RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

Part I

Polar Class Ships and Ice Class Ships

RULES

Rule No.48 27th September 2007

Resolved by Technical Committee on 2nd July 2007

Approved by Board of Directors on 24th July 2007

Rule No.48 27th September 2007
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 has newly established as follows:

Part I POLAR CLASS SHIPS AND ICE CLASS SHIPS

Amendment 1-1

Chapter 1 GENERAL

1.1 General

1.1.1 Application

1 The requirements in this Part apply to ships intended for navigation in 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 of the ship are to be in accordance with the requirements in **Chapter 1** to **Chapter 4** of this Part in addition to those in other Parts.

3 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, the materials, hull structures, equipment and machinery of the ship are to be in accordance with the requirements in **Chapter 1** and **Chapter 5** of this Part in addition to those in other Parts.

1.1.2 Documentation

1 The polar class defined in **1.2.2** or the ice class defined in **1.2.3** 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 **1.2.4-1**, the lower ice waterline specified in **1.2.4-2** and hull area specified in **1.2.5-1** are to be indicated in the shell expansion specified in **2.1.2, Part B**. The corrosion/abrasion additions specified in **2.3** 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 **1.2.4-1**, the lower ice waterline specified in **1.2.4-2** and hull area specified in **1.2.5-2** are to be indicated in the shell expansion specified in **2.1.2, Part B**. The engine output defined in **5.4.1**, the displacement defined in **5.1.2-6** and the dimensions necessary for the engine output calculation required in **5.4.1** 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

Alternative hull construction, equipment, machinery and their arrangements will be accepted by the Society, provided that the Society is satisfied that such construction, equipment, machinery and their arrangements and scantlings are equivalent to those required in this Part.

1.2 Definitions

1.2.1 Application

The definitions of terms and symbols which appear in this Part are to be as specified hear in **1.2**, unless specified elsewhere.

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	*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

Note:

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 0.04 L_{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 0.04 L_{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*.

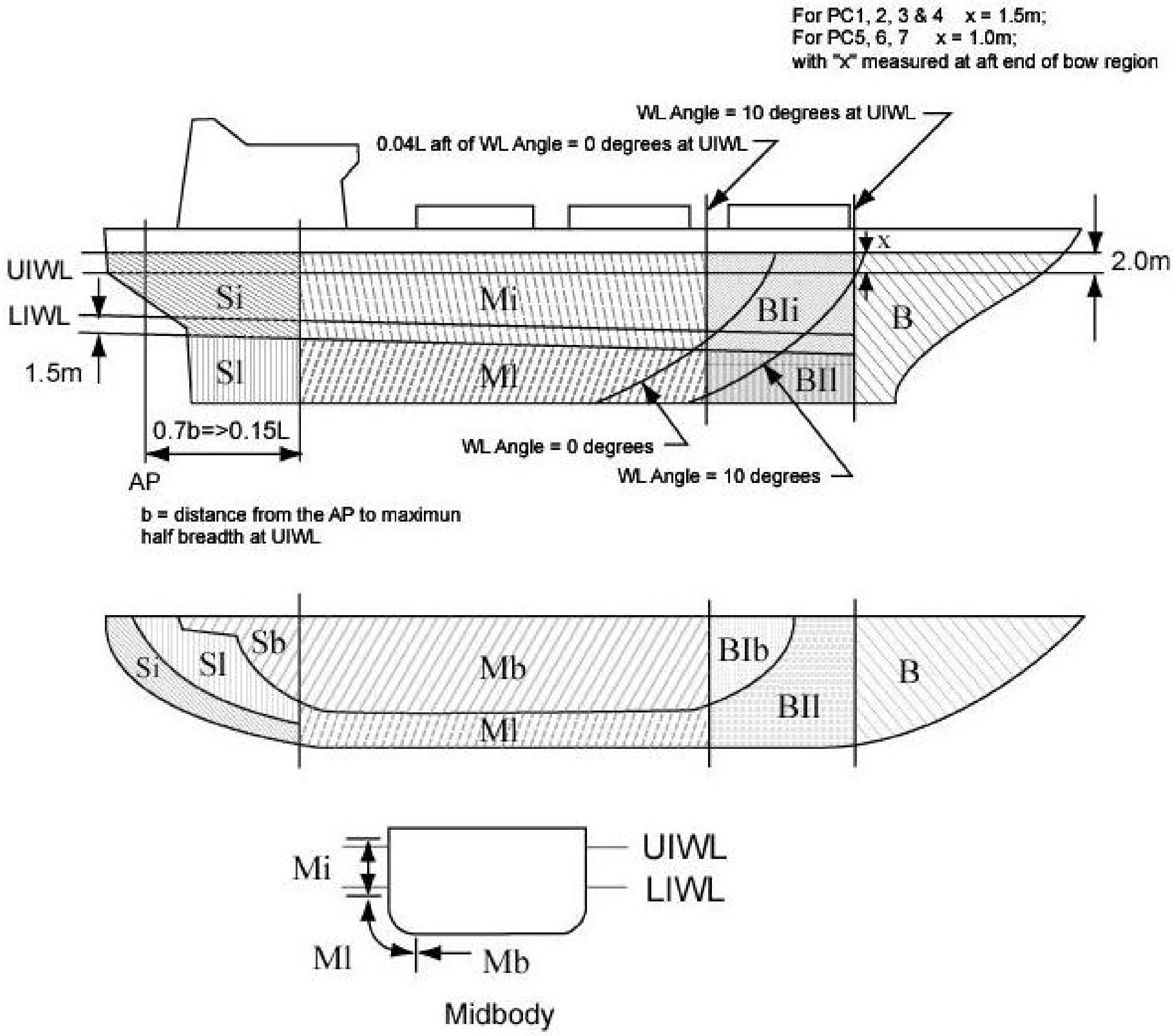
(b) Midbody area of *PC*5, *PC*6 and *PC*7 polar class ships
"Midbody area" is defined as the hull area which is located aft of the aft boundary of the Bow Intermediate area, and forward of the fore boundary of the Stern area, and below the line 1.0 *m* above the *UIWL*.

(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



Note:

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 forward, midship, and aft regions in way of hull part are defined for I*A Super*, I*A*, I*B* and I*C* ice class ships and the forward region is defined for I*D* ice class ships as follows:

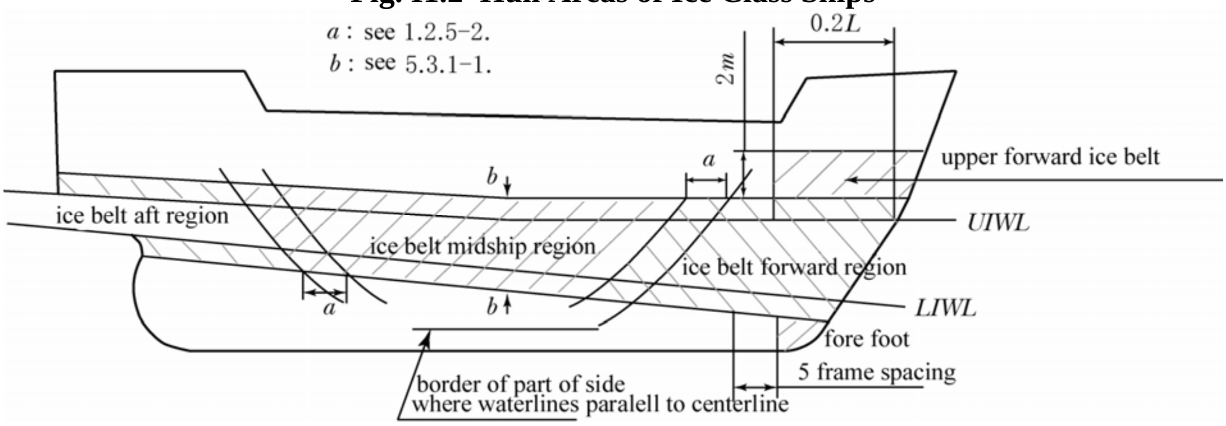
(1) Forward region

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) Midship region
From the aft boundary of the Forward 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) Aft region
From the aft boundary of the midship region to the stern

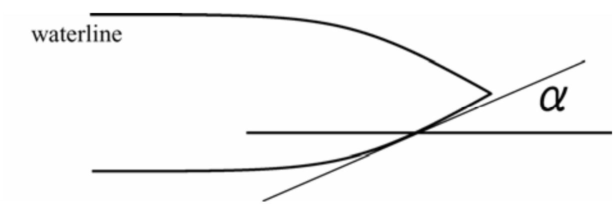
Fig. I1.2 Hull Areas of Ice Class Ships



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**)

Fig. I1.3 Waterline Angle α



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.

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 **Part K**.

2.1.2 Material Classes and Grades

1 Material classes and grades used for the hull structure are given in **Table I2.1**.

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 I2.2**.

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**.

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.

Table I2.1 Material Classes for Structural Members

Structural Members	Material Class	
	Within 0.4*L* amidships	Outside 0.4*L* amidships
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	I	*A/AH*(9)
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	II	*A/AH*(9)
Special: C1. Sheer strake at strength deck (1),(8) C2. Stringer plate in strength deck (1),(8) C3. Deck strake at longitudinal bulkhead (2),(8) C4. Strength deck plating at outboard corners of cargo hatch openings in container carriers and other ships with similar hatch openings configuration (3) C5. Strength deck plating at corners of cargo hatch openings in bulk carriers, ore carriers, combination carriers and other ships with similar hatch openings configuration (4) C6. Bilge strake (5),(6),(8) C7. Longitudinal hatch coamings of length greater than 0.15*L* (7) C8. End brackets and deck house transition of longitudinal cargo hatch openings (7)	III	II I outside 0.6*L* amidships

Notes:

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

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

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

(4) Not to be less than class III within 0.6 *L* amidships and class II within the remaining

length of the cargo region.

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

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

(7) Not to be less than *D/DH*.

(8) Single strakes required to be of class III or of grade *E/EH* and within 0.4 *L* amidships are to have breadths not less than 5L+800 *mm*, need not be greater than 1800 *mm*, unless limited by the geometry of the ship's design.

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

Table I2.2 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 I2.1**, 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 shell 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 I2.1**, 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 I2.3** based on the Material Classes for Structural members in **Table I2.1** and **Table I2.2** above, regardless of polar classes.

Table I2.3 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≤15	*A*	*AH*	*A*	*AH*	*A*	*AH*
15<*t*≤20	*A*	*AH*	*A*	*AH*	*B*	*AH*
20<*t*≤25	*A*	*AH*	*B*	*AH*	*D*	*DH*
25<*t*≤30	*A*	*AH*	*D*	*DH*	*D*	*DH*
30<*t*≤35	*B*	*AH*	*D*	*DH*	*E*	*EH*
35<*t*≤40	*B*	*AH*	*D*	*DH*	*E*	*EH*
40<*t*≤50	*D*	*DH*	*E*	*EH*	*E*	*EH*

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 I2.4** based on the Material Class for Structural Members in **Table I2.1** and **Table I2.2** 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 I2.5**. 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 I2.4 Steel Grades for Weather Exposed Plating

Thickness, t (*mm*)	Material Class I				Material Class II				Material Class III					
	PC1-5		PC6&7		PC1-5		PC6&7		PC1-3		PC4&5		PC6&7	
	MS	*HT*	*MS*	*HT*	*MS*	*HT*	*MS*	*HT*	*MS*	*HT*	*MS*	*HT*	*MS*	*HT*
$t \le 10$	*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 I2.5 Steel Grades for Inboard Framing Members Attached to Weather Exposed Plating

Thickness, t (*mm*)	*PC*1 - *PC*5		*PC*6 及び *PC*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 I2.3**, **Table I2.4** and **Table I2.5**, *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*14A test specimen in **Part K**. Materials other than bronze and austenitic steel are to have an average impact energy value of 20 *J* at -10 ^oC for the *U4* test specimen in **Part K**.

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 ^oC for the *U4* test specimen in **Part K**.

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 ^oC below the lowest design temperature for the *U4* test specimen in **Part K**.

2.2 Welding

2.2.1 General

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

2 All fillet welding within ice-strengthened areas are to be of the double continuous type and their sizes are to be of *F2* or more as specified in **Table C1.4, Part C**.

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 I2.6**.

Table I2.6 Corrosion/Abrasion Additions for Shell Plating

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

Note:

(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**. 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**, 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.

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 I3.1**.

Table I3.1 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. I3.1**.

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.

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

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

where

i : sub-region considered

L' : ship length (*m*) measured at the *UIWL*

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

α : waterline angle (*deg*), see **Fig. I1.3**

β' : normal frame angle (*deg*), see **Fig. I3.1**

Δ_1 : ship displacement (*t*) at the *UIWL*, not to be taken as less than 5000*t*

CF_C : Crushing Failure Class Factor from **Table I3.1**

CF_F : Flexural Failure Class Factor from **Table I3.1**

4 Force *F* is to be obtained from the following formula.

$$F_i = fa_i \times CF_C \times \left(\frac{\Delta_1}{1000}\right)^{0.64} \times 1000 \quad (kN)$$

where

i : sub-region considered

fa_i : shape coefficient of sub-region *i*, see **-3**

CF_C : Crushing Failure Class Factor from **Table I3.1**

Δ_1 : ship displacement (*t*), not to be taken as less than 5000*t*

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.

$AR_i = 7.46 \times \sin(\beta'_i)$

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.

$$Q_i = \left(\frac{F_i}{1000}\right)^{0.61} \times \frac{CF_D}{AR_i^{0.35}} \times 1000 \quad (kN/m)$$

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 I3.1**

7 Pressure P is to be obtained from the following formula:

$$P_i = \left(\frac{F_i}{1000}\right)^{0.22} \times CF_D^{\ 2} \times AR_i^{0.3} \times 1000 \quad (kN/m^2)$$

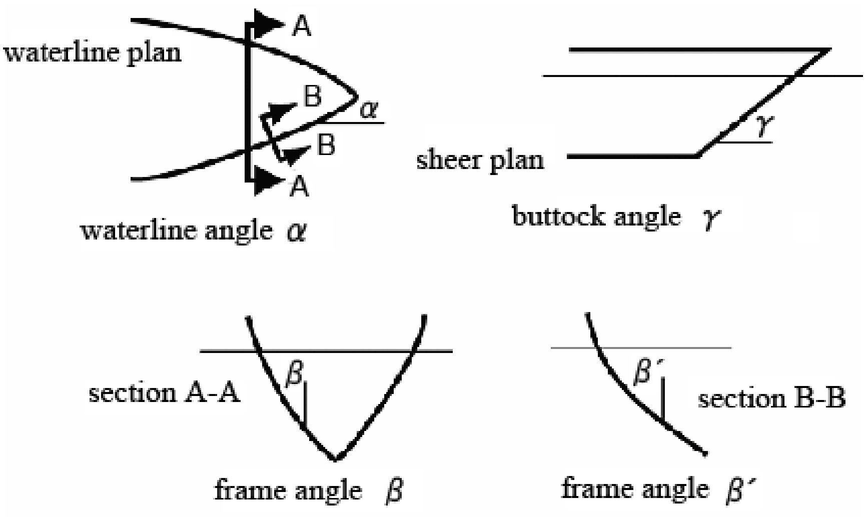
where

i : sub-region considered

CF_D : Load Patch Dimensions Class Factor from **Table I3.1**

F_i and AR_i : the values specified in **-4** and **-5**, respectively

Fig. I3.1 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)

$\tan(\beta) = \tan(\alpha)/\tan(\gamma)$

$\tan(\beta') = \tan(\beta)\cos(\alpha)$

8 In the Bow area, and the Bow Intermediate Icebelt area for *PC*6 and *PC*7polar 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 F_i (kN) in the Bow area

Q_{Bow} : maximum Q_i (kN/m) in the Bow area

P_{Bow} : maximum P_i (kN/m^2) in the Bow area

9 The average pressure, P_{avg}, within a design load patch is determined as follows:

$P_{avg} = F_{Bow} / (b_{Bow} \times w_{Bow})$ (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 *PC*1, *PC*2, *PC*3, *PC*4 and *PC*5 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}

$$F_{NonBow} = 0.36 \times CF_C \times DF \times 1000 \quad (kN)$$

where

CF_C : Crushing Failure Class Factor from **Table I3.1**

DF : ship displacement factor, obtained from the following formula.

$$DF = \left(\frac{\Delta_2}{1000}\right)^{0.64} \text{ if } \frac{\Delta_2}{1000} \le CF_{DIS}$$

$$DF = CF_{DIS}^{\ 0.64} + 0.10 \times \left(\frac{\Delta_2}{1000} - CF_{DIS}\right) \text{ if } \frac{\Delta_2}{1000} > CF_{DIS}$$

where

Δ_2 : ship displacement (t) at the *UIWL*, not to be taken as less than 10000t

CF_{DIS} : Displacement Class Factor from **Table I3.1**

(b) Line load Q_{NonBow}

$$Q_{NonBow} = 0.639 \times \left(\frac{F_{NonBow}}{1000}\right)^{0.61} \times CF_D \times 1000 \quad (kN/m)$$

where

F_{NonBow} : the force (kN) obtained from **(a)**

CF_D : Load Patch Dimensions Class Factor from **Table I3.1**

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:

$P_{avg} = F_{NonBow} / (b_{NonBow} \times w_{NonBow})$ (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 I3.2** are used to account for the pressure concentration on localized structural members.

Table I3.2 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	$PPF_p = (2.2 - 1.2 \times s)$, 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 $S_w \geq 0.5 \times w$ $PPF_s = 2.0 - 2.0 \times S_w / w$, if $S_w < 0.5 \times w$
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 I3.3**.

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 I3.3 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	**	**

Note :

* 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 **3.5.1-2**

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):

$$t_{net} = 500s \times \sqrt{\frac{AF \times PPF_P \times \left(\frac{P_{avg}}{1000}\right)}{\sigma_y}} \times \frac{1}{1 + \frac{s}{2b}} \quad (mm)$$

(2) In the case of longitudinally-framed plating ($\Omega \leq 20$ deg):

$$t_{net} = 500s \times \sqrt{\frac{AF \times PPF_P \times \left(\frac{P_{avg}}{1000}\right)}{\sigma_y}} \times \frac{1}{1 + \frac{s}{2l}} \quad (mm), \text{ if } b \geq s$$

$$t_{net} = 500s \times \sqrt{\frac{AF \times PPF_P \times \left(\frac{P_{avg}}{1000}\right)}{\sigma_y}} \times \sqrt{\frac{2b}{s - \left(\frac{b}{s}\right)^2}} \times \frac{1}{1 + \frac{s}{2l}} \quad (mm), \text{ if } b < s$$

where

Ω : smallest angle (deg) between the chord of the waterline and the line of the first level framing as illustrated in **Fig. I3.2**

s : transverse frame spacing (m) in transversely-framed ships or longitudinal frame spacing (m) in longitudinally-framed ships

AF : Hull Area Factor from **Table I3.3**

PPF_p : Peak Pressure Factor from **Table I3.2**

P_{avg} : average patch pressure (kN/m^2) according to **3.4.3-3**

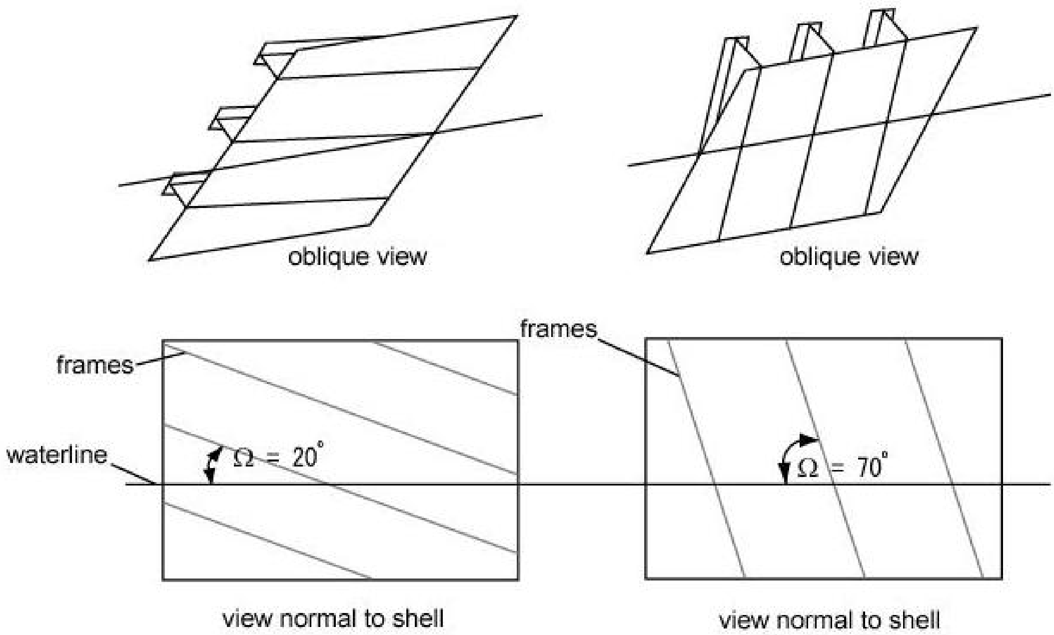
σ_y : minimum upper yield stress of the material (N/mm^2)

b : height (m) of design load patch, where b ≤ (1 – 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 > Ω > 20 deg), linear interpolation is to be used.

Fig. I3.2 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:

$$A_w = \frac{h t_{wn} \sin\varphi_w}{100} \qquad (cm^2)$$

where

h : height of stiffener (mm), see **Fig. I3.3**

t_{wn} : net web thickness (mm), $t_{wn} = t_w - t_c$

t_w : as built web thickness (mm), see **Fig. I3.3**

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. I3.3**. 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 attached plate ($A_{pn} = t_{pn} \times s \times 10$, but not to be taken greater than the net cross-sectional area 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. I3.5**

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. I3.5**

b_w : distance (mm) from mid thickness plane of local frame web to the centre of the flange area, see **Fig. I3.5**

(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:

$$Z_{na} = \frac{100A_{fn} + h_w t_{wn} - 1000 t_{pn} s}{2t_{wn}} \quad (mm)$$

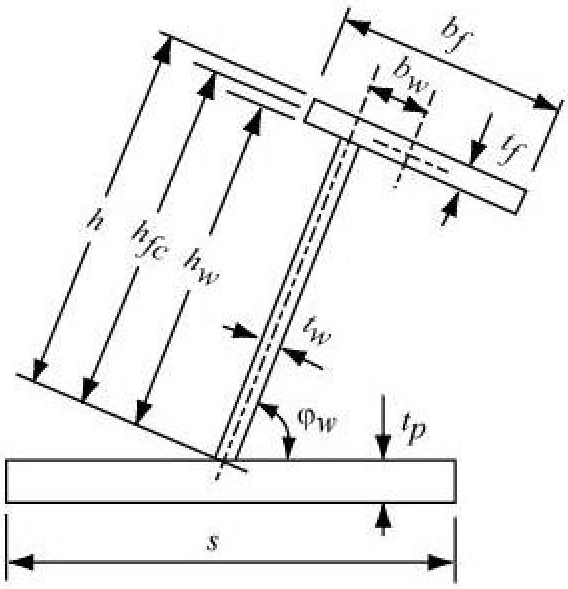
where,

s : frame spacing (m)

The net effective plastic section modulus, Z_p, is given by:

$$Z_p = t_{pn} s z_{na} \sin\varphi_w + \left(\frac{((h_w - z_{na})^2 + z_{na}^2) t_{wn} \sin\varphi_w}{2000} + \frac{A_{fn}\left((h_{fc} - z_{na})\sin\varphi_w - b_w \cos\varphi_w\right)}{10} \right) \quad (cm^3)$$

Fig. I3.3 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, Aw, as defined in **3.5.2-3** is to be not less than

A_t determined as follows:

$$A_t = \frac{100^2 \times 0.5 \times LL \times s \times AF \times PPF_t \times \dfrac{P_{avg}}{1000}}{0.577\sigma_y} \qquad (cm^2)$$

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 I3.3**

PPF_t : Peak Pressure Factor from **Table I3.2**

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:

$$Z_{pt} = \frac{100^3 \times LL \times Y \times s \times AF \times PPF_t \times \dfrac{P_{avg}}{1000} \times a \times A_1}{4\sigma_y} \qquad (cm^3)$$

where

AF, PPF_t,, P_{avg}, LL, b, s, a and σ_y are as given in **3.5.3-2.**

$Y = 1 - 0.5 \times (LL / a)$

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

$$A_1 = \frac{1}{1 + \dfrac{j}{2} + \dfrac{k_w \times j}{2\left(\sqrt{1 - a_1^2} - 1\right)}}$$

(b) When ice load acting near a support

$$A_1 = \frac{1 - \dfrac{1}{2 \times a_1 \times Y}}{0.275 + 1.44 \times k_z^{0.7}}$$

$j = 1$ 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**)

$k_w = 1 / (1 + 2 \times A_{fn} / A_w)$ 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

$z_p = (b_f \times t_{fn}^2 / 4 + b_{eff} \times t_{pn}^2 / 4) / 1000$

b_f : Flange breadth (mm), see **Fig. I3.3**

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. I3.3**

t_{pn} : The fitted net shell plate thickness (*mm*), not to be less than t_{net} as given in **I2.4**.

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:

$$A_L = \frac{100^2\left(AF \times PPF_s \times \dfrac{P_{avg}}{1000}\right) \times 0.5 b_1 a}{0.577 \varphi_y} \quad (cm^2)$$

where

AF : Hull Area Factor from **Table I3.3**

PPF_s : Peak Pressure Factor from **Table I3.2**

P_{avg} : Average pressure (kN/m^2) within load patch according to **3.4.3-3**

$b_1 = k_o \times b_2$ (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:

$b_2 = b\ (1 - 0.25 \times b')$ (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:

$$Z_{pL} = \frac{100^3\left(AF \times PPF_s \times \dfrac{P_{avg}}{1000}\right) \times b_1 \times a^2 \times A_4}{8 \sigma_y} \quad (cm^3)$$

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**)

$k_{wl} = 1 / (1 + 2 \times A_{fn} / A_w)$ 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 I3.2** 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 : $\frac{h_w}{t_{wn}} \leq \frac{282}{\sqrt{\sigma_y}}$

For bulb, tee and angle sections : $\frac{h_w}{t_{wn}} \leq \frac{805}{\sqrt{\sigma_y}}$

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) $t_{wn} = 2.63 \times 10^{-3} \times c_1 \sqrt{\frac{\sigma_y}{5.34 + 4 \times (c_1 / c_2)^2}}$ (*mm*)

where

$c_1 = h_w - 0.8 \times h$ (*mm*)

h_w : web height (*mm*) of stringer / web frame, see **Fig. I3.4**.

h : height (*mm*) of framing member penetrating the member under consideration, 0 if no such framing member, see **Fig. I3.4**.

c_2 : spacing (*mm*) between supporting structure oriented perpendicular to the member under consideration, see **Fig. I3.4**.

σ_y : minimum upper yield stress of the material (*N/mm*^{2})

(b) $t_{wn} = 0.35 \times t_{pn} \sqrt{\frac{\sigma_y}{235}}$ (*mm*)

where

σ_y : minimum upper yield stress of the material (*N/mm*^{2})

t_{wn} : net thickness (*mm*) of the web

t_{pn} : net thickness (*mm*) of the shell plate in way 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:

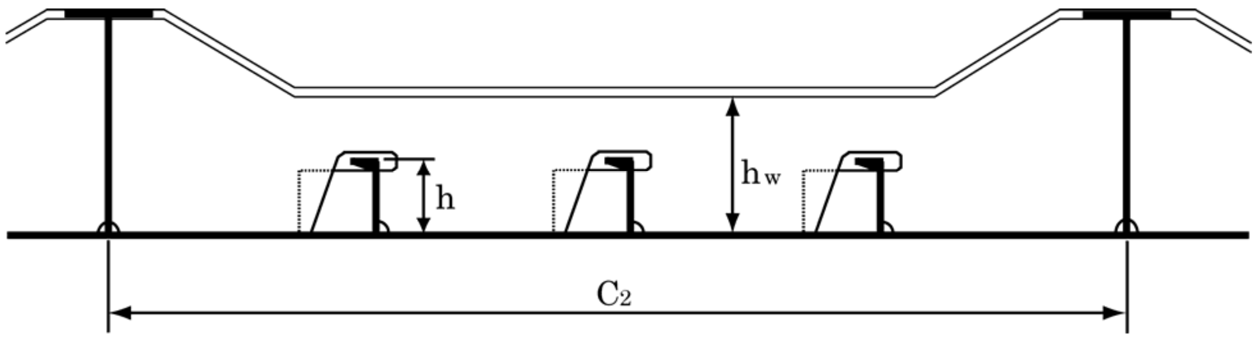
$$\frac{b_{out}}{t_{fn}} \leq \frac{155}{\sqrt{\sigma_y}}$$

where

t_{fn} : net thickness (*mm*) of flange

σ_y : minimum upper yield stress of the material (N/mm^2)

Fig. I3.4 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 **5.3.7** and **5.3.9** 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

1 The design vertical ice force at the bow F_{IB} is to be taken the minimum value of following $F_{IB,1}$ and $F_{IB,2}$.

$$F_{IB,1} = 1000 \times 0.534 \times K_I^{0.15} \times \sin^{0.2}(\gamma_{stem}) \times \sqrt{\frac{\Delta_2}{1000} \times \frac{K_h}{1000}} \times CF_L \qquad (kN)$$

$$F_{IB,2} = 1000 \times 1.20 \times CF_F \qquad (kN)$$

where

K_I : indentation parameter, $K_I = \frac{K_f}{K_h} \times 1000$

where

(a) for the case of a blunt bow form

$$K_f = \left(\frac{2 \times C \times B^{1-e_b}}{1+e_b} \right)^{0.9} \times \tan(\gamma_{stem})^{-0.9\times(1+e_b)}$$

(b) for the case of wedge bow form (α_{stem} < 80 *deg*), e_b =1 and above simplifies to:

$$K_f = \left(\frac{\tan(\alpha_{stem})}{\tan^2(\gamma_{stem})} \right)^{0.9}$$

$K_h = 10 \times A_{WP}$ (kN/m)

CF_L : Longitudinal Strength Class Factor from **Table I3.1**

e_b : bow shape exponent which best describes the waterplane, see **Fig. I3.5** and **Fig. I3.6**

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. I3.1** measured on the centreline)

$$C = \frac{1}{2 \times \left(\frac{L_B}{B}\right)^{e_b}}$$

B : ship moulded breadth (*m*)

L_B : bow length (*m*), see **Fig. I3.5** and **Fig. I3.6**.

Δ_2 : ship displacement (*t*), not to be taken less than 10000*t*

A_{wp} : ship waterplane area (m^2)

CF_F : Flexural Failure Class Factor from **Table I3.1**

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

Fig. I3.5 Bow Shape Definition

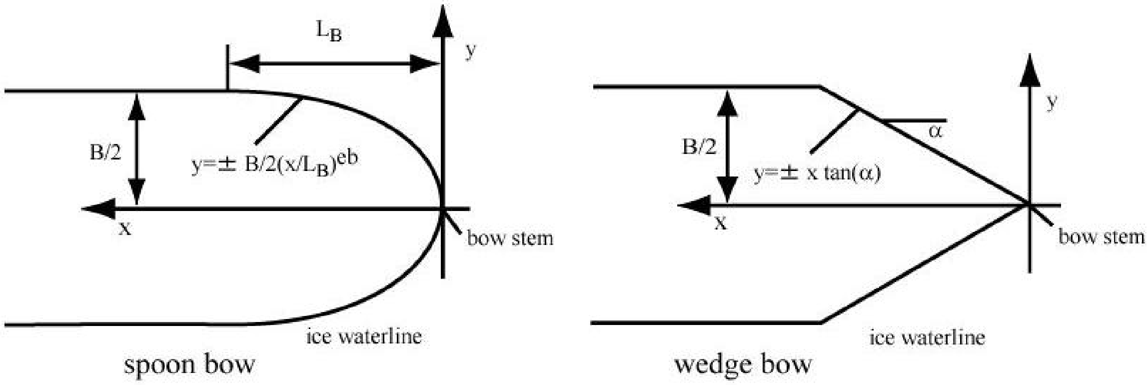
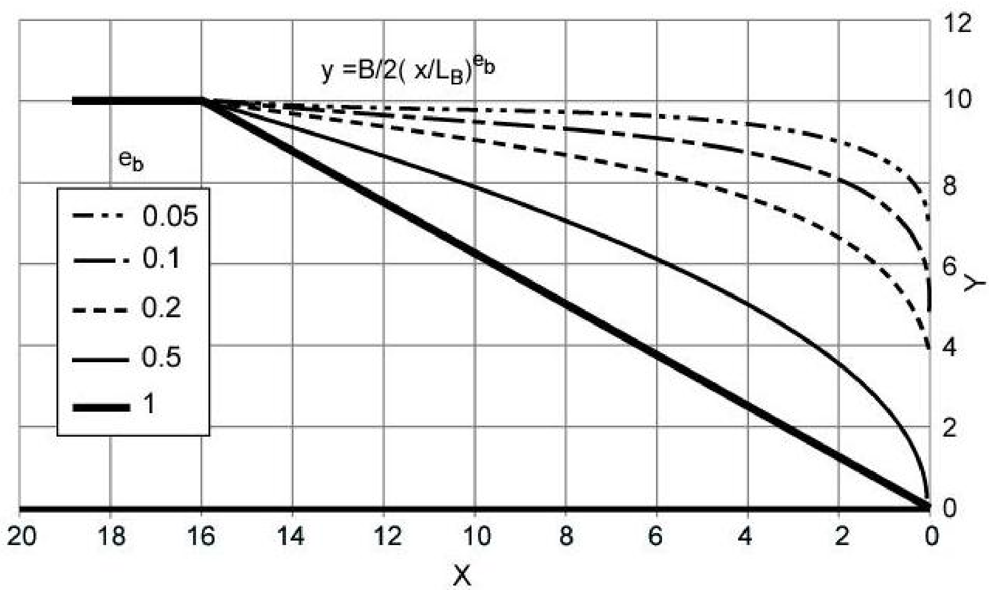


Fig. I3.6 Illustration of e_b Effect on the Bow Shape for B=20 and L_B=16



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:

$$F_I = C_f \times F_{IB} \quad (kN)$$

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 0.6*L* from aft

C_f = 1.0 between 0.9*L* 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 0.2*L* and 0.6*L* from aft

C_f = 0.0 between 0.8*L* 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** 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:

$$M_I = 0.1 \times C_m \times L \times \sin^{-0.2}(\gamma_{stem}) \times F_{IB} \quad (kNm)$$

where

L : ship length (*m*), Rule Length as defined in **2.1.2, Part A**.

γ_{stem} : as given in **3.6.2-1**

F_{IB} : design vertical ice force (*kN*) at the bow, see **3.6.2-1**

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 0.5 *L* and 0.7*L* from aft

C_m = 0.3 at 0.95*L* 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**, by substituting the design vertical ice bending moment for the design vertical wave bending moment.

3.6.5 Longitudinal Strength Criteria

1 The strength criteria provided in **Table I3.4** are to be satisfied. The design stress is not to exceed the permissible stress.

Table I3.4 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	$0.8 \times \sigma_y$	$0.8 \times 0.41 (\sigma_u + \sigma_y)$
Shear	τ_a	$0.8 \times \sigma_y / \sqrt{3}$	$0.8 \times 0.41 (\sigma_u + \sigma_y) / \sqrt{3}$
Buckling	σ_a	σ_c for plating and for web plating of stiffeners $\sigma_c / 1.1$ 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**

τ_c : critical buckling stress (N/mm^2) in shear, according to **15.4, Part C**

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.**

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 $D < \mathrm{D_{limit}}$

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

when $D \geq \mathrm{D_{limit}}$

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

where $D_{\mathrm{limit}} = 0.85 \cdot (H_{ice})^{1.4}$ (m)

(2) For ducted propellers:

when $D < D_{limit}$

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

when $D \geq D_{limit}$

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

where $D_{limit} = 4 \cdot H_{ice}$ (m)

H_{ice}: Ice thickness (*m*) for machinery strength design specified in **Table I4.1**.

S_{ice}: Ice strength index for blade ice force specified in **Table I4.1**.

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 I4.2**)

(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 I4.2**)

(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 I4.2**)

(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 I4.3**)

(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 I4.3**)

Table I4.1 Values of H_{ice} and S_{ice}

Polar class	H_{ice}	S_{ice}
$PC1$	4.0	1.2
$PC2$	3.5	1.1
$PC3$	3.0	1.1
$PC4$	2.5	1.1
$PC5$	2.0	1.1
$PC6$	1.75	1
$PC7$	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 $D < D_{limit}$

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

when $D \geq D_{limit}$

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

where $D_{limit} = \frac{2}{\left(1-\frac{d}{D}\right)} \cdot H_{ice} \quad (m)$

(2) For ducted propellers:

when $D \leq D_{limit}$

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

when $D > D_{limit}$

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

where $D_{limit} = \frac{2}{\left(1 - \frac{d}{D}\right)} \cdot H_{ice} \quad (m)$

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 I4.2**)

(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 I4.2**)

(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 I4.2**)

(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 I4.3**)

(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 I4.3**)

Table I4.2 Load cases for open propeller

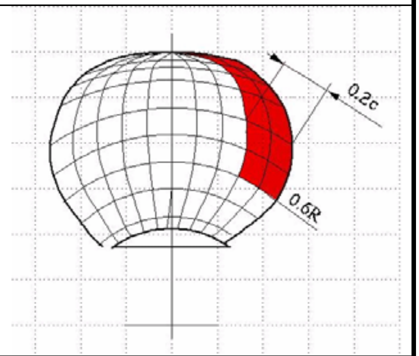
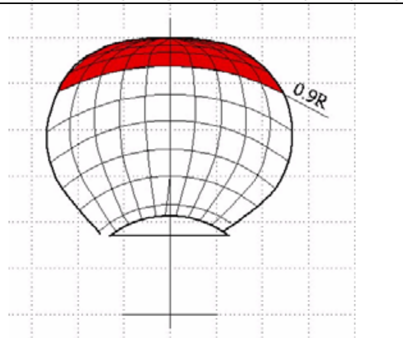
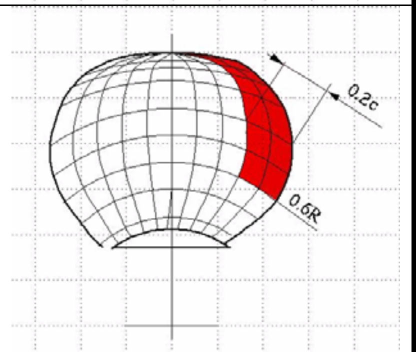
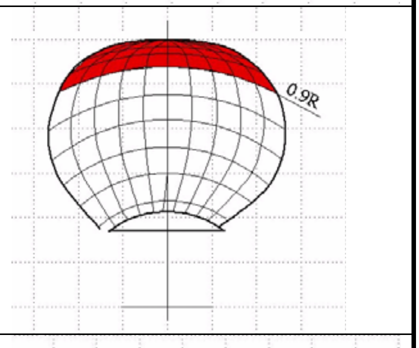
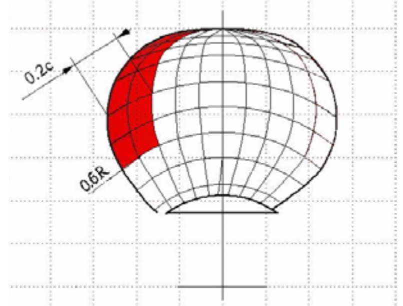
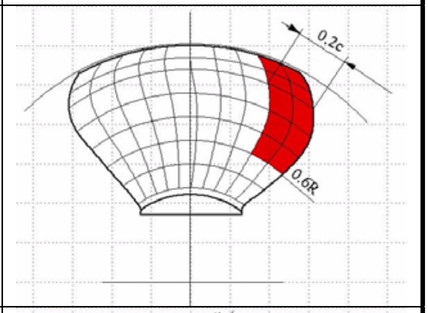
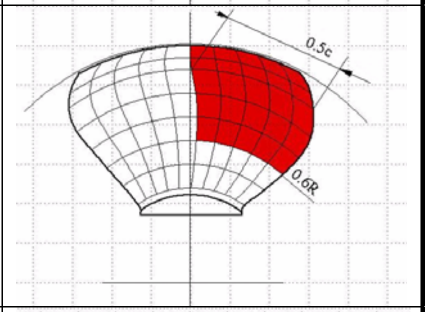
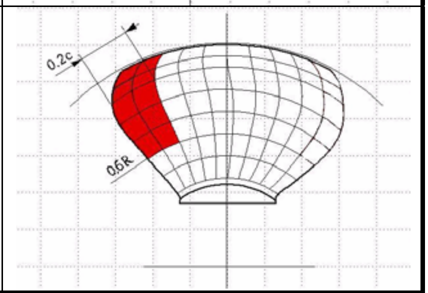
	Force	Loaded area	Right handed propeller blade seen from back
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0.6R to the tip and from the leading edge to 0.2 times the chord length	
Load case 2	50 % of F_b	Uniform pressure applied on the back of the blade (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 I4.3 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 0.6R 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 0.6R 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.

$$Q_{s\max} = 0.25 \cdot F \cdot C_{0.7} \qquad (kNm)$$

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 $D < D_{limit}$

$$Q_{\max} = 105 \cdot S_{qice} \cdot \left(1 - \frac{d}{D}\right) \cdot \left(\frac{P_{0.7}}{D}\right)^{0.16} \cdot \left(\frac{t_{0.7}}{D}\right)^{0.6} \cdot \left(\frac{n}{60} \cdot D\right)^{0.17} \cdot D^3 \qquad (kNm)$$

when $D \geq D_{limit}$

$$Q_{max} = 202 \cdot S_{qice} \cdot (H_{ice})^{1.1} \cdot \left(1 - \frac{d}{D}\right) \cdot \left(\frac{P_{0.7}}{D}\right)^{0.16} \cdot \left(\frac{t_{0.7}}{D}\right)^{0.6} \cdot \left(\frac{n}{60} \cdot D\right)^{0.17} \cdot D^{1.9} \quad (kNm)$$

where: $D_{limit} = 1.81 \cdot H_{ice}$ (m)

(2) For ducted propellers:

when $D \le D_{limit}$

$$Q_{max} = 74 \cdot S_{qice} \cdot \left(1 - \frac{d}{D}\right) \cdot \left(\frac{P_{0.7}}{D}\right)^{0.16} \cdot \left(\frac{t_{0.7}}{D}\right)^{0.6} \cdot \left(\frac{n}{60} \cdot D\right)^{0.17} \cdot D^{3} \quad (kNm)$$

when $D > D_{limit}$

$$Q_{max} = 141 \cdot S_{qice} \cdot (H_{ice})^{1.1} \cdot \left(1 - \frac{d}{D}\right) \cdot \left(\frac{P_{0.7}}{D}\right)^{0.16} \cdot \left(\frac{t_{0.7}}{D}\right)^{0.6} \cdot \left(\frac{n}{60} \cdot D\right)^{0.17} \cdot D^{1.9} \quad (kNm)$$

where: $D_{limit} = 1.8 \cdot H_{ice}$ (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 I4.4**

$P_{0.7}$: 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 I4.5**.

Table I4.4 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 I4.5 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	$0.85\,n_n$

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

$T_f = 1.1 \cdot F_f$ (kN)

(2) Maximum backward propeller ice thrust

$T_b = 1.1 \cdot F_b$ (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. I4.1**)

(a) when $\varphi = 0 \; to \; \alpha_i$ $(deg.)$

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

(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 I4.6**

(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:

$$N_Q = 2 \cdot H_{ice}$$

(b) The number of impacts:

$$Z \cdot N_Q$$

Where:

H_{ice} :As specified in **Table I4.1**

Z : Number of propeller blades

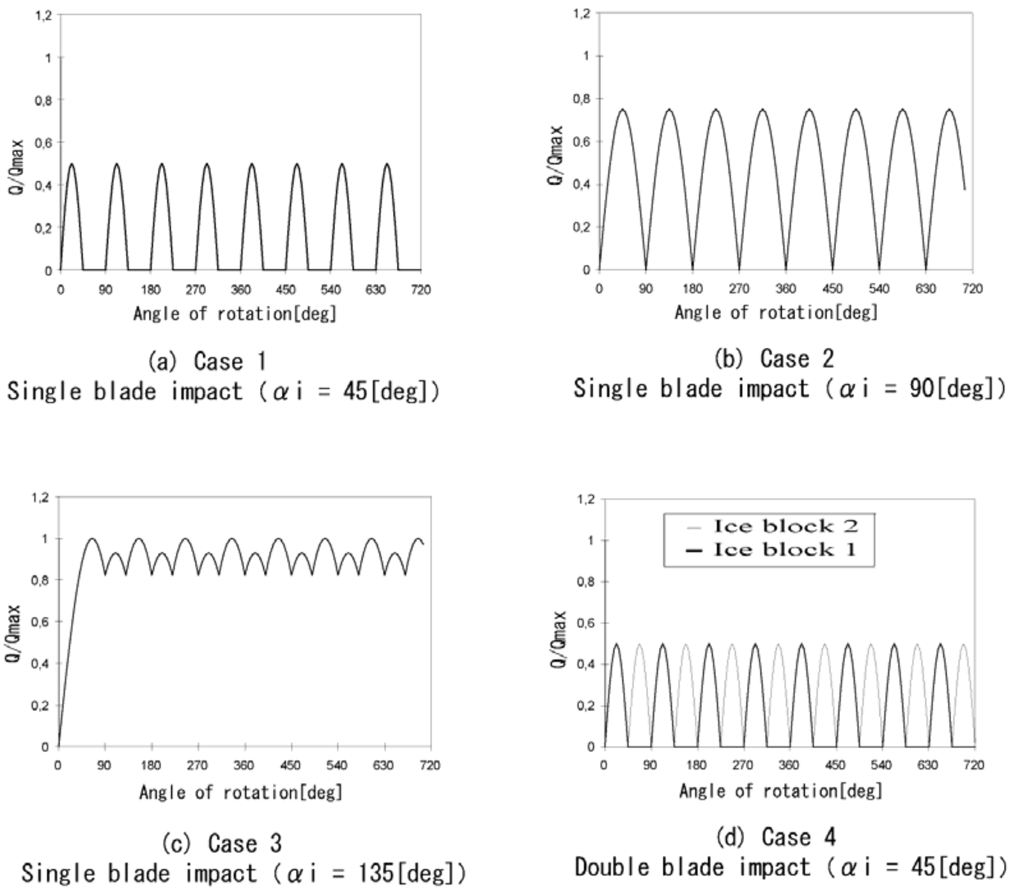
2 The response torque at any shaft component is to be analyzed considering excitation torque at the propeller specified in **-1**, actual engine torque and mass elastic system.

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 I4.6** and the response is to be applied on top of the mean hydrodynamic torque in bollard condition at the considered propeller rotational speed.

Table I4.6 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.I4.1 Example of the shape of the propeller ice torque excitation (Four bladed propeller)



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:

$T_r = T_n + \alpha \cdot T_f$ (*kN*)

(2) Maximum shaft thrust backwards:

$T_r = \beta \cdot T_b$ (*kN*)

where:

T_n : Propeller bollard thrust (*kN*) If not known, T_n is to be taken as specified in **Table I4.7**

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 I4.7 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:

$$\frac{0.3 \cdot c \cdot t^2 \cdot \sigma_{ref}}{0.8 \cdot D - 2 \cdot r} 10^3 \quad (kN)$$

where:

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

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} : $0.7 \cdot \sigma_u$ or $0.6 \cdot \sigma_{0.2} + 0.4 \cdot \sigma_u$, (*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.

$$x \cdot S \cdot S_{ice} \sqrt{\frac{3\ p_{ice}}{\sigma_{ref}}} \quad (mm)$$

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 45 *mm*. 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 45 *mm*.

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 I4.1**

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:

$$a_l = \left(\frac{F_{IB}}{\Delta}\right)\left\{\left[1.1\tan(\gamma+\phi)\right]+\left[\frac{7H}{L}\right]\right\} \qquad (m/s^2)$$

(2) Combined vertical impact acceleration at any point along the hull girder:

$$a_v = 2.5\left(\frac{F_{IB}}{\Delta}\right)F_X \qquad (m/s^2)$$

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:

$$a_t = 3F_i\frac{F_X}{\Delta} \qquad (m/s^2)$$

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**
H : Distance (*m*) from the *UIWL* to the point being considered
F_{IB} : Vertical impact force (*kN*) defined in **3.6.2-1**
F_i : Force (*kN*) defined in **3.4.2-4**

4.6 Auxiliary Systems and Piping Systems

4.6.1 Auxiliary Systems

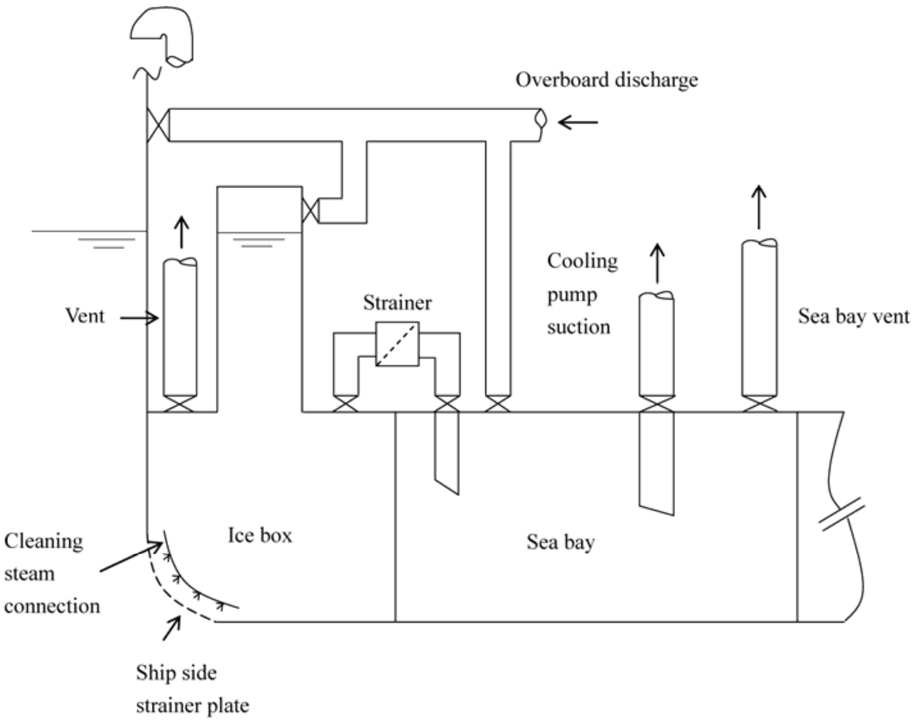
1 Machinery is to be protected from the harmful effects of ingestion or accumulation of ice or snow. Where continuous operation is necessary, means are to be provided to purge the system of accumulated ice or snow.
2 Means are to be provided to prevent tanks containing liquids to be damaged by freezing.
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 1 m^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. I4.2**)
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. Cleaning pipes are to be

provided with screw-down type non return valves.

Fig.I4.2 Example of the sea inlets and cooling water systems



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.

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.

Chapter 5 Ice Class Ships

5.1 General

5.1.1 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 2002 or in the Canadian Arctic complying with the Arctic Shipping Pollution Prevention Regulations.

5.1.2 Maximum and Minimum Draught

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, but need not exceed $4h_0$

$$(2.0 + 0.00025\Delta)h_0\ (m)$$

where:

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

h_0 : Constant given in **Table I5.1** according to the respective ice class

Table I5.1 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

5.2 Design Ice Pressures

5.2.1 Design Ice Pressures

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

$$C_d C_1 C_a p_0 \quad (MPa)$$

where:

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

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

Δ : Displacement (t) of the ship on the maximum draught specified in **5.1.2-6**

H : Engine output (kW)

a and b : As given in **Table I5.2** according to the region under consideration and the value of k.

C_1 : As given in **Table I5.3** 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 need not to exceed 1.0 and where C_a is less than 0.6, C_a is to be taken as 0.6.

$$C_a = \frac{47 - 5l_a}{44}$$

l_a :To be taken as specified in **Table I5.4** according to the structural member under consideration.

Table I5.2 Value of *a* and *b*

	Forward region		Midship & Aft region	
	$k \leq 12$	k>12	$k \leq 12$	k>12
a	30	6	8	2
b	230	518	214	286

Table I5.3 Coefficient C_1

Ice Class	Forward region	Midship region	Aft 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 I5.4 Value of l_a

Structural member	Type of framing	l_a (m)
Shell	Transverse	Frame spacing
	Longitudinal	2-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 in a vertical plane parallel to the centerline of the ship. However, if the ship's side deviates more than 20 degrees from this plane, the frame distances and spans are to be measured along the side of the ship.

2 *h* is the height of the area under the ice pressure (*P*) specified in **-1**. and is to be as given in **Table I5.5** according to the ice class.

Table I5.5 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

5.3 Hull Structures and Equipment

5.3.1 Shell Plating

1 The vertical extension of the ice belt is to be as given in **Table I5.6** 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 Midship region.

(2) Upper forward 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 midship 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 I5.6 Vertical Extension of the Ice Belt

Ice Class	Above the *UIWL*	Below the *LIWL*
I*A Super*	0.6*m*	0.75*m*
I*A*	0.5*m*	0.6*m*
I*B*	0.4*m*	0.5*m*
I*C*	0.4*m*	0.5*m*
I*D*	0.4*m*	0.5*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: $667s\sqrt{\dfrac{f_1 p_{PL}}{\sigma_y}}+t_c$ (mm)

For the longitudinal framing: $667s\sqrt{\dfrac{p_{PL}}{f_2\sigma_y}}+t_c$ (mm)

where:

s : Frame spacing (m)

p_{PL} : 0.75p (MPa)

p : As specified in **5.2.1-1**

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

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

h : As specified in **5.2.1-2**

σ_y : Yield stress of the materials (N/mm^2): For mild steel σ_y is to be taken as 235 N/mm^2

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

5.3.2 General Requirements for Frames

1 The vertical extension of the ice strengthening of the framing is to be at least as given in **Table I5.7** according to the respective ice classes and regions. Where an upper forward ice belt is required in **5.3.1-1**, 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 all the supporting web frames and bulkheads by brackets. 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 region for I*A Super* ice class ships, in the forward and midship regions for I*A* ice class ships and in the forward regions for I*B*, I*C* and I*D* ice class ships, followings are to apply in the ice strengthening area.

(1) Frames which are at a small angle to the shell, are to be supported against tripping by brackets, intercostals, stringers or similar at a distance preferably not exceeding 1,300 *mm*.

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

(3) The web thickness of the frames is to be at least one half of the thickness of the shell plating and at least 9 *mm*.

(4) 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 **(3)**, to a depth corresponding to the height of adjacent frames.

Table I5.7 Vertical Extension of the Ice Strengthening of Framing

Ice Class	Region		Above the *UIWL* (*m*)	Below the *LIWL* (*m*)
I*A Super*	forward	from stem to 0.3*L* abaft it	1.2	to double bottom or below top of floors
		abaft 0.3*L* from stem	1.2	1.6
	midship		1.2	1.6
	aft		1.2	1.2
I*A* I*B* I*C*	forward	from stem to 0.3*L* abaft it	1.0	1.6
		abaft 0.3*L* from stem	1.0	1.3
	midship		1.0	1.3
	aft		1.0	1.0
I*D*	forward	from stem to 0.3*L* abaft it	1.0	1.6
		abaft 0.3*L* from stem	1.0	1.3

5.3.3 Transverse Frames

1 The section modulus of a main or intermediate transverse frame specified in **5.3.2-1** is to be not less than that obtained from the following formula:

$$\frac{pshl}{m_t \sigma_y} \times 10^6 \quad (cm^3)$$

where:

p: As specified in **5.2.1-1**

s: Frame spacing (m) (See the note to **Table I5.4**)

h: As specified in **5.2.1-2**

l: Span of the frame (m) (See the note to **Table I5.4**)

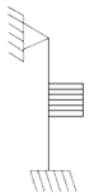
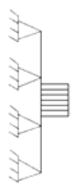
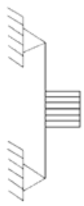
m_t: As given by the following formula

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

m_0: As specified in **Table I5.8**

σ_y: As specified in **5.3.1-2**.

Table I5.8 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 **5.3.5**. 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. Where an intermediate frame is outside the forward region and the higher deck is situated more than 1.8 *m* above the ice belt, an upper termination of such an intermediate frame may be decided as appropriately.

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 **5.3.5**. 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.

5.3.4 Longitudinal Frames

1 The spacing of longitudinal frames in the extension specified in **5.3.2-1** is not to exceed 0.35 *m* for I*A Super* and I*A* ice class ships and is to be in no case exceed 0.45 *m*. Where deemed as necessary by the Society, larger frame spacing may be permitted.

2 The section modulus and shear area of a longitudinal frame in the extension specified in **5.3.2-1** are not to be less than those obtained by the following formulae:

Section modulus : $\frac{f_3 f_4 p h l^2}{m \sigma_y} \times 10^6 \quad (cm^3)$

Shear area : $\frac{\sqrt{3} f_3 p h l}{2 \sigma_y} \times 10^4 \quad (cm^2)$

f_3 : Factor which takes account of the load distribution to adjacent frames as given by the following formula.
$(1 - 0.2h/s)$

h : As specified in **5.2.1-2**

s : Frame spacing (*m*) (See the note to **Table I5.4**)

f_4 : Factor which takes account of the concentration of load to the point of support is to be taken as 0.6.

p : As specified in **5.2.1-1**

l : Span of the longitudinal frame (*m*) (See the note to **Table I5.4**)

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.

σ_y : As specified in **5.3.1-2**

5.3.5 Ice Stringers

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

Section modulus : $\dfrac{f_5 phl^2}{m\ \sigma_y} \times 10^6 \qquad (cm^3)$

Shear area : $\dfrac{\sqrt{3} f_5 phl}{2\sigma_y} \times 10^4 \qquad (cm^2)$

f_5: Factor which takes account of the distribution of load to the transverse frames is to be taken as 0.9.

p: As specified in **5.2.1-1**

h: As specified in **5.2.1-2**

However, the product of p and h is not to be taken as less than 0.30

l: Span of the stringer (*m*)

m : Boundary condition factor as defined in **5.3.4-2**

σ_y: As specified in **5.3.1-2**

2 The section modulus and 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 : $\dfrac{f_6 phl^2}{m\ \sigma_y}(1 - h_s / l_s) \times 10^6 \qquad (cm^3)$

Shear area : $\dfrac{\sqrt{3} f_6 phl}{2\sigma_y}(1 - h_s / l_s) \times 10^4 \qquad (cm^2)$

f_6: Factor which takes account of load to the transverse frames is to be taken as 0.95.

p: As specified in **5.2.1-1**

h: As specified in **5.2.1-2**

However, the product of p and h is not to be taken as less than 0.30

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 **5.3.4-2**

σ_y: As specified in **5.3.1-2**

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 $p \times h$ may by taken as less than 0.30 but in no case less than 0.20. 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.

5.3.6 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:

$phs \quad (MN)$

p: Ice pressure (*MPa*) as specified in **5.2.1-1**, in calculating C_a however, l_a is to be taken as $2s$.

h: As specified in **5.2.1-2**

However, the product of p and h is not to be taken as less than 0.30

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:

$phs \cdot (1 - h_s / l_s)$ (MN)

h_s and l_s : As specified in **5.3.5-2**

3 When a web frame is represented by the structure model shown in **Fig. I5.2**, the section modulus and shear area are to be calculated by the following formulae:

Shear area: $\dfrac{\sqrt{3} \cdot \alpha Q}{\sigma_y} \times 10^4$ (cm^2)

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

Q : Maximum calculated shear force under the load (F) transferred to a web frame from an ice stringer or from longitudinal framing, as given in the following formula:

$Q = k_1 \cdot F$

M : Maximum calculated bending moment under the load (F) transferred to a web frame from an ice stringer or from longitudinal framing, as given in the following formula:

$M = k_2 \cdot F \cdot l$

k_1 : The value is not to be less than those obtained from the following formulae, whichever is greater. For the lower part of the web frame the smallest l_F within the ice belt is to be used. For the upper part of the biggest l_F within the ice belt is to be taken.

$1 + 0.5(l_F / l)^3 - 1.5(l_F / l)^2$

$1.5(l_F / l)^2 - 0.5(l_F / l)^3$

k_2 : As given by the following formula:

$0.5(l_f / l)^3 - 1.5(l_f / l)^2 + (l_f / l)$

F : As specified in **-1** or **-2**

l : Span (m) of the web frame

l_F : Distance (m) from the lowest support of the web frame to the stringer or longitudinal in question

α and γ : As given in **Table I5.9**. For intermediate values of A_f / A_w is to be obtained by linear interpolation.

A : Required shear area (cm^2) obtained by using k_1 obtained by the following formula:

$1 + 0.5(l_F / l)^3 - 1.5(l_F / l)^2$

A_a : Actual cross sectional area (cm^2) of the web frame

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

A_w : Cross sectional area (cm^2) of web plate

σ_y : As specified in **5.3.1-2**

Fig. I5.2 Structural Model of Web Frame

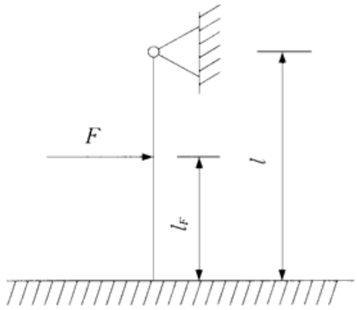


Table I5.9 Value of α and γ

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 For other web frame configurations and boundary condition than specified in the preceding **-3**, a direct stress calculation is to be carried out. The concentrated load on the web frame is specified in the preceding **-1.** The point of application is in each case to be chosen in relation to the arrangement of stringers and longitudinal frames so as to obtain the maximum shear and bending moments. Allowable stresses are specified in **Table I5.10**.

Table I5.10 Allowable stresses

Stress	Allowable stress
Shear stress (τ)	$\sigma_y / \sqrt{3}$
Bending stress (σ_b)	σ_y
Equivalent stress ($\sigma_c = \sqrt{\sigma_b^2 + 3\tau^2}$)	σ_y

Note:

σ_y : As specified in **5.3.1-2**

5.3.7 Stem

1 A sharp edged stem as given by **Fig. I5.3** improves the maneuverability of the ship in ice and is recommended particularly for smaller ships with length below 150 *metres*.

2 The plate thickness of a shaped plate stem and in the case of a blunt bow, any part of the shell which forms an angle of 30 *degrees* or more to the centre line in a horizontal plane, is to be obtained from the formula in **5.3.1-2**

where:

s : Spacing (m) of elements supporting the plate

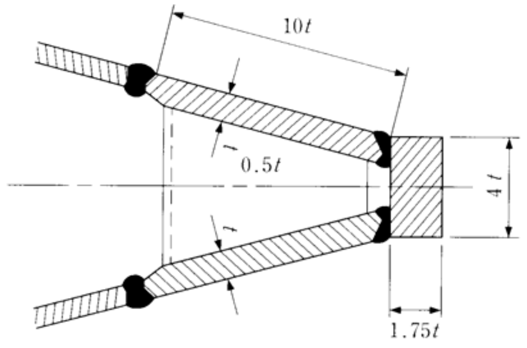
p_{PL} : Pressure (*MPa*) as specified in **5.2.1**

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 0.6 *m* 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 forward ice belt is required in **5.3.1-1** to the upper limit of this.

Fig. I5.3 Shape Edged Stem



t = Thickness (*mm*) of side plating

5.3.8 Arrangements for Towing

1 A mooring pipe with an opening not less than 250 by 300 *mm*, a length of at least 150 *mm* and an inner surface radius of at least 100 *mm* is to be fitted in the bow bulwark at the centre line.

2 A bitt or other means for securing a towline, dimensioned to stand the breaking force of the towline of the ship is to be fitted.

3 On ships with a displacement not exceeding 30,000 *tons* the part of the bow which extends to a height of at least 5 *metres* above the *UIWL* and at least 3 *metres* back from the stem, is to be strengthened to take the stresses caused by fork towing. For this purpose intermediate frames is to be fitted and the framing is to be supported by stringers or decks.

5.3.9 Stern

1 The clearance between the propeller blade tip and the stern frame is to be sufficient 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 A wide transom stern extending below the *UIWL* will seriously impede the capability of the ship to back 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 as for the midship region.

5 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 aft region and the stern area. This fact is to be considered in the design of the aft/stern structure.

5.3.10 Bilge Keel

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 It is recommended that bilge keels are cut up into several shorter independent lengths.

5.4 Propulsion Systems

5.4.1 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*.

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

H : Engine output (*kW*)

K_e : Constant given in **Table I5.11**

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

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

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** and a draught amidships of length L_f corresponding to the *LIWL* according to **1.2.4-2**.

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. I5.4**

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*, see **Fig. I5.4.**

A_{wf} : Area (m^2) of the waterline of the bow at the actual ice class draught, see **Fig. I5.4.**

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

φ_1, φ_2, α : The angle (*deg*) between the ship and the water plane at the actual ice class draught, see **Fig. I5.4**. Where the value of φ_1 and φ_2 is greater than 90 *degrees*, 90 *degrees* is to be used in the calculations.

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

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

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

(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 I5.12**

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

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

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

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

f_1, f_2, f_3, f_4, g_1, g_2 and g_3 : Value given in **Table I5.12**

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.

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

Fig. I5.4 Dimensions

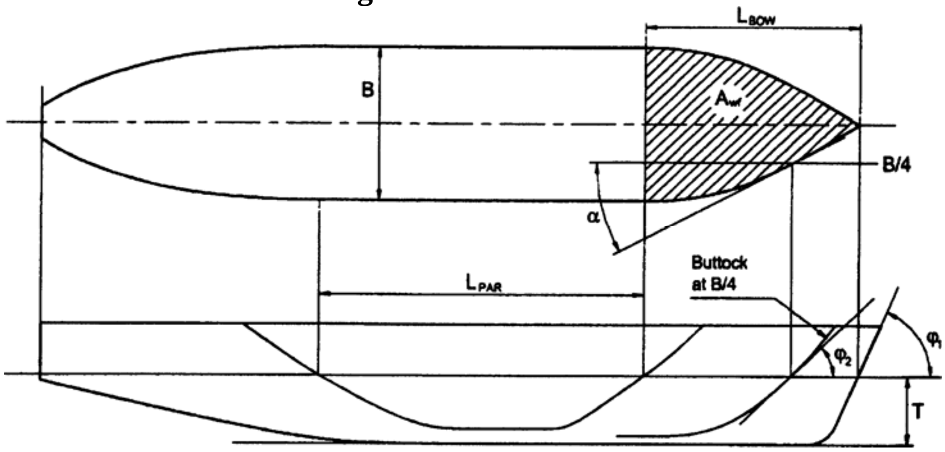


Table I5.11 Value of Constant K_e

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 I5.12 Value of f_1, f_2, f_3, f_4, g_1, g_2, g_3, C_3, C_4, C_5

f_1 :	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 2005 or 1 January in the year when 20 *years* have elapsed since the year the ship was delivered, whichever comes the latest. 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**.

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

H : Engine output (*kW*)

K_e : Constant given in **Table I5.11**

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*)

$$R_{CH} = C_1 + C_2 + C_3(H_F + H_M)^2(B + 0.658H_F) + C_4LH_F^2 + C_5(LT/B^2)^3(B/4)$$

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

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

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

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

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

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

(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 I5.13**

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.

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

Table I5.13 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:	845 (N/m^3)
f_2:	45.8 (N/m)	g_2:	170 (N/m)	C_4:	42 (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 I5.14**, 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: 1.0 *m* of the brash ice and a 0.1 *m* thick consolidated layer of ice

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

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

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

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

5.4.2 Ice Torque

1 Dimensions of propellers, shafting and gearing are to be determined taking into account the impact when a propeller blade hits ice. The ensuing load is hereinafter called the ice torque.

2 The ice torque (*M*) is to be less than the value determined by the following formula when the ice torque is used for the calculation of propeller in **5.4.3** and reduction gears in **5.4.5**:

mD_p^2 (*kN-m*)

where:

D_p: Diameter of propeller (*m*)

m: Constant given in **Table I5.15**

3 If the propeller is not fully submerged when the ship is in ballast condition, the ice torque for ice class ships with I*A* is to be used for ice class ships with I*B*, I*C* and I*D*.

Table I5.14 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
$A_{wf}/(L \cdot B)$	0.09	0.27

Table I5.15 Value of Constant *m*

Ice Class	*m*
I*A Super*	21.09
I*A*	15.70
I*B*	13.05
I*C*	11.97
I*D*	11.97

5.4.3 Propellers

1 As for the materials of the propellers, the elongation of the materials used is not to be less than 19% for *U*14*A* test specimen specified in **Part K**, and absorbed energy for the Charpy impact test is not to be less than 21 *J* at -10°C for *U*4 test specimen specified in **Part K**.

2 Width and thickness of the propeller at each blade section specified below are to be determined as follows, the blade thickness at $0.125D_P$ radius, however, is not to be less than the value determined by the formula in **7.2.1, Part D**.

(1) For solid propellers

at the radius $0.125D_P$:

$$wt^2 = \frac{26490}{\sigma_b\left(0.65 + 0.7\,P/D_P\right)}\left(27.2\frac{H_S}{ZR} + 2.24M\right)$$

at the radius $0.3D_P$:

$$wt^2 = \frac{9320}{\sigma_b\left(0.65 + 0.7\,P/D_P\right)}\left(27.2\frac{H_S}{ZR} + 2.85M\right)$$

(2) For controllable pitch propellers

at the radius $0.175D_P$:

$$wt^2 = \frac{21090}{\sigma_b\left(0.65 + 0.7\,P/D_P\right)}\left(27.2\frac{H_S}{ZR} + 2.34M\right)$$

at the radius $0.3D_P$:

$$wt^2 = \frac{9320}{\sigma_b\left(0.65 + 0.7\,P/D_P\right)}\left(27.2\frac{H_S}{ZR} + 2.85M\right)$$

w: Length (*cm*) of the expanded cylindrical section of the blade, at the radius in question

t: The corresponding maximum blade thickness (*cm*)

P : Propeller pitch (*m*) at the radius in question. For controllable pitch propeller, 70% of the nominal pitch is to be used.

D_P : Diameter (*m*) of propeller

H_S : Shaft engine output (*kW*)

Z : Number of blades

R : Number of revolution (*rpm*) at the maximum continuous engine output of main engine

σ_b : Specified minimum tensile strength (*N/mm*^{2}) of the propeller blade material

3 The blade tip thickness at the radius $0.5D_p$ is not less than the value determined by the following formula:

(1) I*A Super* ice class ships $(20 + 2D_p)\sqrt{\frac{490}{\sigma_b}}$ (*mm*)

(2) Ice class ships other than I*A Super* $(15 + 2D_p)\sqrt{\frac{490}{\sigma_b}}$ (*mm*)

where:

D_p and σ_b :As specified in **-2**

4 The blade thickness of other sections is to conform to a smooth curve connecting the section thickness as determined by the above **-2** and **-3**.

5 The thickness of blade edges is to be less than 50% of the blade tip thickness determined by the above **-3** For solid propellers, the measured points are the position equal to 1.25 *times* the required blade tip thickness in the above **-3** from leading and following edges, respectively. For controllable pitch propellers, this applies only to the leading edge.

6 The strength of mechanisms in the boss of a controllable pitch propeller is to be 1.5 *times* that of the blade, when a load is applied at the radius $0.45D_p$ in the weakest direction of the blade.

5.4.4 Shaftings

1 The diameter of the propeller shaft at the stern tube bearing is not to be less than obtained from the following formula:

$$10.8\sqrt[3]{\frac{\sigma_b wt^2}{\sigma_y}} \quad (mm)$$

where:

w : Actual length (*cm*) of the expanded section of the blade at the radius $0.125D_p$

t : Actual maximum blade thickness (*cm*) at the radius $0.125D_p$

σ_b : Specified minimum tensile strength (*N /mm*^{2}) of the propeller blade material

σ_y : Specified minimum yield point (*N /mm*^{2}) of the propeller shaft material

2 If the shaft diameter of the propeller boss is greater than $0.25D_p$, the diameter of the propeller shaft at stern tube bearing is not to be less than that obtained from the following formula:

$$11.5\sqrt[3]{\frac{\sigma_b wt^2}{\sigma_y}} \quad (mm)$$

where:

w : Actual length (*cm*) of expanded section of the blade at the radius $0.175D_p$

t : Actual maximum blade thickness (*cm*) at the radius $0.175D_p$

σ_b and σ_y : As specified in **-1**

3 If the shaft diameter derived from the above **-1** or **-2** is less than the required diameter specified in **6.2.4, Part D**, the latter is to be used.

4 For I*A Super* ice class ships, the diameters of intermediate shafts and thrust shafts in external bearings are not to be less than 1.1 *times* the required value, specified in **6.2.2** and **6.2.3, Part D**, respectively.

5.4.5 Reduction Gearing

1 Where the reduction gearing is fitted between the main engine and the propeller shafting, the external load magnification coefficient K_1 specified in **5.3.3, Part D**, is to be substituted by the value determined by the following formula:

$$\frac{1}{\frac{1}{K_1}+\frac{1}{1+J_1/J_h}\cdot\frac{M}{M_0}}$$

where:

K_1 : Coefficient specified in **5.3.3, Part D**

M : Ice torque (*kN-m*) specified in **5.4.2.**

M_0 : Mean torque of the propeller shaft determined by the following formula.

$M_0 = 9.55 H_S / R$ (*kN-m*)

H_S : Shaft engine output (*kW*)

R :Number of revolution (*rpm*) at the maximum continuous engine output of engine

J_1 : Total mass moment of inertia of the output shaft of the reduction gearing, propeller and propulsion shafting, where including propeller with an additional mass of 30% for water.

J_h : Total mass moment of inertia the main engine, flywheel and reduction gearing except output shaft. Where the revolutions of the engine differ from those of the propeller, equivalent mass moment of inertia corrected by the gear ratio is to be used.

5.4.6 Starting Arrangements

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

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

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

5.4.7 Sea Inlet and Cooling Water Systems

1 The cooling water system is to be designed to ensure a supply of cooling water when navigating in ice.

2 To satisfy the preceding **-1**, 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 in **(2)**, **(3)** and **(5)**:

(1) The sea inlet is to be situated near the centre line of the ship and well aft if possible.

(2) As a guidance for design the volume of sea chest is to be about $1m^3$ for every 750*kW* engine output of the ship including the out put of auxiliary engines necessary for the ship's service.

(3) The sea chest is to be sufficiently high to allow ice to accumulate above the inlet pipe.

(4) A pipe for discharge cooling water, allowing full capacity discharge, is to be connected to sea chest.

(5) The area through grating holes is not to be less than 4 *times* the inlet pipe sectional area.

3 Where more than two sea chests are arranged, requirements of the preceding **-2(2)** and **(3)** above may be suitably considered. In this case, these sea chests are to be arranged for alternating intake and discharge of cooling water, as well as the requirements in the preceding **(1)**, **(4)** and **(5)** are complied with.

4 Heating coils may be installed in the upper part of the chest or chests.

5.4.8 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 this Part 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 I5.16**.

Table I5.16 Minimum Speed

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

2 For I*A Super* and I*A* ice class ships, the rudder stock and the upper edge of the rudder are to be protected against ice pressure by an ice knife or equivalent means.

3 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 effective.

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

(3) Where possible, rudder stoppers working on the blade or rudder stock are to be fitted.

EFFECTIVE DATE AND APPLICATION (Amendment 1-1)

1. The effective date of the amendments is 1 March 2008.

2. Notwithstanding the amendments to the Rules, the current requirements may apply to ships for which the date of contract for construction* is before the effective date.
*"contract for construction" is defined in IACS Procedural Requirement(PR) No.29 (Rev.4).

IACS PR No.29 (Rev.4)

1. The date of "contract for construction" of a vessel is the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. This date and the construction numbers (i.e. hull numbers) of all the vessels included in the contract are to be declared to the classification society by the party applying for the assignment of class to a newbuilding.

2. The date of "contract for construction" of a series of vessels, including specified optional vessels for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective owner and the shipbuilder.
For the purpose of this Procedural Requirement, vessels built under a single contract for construction are considered a "series of vessels" if they are built to the same approved plans for classification purposes. However, vessels within a series may have design alterations from the original design provided:
(1) such alterations do not affect matters related to classification, or
(2) If the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective owner and the shipbuilder or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to the Society for approval.
The optional vessels will be considered part of the same series of vessels if the option is exercised not later than 1 year after the contract to build the series was signed.

3. If a contract for construction is later amended to include additional vessels or additional options, the date of "contract for construction" for such vessels is the date on which the amendment to the contract, is signed between the prospective owner and the shipbuilder. The amendment to the contract is to be considered as a "new contract" to which **1.** and **2.** above apply.

4. If a contract for construction is amended to change the ship type, the date of "contract for construction" of this modified vessel, or vessels, is the date on which revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder.

Notes:
1. This Procedural Requirement applies to all IACS Members and Associates.
2. This Procedural Requirement is effective for ships "contracted for construction" on or after 1 January 2005.
3. Revision 2 of this Procedural Requirement is effective for ships "contracted for construction" on or after 1 April 2006.
4. Revision 3 of this Procedural Requirement was approved on 5 January 2007 with immediate effect.
5. Revision 4 of this Procedural Requirement was adopted on 21 June 2007 with immediate effect.

Amendment 1-2

Chapter 5 Ice Class Ships

5.1 General

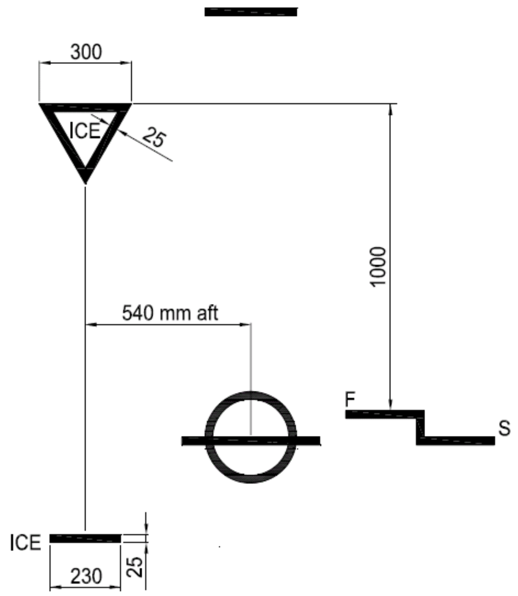
5.1.2 Maximum and Minimum Draught

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 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. I5.1**)

Fig. I5.1 Ice Class Draught Marking



Notes

1. The upper edge of the warning triangle is to be located vertically above the Ice mark, 1000 *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.

EFFECTIVE DATE AND APPLICATION (Amendment 1-2)

1. The effective date of the amendments is 1 July 2007.

2. Notwithstanding the amendments to the Rules, the current requirements may apply to ships the keels of which were laid or which were at *a similar stage of construction* before the effective date.

(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

Notice No.51 27th September 2007
Resolved by Technical Committee on 2nd July 2007

Notice No.51 27th September 2007
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 has newly established as follows:

GUIDANCE FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

Part I Polar Class Ships and Ice Class Ships

I1 GENERAL APPLICATION

I1.1 General

I1.1.1 Apprication

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

I2.2.2 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 Classification of Ice Strengthening

1 The correspondence of ice classes specified in **1.2.3, Part I of the Rules** with those in the *Finnish-Swedish Ice Class Rules* 2002 is as given in **Table I1.2.3-1**.

2 The correspondence of ice classes specified in **1.2.3, Part I of the Rules** with those in the *Arctic Shipping Pollution Prevention Regulations* is as given in **Table I1.2.3-2**.

Table I1.2.3-1 The correspondence of ice classes between the Rules and the Finnish-Swedish Ice Class Rules 2002

Ice Class of the _Finnish-Swedish Ice Class Rules_ 2002	Ice Class of the Rules
I_A Super_	NS*(Class **I**_A Super_ Ice Strengthening) NS (Class **I**_A Super_ Ice Strengthening)
I_A_	NS*(Class **I**_A_ Ice Strengthening) NS (Class **I**_A_ Ice Strengthening)
I_B_	NS*(Class **I**_B_ Ice Strengthening) NS (Class **I**_B_ Ice Strengthening)
I_C_	NS*(Class **I**_C_ Ice Strengthening) NS (Class **I**_C_ Ice Strengthening)
II	NS*(Class **I**_D_ Ice Strengthening) NS (Class **I**_D_ Ice Strengthening) NS* NS

Table I1.2.3-2 The correspondence of ice classes between the Rules and the Arctic Shipping Pollution Prevention Regulations

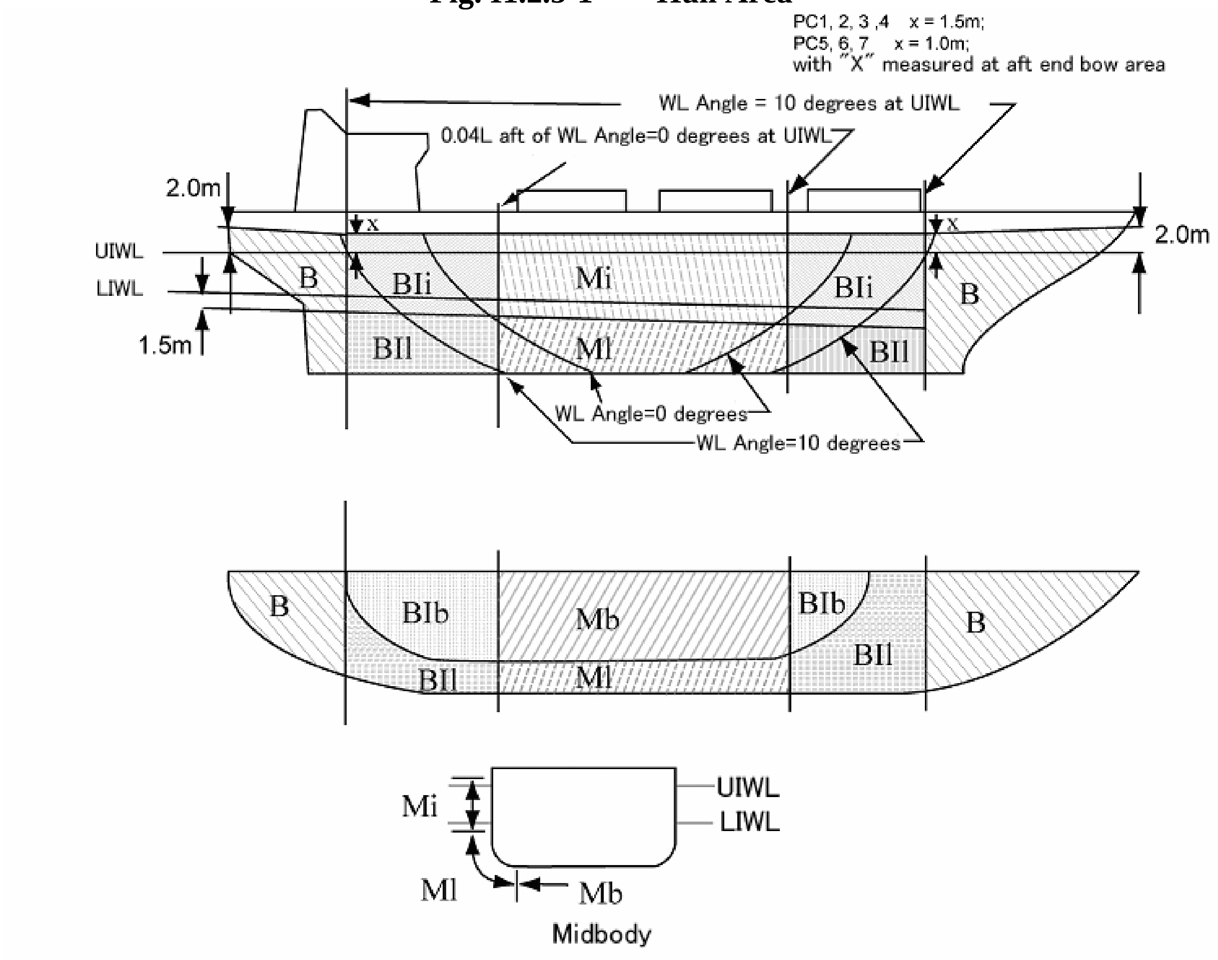
Ice Class of the _Arctic shipping Pollution Prevention Regulations_	Ice Class of the Rules
Type A	NS*(Class **I**_A Super_ Ice Strengthening) NS (Class **I**_A Super_ Ice Strengthening)
Type B	NS*(Class **I**_A_ Ice Strengthening) NS (Class **I**_A_ Ice Strengthening)
Type C	NS*(Class **I**_B_ Ice Strengthening) NS (Class **I**_B_ Ice Strengthening)
Type D	NS*(Class **I**_C_ Ice Strengthening) NS (Class **I**_C_ Ice Strengthening) NS*(Class **I**_D_ Ice Strengthening) NS (Class **I**_D_ Ice Strengthening)
Type E	NS* NS

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 For the application of **Chapter 5, 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, 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

I2 MATERIALS AND WELDINGS

I2.1 Material

I2.1.2 Material Classes

1 Where stainless clad steel is used for hull structure, **Table I2.3**, **Table I2.4** and **Table I2.5** are to apply according to thickness of the base metal in lieu of thickness of the plates.

2 For the ships designed by determining a design temperature based on **2.1.2-3, Part I of the Rules**, the application of steels is to be suitable for the requirements of **C1.1.12-1.** 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**.

I3 Hull Structure

I3.2 Stability

I3.2.1 Accretion of Ice

1 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 30 kg/m^2 or more is to be considered for the horizontal area on the weather exposed deck.

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

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

I5 Ice Class Ships

I5.1 General

I5.1.1 Application

1 For ice class ships trading in Northern Baltic in the winter under the control of the regulation "*Finnish-Swedish Ice Class Rules 2002*", the regard needs to be paid to the followings as extracted from that regulation.

(1) The administrations of Sweden and Finland (hereafter the administrations) 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) Ice class ships entitled to assistance under these restrictions are requested to follow the instructions by the icebreaker when operating in icebound waters and will receive assistance when such is needed.

(3) The administrations can not take responsibility for the safety of ice class ships which enter ice bound waters ignoring the size and ice class restrictions or any instructions by the icebreakers.

(4) 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.

(5) 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.

(6) If a ship because of very unconventional proportions, hull from or propulsion arrangements, or any other characteristics, in practice turns out to have exceptionally poor ice going capability the administrations may lower its ice class.

(7) It shall be noted that for ice class ships of moderate size (displacement not exceeding 30000 *tons*) fork towing in many situations is the most efficient way of assisting in ice.

(8) Ice class ships with a bulb protruding more than 2.5 *m* forward of the forward perpendicular are often difficult to tow in this way.

(9) 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 I5.1.1-1**.

Table I5.1.1-1

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**.

I5.3 Hull Structures and Equipments

I5.3.2 General Requirements for Frames

1 With respect to the provisions of **5.3.2-2, Part I of the Rules**, for longitudinal frames, where deemed as unavoidable by the Society, no end brackets may be accepted. In this case, for facilitating transmission of the ice load to main hull structures, the web of such frames is to be attached to web frames by double lugs and web frame stiffeners, welded to the flange of the frame, fitted in way of every frame support, and effective support structures at frame terminations. In the application of the formula specified in **5.3.4-2, Part I of the Rules**, value of m is not to be taken larger than 11.

2 Where larger spacing is adopted for longitudinals according to the conditional clause in **5.3.4-1, Part I of the Rules**, web thickness of the frames specified in **5.3.2-3(3), Part I of the Rules** need not to exceed one half of the required shell plating thickness as required for frame spacing of 0.45 m assuming the yield stress of the plate not more than that used for the frame.

I5.3.4 Longitudinal Frames

1 With respect to the provisions of **5.3.4, 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 **5.3.1-1, Part I of the Rules** and those just above and below the edge of the ice belt, except where deemed necessary by the Society. 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 spacing specified in **5.3.4-1, Part I of the Rules**, the same frame spacing of s is to be extended to the second longitudinal frames above and below the ice belt.

2 With respect to the provisions of **5.3.4-2, 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 followings:

(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.

I5.3.5 Ice Stringers

With respect to the provisions of **5.3.5, 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 **I5.3.4-2**.

I5.4 Propulsion Systems

I5.4.3 Propellers

1 The diameter of blade fixing bolts of controllable pitch propellers and built-up propellers is not to be less than the value obtained from the following formula:

$$d = 1.5\sqrt{\frac{1}{\sigma_0 n}\left(\frac{\left(A + \pi M \times 10^5\right)K_3}{L} + F_c\right)}$$

where:

σ_0 : Specified yield point or 0.2% proof stress (*N/mm*^{2}) of bolt material. However, if $\sigma_0 < 0.69\sigma_B + 110.5$, it is to be taken as $0.69\sigma_B + 110.5$ and, if $\sigma_0 > 662.5$ *N/mm*^{2}, it is to be taken as 662.5 *N/mm*^{2}.

M : Ice torque (*kN-m*) specified in **5.4.2-2, Part I** of the Rules.

Other symbols used herein are the same as those specified in **7.2.2-2, Part D of the Rules**.

2 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 :

$$F_V' = F_V + 4.46\frac{M}{R_0}\times 10^5 \quad (N)$$

where:

M : Ice torque (*kN-m*) specified in **5.4.2-2, 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**.

EFFECTIVE DATE AND APPLICATION

1. The effective date of the amendments is 1 March 2008.

2. Notwithstanding the amendments to the Guidance, the current requirements may apply to ships for which the date of contract for construction* is before the effective date.
*"contract for construction" is defined in IACS Procedural Requirement(PR) No.29 (Rev.4).

IACS PR No.29 (Rev.4)

1. The date of "contract for construction" of a vessel is the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. This date and the construction numbers (i.e. hull numbers) of all the vessels included in the contract are to be declared to the classification society by the party applying for the assignment of class to a newbuilding.

2. The date of "contract for construction" of a series of vessels, including specified optional vessels for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective owner and the shipbuilder.
For the purpose of this Procedural Requirement, vessels built under a single contract for construction are considered a "series of vessels" if they are built to the same approved plans for classification purposes. However, vessels within a series may have design alterations from the original design provided:
(1) such alterations do not affect matters related to classification, or
(2) If the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective owner and the shipbuilder or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to the Society for approval.
The optional vessels will be considered part of the same series of vessels if the option is exercised not later than 1 year after the contract to build the series was signed.

3. If a contract for construction is later amended to include additional vessels or additional options, the date of "contract for construction" for such vessels is the date on which the amendment to the contract, is signed between the prospective owner and the shipbuilder. The amendment to the contract is to be considered as a "new contract" to which **1.** and **2.** above apply.

4. If a contract for construction is amended to change the ship type, the date of "contract for construction" of this modified vessel, or vessels, is the date on which revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder.

Notes:
1. This Procedural Requirement applies to all IACS Members and Associates.
2. This Procedural Requirement is effective for ships "contracted for construction" on or after 1 January 2005.
3. Revision 2 of this Procedural Requirement is effective for ships "contracted for construction" on or after 1 April 2006.
4. Revision 3 of this Procedural Requirement was approved on 5 January 2007 with immediate effect.
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