Vertical Ice Force at the Bow

The design vertical ice force at the bow F_{IB} is to be taken the minimum value of following $F_{IB,1}$ and $F_{IB,2}$.

$$F_{IB,1} = 1000 \times 0.534 K_I^{0.15} \sin^{0.2}(\gamma_{stem}) \sqrt{\frac{\Delta_2}{1000} \frac{K_h}{1000}} CF_L \quad (kN)$$

$$F_{IB,2} = 1000 \times 1.20 CF_F \quad (kN)$$

where

K_I : indentation parameter, $K_I = 1000 \dfrac{K_f}{K_h}$

where

(a) for the case of a blunt bow form

$$K_f = \left(\frac{2CB^{1-e_b}}{1+e_b} \right)^{0.9} \tan(\gamma_{stem})^{-0.9(1+e_b)}$$

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

$$K_f = \left(\frac{\tan(\alpha_{stem})}{\tan^2(\gamma_{stem})} \right)^{0.9}$$

$$K_h = 10 A_{WP} \quad (kN/m)$$

CF_L : Longitudinal Strength Class Factor from **Table 3.4.1-1**

e_b : bow shape exponent which best describes the waterplane, see **Fig. 3.6.2-1** and **Fig. 3.6.2-2**

e_b = 1.0 for a simple wedge bow form

e_b = 0.4 to 0.6 for a spoon bow form

e_b = 0 for a landing craft bow form

An approximate e_b determined by a simple fit is acceptable

γ_{stem}: stem angle (deg) to be measured between the horizontal axis and the stem tangent at the *UIWL* (buttock angle (deg) as per **Fig. 3.4.2-1** measured on the centreline)

α_{stem} : waterline angle (deg) measured in way of the stem at the *UIWL*, see **Fig. 3.6.2-1**

$$C = \frac{1}{2\left(\frac{L_B}{B}\right)^{e_b}}$$

B : ship moulded breadth (m)

L_B : bow length (m), see **Fig. 3.6.2-1** and **Fig. 3.6.2-2**.

Δ_2 : ship displacement (t), not to be taken less than 10,000t

A_{wp} : ship waterplane area (m^2)

CF_F : Flexural Failure Class Factor from **Table 3.4.1-1**

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

Fig. 3.6.2-1 Bow Shape Definition

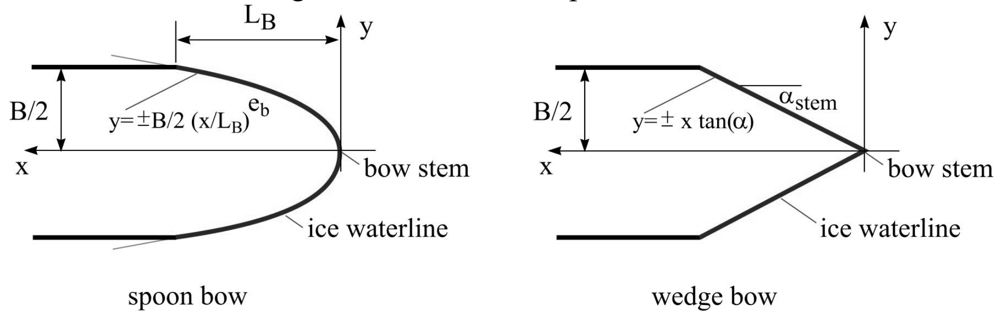
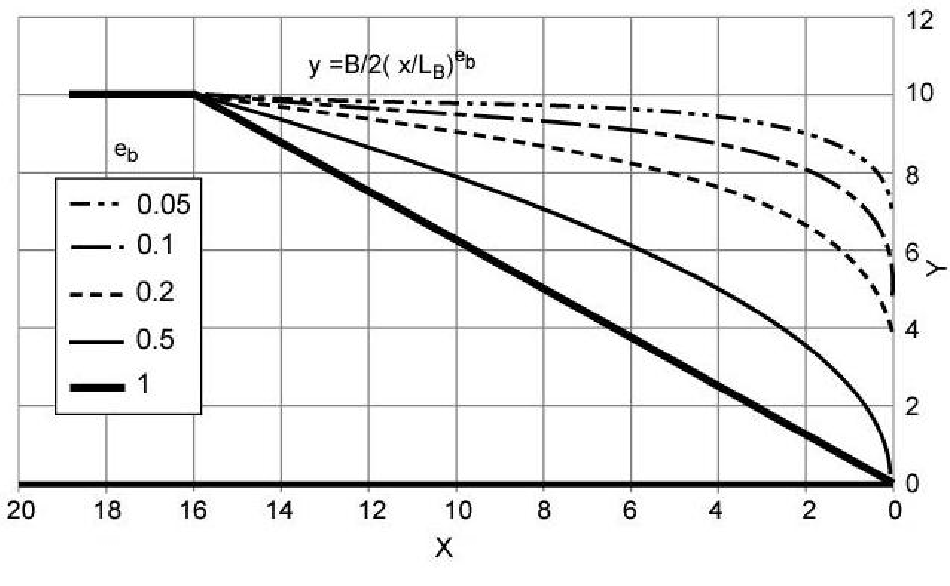


Fig. 3.6.2-2 Illustration of e_b Effect on the Bow Shape for B=20 and L_B=16



3.6.3 Design Vertical Shear Force

1 The design vertical ice shear force F_I along the hull girder is to be taken as:

$F_I = C_f F_{IB}$ (kN)

where

C_f= longitudinal distribution factor to be taken as follows:

(a) Positive share force

C_f = 0.0 between the aft end of L and 0.6L from aft

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

(b) Negative share force

C_f = 0.0 at the aft end of L

C_f = -0.5 between 0.2L and 0.6L from aft

C_f = 0.0 between 0.8L from aft and the forward end of L

Intermediate values are to be determined by linear interpolation

2 The applied vertical shear stress τ_a is to be determined along the hull girder in a similar manner as in **15.4.2-2, Part C of the Rules** by substituting the design vertical ice shear force for the design vertical wave shear force.

3.6.4 Design Vertical Ice Bending Moment

1 The design vertical ice bending moment M_I along the hull girder is to be taken as:

$$M_I = 0.1 C_m L' \sin^{-0.2}(\gamma_{stem}) F_{IB} \quad (kNm)$$

where

L': ship length (m) measured on the *UIWL* from the forward side of the stem to the after side of the rudder post, or the centre of the rudder stock if there is no rudder post. L' is to be not less than 96% and need not exceed 97% of the extreme length on the *UIWL*.

γ_{stem}: as given in **3.6.2**

F_{IB}: design vertical ice force (kN) at the bow, see **3.6.2**

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

C_m = 0.0 at the aft end of L

C_m = 1.0 between 0.5L and 0.7L from aft

C_m = 0.3 at 0.95L from aft

C_m = 0.0 at the forward end of L

Intermediate values are to be determined by linear interpolation.

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

2 The applied vertical bending stress σ_a is to be determined along the hull girder in a similar manner as in **15.4.2-1, Part C of the Rules**, by substituting the design vertical ice bending moment for the design vertical wave bending moment.

3.6.5 Longitudinal Strength Criteria

The strength criteria provided in **Table 3.6.5-1** are to be satisfied. The design stress is not to exceed the permissible stress.

Table 3.6.5-1 Longitudinal Strength Criteria

Failure Mode	Applied Stress	Permissible Stress when $\sigma_y / \sigma_u \le 0.7$	Permissible Stress when $\sigma_y / \sigma_u > 0.7$
Tension	σ_a	$0.8\ \sigma_y$	$0.8 \times 0.41\ (\sigma_u + \sigma_y)$
Shear	τ_a	$0.8\ \sigma_y / \sqrt{3}$	$0.8 \times 0.41\ (\sigma_u + \sigma_y) / \sqrt{3}$
Buckling	σ_a	σ_c for plating and for web plating of stiffeners σ_c / 1.1 for stiffeners	
	τ_a	τ_c	

where

σ_a : applied vertical bending stress (N/mm^2)

τ_a : applied vertical shear stress (N/mm^2)

σ_y : minimum upper yield stress of the material (N/mm^2)

σ_u : ultimate tensile strength of material (N/mm^2)

σ_c : critical buckling stress (N/mm^2) in compression, according to **15.4, Part C of the Rules**

τ_c : critical buckling stress (N/mm^2) in shear, according to **15.4, Part C of the Rules**

Chapter 4 MACHINERY INSTALLATIONS

4.1 General

4.1.1 Scope

The requirements of this chapter apply to main propulsion, steering gear, emergency and essential auxiliary systems essential for the safety of the ship and survivability of the crew.

4.1.2 Drawings and Data

Drawings and data to be submitted in this chapter are as follows:

(1) Details of the environmental conditions and the required polar class for the machinery, if different from the polar class of hull structure
(2) Detailed drawings of the main propulsion machinery (including information on essential main propulsion load control functions)
(3) Operational limitations of the main propulsion, steering, emergency and essential auxiliaries
(4) Descriptions detailing how main, emergency and auxiliary systems are located and protected to prevent problems from freezing, ice and snow
(5) Evidence of their capability to operate in intended environmental conditions
(6) Calculations and documentation indicating compliance with the requirements of this chapter
(7) Drawings and data which are deemed necessary by the Society

4.1.3 System Design

1 Additional fire safety measures are to be arranged in accordance with the requirements in **5.2.3, 7.4, 10.2.1-2, 10.5.3-1** and **10.5.5-2, Part R of the Rules**.

2 Any automation plant (control, alarm, safety and indication systems) for essential systems installed is to be maintained in accordance with the requirements in **Chapter 4 of the Rules for Automatic and Remote Control Systems**.

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

4 Single screw polar class ships classed *PC*1 to *PC*5 are to have means provided to ensure sufficient vessel operation in the case of propeller damage including a controllable pitch mechanism.

4.2 Design Loads

4.2.1 General

1 In the design of the propeller, propulsion shafting system and power transmission system, the following are to be taken into account.

(1) Maximum backward blade force
(2) Maximum forward blade force
(3) Maximum blade spindle torque
(4) Maximum propeller ice torque
(5) Maximum propeller ice thrust
(6) Design torque on propulsion shafting system
(7) Maximum thrust on propulsion shafting system

(8) Blade failure load

2 The loads specified in **-1** are to comply with the following:

(1) The ice loads cover open and ducted type propellers situated at the stern of a ship having controllable pitch or fixed pitch blades. Ice loads on bow propellers and pulling type propellers are to receive special consideration.

(2) The given loads in this chapter are expected, single occurrence, maximum values for the whole ships service life for normal operation conditions. The loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice.

(3) The loads apply also for azimuthing (geared and podded) thrusters considering loads due to propeller ice interaction. However, ice loads due to ice impacts on the body of azimuthing thrusters are not covered by this chapter.

(4) The loads are total loads (unless otherwise stated) during interaction and are to be applied separately (unless otherwise stated) and are intended for component strength calculations only.

4.2.2 Maximum Backward Blade Force

1 The maximum backward blade force which bends a propeller blade backwards when a propeller mills an ice block while rotating ahead is to be given by the following formulae:

(1) For open propellers:

when $D < D_{\text{limit}}$

$$F_b = 27 S_{ice} \left(\frac{n}{60} D \right)^{0.7} \left(\frac{EAR}{Z} \right)^{0.3} D^2 \quad (kN)$$

when $D \geq D_{\text{limit}}$

$$F_b = 23 S_{ice} (H_{ice})^{1.4} \left(\frac{n}{60} D \right)^{0.7} \left(\frac{EAR}{Z} \right)^{0.3} D \quad (kN)$$

where $D_{\text{limit}} = 0.85 (H_{ice})^{1.4} \quad (m)$

(2) For ducted propellers :

when $D < \mathrm{D}_{\text{limit}}$

$$F_b = 9.5 S_{ice} \left(\frac{n}{60} D \right)^{0.7} \left(\frac{EAR}{Z} \right)^{0.3} D^2 \quad (kN)$$

when $D \geq \mathrm{D}_{\text{limit}}$

$$F_b = 66 S_{ice} (H_{ice})^{1.4} \left(\frac{n}{60} D \right)^{0.7} \left(\frac{EAR}{Z} \right)^{0.3} D^{0.6} \quad (kN)$$

where $D_{\text{limit}} = 4 H_{ice} \quad (m)$

H_{ice} : Ice thickness (m) for machinery strength design specified in **Table 4.2.2-1**.

S_{ice} : Ice strength index for blade ice force specified in **Table 4.2.2-1**.

D : Propeller diameter (m)

EAR : Expanded blade area ratio

n : Nominal rotational propeller speed (*rpm*) at maximum continuous revolutions in free running condition for controllable pitch propellers and 85% of the nominal rotational propeller speed at maximum continuous revolutions in free running condition for fixed pitch propellers (regardless of driving engine type)

2 The maximum backward blade force F_b is to be applied as a uniform pressure distribution to an area of the blade for the following load cases.

(1) For open propellers:

(a) F_b specified in **-1(1)** is applied to an area from 0.6R to the tip and from the blade leading edge to a value of 0.2 chord length. (See load case 1 in **Table 4.2.2-2**)

(b) A load equal to 50% of F_b specified in **-1(1)** is applied on the propeller tip area outside of 0.9R. (See load case 2 in **Table 4.2.2-2**)

(c) For reversible propellers, a load equal to 60% of F_b specified in **-1(1)** is applied to an area from 0.6R to the tip and from the blade trailing edge to a value of 0.2 chord length. (See load case 5 in **Table 4.2.2-2**)

(2) For ducted propellers:

(a) F_b specified in **-1(2)** is applied to an area from 0.6R to the tip and from the blade leading edge to a value of 0.2 chord length. (See load case 1 in **Table 4.2.2-3**)

(b) For reversible propellers, a load equal to 60 % of the F_b specified in **-1(2)** is applied to an area from 0.6R to the tip and from the blade trailing edge to a value of 0.2 chord length. (See load case 5 in **Table 4.2.2-3**)

Table 4.2.2-1 Values of H_{ice} and S_{ice}

Polar class	H_{ice}	S_{ice}
*PC*1	4.0	1.2
*PC*2	3.5	1.1
*PC*3	3.0	1.1
*PC*4	2.5	1.1
*PC*5	2.0	1.1
*PC*6	1.75	1
*PC*7	1.5	1

4.2.3 Maximum Forward Blade Force

1 Maximum forward blade force which bends a propeller blade forwards when a propeller interacts with an ice block while rotating ahead is to be given by the following formulae:

(1) For open propellers:

when $D < D_{\mathrm{limit}}$

$$F_f = 250\left(\frac{EAR}{Z}\right)D^2 \quad (kN)$$

when $D \geq D_{\mathrm{limit}}$

$$F_f = 500H_{ice}\left(\frac{EAR}{Z}\right)\left(\frac{1}{1-\frac{d}{D}}\right)D \quad (kN)$$

where $D_{limit} = \frac{2}{\left(1-\frac{d}{D}\right)} H_{ice} \quad (m)$

(2) For ducted propellers:

when $D \leq D_{limit}$

$$F_f = 250\left(\frac{EAR}{Z}\right)D^2 \quad (kN)$$

when $D > D_{limit}$

$$F_f = 500 H_{ice}\left(\frac{EAR}{Z}\right)\left(\frac{1}{1-\frac{d}{D}}\right)D \quad (kN)$$

where $D_{limit} = \frac{2}{\left(1-\frac{d}{D}\right)} H_{ice} \quad (m)$

H_{ice}, D and EAR : As specified in **4.2.2-1**.

d : Propeller boss diameter (m)

Z : Number of propeller blades

2 The maximum forward blade force F_f is to be applied as a uniform pressure distribution to an area of the blade for the following load cases.

(1) For open propellers:

(a) F_f specified in **-1(1)** is applied to an area from 0.6R to the tip and from the blade leading edge to a value of 0.2 chord length. (See load case 3 in **Table 4.2.2-2**)

(b) A load equal to 50% of F_f specified in **-1(1)** is applied on the propeller tip area outside of 0.9R. (See load case 4 in **Table 4.2.2-2**)

(c) For reversible propellers, a load equal to 60% of F_f specified in **-1(1)** is applied to an area from 0.6R to the tip and from the blade trailing edge to a value of 0.2 chord length. (See load case 5 in **Table 4.2.2-2**)

(2) For ducted propellers:

(a) F_f specified in **-1(2)** is applied to an area from 0.6R to the tip and from the blade leading edge to a value of 0.5 chord length. (See load case 3 in **Table 4.2.2-3**)

(b) For reversible propellers, a load equal to 60% of F_f specified in **-1(2)** is applied to an area from 0.6R to the tip and from the blade trailing edge to a value of 0.2 chord length. (See load case 5 in **Table 4.2.2-3**)

Table 4.2.2-2 Load Cases for Open Propeller

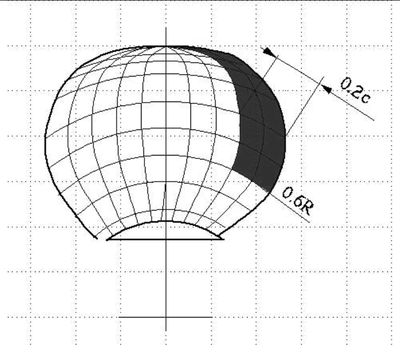
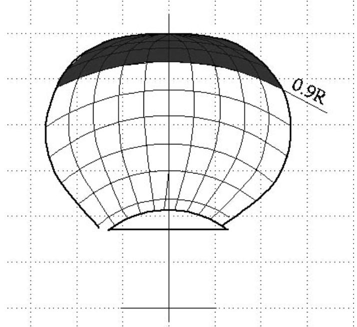
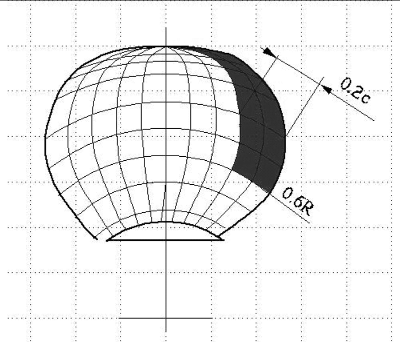
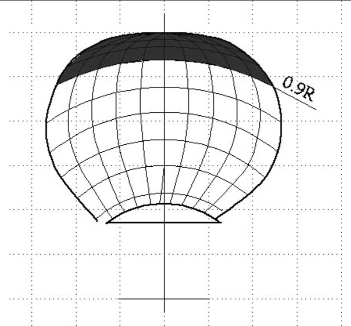
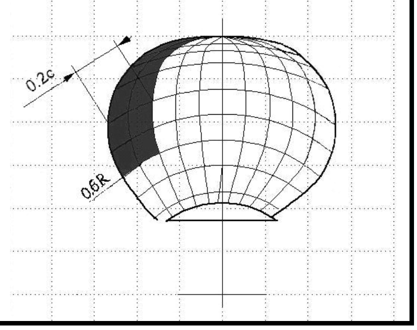
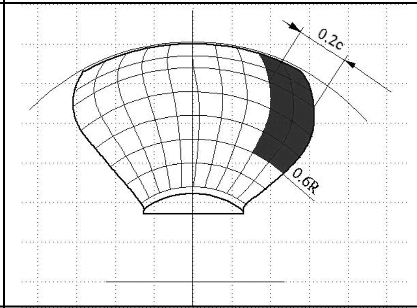
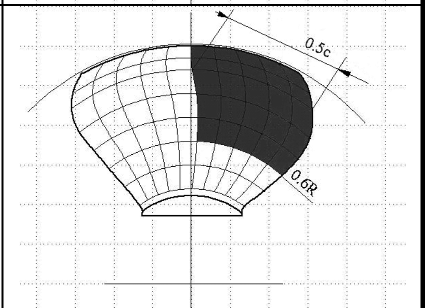
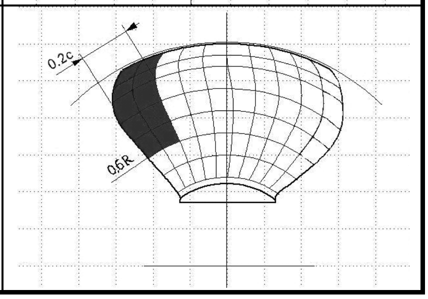
	Force	Loaded area	Right handed propeller blade seen from back
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0.6R to the tip and from the leading edge to 0.2 times the chord length	
Load case 2	50% of F_b	Uniform pressure applied on the back of the blade (suction side) on the propeller tip area outside of 0.9R radius	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6R to the tip and from the leading edge to 0.2 times the chord length	
Load case 4	50% of F_f	Uniform pressure applied on the propeller face (pressure side) on the propeller tip area outside of 0.9R radius	
Load case 5	60% of F_f or F_b which one is greater	Uniform pressure applied on propeller face (pressure side) to an area from 0.6R to the tip and from the trailing edge to 0.2 times the chord length	

Table 4.2.2-3 Load Cases for Ducted Propeller

	Force	Loaded area	Right handed propeller blade seen from back
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0.6*R* to the tip and from the leading edge to 0.2 times the chord length	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from the leading edge to 0.5 times the chord length	
Load case 5	60% of F_f or F_b which one is greater	Uniform pressure applied on propeller face (pressure side) to an area from 0.6*R* to the tip and from the trailing edge to 0.2 times the chord length	

4.2.4 Maximum Blade Spindle Torque

Spindle torque around the spindle axis of the blade fitting is to be calculated both for the load case specified in **4.2.2** and **4.2.3** for F_b and F_f. Where these spindle torque values are less than the default value obtained from the following formula, the default value is to be used.

$$Q_{s\max} = 0.25FC_{0.7} \quad (kNm)$$

where:

$C_{0.7}$: Length (m) of the blade chord at 0.7R radius

F : Either F_b determined in **4.2.2-1** or F_f determined in **4.2.3-1,** whichever has the greater absolute value.

4.2.5 Maximum Propeller Ice Torque

Maximum propeller ice torque applied to the propeller is to be given by the following formulae:

(1) For open propellers:

when $D < \mathrm{D}_{\mathrm{limit}}$

$$Q_{\max} = 105S_{qice}\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}\left(\frac{t_{0.7}}{D}\right)^{0.6}\left(\frac{n}{60}D\right)^{0.17}D^3 \quad (kNm)$$

when $D \geq D_{limit}$

$$Q_{max} = 202 S_{qice} (H_{ice})^{1.1} \left(1 - \frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16} \left(\frac{t_{0.7}}{D}\right)^{0.6} \left(\frac{n}{60} D\right)^{0.17} D^{1.9} \quad (kNm)$$

where $D_{limit} = 1.81 H_{ice} \quad (m)$

(2) For ducted propellers:

when $D \leq D_{limit}$

$$Q_{max} = 74 S_{qice} \left(1 - \frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16} \left(\frac{t_{0.7}}{D}\right)^{0.6} \left(\frac{n}{60} D\right)^{0.17} D^{3} \quad (kNm)$$

when $D > D_{limit}$

$$Q_{max} = 141 S_{qice} (H_{ice})^{1.1} \left(1 - \frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16} \left(\frac{t_{0.7}}{D}\right)^{0.6} \left(\frac{n}{60} D\right)^{0.17} D^{1.9} \quad (kNm)$$

where: $D_{limit} = 1.8 H_{ice} \quad (m)$

H_{ice}, D and d : As specified in **4.2.2-1** and **4.2.3-1**

S_{qice} : Ice strength index for blade ice torque specified in **Table 4.2.5-1**

$P_{0.7}$: Propeller pitch (m) at $0.7R$

For controllable pitch propellers, $P_{0.7}$ is to correspond to maximum continuous revolutions in bollard condition. If not known, $P_{0.7}$ is to be taken as 0.7 $P_{0.7n}$, where $P_{0.7n}$ is propeller pitch at maximum continuous revolutions in free running condition.

$t_{0.7}$: Maximum thickness (mm) at $0.7R$

n : Rotational propeller speed (rpm) at bollard condition

If not known, n is to be taken as specified in **Table 4.2.5-2**.

Table 4.2.5-1 Value of S_{qice}

Polar class	S_{qice}
*PC*1	1.15
*PC*2	1.15
*PC*3	1.15
*PC*4	1.15
*PC*5	1.15
*PC*6	1
*PC*7	1

Table 4.2.5-2 Rotational Propeller Speed

Propeller type	n
Controllable pitch propellers	n_n
Fixed pitch propellers driven by turbine or electric motor	n_n
Fixed pitch propellers driven by diesel engine	$0.85n_n$

n_n : Nominal rotational speed (rpm) at maximum continuous revolutions in free running condition

4.2.6 Maximum Propeller Ice Thrust

Maximum propeller ice torque applied to the shaft is to be given by the following formulae:

(1) Maximum forward propeller ice thrust

$T_f = 1.1\ F_f\ (kN)$

(2) Maximum backward propeller ice thrust

$T_b = 1.1\ F_b\ (kN)$

where

F_f : As determined in **4.2.3-1**

F_b : As determined in **4.2.2-1**

4.2.7 Design Torque on Propulsion Shafting System

1 The propeller ice excitation torque for shaft line dynamic analysis is to comply with the following requirements.

(1) The excitation torque is to be described by a sequence of blade impacts which are of half sine shape and occur at the blade. The total ice torque is to be obtained by summing the torques of single ice blade ice impacts taking into account the phase shift. Single ice blade impact is to be given by the following formula. (See **Fig. 4.2.7-1**)

(a) when $\varphi = 0\ to\ \alpha_i\ \ (deg)$

$Q(\varphi) = C_q Q_{\max} \sin(\varphi(180/\alpha_i))$

(b) when $\varphi = \alpha_i$ to $360\ \ (deg)$

$Q(\varphi) = 0$

where

$Q_{\max}$: As specified in **4.2.5**

C_q and α_i : As specified in **Table 4.2.7-1**

(2) The number of propeller revolutions and the number of impacts during the milling sequence are to be given by the following formulae. For bow propellers, the number of propeller revolutions and the number of impacts during the milling sequence are subject to special consideration.

(a) The number of propeller revolutions:

$N_Q = 2H_{ice}$

(b) The number of impacts:

ZN_Q

Where

H_{ice} : As specified in **Table 4.2.2-1**

Z : Number of propeller blades

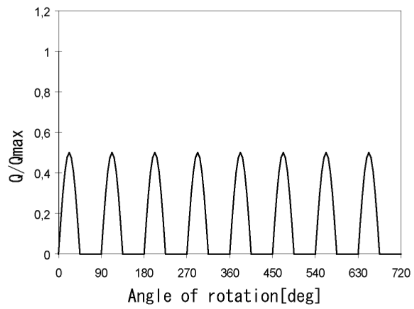
2 The response torque at any shaft component is to be analyzed considering excitation torque at the propeller specified in **-1**, actual engine torque and mass elastic system.

3 The design torque of the shaft component is to be determined by means of torsional vibration analysis of the propulsion line. Calculation is to be carried out for all excitation cases specified in **Table 4.2.7-1** and the response is to be applied on top of the mean hydrodynamic torque in bollard condition at the considered propeller rotational speed.

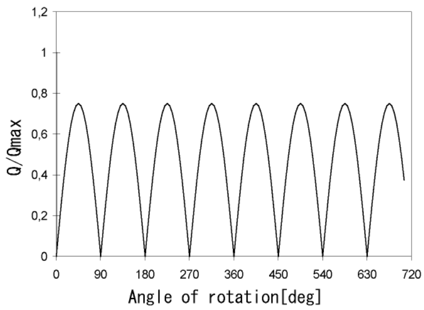
Table 4.2.7-1 Values of C_q and α_i

Torque excitation	Propeller-ice interaction	C_q	α_i
Case 1	Single ice block	0.5	45
Case 2	Single ice block	0.75	90
Case 3	Single ice block	1.0	135
Case 4	Two ice blocks with 45 degree phase in rotation angle	0.5	45

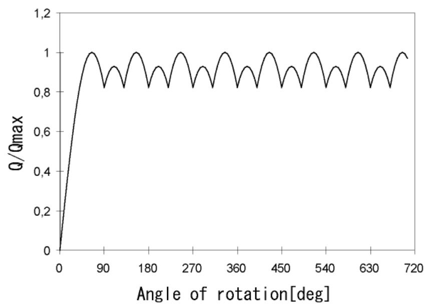
Fig.4.2.7-1 Example of the Shape of the Propeller Ice Torque Excitation (four bladed propeller)



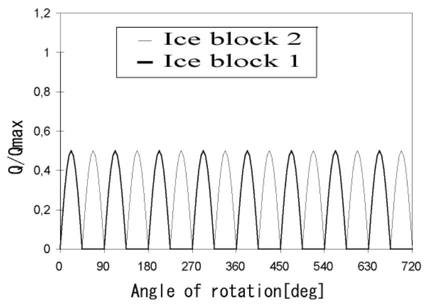
(a) Case 1
Single blade impact (αi = 45[deg])



(b) Case 2
Single blade impact (αi = 90[deg])



(c) Case 3
Single blade impact (αi = 135[deg])



(d) Case 4
Double blade impact (αi = 45[deg])

4.2.8 Maximum Thrust on Propulsion Shafting System

Maximum response thrust along the propeller shaft line is to be given by the following formulae:

(1) Maximum shaft thrust forwards:

$T_r = T_n + \alpha T_f \quad (kN)$

(2) Maximum shaft thrust backwards:

$T_r = \beta T_b \quad (kN)$

where:

T_n : Propeller bollard thrust (kN) If not known, T_n is to be taken as specified in **Table 4.2.8-1**

T_f and T_b : Maximum propeller ice thrust (kN) determined in **4.2.6**

α and β : Thrust magnification factors due to axial vibration given by the following Alternatively the factors may be calculated by dynamic analysis.

α = 2.2
β = 1.5

Table 4.2.8-1 Value of T_n

Propeller type	T_n
Controllable pitch propellers (open)	$1.25T$
Controllable pitch propellers (ducted)	$1.1T$
Fixed pitch propellers driven by turbine or electric motor	T
Fixed pitch propellers driven by diesel engine (open)	$0.85T$
Fixed pitch propellers driven by diesel engine (ducted)	$0.75T$

T : Nominal propeller thrust (kN) at maximum continuous revolutions in free running open water conditions

4.2.9 Blade Failure Load

1 The blade failure load is to be given by the following formula:

$$\frac{0.3ct^2\sigma_{ref}}{0.8D-2r}\times 10^3 \quad (kN)$$

where

$\sigma_{ref} = 0.6\sigma_{0.2} + 0.4\sigma_u \quad (MPa)$

σ_u : Tensile stress of blade material (MPa)

$\sigma_{0.2}$: Yield stress or 0.2% proof strength of blade material (MPa)

c, t and r : The actual chord length, thickness and radius of the cylindrical root section of the blade at the weakest section outside root fillet (typically will be at the termination of the fillet into the blade profile), respectively

2 The force is to be acting at $0.8R$ in the weakest direction of the blade and at a spindle arm of 2/3 the distance of the axis of blade rotation of the leading and trailing edge whichever is greater.

4.3 Design of Propulsion Shafting System

4.3.1 General

In the design of the propulsion shafting system, the following are to be taken into account.

(1) The propulsion shafting system is to have sufficient strength for the loads specified in **4.2**.

(2) The blade failure load given in **4.2.9** is not to damage the propulsion shafting system other than the propeller blade itself.

(3) The propulsion shafting system is to have sufficient fatigue strength.

4.3.2 Azimuthing Main Propulsors

In the design of the azimuthing main propulsors, the following are to be taken into account in addition to the requirements specified in **4.3.1**.

(1) Loading cases which are extraordinary for propulsion units are to be taken into account. Estimation of the loading cases is to reflect the operational realities of the ship and the thrusters.

(2) The steering mechanism, the fitting of the unit and body of the thruster are to be designed to

withstand the loss of a blade without damage.

(3) The plastic bending of a blade is to be considered in the propeller blade position, which causes the maximum load on the studied component.

(4) Azimuth thrusters are to be designed for estimated loads specified in **3.5.10**.

4.3.3 Propeller Blade

1 Blade stresses are to be calculated using backward and forward loads given in **4.2.2** and **4.2.3**. The stresses are to be calculated with recognized and well documented FE-analysis or acceptable alternative methods. The backward load and the forward load are to be applied separately.

2 The calculated blade stress σ_{calc} for maximum ice load is to comply with the following.

$$\sigma_{calc} < \frac{\sigma_{ref}}{S}$$

Where

$S = 1.5$

σ_{ref} : $0.7\sigma_u$ or $0.6\sigma_{0.2} + 0.4\sigma_u$, ($MPa$), whichever is less

σ_u and $\sigma_{0.2}$:the stresses (MPa) as defined in **4.2.9-1**

4.3.4 Blade Edge Thickness

1 The blade edge thickness and tip thickness are to be greater than the values obtained by the following formula. The requirement for edge thickness is to be applied for the leading edge and in case of reversible rotation open propellers, also the trailing edge.

$$S\ x\ S_{ice}\sqrt{\frac{3\ p_{ice}}{\sigma_{ref}}} \quad (mm)$$

x : Distance from the blade edge measured along the cylindrical sections from the edge and is to be 2.5% of chord length

However not to be taken greater than 45mm. In the tip area (above 0.975R) the value is to be taken as 2.5% of 0.975R section length and is to be measured perpendicularly to the edge, however not to be taken greater than 45mm.

S : Safety factor given below:

S = 2.5 (for trailing edge)

= 3.5 (for leading edge)

= 5.0 (for tip)

S_{ice} : Value specified in **Table 4.2.2-1**

p_{ice} : Ice pressure =16 (MPa)

σ_{ref} : Value specified in **4.2.9-1**

2 Tip thickness is to be the maximum measured thickness in the tip area above 0.975R radius. The edge thickness in the area between the position of maximum tip thickness and edge thickness at 0.975R radius is to be interpolated between edge and tip thickness values and smoothly distributed.

4.3.5 Controllable Pitch Propeller and Built-up Propeller

The strengths of the pitch control gear of the controllable pitch propeller and the blade bolts of the controllable pitch propeller, and the built-up propeller are to be evaluated in consideration of the stress generated when the loads in **4.2.4** and **4.2.9** act on the propeller blade. The safety factor is to be deemed appropriate by the Society.

4.3.6 Shafting

1 For evaluating the strength of shafting systems, twisting moment, bending moment and thrust which may be initiated by ice interaction with the propeller are to be taken into account. Safety factors for yielding and fatigue are to be deemed appropriate by the Society.

2 The strengths of the thrust shaft, intermediate shaft, propeller shaft and stern tube shaft are to be evaluated by calculating the maximum equivalent stresses (von Mises) on the shafts.

3 The strengths of the propeller shaft and connection parts of the propeller are also to be evaluated in consideration of the stress caused by the load given in **4.2.9** acting on the propeller blade.

4.4 Prime Movers

4.4.1 Main Engine

The main engine is to be capable of being started and running the propeller with the controllable pitch in full pitch.

4.4.2 Starting Arrangement for Emergency Generating Sets

Provisions are to be made for heating arrangements to ensure that cold emergency power units are able to start at an ambient temperature applicable to the polar class ship.

4.5 Fastening Loading Accelerations

4.5.1 Machinery Fastening Loading Accelerations

Supports of essential equipment and main propulsion machinery are to be suitable for the accelerations given by the following formulae. Accelerations are to be considered as acting independently.

(1) Maximum longitudinal impact acceleration at any point along the hull girder:

$$a_l = \left(\frac{F_{IB}}{\Delta}\right)\left\{\left[1.1\tan(\gamma+\phi)\right]+\left[\frac{7H}{L}\right]\right\} \quad (m/s^2)$$

(2) Combined vertical impact acceleration at any point along the hull girder:

$$a_v = 2.5\left(\frac{F_{IB}}{\Delta}\right)F_X \quad (m/s^2)$$

Where

F_X = 1.3 (at fore perpendicular)

=0.2 (at midships)

=0.4 (at aft perpendicular)

=1.3 (at aft perpendicular for vessels conducting ice breaking astern)

Intermediate values to be interpolated linearly.

(3) Combined transverse impact acceleration at any point along hull girder:

$$a_t = 3F_i\frac{F_X}{\Delta} \quad (m/s^2)$$

Where

F_X = 1.5 (at fore perpendicular)

=0.25 (at midships)
=0.5 (at aft perpendicular)
=1.5 (at aft perpendicular for vessels conducting ice breaking astern)

Intermediate values to be interpolated linearly.

where

- ϕ : Maximum friction angle (*deg*) between steel and ice, normally taken as 10 degrees
- γ : Bow stem angle (*deg*) at the *UIWL*
- Δ: Displacement at the *UIWL* (*t*)
- L: Length of ship (*m*) defined in **2.1.2, Part A of the Rules**
- H: Distance (*m*) from the *UIWL* to the point being considered
- F_{IB}: Vertical impact force (*kN*) defined in **3.6.2**
- F_i: Force (*kN*) defined in **3.4.2-4**

4.6 Auxiliary Systems and Piping Systems

4.6.1 Auxiliary Systems

1 Machinery is to be protected from the harmful effects of ingestion or accumulation of ice or snow. Where continuous operation is necessary, means are to be provided to purge the system of accumulated ice or snow.

2 Means are to be provided to prevent tanks containing liquids to be damaged by freezing.

3 Vent pipes, intake and discharge pipes and associated systems are to be designed to prevent blockage due to freezing or ice and snow accumulation.

4.6.2 Sea Inlets and Cooling Water Systems

1 Cooling water systems for machinery that are essential for the propulsion and safety of the vessel, including sea chests inlets are to be designed for the environmental conditions applicable to the polar class.

2 The construction of the sea chests is to comply with the following requirements:

(1) At least two sea chests are to be arranged as ice boxes for *PC*1, *PC*2, *PC*3, *PC*4 and *PC*5 polar class ships.

(2) At least one ice box is to be arranged preferably near the centerline for *PC*6 and *PC*7 polar class ships.

(3) The calculated volume for each of the ice boxes is to be at least $1m^3$ for every 750*kW* of the engine output of the ship including the output of auxiliary engines.

(4) Ice boxes are to be designed for an effective separation of ice and venting of air. (See example of **Fig. 4.6.2-1**)

3 Sea inlet valves are to be secured directly to the ice boxes or the sea bays. The valve is to be a full bore type.

4 Ice boxes and sea bays are to have vent pipes and to have shut off valves connected direct to the shell.

5 Means are to be provided to prevent freezing of sea bays, ice boxes, ship side valves and fittings above the *LIWL*.

6 Efficient means are to be provided to re-circulate cooling seawater to the ice box. Total sectional area of the circulating pipes is not to be less than the area of the cooling water discharge pipe.

7 Detachable gratings or manholes are to be provided for ice boxes. Manholes are to be located above the *UIWL*.

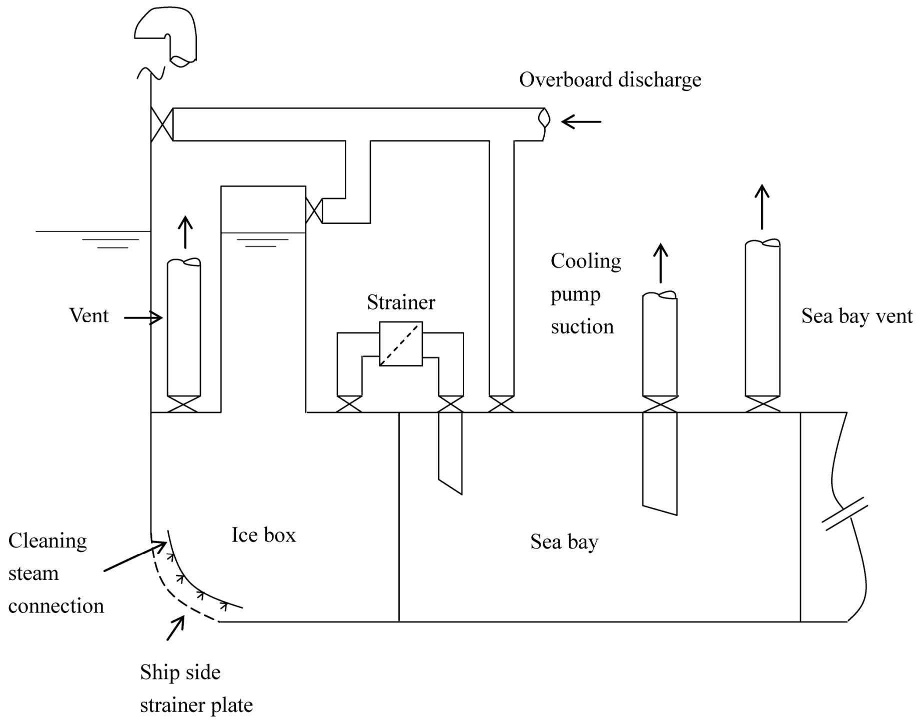
8 Openings in ship sides for ice boxes are to be fitted with gratings, or holes or slots in shell plates. The net area through these openings is to be not less than 5 times the area of the inlet pipe. The diameter of holes and width of the slot in shell plating is to be not less than 20*mm*.

9 Gratings of the ice boxes are to be provided with a means of cleaning with a low pressure steam connection. Cleaning pipes are to be provided with screw-down type non return valves.

4.6.3 Ballast Tanks

Efficient means are to be provided to prevent freezing in fore and after peak tanks and wing tanks located above the *LIWL* and where otherwise found necessary.

Fig.4.6.2-1 Example of the Sea Inlets and Cooling Water Systems



4.7 Ventilation System

4.7.1 Ventilation System

1 The air intakes for machinery and accommodation ventilation are to be located on both sides of the ship.

2 The air intakes specified in **-1** are to be provided with a means of heating.

3 The temperature of inlet air provided to machinery from the air intakes is to be suitable for the safe operation of the machinery.

4.8 Rudders and Steering Arrangements

4.8.1 Rudders and Steering Arrangements

1 An ice knife is to be fitted to protect the rudder against ice pressure. The ice knife is to be extended below the *LIWL*.

2 Rudder stoppers to protect the steering arrangements are to be effective.

3 The components of the steering gear are to be dimensioned to stand the yield torque of the rudder stock.

4 Relief valves for hydraulic pressure of the steering arrangements are to be effective.

EFFECTIVE DATE AND APPLICATION

1. The effective date of the amendments is 1 January 2017.

2. Notwithstanding the amendments to the Rules, the current requirements apply to ships the keels of which were laid or which were at *a similar stage of construction* before the effective date except for in cases where the amendments are to be retroactively applied.
(Note) The term "*a similar stage of construction*" means the stage at which the construction identifiable with a specific ship begins and the assembly of that ship has commenced comprising at least 50 *tonnes* or 1% of the estimated mass of all structural material, whichever is the less.

GUIDANCE FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

Part I Polar Class Ships and Ice Class Ships

GUIDANCE

2016 AMENDMENT NO.2

Notice No.83 27th December 2016
Resolved by Technical Committee on 27th July 2016

Notice No.83 27th December 2016
AMENDMENT TO THE GUIDANCE FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

"Guidance for the survey and construction of steel ships" has been partly amended as follows:

Part I POLAR CLASS SHIPS AND ICE CLASS SHIPS

I1 has been amended as follows.

I1 GENERAL APPLICATION

I1.1 General

I1.1.1 Application

In addition to the requirements of **Part I of the Rules**, additional requirements deemed appropriate by the Society may be applied to any icebreaker 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.

I1.1.2 Documentation

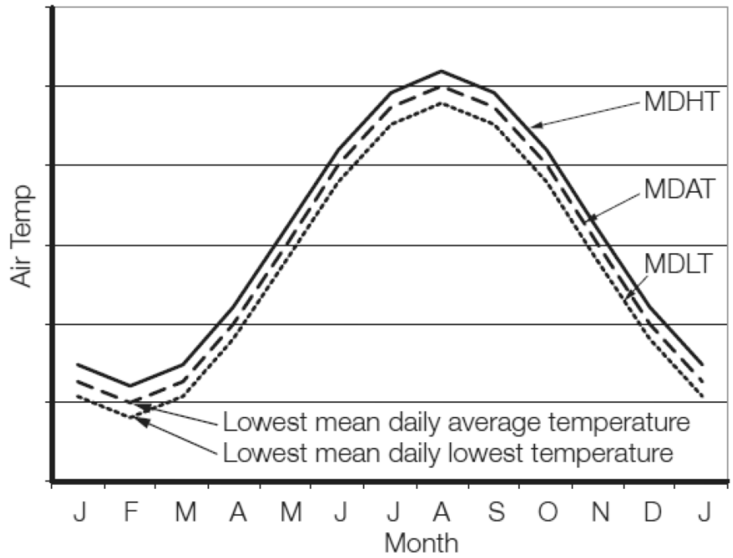
1 With respect to the provisions of **1.1.2-1 and 1.1.2-2, Part I of the Rules**, draughts at fore, midship and aft corresponding to the upper ice waterline and the lower ice waterline are to be registered in the Classification Register as descriptive notes for a polar class ship.
2 With respect to the provisions of **1.1.2-1 and 1.1.2-3, Part I of the Rules**, draughts at fore, midship and aft corresponding to the upper ice waterline and the lower ice waterline are to be registered in the Classification Register as descriptive notes for an ice class ship.

I1.2 Definitions

I1.2.1 Terms

"Mean Daily Low Temperature" (*MDLT*) as specified in **1.2.1(19), Part I of the Rules** is to refer to **Fig. I1.2.1-1**.

Fig. I1.2.1-1 Mean Daily Low Temperature



(Notes)

1. Terms used in the figure above are as follows:
   MDHT – Mean Daily High Temperature
   MDAT – Mean Daily Average Temperature
   MDLT – Mean Daily Low Temperature
2. *MDLT* is determined as follows:
   (1) Determine the daily low temperature for each day for a 10 year period.
   (2) Determine the average of the values over the 10 year period for each day.
   (3) Plot the daily averages over the year.
   (4) Take the lowest of the averages for the season of operation.

I1.2.2 Polar Classes

1 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 classification certificate. Compliance of the hull or machinery with the requirements of a higher polar class is also to be indicated in the Classification Register.

2 The term concerning ice conditions in the **Table I1.1, Part I of the Rules** means as follows.

(1) Thick first-year ice:
Thick first-year ice is a first-year ice of about 120-250*cm* in thickness and has a high strength. Only when strong pressure is received, this ice forms an ice hill of about 150-250cm in height.

(2) Medium first-year ice:
Medium first-year ice is a first-year ice of about 70-120*cm* in thickness. In the ice water regions other than Polar Regions, this kind of one-year ice is a limit stage of growth, and it is formed in the severest winter. In this kind of ice, there might be a lot of intersecting ice hills, and the height of the ice hill reaches 170*cm*. This kind of ice melts in summer and disappears almost completely.

(3) Thin first-year ice:
Thin first-year ice is a first-year ice of about 70-120*cm* in thickness. In this kind of ice, there might be straight ice hills, and the height of the ice hill reaches 30-75*cm* on the average. Thin first-year ice may be subdivided to the thin fires-year in the first stage (30-50*cm* in thickness) and second stages (50-70*cm* in thickness).

I1.2.~~3~~<u>2</u> Ice Class <u>Ships</u>

1 The correspondence of ice classes specified in **1.2.~~3~~<u>2</u>, Part I of the Rules** with those in the *Finnish-Swedish Ice Class Rules 2010* is as given in **Table I1.2.~~3~~<u>2</u>-1**.

2 The correspondence of ice classes specified in **1.2.~~3~~<u>2</u>, Part I of the Rules** with those in the *Arctic Shipping Pollution Prevention Regulations* is as given in **Table I1.2.~~3~~<u>2</u>-2**.

Table I1.2.~~3~~<u>2</u>-1 The Correspondence of Ice Classes between the Rules and the *Finnish-Swedish Ice Class Rules 2010*

Ice Class of the *Finnish-Swedish Ice Class Rules 2010*	Ice Class of the Rules
I*A Super*	I*A Super*
I*A*	I*A*
I*B*	I*B*
I*C*	I*C*
II	I*D* No ice class

Table I1.2.~~3~~<u>2</u>-2 The Correspondence of Ice Classes between the Rules and the Arctic Shipping Pollution Prevention Regulations

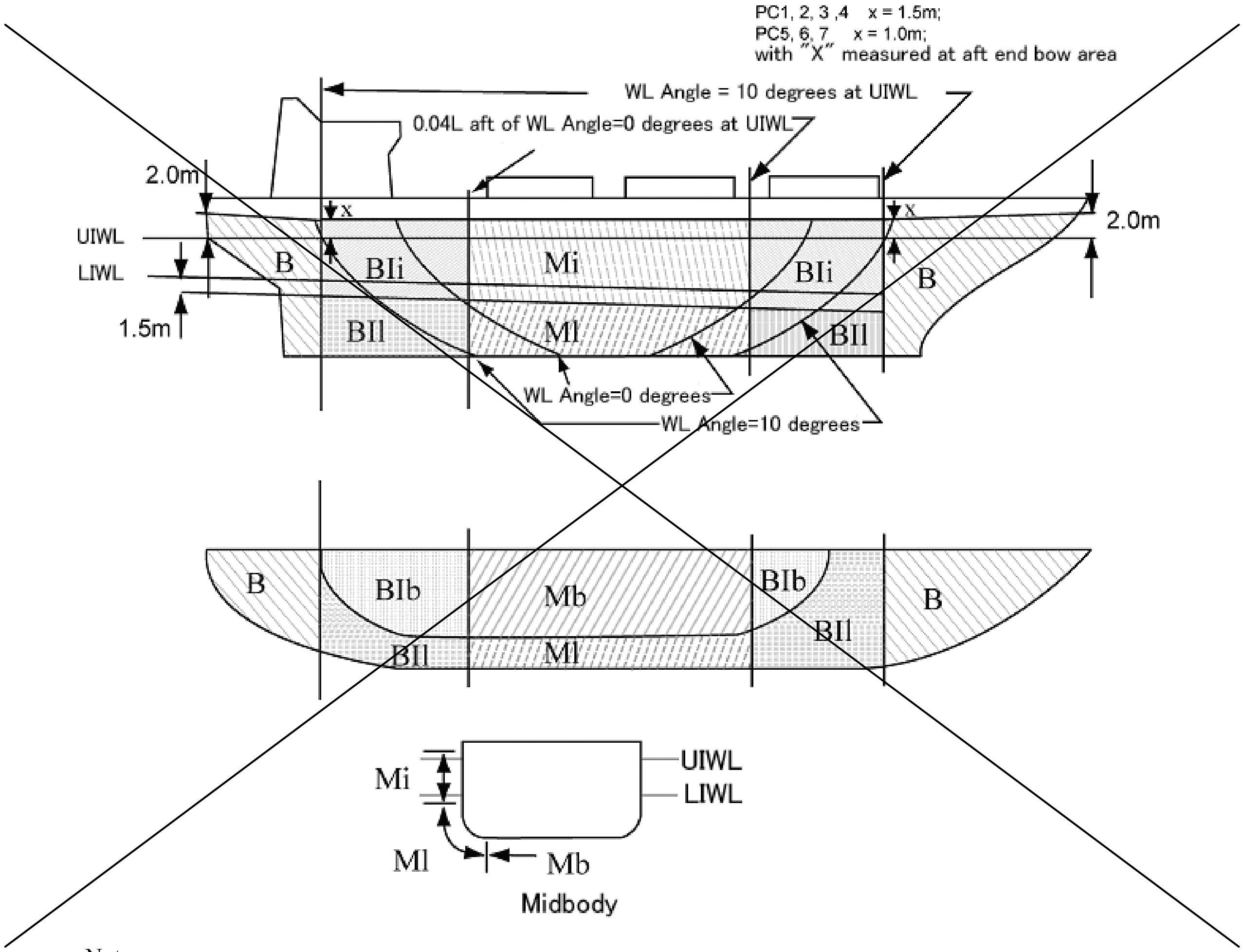
Ice Class of the *Arctic shipping Pollution Prevention Regulations*	Ice Class of the Rules
Type A	I*A Super*
Type B	I*A*
Type C	I*B*
Type D	I*C* I*D*
Type E	No ice class

~~**I1.2.5 Hull Areas**~~

~~**1** If a polar class ship that installed special icebreaking stern structure and propulsion unit intended to operate astern in ice regions corresponds to the proviso in **1.2.5-1, Part I of the Rules**, the hull area of the ship is to refer to **Fig. I1.2.5-1**.~~

~~**2**~~<u>**3**</u> For the application of **Chapter ~~5~~<u>8</u>, Part I of the Rules**, fore and aft perpendiculars are to be determined in the same manner as those of length L_f. The upper ice waterline specified in **1.2.~~4~~-1<u>(23)</u>, Part I of the Rules** may be, in general, a broken line having different draughts fore and aft.

~~Fig. I1.2.5-1 Hull Area~~



~~Note:~~

~~Symbols in the figure are as follows:~~

~~B: Bow Area~~

~~BIi: Bow Intermediate Icebelt Area~~

~~BIl: Bow Intermediate Lower Area~~

~~Bib: Bow Intermediate Bottom Area~~

~~Mi: Midbody Icebelt Area~~

~~Ml: Midbody Lower Area~~

~~Mb: Midbody Bottom~~

I1.3 Performance Standards (*Polar Code*, Part I-B, 2.3)

I1.3.1 General

For "performance standards" specified in **1.3.1**, **Part I of the Rules**, a system previously accepted based on manufacturer certifications, classification society certifications and/or satisfactory service of existing systems may be acceptable for installation on new and existing ships if no performance or testing standards are accepted by the *IMO*.

I1.5 Operational Assessment (*Polar Code*, Part I-B, 2.1, 2.2)

I1.5.1 Operational Assessment

1 "Operational limitations" specified in **1.5.1**, **Part I of the Rules** is to be determined using systems, tools or analysis that evaluate the risks posed by the anticipated ice conditions to the ship, taking into account factors such as its ice class, seasonal changing of ice strength, icebreaker support, ice type, thickness and concentration. The ship's structural capacity to resist ice load and the ship's planned operations are to be considered. The limitations are to be incorporated into an ice operational decision support system.

2 "Operational limitations" specified in **1.5.1**, **Part I of the Rules** is to be determined using an appropriate methodology, such methodologies exist, have been in use for a number of years and have been validated with service experience. Existing methodologies and other systems may be acceptable to the Society.

3 For the purpose of **1.5.1**, **Part I of the Rules**, operation in ice is to take into account the following:

(1) Any operational limitations of the ship

(2) Extended information on the ice operational methodology contained in the *PWOM*

(3) The condition of the ship and ship's systems

(4) Historical weather/ice data

(5) Weather/ice forecasts for the intended area of operation

(6) Current conditions including visual ice observations, sea state, visibility

(7) The judgment of qualified personnel

4 The "Operational Assessment" specified in **1.5.1**, **Part I of the Rules** is to be carried out by following steps:

(1) identify relevant hazards specified in **1.4.1**, **Part I of the Rules** and other hazards based on a review of the intended operations;

(2) develop a model, which is to refer to Appendix 3 of *MSC-MEPC*.2/*Circ*.12 "*Revised Guidelines for Formal Safety Assessment (FSA) for use in the IMO Rule-Making Process*" and standard *IEC*/*ISO* 31010 "*Risk management – Risk assessment techniques*", to analyse risks considering:
   - (a) development of accident scenarios;
   - (b) probability of events in each accident scenario; and
   - (c) consequence of end states in each scenario;

(3) assess risks and determine acceptability:
   - (a) estimate risk levels in accordance with the selected modelling approach; and
   - (b) assess whether risk levels are acceptable; and

(4) in the event that risk levels determined in steps **(1)** to **(3)** are considered to be too high, identify current or develop new risk control options that aim to achieve one or more of the following:
   - (a) reduce the frequency of failures through better design, procedures, training, etc.;
   - (b) mitigate the effect of failures in order to prevent accidents;
   - (c) limit the circumstances in which failures may occur; or
   - (d) mitigate consequences of accidents; and
   - (e) incorporate risk control options for design, procedures, training and limitations, as applicable.

I2 and I3 have been deleted, I5 has been renumbered to I8, and I2, I3, I6 and I7 have been added as follows.

I2 POLAR WATER OPERATIONAL MANUAL (PWOM)

I2.3 Regulations

I2.3.1 Polar Water Operational Manual (*Polar Code*, Part I-B, 3.1)

The Polar Water Operational Manual (*PWOM*) is intended to address all aspects of operations addressed by **Chapter 2**, **Part I of the Rules**. When appropriate information, procedures or plans exist elsewhere in a ship's documentation, the *PWOM* itself does not need to replicate this material, but may instead cross-reference the relevant reference document. A model table of contents is found in Appendix 2 of *IMO Res. MSC*.385(94) and *MEPC*.264(68) *"International Code for Ships Operating in Polar Waters (Polar Code)"* as amended. Not every section outlined below will be applicable to every polar ship. Many category *C* ships that undertake occasional or limit polar voyages will not need to have procedures for situations with a very low probability of occurrence. However, it may still be advisable to retain a common structure for the *PWOM* as a reminder that if assumptions change then the contents of the manual may also need to be updated. Noting an aspect as "not applicable" also indicates to the Society that this aspect has been considered and not merely omitted.

I2.3.4 Procedures for Incidents in Polar Waters (*Polar Code*, Part I-B, 3.3)

For the purpose of **2.3.4**, **Part I of the Rules**, in developing the ship's contingency plans, ships are to consider damage control measures arrangements for emergency transfer of liquids and access to tanks and spaces during salvage operations.

I2.3.6 Procedures for Icebreaker Assistance (*Polar Code*, Part I-B, 3.2)

With respect to navigation with icebreaker assistance specified in **2.3.6**, **Part I of the Rules**, the following are to be considered:

(1) while approaching the starting point of the ice convoy to follow an icebreaker/icebreakers or in the case of escorting by icebreaker of one ship to the point of meeting with the icebreaker, ships are to establish radio communication on the VHF channel 16 and act in compliance with the icebreaker's instructions;

(2) the icebreaker rendering the icebreaker assistance of ship ice convoy is to command ships in the ice convoy;

(3) position of a ship in the ice convoy is to be determined by the icebreaker rendering the assistance;

(4) ship within the ice convoy, in accordance with the instructions of the icebreaker rendering the assistance, is to establish communication with the icebreaker by VHF channel indicated by the icebreaker;

(5) the ship, while navigating in the ice convoy, is to ensure compliance with the instructions of the icebreaker;

(6) position in the ice convoy, speed and distance to a ship ahead is to be as instructed by the icebreaker;

(7) the ship is to immediately notify the icebreaker of any difficulties to maintain the position

within the ice convoy, speed and/or distance to any other ship in the ice convoy; and

(8) the ship is to immediately report to the icebreaker of any damage.

I3 SHIP STRUCTURE

I3.3 Regulations (with reference to *Polar Code*, Part I-B, 4)

I3.3.1 Materials of Structures

1 For the purpose of **3.3.1**, **Part I of the Rules**, "other standards offering an equivalent level of safety" are to comply with the following **-2** to **-7** below.

2 "Other standards offering an equivalent level of safety" are to be determined by the following.

(1) The basic approach for considering equivalency for categories *A* and *B* ships can be the same for both new and existing ships.

(2) For ice classes under category *C*, additional information on comparisons of strengthening levels is available for the guidance.

(3) The responsibility for generating the equivalency request and supporting information required is to rest with the owner/operator.

(4) Review/approval of any equivalency request is to be undertaken by the Society.

(5) If there is not full and direct compliance, then an equivalent level of risk are to be as deemed appropriate by the Society.

(6) An increase in the probability of an event can be balanced by a reduction in its consequences. Alternatively, a reduction in probability could potentially allow acceptance of more serious consequences. Using a hull area example, a local shortfall in strength level or material grade could be accepted if the internal compartment is a void space, for which local damage will not put the overall safety of the ship at risk or lead to any release of pollutants.

3 The scope of a simplified equivalency assessment (referring to paragraphs **-5(1)** to **(3)** below) is expected to be limited to materials selection, structural strength of the hull and propulsion machinery.

4 For existing ships, service experience can assist in risk assessment. As an example, for an existing ship with a record of polar ice operations a shortfall in the extent of the ice belt (hull areas) may be acceptable if there is no record of damage to the deficient area; i.e. a ship that would generally meet *PC*5 requirements but in limited areas is only *PC*7 could still be considered as a category *A*, *PC*5 ship. In all such cases, the ship's documentation is to make clear the nature and scope of any deficiencies.

5 The assessment procedure for equivalency

(1) select the target Polar Class for equivalency;

(2) compare materials used in the design with minimum requirements of the Polar Class; identify any shortfalls; and

(3) compare strength levels of hull and machinery components design with requirements of the Polar Class; quantify levels of compliance.

6 Where gaps in compliance are identified in steps **-5(1)** to **(3)** above, additional steps are to be necessary to demonstrate equivalency, as outlined below:

(1) identify any risk mitigation measures incorporated in the design of the ship;

(2) where applicable, provide documentation of service experience of existing ships, in conditions relevant to the target ice class for equivalency; and

(3) undertake an assessment, taking into account information from steps **-5(1)** to **(3)** and **-6(1)** and **(2)**, as applicable, and on the principles outlined in paragraphs **-2** to **-5** above.

7 Documentation provided with an application for equivalency is to identify each stage that has been undertaken, and sufficient supporting information to validate assessments.

I3.3.2 Hull Structures

"Other standards offering an equivalent level of safety" specified in **3.3.2(1)(b)** and **(2)(b)**, **Part I of the Rules** are to comply with the requirements in **I3.3.1**.

I6 MACHINERY INSTALLATIONS

I6.3 Regulations (Related to *Polar Code*, Part I-B, 7)

I6.3.1 General

In applying **6.3.1(3), Part I of the Rules**, the seawater supplies for machinery systems "designed to prevent ingestion of ice" are to be in accordance with *MSC*/*Circ*.504.

I6.3.2 Ships intended to Operate in Low Air Temperatures

The wording "other standards offering an equivalent level of safety" specified in **6.3.2(3)(b), Part I of the Rules** means those in accordance with **I3.3.1**.

I6.3.3 Ice Strengthened Ships

The wording "other standards offering an equivalent level of safety" specified in **(1)(b)**and **(2)(b)** of **6.3.3(3), Part I of the Rules** means those in accordance with **I3.3.1**.

I7 FIRE SAFETY/PROTECTION

I7.3 Regulations

I7.3.3 Ships Intended to Operate in Low Air Temperatures

The wording “acceptable to the Society” specified in **7.3.3(2), Part I of the Rules** means those as follows:

(1) Materials taking into account **Chapter 2, Annex 1, Part I of the Rules** “**Special Requirements for the Materials, Hull Structures, Equipment and Machinery of Polar Class Ships**”; or

(2) Materials taking into account other standards offering an equivalent level of safety to those specified in **(1)** above based on the polar service temperature.

I8 has been amended as follows.

I~~5~~8 ICE CLASS SHIPS

I~~5~~8.1 General

I~~5~~8.1.1 Application

1 For ice class ships trading in the Northern Baltic in the winter under the control of the regulation "*Finnish-Swedish Ice Class Rules 2010*", regard needs to be paid to the following as extracted from "*Guidelines for the Application of the Finnish-Swedish Ice Class Rules*".

(1) The administrations of Sweden and Finland provide icebreaker assistance to ice class ships bound for ports in respective countries in the winter season. Depending on the ice conditions, restrictions in regard to the size and ice class of ships entitled to icebreaker assistance are enforced.

(2) Merely the compliance with these regulations must not be assumed to guarantee any certain degree of capability to advance in ice without icebreaker assistance nor to withstand heavy ice jamming.

(3) It should be noted that small ice class ships will have somewhat less ice going capability as compared with larger ice class ships having the same ice class.

(4) It shall be noted that for ice class ships of moderate size (displacement not exceeding 30,000 *tons*) notch towing in many situations is the most efficient way of assisting in ice.

(5) Ice class ships with a bulb protruding more than 2.5*m* forward of the forward perpendicular, ice class ships with too blunt of a bow shape and ice class ships with an ice knife fitted above the bulb are often difficult for notch towing.

(6) When the bow is too high in the ballast condition, ice class ships may be trimmed to get the bow down.

(7) An ice strengthened ship is assumed to operate in open sea conditions corresponding to a level ice thickness not exceeding h_0. The design height (h) of the area actually under ice pressure at any particular point of time is, however, assumed to be only a fraction of the ice thickness. The values for h_0 and h are given in **Table I~~5~~8.1.1-1**.

Table I~~5~~8.1.1-1

Ice Class	h_0 (m)	h (m)
I*A Super*	1.00	0.35
I*A*	0.80	0.30
I*B*	0.60	0.25
I*C*	0.40	0.22

2 For the ice class ship to be entitled to an ice notation, calculation sheet of main propulsion engine output is to be submitted in addition to drawings and data for reference in **2.1.2(2), Part D of the Rules**.

I~~5~~8.3 Hull Structures and Equipment

I~~5~~8.3.2 General Requirements for Frames

1 With respect to the provisions of **~~5~~8.3.2-2, Part I of the Rules**, where longitudinal frames are running through supporting structures such as web frames or transverse bulkheads, brackets are to be fitted on both sides of the supporting structures. (See **Fig. I~~5~~8.3.2-1**) Where transverse frames are running through supporting structures such as deck or ice stringers within the ice belt, it is recommended that brackets are also fitted on the above side of the supporting structures. (See **Fig. I~~5~~8.3.2-2**) The standard arm length of a bracket is not to be less than the depth of a frame web.

Fig. I~~5~~8.3.2-1 Brackets for Longitudinal Side Frames

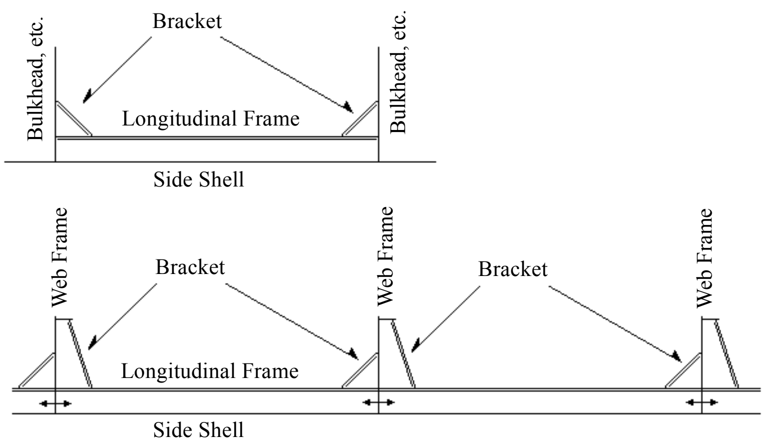
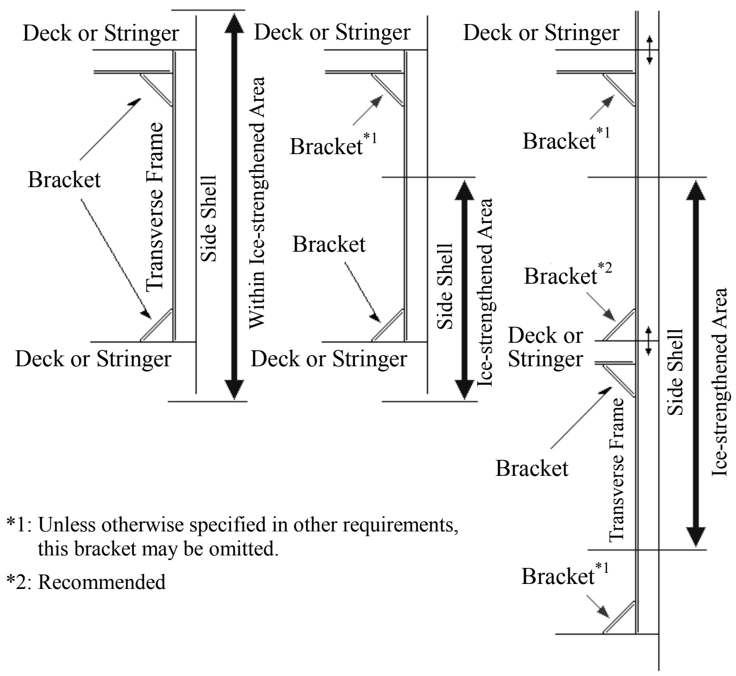


Fig. I~~5~~8.3.2-2 Brackets for Transverse Side Frames



I~~5~~8.3.4 Longitudinal Frames

1 With respect to the provisions of **~~5~~8.3.4, Part I of the Rules**, vertical extension of ice strengthening of longitudinal framing may be limited to longitudinal frames within the ice belt specified in **~~5~~8.3.1-1, Part I of the Rules** and those just above and below the edge of the ice belt, except where deemed necessary by the Society. In this case, the spacing of longitudinal frames just above and below the edge of the ice belt is to be the same as the frame spacing in the ice belt. Notwithstanding the above, the longitudinal frames just above and below the edges of the ice belt are closer than 50% of s to the upper and lower edges of the ice belt respectively, where s is the frame spacing in the ice belt s is to be extended to the second longitudinal frame above and below the ice belt.

2 With respect to the provisions of **~~5~~8.3.4-1, Part I of the Rules**, boundary condition factor m for frames in conditions deviating from those of continuous beam is to be determined in accordance with the following:

(1) For conditions deemed as those fixed at both ends: $m = 12$

(2) For conditions deemed as those simple supported at both ends: $m = 8$

(3) For conditions other than **(1)** or **(2)**, boundary condition factor m is to be determined by calculation using simple beam theory, but in no case that m is not to be greater than 13.3.

I~~5~~8.3.5 Ice Stringers

With respect to the provisions of **~~5~~8.3.5, Part I of the Rules**, boundary condition factor m for ice stringers in conditions deviating from those of continuous beam is to be determined in accordance with **I~~5~~8.3.4-2**.

I~~5~~8.3.8 Arrangements for Towing

The wording "special consideration" specified in **~~5~~8.3.8, Part I of the Rules** refers to the following:

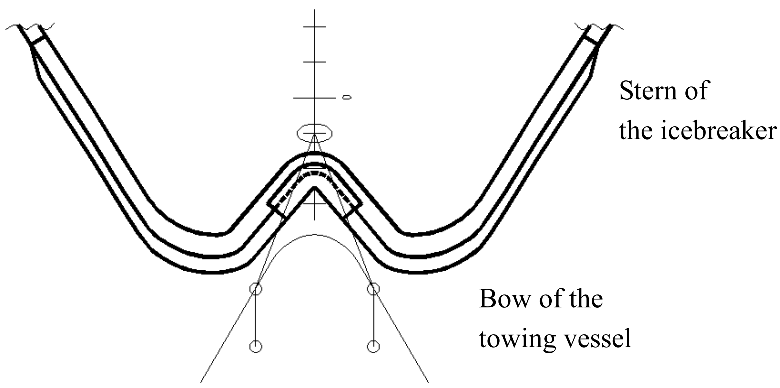
(1) The towing arrangement uses a thick wire which is split into two slightly thinner wires as shown in **Fig.I~~5~~8.3.8-1**.

(2) Two fairleads are to be fitted symmetrically off the centreline with one bollard each.

(3) The distance of the bollards from the centreline is approximately 3 *m*. The bollards are to be aligned with the fairleads allowing the towlines to be fastened straight onto them.

(4) Bollards or other means for securing towlines are structurally designed to withstand the breaking force of the towline of the ship.

Fig. I~~5~~8.3.8-1 The Typical Towing Arrangement

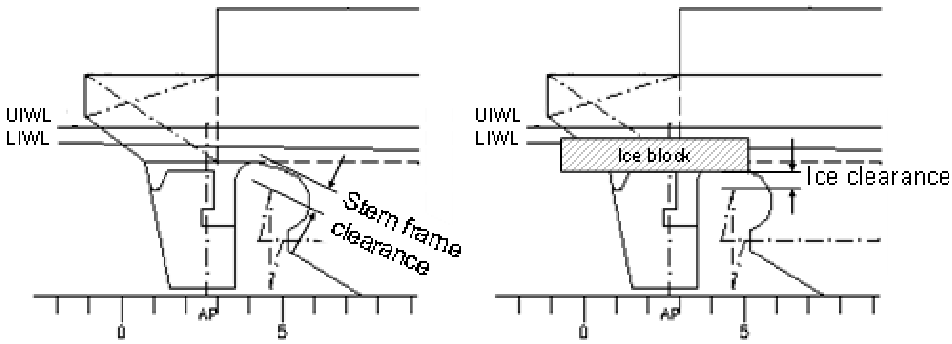


I~~5~~8.3.9 Stern

1 The clearance between the propeller blade tip and the stern frame is not to be less than 0.5*m* to prevent high loads from occurring on the blade tip. The ice clearance between the propeller blade tip and the bottom of the level ice sheet is to be positive when the level ice thickness is taken as specified in **Table I~~5~~8.1**. (See **Fig. I~~5~~8.3.9-1**)

2 A wide transom stern extending below the *UIWL* will seriously impede the capability of the ship to astern in ice. Therefore, a transom stern is not to be extended below the *UIWL* if this can be avoided. If unavoidable, the part of the transom stern below the *UIWL* is to be kept as narrow as possible. The part of a transom stern situated within the ice belt is to be strengthened at least as for the midbody region.

Fig. I~~5~~8.3.9-1 The Clearance between the Stern Frame and the Propeller (left) and the Ice Sheet and the Propeller when the Ship is at *LIWL* (right)



I~~5~~8.3.10 Bilge Keel

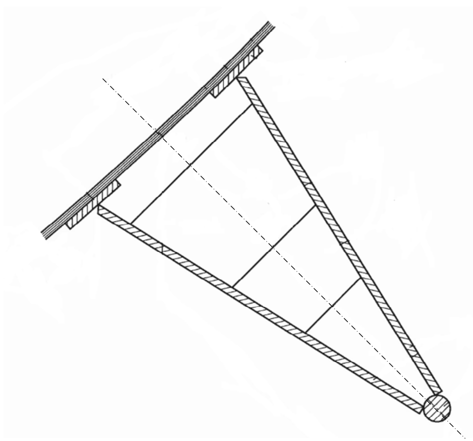
The wording "special consideration" specified in **~~5~~8.3.10, Part I of the Rules** refers to the following:

(1) The connection of bilge keels to the hull is to be so designed that the risk of damage to the hull, in case a bilge keel is ripped off, is minimized.

(2) Bilge keels are recommended to be constructed as shown in **Fig. I~~5~~8.3.10-1**.

(3) It is recommended that bilge keels are cut up into several shorter independent lengths.

Fig. I~~5~~8.3.10-1 An Example of Bilge Keel Construction



I~~5~~8.4 Fundamental Requirements of Machinery

I~~5~~8.4.3 Rudders and Steering Arrangements

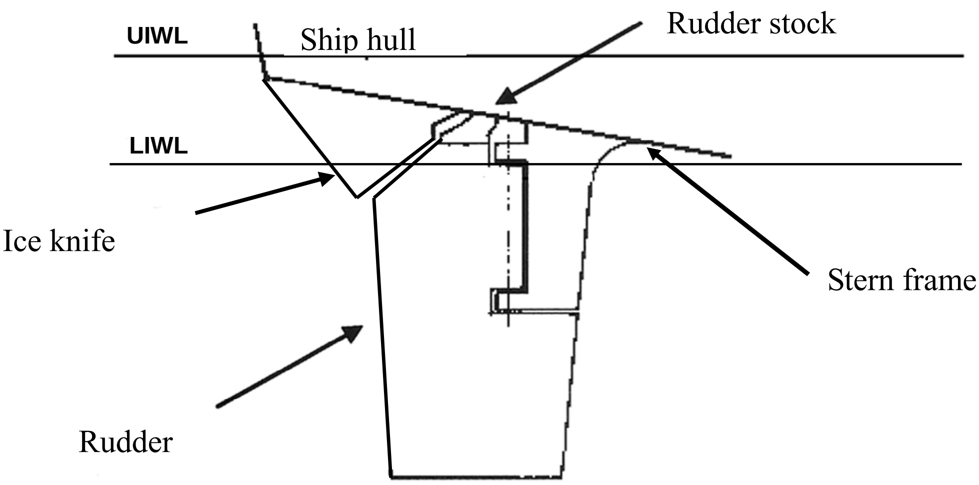
The wording "Ice knife" specified in **~~5~~8.4.3-3, Part I of the Rules** refers to the following and special consideration is to be given to the strength and proper shape of the ice knife.

(1) The ice knife bottom is to be below water in all draughts

(2) Where the ship is not intended to go astern in ice at some draught, a smaller ice knife may be used.

(3) An ice knife is recommended to be installed on all ships with ice class I*A Super* or I*A*.

Fig. I~~5~~8.4.3-1 An Example of an Adequate Ice Knife Design



I~~5~~8.6 Design of Propellers and Propulsion Shafting Systems

I~~5~~8.6.3 Propeller Bossing and CP Mechanism

Where the propeller is force-fitted on the propeller shaft without key, the lower limit of pull-up length is to be determined according to **7.3.1-1, Part D of the Rules**, substituting F_V' given by following formula for F_V and the thrust T is to be determined according to maximum thrust T_r given by **~~5~~8.5.7, Part I of the Rules**:

$$F_V' = F_V + 4.46\frac{Q_{max}}{R_0}\times 10^5 \quad (N)$$

where:

Q_{max} : Maximum propeller ice torque (kNm) specified in **~~5~~8.5.8, Part I of the Rules**.

R_0 : Radius (mm) of the propeller shaft cone part at the mid-length

F_V : Tangential force (N) acting on contact surface specified in **7.3.1-1, Part D of the Rules**.

I~~5~~8.7 Alternative Designs

I~~5~~8.7.1 Alternative Design

The examination specified in **~~5~~8.7, Part I of the Rules**, may be according to the following **(1)** to **(3)**.

(1) The study has to be based on ice conditions given for the different ice classes specified in **~~5~~8.5, Part I of the Rules**. It has to include both fatigue and maximum load design calculations and fulfill the pyramid strength principle, as given in **~~5~~8.5.1, Part I of the Rules**.

(2) Loading

Loads on propeller blades and propulsion systems are to be based on acceptable estimations of hydrodynamic and ice loads.

(3) Design levels

(a) Analysis is to indicate that all components transmitting random (occasional) forces, excluding propeller blade, are not subjected to stress levels in excess of the yield stress of the component material, within a reasonable safety margin.

(b) Cumulative fatigue damage calculations are to indicate reasonable safety factors. Due account is to be taken of material properties, stress raisers, and fatigue enhancements.

(c) Vibration analysis is to be carried out and is to indicate that complete dynamic systems are free from harmful torsional resonances resulting from propeller/ice interaction.

EFFECTIVE DATE AND APPLICATION

1. The effective date of the amendments is 1 January 2017.

2. Notwithstanding the amendments to the Guidance, the current requirements apply to ships the keels of which were laid or which were at *a similar stage of construction* before the effective date except for in cases where the amendments are to be retroactively applied.

(Note) The term "*a similar stage of construction*" means the stage at which the construction identifiable with a specific ship begins and the assembly of that ship has commenced comprising at least 50 *tonnes* or 1% of the estimated mass of all structural material, whichever is the less.