BUREAU VERITAS MARINE & OFFSHORE

RULE NOTE

SHIPS OPERATING IN POLAR WATERS AND ICEBREAKERS

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These rules are provided within the scope of the Bureau Veritas Marine & Offshore General Conditions, enclosed at the end of Part A of NR467, Rules for the Classification of Steel Ships. The latest version of these General Conditions is available on the Bureau Veritas Marine & Offshore website.

BUREAU VERITAS MARINE & OFFSHORE

Tour Alto
4 place des Saisons
92400 Courbevoie - France
+33 (0)1 55 24 70 00

marine-offshore.bureauveritas.com/rules-guidelines

Rule Note
NR527

SHIPS OPERATING IN POLAR WATERS AND ICEBREAKERS

January 2026

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Section 1 General

1 General

1.1 Application

1.1.1 This Rule Note applies to ships constructed of steel and intended for navigation in ice-infested polar waters, including icebreakers. This Rule Note gives the requirements for the assignment of:

- one of the additional class notations **POLAR CLASS**
- one of the service notations **icebreaker**
- one of the additional service features **POLAR CAT**.

The requirements of this Rule Note apply in addition to the applicable requirements of NR467 Rules for the Classification of Steel Ships.

1.1.2 Selection of an additional class notation POLAR CLASS or a service notation Icebreaker

It is the responsibility of the Owner to select an appropriate additional class notation **POLAR CLASS** or an appropriate service notation **icebreaker**. The ice descriptions given in Tab 2 and Tab 3 are intended to guide Owners, Designers and Administrations in selecting an appropriate additional class notation **POLAR CLASS** or an appropriate service notation **icebreaker** to match the requirements for the ships with its intended voyages or services.

Note 1: Complementary information may be found in NI543 Ice Reinforcement Selection in Different World Navigation Areas concerning the choice of the appropriate notation in function of the area of navigation and the period of the year.

1.1.3 Selection of an additional service feature POLAR CAT

For ships intended for navigation in polar waters and given in SOLAS XIV/2.1.1, one of the following additional service features, as defined in Article [4], is to be assigned and selected according to the ship categories of the IMO International Code for Ships Operating in Polar Waters (Polar Code):

- **POLAR CAT-A** for category A ship
- **POLAR CAT-B** for category B ship
- **POLAR CAT-C** for category C ship.

For ships not listed in SOLAS XIV/2.1.1, the assignment of an additional service feature **POLAR CAT** may be specially considered by the Society.

Polar waters means Arctic waters and/or the Antarctic area. Fig 1 and Fig 2 are given for illustrative purposes only.

Antarctic area means the sea area south of latitude 60° S.

Arctic waters means those waters which are located

a) north of a line from the latitude 58º00′.0 N and longitude 042º00′.0 W

b) to latitude 64º37′.0 N, longitude 035º27′.0 W

c) and thence by a rhumb line to latitude 67º03′.9 N, longitude 026º3′.4 W

d) and thence by a rhumb line to the latitude 70º49′.56 N and longitude 008º59′.61 W (Sørkapp, Jan Mayen)

e) and by the southern shore of Jan Mayen to 73º31′.6 N and 019º01′.0 E by the Island of Bjørnøya,

f) and thence by a great circle line to the latitude 68°38′.29 N and longitude 043°23′.08 E (Cap Kanin Nos)

g) and hence by the northern shore of the Asian Continent eastward to the Bering Strait

h) and thence from the Bering Strait westward to latitude 60º N as far as Il′pyrskiy

i) and following the 60th North parallel eastward as far as and including Etolin Strait

j) and thence by the northern shore of the North American continent as far south as latitude 60º N

k) and thence eastward along parallel of latitude 60º N, to longitude 056°37′.1 W

l) and thence to the latitude 58º00′.0 N, longitude 042º00′.0 W.

1.1.4 Definition of Icebreaker

"Icebreaker" refers to any ship 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.

1.1.5 According to the notation, the functions of the ship and its equipment, the following Sections apply:

- Sec 2: structural requirements for additional class notations **POLAR CLASS** and service notations **icebreaker**
- Sec 3: machinery requirements for additional class notations **POLAR CLASS** and service notations **icebreaker**
- Sec 4: requirements for additional service features **POLAR CAT**.

1.1.6 Restrictions

If hull and machinery are constructed such as to comply with the requirements of different additional class notations **POLAR CLASS**, then both the hull and the machinery are to be assigned the lower of these additional class notations in the Certificate of Classification. Compliance of hull or machinery with the requirements of a higher additional class notation **POLAR CLASS** is also to be indicated in the Annex to the Certificate of Classification.

The same principle applies to ships having a service notation **icebreaker**.

Figure 1 : Antarctic area

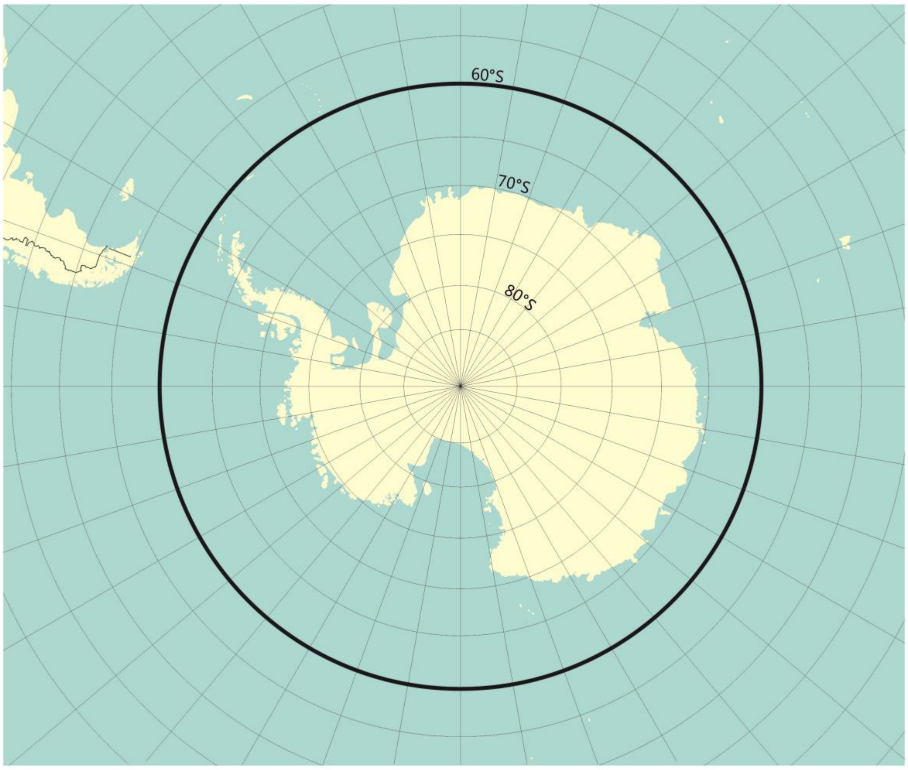


Figure 2 : Arctic waters

1.2 Additional requirement

1.2.1 Ships with additional class notation POLAR CLASS or service notation icebreaker

Ships complying with the requirements of this Rule Note in order to be assigned one of the additional class notations **POLAR CLASS** or one of the service notations **icebreaker** are also to comply with the requirements for the assignment of the additional class notation **COLD BASIC (H t_{DH} , E t_{DE})** or **COLD (H t_{DH} , E t_{DE})** (see NR467, Pt F, Ch 8, Sec 4).

Note 1: Ships with the additional class notation **POLAR CLASS 6** or **POLAR CLASS 7** and not intended to operate in low air temperature may be exempted of the additional class notation **COLD BASIC (H t_{DH} , E t_{DE})** or **COLD (H t_{DH} , E t_{DE})**.

1.2.2 Ships with additional service feature POLAR CAT

Ships complying with the requirements of this Rule Note in order to be assigned one of the additional service feature **POLAR CAT** and intended to operate in low air temperature, as defined in Sec 4, [1.2.1], are also to comply with the requirements for the assignment of the additional class notation **COLD BASIC (H t_{DH} , E t_{DE})** or **COLD (H t_{DH} , E t_{DE})**, where the temperatures t_{DH} and t_{DE} are as defined in Sec 4, [1.2.4]. The requirements for the additional class notations **COLD BASIC (H t_{DH} , E t_{DE})** and **COLD (H t_{DH} , E t_{DE})** are given in NR467, Pt F, Ch 8, Sec 4.

1.3 Ice waterlines

1.3.1 Upper ice waterline

The upper ice waterline (UIWL) is defined by the maximum draughts fore, amidships and aft, in ice navigation.

1.3.2 Lower ice waterline

The lower ice waterline (LIWL) is defined by the minimum draughts fore, amidships and aft, in ice navigation.

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

1.3.3 Information to be submitted

UIWL and LIWL upon which the design of the ship is based are to be specified by the Designer in the plans submitted for approval to the Society and are to be stated on the Certificate of Classification.

1.4 Bow form

1.4.1 Bows with vertical sides and bulbous bows are to be avoided for ships having one of the additional class notations **POLAR CLASS 1** to **POLAR CLASS 5**.

For ships having the additional class notation **POLAR CLASS 6** or **POLAR CLASS 7** and a bow with vertical sides or a bulbous bow, the operational limitations are to be explicitly stated on the Certificate of Classification (e.g. restricted from intentional ramming).

1.5 Shallow water

1.5.1 Shallow water may be considered as less than 2 metres keel clearance.

1.6 Output of propulsion machinery

1.6.1 Scope

The minimum engine output requirement given in [1.6.2] is only applicable to ships having one of the service notations **icebreaker**.

1.6.2 Minimum propulsion machinery output

The design engine output, which is the maximum output the propulsion machinery can continuously deliver to the propeller, is not to be less than the value given in Tab 1 for the corresponding service notation.

Table 1 : Minimum engine output

Service notation	Minimum engine output (kW)
icebreaker 1	44000
icebreaker 2	22000
icebreaker 3	11000
icebreaker 4	6000
icebreaker 5 **icebreaker 6** **icebreaker 7**	no minimum engine output
Note 1: For ships having the propulsion power determined by model tests or by full scale measurements, lower values of minimum engine output may be accepted, on a case-by-case basis.	

2 Additional class notations POLAR CLASS

2.1 Scope

2.1.1 Ships having one of the additional class notations **POLAR CLASS** are to have the hull form and the propulsion power such that the ship can operate independently at continuous speed in the representative ice conditions described in Tab 2.

For ships not designed to operate independently in ice, such operational intent or limitations are to be explicitly stated on the Certificate of Classification.

Ramming is to be avoided for ships with one of the additional class notations **POLAR CLASS**.

3 Service notations Icebreaker

3.1 Scope

3.1.1 Ships having one of the service notations **icebreaker** are intended to sail without icebreaker assistance up to the continuous ice conditions described in Tab 2.

Ships with one of the service notations **icebreaker 1** to **icebreaker 4** can perform unlimited ramming.

Ships with one of the service notations **icebreaker 5** to **icebreaker 7** can exceptionally perform ramming but this is not to be repeated if the ice does not fail at the first attempt.

Table 2 : POLAR CLASS and Icebreaker description

POLAR CLASS or **icebreaker**	Operations	Ice description **(1)**	Typical range of ice thickness (m) **(2)**
1	year-round	all polar waters	3,0 - 4,0
2	year-round	moderate multi-year ice	2,5 - 3,0
3	year-round	second-year ice which may include multi-year ice inclusions	2,0 - 2,5
4	year-round	thick first-year ice which may include old ice inclusions	1,5 - 2,0
5	year-round	medium first-year ice which may include old ice inclusions	1,0 - 1,5
6	summer/ autumn	medium first-year ice which may include old ice inclusions	0,7 - 1,0
7	summer/ autumn	thin first-year ice which may include old ice inclusions	0,5 - 0,7

(1) Based on World Meteorological Organization (WMO) Sea Ice Nomenclature

(2) For **POLAR CLASS** assuming independent operation in ice concentration (portion of sea covered by the ice, expressed in tenths) of less than 6/10 and for **Icebreaker** assuming independent operation in ice concentration of more than 6/10.

4 Additional service features POLAR CAT

4.1 Scope

4.1.1 The additional service features **POLAR CAT** are defined as follows:

- **POLAR CAT-A** is assigned to ships designed for operation in polar waters in at least medium first-year ice, which may include old ice inclusions
- **POLAR CAT-B** is assigned to ships designed for operation in polar waters in at least thin first-year ice, which may include old ice inclusions, but in ice conditions less severe than for **POLAR CAT-A**
- **POLAR CAT-C** is assigned to ships designed to operate in open water or ice conditions less severe than those included in **POLAR CAT-A** or **POLAR CAT-B**.

4.1.2 The allowed additional service features **POLAR CAT** are given in Tab 3 with respect to the ice classes or the service notations **Icebreaker** assigned to the ships.

Table 3 : Additional service features POLAR CAT

Ice class or service notation	**POLAR CAT-A**	**POLAR CAT-B**	**POLAR CAT-C**
POLAR CLASS 1, **POLAR CLASS 2**, **POLAR CLASS 3**, **POLAR CLASS 4**, **POLAR CLASS 5** **Icebreaker 1**, **Icebreaker 2**, **Icebreaker 3**, **Icebreaker 4**, **Icebreaker 5**	X	–	–
POLAR CLASS 6, **POLAR CLASS 7** **Icebreaker 6**, **Icebreaker 7**	–	X	–
Other or none	–	–	X

Note 1: X : Allowed; – : Not allowed.

Section 2 Structural Requirements for Polar Class Ships and Icebreakers

Symbols

L_{ui} : Rule length, in m, measured horizontally from the fore side of the stem at the intersection with the upper ice waterline (UIWL) to the after side of the rudder post, or the centre of the rudder stock if there is no rudder post. L_{UI} is not to be less than 96%, and need not be greater than 97%, of the extreme length of the upper ice waterline (UIWL) measured horizontally from the fore side of the stem. In ships with unusual stern and bow arrangement the length L_{UI} will be specially considered.

FE_{ui} : Fore end, perpendicular to the upper ice waterline (UIWL) at the forward side of the stem

AE_{ui} : Aft end, perpendicular to the upper ice waterline (UIWL) at a distance L_{ui} aft of the fore end

B_{ui} : Ship moulded breadth, in m, at the upper ice waterline (UIWL)

Δ_{ui} : Ship displacement at the upper ice waterline (UIWL), in t. Where multiple waterlines are used for determining the UIWL, the displacement is to be determined from the waterline corresponding to the greatest displacement

x : Distance, in m, from the aft end (AE_{ui}) to the section under consideration

x_i : Distance, in m, from the aft end (AE_{ui}) to the mid-length position of each sub-region of bow area

b : b_{Bow} or b_{NonBow} , in m, as appropriate for the area under consideration

b_{Bow} : Height of the design load patch, in m, in the bow area, defined in [4.3.8]

b_{NonBow} : Height of the design load patch, in m, in hull areas other than the bow area, defined in [4.4.4]

b_f : Flange width, in mm, of a stiffener (see Fig 8)

C_{AF} : Hull area factor, defined in [4.6.1]

c_{ARi} : Load patch aspect ratio, defined in [4.3.4]

C_C : Crushing failure class factor, defined in [4.2.1]

C_D : Load patch dimensions class factor, defined in [4.2.1]

c_i : Shape coefficient, defined in [4.3.3]

C_F : Flexural failure class factor, defined in [4.2.1]

C_L : Longitudinal strength class factor, defined in [4.2.1]

C_Δ : Displacement class factor, defined in [4.2.1]

C_{PP}, C_{PM}, C_{PS}: Peak pressure factors, defined in [4.5.2]

E : Young's modulus, in N/mm^2, to be taken equal to:

- $E = 2,06 \cdot 10^5$ N/mm^2 for steels in general
- $E = 1,95 \cdot 10^5$ N/mm^2 for stainless steels
- $E = 7,00 \cdot 10^4$ N/mm^2 for aluminium alloys

F_{Bow} : Total glancing impact force in the bow area, in kN, defined in [4.3.5]

F_{NonBow} : Total glancing impact force in hull areas other than the bow area, in kN, defined in [4.4.1]

h_w : Web height, in mm, of a stiffener (see Fig 8)

ℓ : Span, in m, of ordinary stiffeners

M_{SW-min} : Minimum permissible still water bending moment in seagoing condition, in kN.m, defined in NR467, Pt B, Ch 5, Sec 4, [2.2.1]

p_{avg} : Design ice load average pressure, in kN/m^2, defined in [4.5.1]

p_{Bow} : Total glancing impact pressure in the bow area, in kN/m^2, defined in [4.3.7]

q_{Bow} : Total glancing impact line load in the bow area, in kN/m, defined in [4.3.6]

q_{NonBow} : Total glancing impact line load in hull areas other than the bow area, in kN/m, defined in [4.4.3]

Q_{SW} : Permissible maximum and minimum still water shear force in seagoing condition, in kN, defined in NR467, Pt B, Ch 5, Sec 4, [2.3.1]

R_{eH} : Minimum yield stress of the material, in N/mm^2

R_m : Specified minimum tensile strength of the material, in N/mm^2, defined in NR467, Pt B, Ch 1, Sec 3, Tab 2

s : Spacing, in m, of ordinary stiffeners

t_C : Corrosion/abrasion addition, in mm, defined in [3.1]

t_f : Net flange thickness, in mm, of a stiffener (see Fig 8)

t_{net} : Net plate thickness required to resist ice loads, in mm, defined in [6.2]

t_p : Net thickness, in mm, of attached plating of a stiffener (see Fig 8)

t_w : Net web thickness, in mm, of a stiffener (see Fig 8)

w : w_{Bow} or w_{NonBow} , in m, as appropriate for the area under consideration

w_{Bow} : Width of the design load patch, in m, in the bow area, defined in [4.3.8]

w_{NonBow} : Width of the design load patch, in m, in hull areas other than the bow area, defined in [4.4.4]

α : Upper ice waterline angle, in degree (see Fig 3)

γ : Buttock angle at the upper ice waterline (angle of buttock line measured from horizontal), in degree (see Fig 3)

β : Frame angle, in degree, when the value is unknown, the frame angle may be defined by:

$\tan\beta = \tan\alpha / \tan\gamma$ (see Fig 3)

θ : Normal frame angle at the upper ice waterline, in m, defined by:

$\tan\theta = \tan\beta \cdot \cos\alpha$ (see Fig 3).

1 General

1.1 Hull areas

1.1.1 The hull of all ships having an additional class notation **POLAR CLASS** or a service notation **icebreaker** is divided into areas reflecting the magnitude of the loads that are expected to act upon them.

In the longitudinal direction, there are four regions:

- Bow (B)
- Bow Intermediate (BI)
- Midbody (M)
- Stern (S).

The Bow Intermediate, Midbody and Stern regions are further divided in the vertical direction into:

- Bottom (b)
- Lower (ℓ)
- Icebelt regions (i).

The extent of each hull area is indicated in Fig 1 for **POLAR CLASS** ships and **icebreaker** ships, where h_i , measured at aft end of Bow region, in m, is given in Tab 1.

Table 1 : Value of h_i for hull area extents

POLAR CLASS or **icebreaker**	h_i , in m
1 to **4**	1,5
5 to **7**	1,0

1.1.2 The upper ice waterline (UIWL) and the lower ice waterline (LIWL) are defined in Sec 1, [1.3].

1.1.3 The boundary between the Bow and Bow Intermediate regions is to be located:

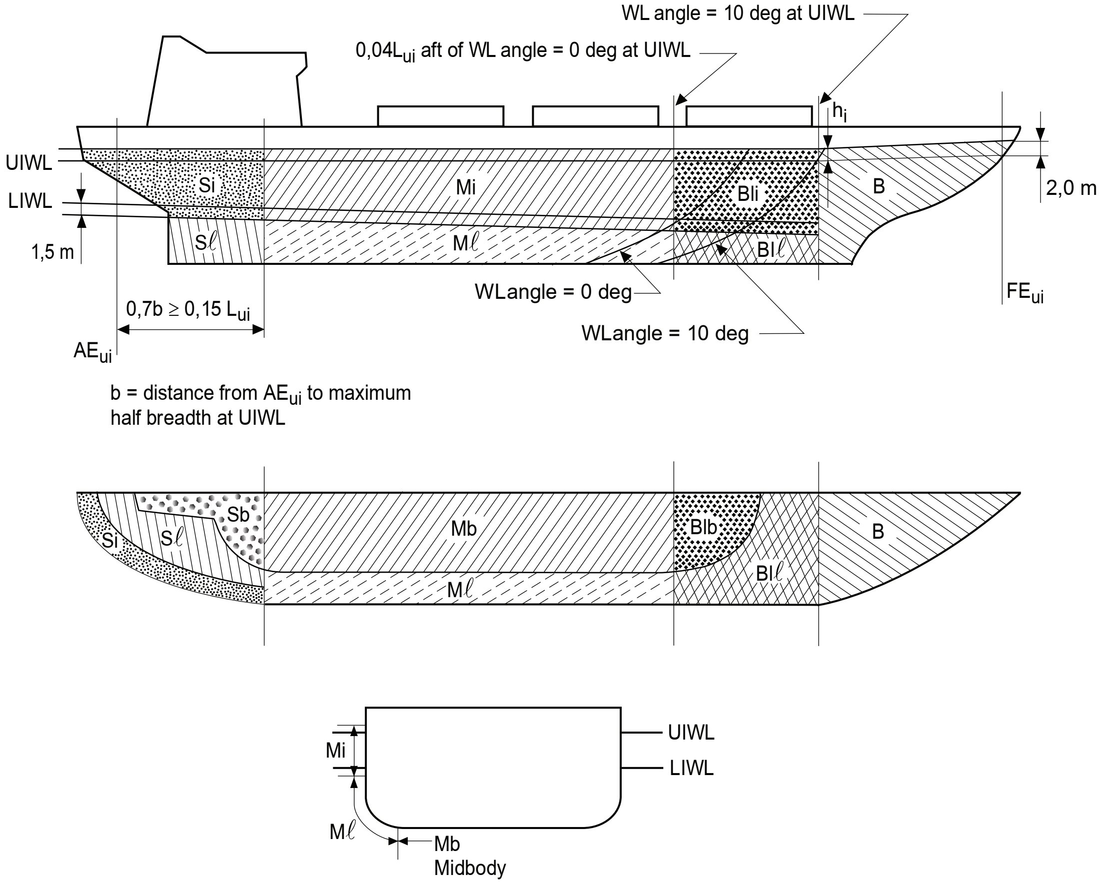
- afterward of the intersection point of the line of the stem and the ship baseline, and
- forward of 0,45 L_{ui} aft of the fore end (FE_{ui}).

1.1.4 The boundary between the bottom and lower regions is to be taken at the point where the shell is inclined 7° from the horizontal plan in any direction, including transversally and longitudinally.

1.1.5 If a ship is intended to operate astern in ice infested polar waters, the aft section of the ship is to be designed using the Bow and Bow Intermediate hull area requirements for the glancing impact scenario only (i.e. excluding the ramming impact scenario).

1.1.6 For ships having one of the service notations **icebreaker**, the forward boundary of the stern region is to be at least 0,04L_{ui} forward of the section where the parallel ship side at the upper ice waterline (UIWL) ends.

Figure 1 : Hull area extents



1.2 Hull shape

1.2.1 For ships having one of the additional class notations **POLAR CLASS** or one of the service notations **icebreaker**, the maximum values of the angles γ_{stem} and α_{bow} for the bow form (see Fig 2 with B_{ui} evaluated at the midship section) are given as a guidance in Tab 2.

Figure 2 : Definition of angles γ_{stem} and α_{bow}

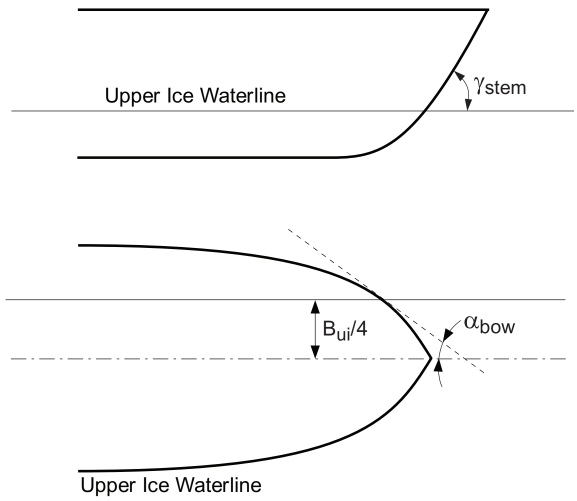


Table 2 : Maximum value of angles γ_{stem} and α_{bow} for the bow form

POLAR CLASS or **icebreaker**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Buttock angle at the stem γ_{stem} ,in degree	25	25	30	30	45	60	70
Waterline angle at the bow α_{bow}, in degree	30	30	30	30	40	40	40

2 Materials and welding

2.1 Material classes and grades

2.1.1 The material grade for hull structure is to be not less than those given in Tab 3 and Tab 5, based on the as-built thickness of the material, the assigned additional class notation **POLAR CLASS** or service notation **icebreaker**, and the material classes of structural members given in Tab 4.

2.1.2 Material classes specified in NR467, Pt B, Ch 4, Sec 1, Tab 3 are applicable to ships having one of the additional class notations **POLAR CLASS** or one of the services notations **icebreaker**, regardless of the ship length.

In addition, material classes for weather and sea exposed structural members and for members attached to the weather and sea exposed shell plating are given in Tab 4.

Where the material classes in Tab 4 and those in NR467, Pt B, Ch 4, Sec 1, Tab 3 differ, the higher material class is to be applied.

2.1.3 Material grades for all plating and attached framing of hull structures and appendages situated below the level of 0,3 m below the lower ice waterline (LIWL), as shown in Fig 4, are to be obtained from Tab 5, based on the material classes for structural members in Tab 4, regardless of the additional class notation **POLAR CLASS** or service notation **icebreaker** assigned.

2.1.4 Material grades for all weather exposed plating of hull structures and appendages, situated above the level of 0,3 m below the lower ice waterline (LIWL), as shown in Fig 4, are to be not less than those given in Tab 3.

Material grades for weather exposed equipment and machinery including foundations (e.g. winches, doors) are to be not less than those given in Tab 3 for material class II.

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

2.1.6 For other steels (e.g. austenitic-ferritic stainless steels) exposed to low external temperatures, the material is to be tested with an average transverse impact energy not less than 20 J taken from three Charpy V-notch tests at 10°C below the lowest external temperature.

Figure 3 : Definition of hull angles

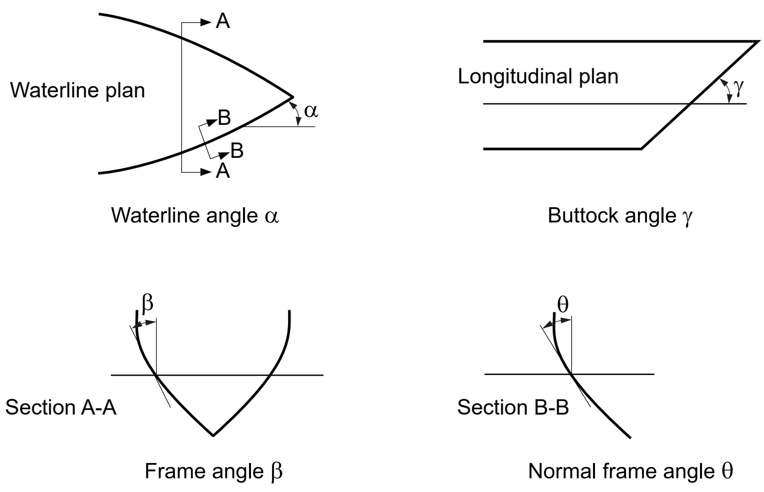


Figure 4 : Steel grade requirements for submerged and weather exposed shell plating

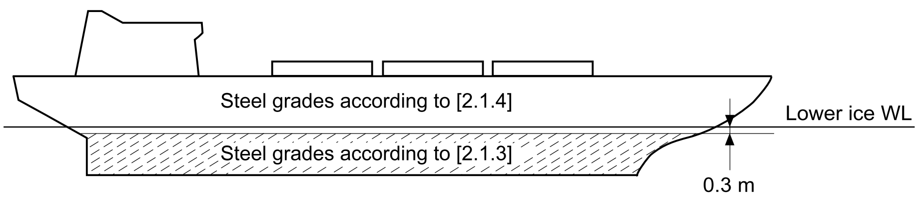


Table 3 : Material grades for weather exposed plating

As-built thickness t, in mm	POLAR CLASS or icebreaker													
	1 to **5**		**6** and **7**		**1** to **5**		**6** and **7**		**1** to **3**		**4** and **5**		**6** and **7**	
	Material class I				Material class II				Material class III					
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 10	B	AH	B	AH	B	AH	B	AH	E	EH	E	EH	B	AH
10 < t ≤ 15	B	AH	B	AH	D	DH	B	AH	E	EH	E	EH	D	DH
15 < t ≤ 20	D	DH	B	AH	D	DH	B	AH	E	EH	E	EH	D	DH
20 < t ≤ 25	D	DH	B	AH	D	DH	B	AH	E	EH	E	EH	E	EH
25 < t ≤ 30	D	DH	B	AH	E	EH **(1)**	D	DH	E	EH	E	EH	E	EH
30 < t ≤ 35	D	DH	B	AH	E	EH	D	DH	E	EH	E	EH	E	EH
35 < t ≤ 40	D	DH	D	DH	E	EH	D	DH	N.A.	FH	E	EH	E	EH
40 < t ≤ 45	E	EH	D	DH	E	EH	D	DH	N.A.	FH	E	EH	E	EH
t > 45	E	EH	D	DH	E	EH	D	DH	N.A.	FH	N.A.	FH	E	EH

(1) 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.
Note 1: Weather exposed plating includes weather-exposed plating of hull structures and appendages, as well as their outboard framing members, situated above a level of 0,3 m below the lowest ice waterline.
Note 2: "NSS" and "HSS" mean, respectively: "Normal Strength Steel" and "Higher Strength Steel".
Note 3: "N.A." means "Not Applicable".

Table 4 : Material classes for structural members

Structural member	Material class
Shell plating (including bottom and bilge) within the bow and bow intermediate icebelt hull areas (B, BI)	II
All weather and sea exposed SECONDARY and PRIMARY (as defined in NR467, Pt B, Ch4, Sec 1, Tab 3) structural members outside 0,4 L_{ui} amidships	I
Plating materials for stem and stern frames, rudder horn, rudder, propeller nozzle, shaft brackets, ice skeg, ice knife and other appendages subject to ice impact loads	II
All inboard framing members attached to the weather and sea-exposed plating including any contiguous inboard member within 600 mm of the plating	I
Weather-exposed plating and attached framing which are open to sea during cold weather operations (e.g. cargo holds of ships with open hatches during their trade or other weather exposed areas)	I
All weather and sea exposed SPECIAL (as defined in NR467, Pt B, Ch4, Sec 1, Tab 3) structural members within 0,2 L_{ui} from FE	II

Table 5 : Material grade requirements for classes I, II and III

As-built thickness t, in mm	Material class I		Material class II		Material class III	
	NSS	HSS	NSS	HSS	NSS	HSS
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
50 < t ≤ 60	D	DH	E	EH	F	FH
60 < t ≤ 80	E	EH	F	FH	F	FH
80 < t ≤ 100	F	FH	F	FH	F	FH

Note 1: "NSS" and "HSS" mean, respectively: "Normal Strength Steel" and "Higher Strength Steel".

2.2 Welding

2.2.1 All weldings within ice-strengthened areas are to be of the double continuous type.

2.2.2 Leg length

Within ice-strengthened areas, the minimum leg length of fillet weld T connections for ordinary stiffeners is to be obtained, in mm, from the formula defined in NR467, Pt B, Ch 13, Sec 3, [3.2.6], where the welding factor w_F is to be replaced by the coefficient w_{Fice}, defined as follows:

$w_{Fice} = R_0 R_1 w_F$

where:

w_F : Welding factor defined in NR467, Pt B, Ch 13, Sec 3, Tab 1

R_0 : Area coefficient to be taken as defined in Tab 6

R_1 : Area ratio to be taken equal to:

$$R_1 = \frac{A_R}{A_w}$$

not less than 0,8

A_R : Required net effective shear area, taken equal to A_t as defined in [7.5.2] or A_L as defined in [7.6.1]

A_w : Actual net effective shear area, as defined in [7.2.1]

Table 6 : Area coefficient

Location		R_0
Ordinary stiffener connection to side	In general (80% of span)	2,5
	At ends	4
Ordinary stiffener connection to bottom	In general (80% of span)	3,2
	At ends	4.5

3 Corrosion/abrasion additions and steel renewal

3.1 Corrosion/abrasion additions

3.1.1 The value of the corrosion/abrasion additions t_C to be applied to shell plating is to be taken equal to the greater of the two following values:

- t_C obtained from NR467, Pt B, Ch 4, Sec 3, [1.2]
- t_C obtained from Tab 7, subject to the fitting of an effective protection against corrosion and ice-induced abrasion.

Effective protection against corrosion and ice-induced abrasion is recommended for all external surfaces of the shell plating. This protection is to be qualified by the applicant according to a recognised standard at the discretion of the Society.

3.1.2 The value of the corrosion/abrasion additions t_C to be applied to all internal structures within the ice-strengthened hull areas, including plated members adjacent to the shell, as well as stiffeners webs and flanges, is to be taken equal to the greater of the two following values:

- t_C obtained from NR467, Pt B, Ch 4, Sec 3, [1.2]
- t_C = 1,0 mm.

Table 7 : Total corrosion/abrasion additions t_C for both sides of the shell plating

Hull area	**POLAR CLASS** or **icebreaker**					
	1 to **3**	**4** and **5**	**6** and **7**	**1** to **3**	**4** and **5**	**6** and **7**
	t_C, in mm					
	With effective protection			Without effective protection		
Bow (B) Bow Intermediate, Icebelt regions (BIi)	3,5	2,5	2,0	7,0	5,0	4,0
Bow Intermediate, Lower (BIℓ) Midboby, Icebelt regions (Mi) Stern, Icebelt regions (Si)	2,5	2,0	2,0	5,0	4,0	3,0
Midbody, Lower, Bottom (Mℓ, Mb) Stern, Lower, Bottom (Sℓ, Sb) Bow Intermediate, Bottom (BIb)	2,0	2,0	2,0	4,0	3,0	2,5

4 Design ice loads

4.1 General

4.1.1 For ships having one of the additional class notations **POLAR CLASS** or service notation**s icebreaker**, a glancing impact on the bow is the design scenario for determining the scantlings required to resist ice loads.

4.1.2 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.

4.1.3 Within the bow area for **POLAR CLASS 1** to **POLAR CLASS 7** or for **icebreaker 1** to **icebreaker 7**, and for bow intermediate icebelt area for **POLAR CLASS 6** or **POLAR CLASS 7**, the ice load parameters (p_{avg} , w and b) are function of the actual bow shape. To determine the ice load parameters, it is required to calculate the following ice load characteristics for sub-regions of the bow area:

- shape coefficient c_i
- total glancing impact force F_i
- line load q_i
- pressure p_i
- load patch aspect ratio c_{ARi} .

4.1.4 In other ice-strengthened areas, the ice load parameters (p_{avg} , w_{NonBow} and b_{NonBow}) are determined independently of the hull shape and based on a fixed load patch aspect ratio c_{AR} taken equal to:

c_{AR} = 3,6.

4.1.5 Bow with icebreaking form

Design ice loads calculated according to [4.3] are applicable for bow with icebreaking form where (see Fig 3):

- the buttock angle at the stem γ_{stem} is positive and less than 80 degree, and
- the normal frame angle θ at the centre of the foremost sub-region is greater than 10 degree.

4.1.6 Bow with non-icebreaking form

For ships having the additional class notation **POLAR CLASS 6** or **POLAR CLASS 7**, bow with vertical sides (i.e. where the normal frame angles θ at the considered sub-regions are between 0 and 10 degree (see Fig 3)) is acceptable.

In that case, the design ice loads calculated according to [4.3] for non-icebreaking form are applicable.

4.1.7 Bulb of bulbous bow

For ships having the additional class notation **POLAR CLASS 6** or **POLAR CLASS 7** a bulbous bow is acceptable.

In that case, the design ice loads (F_{bow}, q_{bow} and p_{bow}) applicable to the bulb are to be taken as the maximum between:

a) ice loads calculated according to [4.3] for non-icebreaking form,

b) ice loads calculated according to [4.3] for icebreaking form and assuming:

   - the shape coefficient c_i = 0,6
   - the load patch aspect ratio c_{ARi} = 1,3

4.1.8 Other bow forms

For ships with bow forms other than those defined in [4.1.5] and [4.1.6], the design ice loads are to be specially considered by the Society.

4.1.9 Ship structures not directly subjected to ice loads may still experience inertial loads from cargo, fuel, ballast, and equipment resulting from ship/ice interaction. These inertial loads are to be calculated with accelerations defined in Sec 3, [6] and considered in the design of such structures.

4.2 Glancing impact load characteristics - Class factors

4.2.1 The parameters defining the glancing impact load characteristics are reflected in the class factors listed in Tab 8 and Tab 9.

Table 8 : Glancing impact load characteristics - Class factors for icebreaking form

POLAR CLASS or icebreaker	C_C (crushing failure)	C_F (flexural failure)		C_D (load patch dimensions)	C_Δ (displacement)	C_L (longitudinal strength)
		Brackish water **(1)**	Open sea			
1	17,69	76,92	68,60	2,01	250000	7,46
2	9,89	54,45	46,80	1,75	210000	5,46
3	6,06	25,64	21,17	1,53	180000	4,17
4	4,50	17,05	13,48	1,42	130000	3,15
5	3,10	11,94	9,00	1,31	70000	2,50
6	2,40	8,70	5,49	1,17	40000	2,37
7	1,80	6,69	4,06	1,11	22000	1,81

(1) Brackish water is applicable for ships sailing in water with salinity between sea water and fresh water salinity (typically less than 31 ppt).

Table 9 : Glancing impact load characteristics - Class factors for non-icebreaking form

POLAR CLASS	C_C (crushing failure)	C_Q (line load)	C_P (pressure)
6	3,43	2,82	0,65
7	2,60	2,33	0,65

4.3 Bow area

4.3.1 In the bow area, force F_{Bow}, line load q_{Bow}, pressure p_{Bow} and load patch aspect ratio c_{AR} associated with the glancing impact load scenario are function of the hull angles measured at the upper ice waterline (UIWL). The influence of the hull angles is captured through calculation of a bow shape coefficient c_i. The hull angles are defined in Fig 3.

4.3.2 The waterline length of the bow region is to be divided into four sub-regions "i" of equal length. Forces F_i, line loads q_i, pressures p_i, bow shape coefficients c_i and load patch aspect ratios c_{ARi} are to be calculated with respect to the mid-length position x_i of each sub-region.

4.3.3 Shape coefficient

The shape coefficient c_i, in each sub-region i of the bow area, is to be obtained from the following formulae:

- for icebreaking form (see [4.1.5]):

  $c_i = \text{Min}\,(c_{i,1}\,;\,c_{i,2}\,;\,c_{i,3})$ when $\theta_i > 0$

  $c_i = 0{,}60$ when $\theta_i = 0$

- for non-icebreaking form (see [4.1.6]):

  $c_i = \alpha_i / 30$

where:

$$c_{i,1} = \left\{0{,}097 - \left[0{,}68\left(0{,}85 - \frac{x_i}{L_{ui}}\right)^2\right]\right\}\frac{\alpha_i}{\sqrt{\theta_i}}$$

$$c_{i,2} = \frac{99{,}81\ C_F}{C_C\ \Delta_{ui}^{0,64}\ \sin\theta_i}$$

$c_{i,3} = 0{,}60$

Δ_{ui} : Displacement at the upper ice waterline (UIWL), in t, to be taken not less than 5000 t

θ_i : Normal frame angle, in degree, in sub-region i of the bow area.

4.3.4 Load patch aspect ratio

The load patch aspect ratio c_{ARi}, in each sub-region i of the bow area, is to be obtained from the following formula:

$c_{ARi} = 7{,}46 \sin\theta_i$

to be taken not less than 1,3.

4.3.5 Design ice force

The force F_{Bow}, in kN, is to be obtained from the following formula:

$F_{Bow} = \text{Max}\,(F_i)$

where:

F_i : Force in sub-region i of the bow area, in kN, taken equal to:

- for icebreaking form (see [4.1.5]):

$$F_i = 12{,}02\ c_i C_C \Delta_{ui}^{0,64}$$

- for non-icebreaking form (see [4.1.6]):

$$F_i = 38{,}90\ c_i C_C \Delta_{ui}^{0,47}$$

Δ_{ui} : Displacement as defined in [4.3.3].

4.3.6 Line load

The line load q_{Bow}, in kN/m, is to be obtained from the following formula:

$q_{Bow} = Max\ (q_i)$

where:

q_i : Line load in sub-region i of the bow area, in kN/m, taken equal to:

- for icebreaking form (see [4.1.5]):

$$q_i = \frac{14{,}79\ C_D\ F_i^{0,61}}{c_{ARi}^{0,35}}$$

- for non-icebreaking form (see [4.1.6]):

$$q_i = 218{,}77\ C_Q\ F_i^{0,22}$$

4.3.7 Pressure

The pressure p_{Bow}, in kN/m², is to be obtained from the following formula:

$p_{Bow} = Max\ (p_i)$

where:

p_i : Pressure in sub-region i of the bow area, in kN/m², taken equal to:

- for icebreaking form (see [4.1.5]):

$$p_i = 218{,}77\ F_i^{0,22}\ C_D^2\ c_{ARi}^{0,3}$$

- for non-icebreaking form (see [4.1.6]):

$$p_i = 20{,}89\ C_P\ F_i^{0,56}$$

4.3.8 Design load patch

The dimensions, in m, of the design load patch are to be obtained from the following formulae:

$$w_{Bow} = \frac{F_{Bow}}{q_{Bow}}$$

$$b_{Bow} = \frac{q_{Bow}}{p_{Bow}}$$

4.4 Hull areas other than the bow area

4.4.1 Design ice force

The force F_{NonBow}, in kN, is to be obtained from the following formulae:

- for $\Delta_{ui} \le C_\Delta$:

$$F_{NonBow} = 4{,}33\ C_C\ \Delta_{ui}^{0,64}$$

- for $\Delta_{ui} > C_\Delta$:

$$F_{NonBow} = 0{,}36\ C_C [12{,}02\ C_\Delta^{0,64} + 0{,}10\ (\Delta_{ui} - C_\Delta)]$$

where:

Δ_{ui} : Displacement at the upper ice waterline (UIWL), in t, to be taken not less than 10000 t.

4.4.2 Design ice force on the bottom area for navigation in shallow water

In case of navigation in shallow water (as defined in Sec 1, [1.5]), the following force F_{NonBow}, in kN, is to be considered for bottom area (BIb, Mb and Sb), in addition to [4.4.1]:

$$F_{NonBow} = \frac{\Delta_{ui}\ V^2}{(C_B / C_W - 0{,}5)\ T}\ 10^{-3}$$

where:

T : Maximum fore draught in ice navigation, in m

C_W : Waterplane coefficient at draught T, taken as:

$$C_W = \frac{A_{WP}}{L_{ui} B_{ui}}$$

A_{WP} : Waterplane area at draught T

C_B : Block coefficient at draught T, taken as:

$$C_B = \frac{\Delta_{ui}}{1,025 L_{ui} B_{ui} T}$$

Δ_{ui} : Displacement as defined in [4.4.1]

V : Ship speed, in knots.

The highest requirement for bottom scantlings determined with both F_{NonBow} from [4.4.1] and [4.4.2] and the applicable hull area factor (C_{AF}) is to be applied.

4.4.3 Line load

The line load q_{NonBow}, in kN/m, is to be obtained from the following formula:

$$q_{NonBow} = 9,451 \, C_D \, F_{NonBow}^{0,61}$$

4.4.4 Design load patch

The dimensions, in m, of the design load patch are to be obtained from the following formulae:

$$w_{NonBow} = \frac{F_{NonBow}}{q_{NonBow}}$$

$$b_{NonBow} = \frac{w_{NonBow}}{3,6}$$

4.5 Pressure within the design load patch

4.5.1 Average pressure

In the bow area and in hull areas other than the bow area, the average pressure p_{avg}, in kN/m^2, within a design load patch, is to be obtained from the following formula:

$$p_{avg} = \frac{F}{w\,b}$$

where:

F : F_{Bow} or F_{NonBow}, in kN, as appropriate for the area under consideration.

4.5.2 Pressure concentration

The peak pressure factors C_{PP}, C_{PM} and C_{PS} defined in Tab 10 are to be used to account for the pressure concentration that occurs within the load patch on small areas of structural members, except for a grillage system (see [7.8.3]).

Table 10 : Peak pressure factors C_{PP}, C_{PM} and C_{PS}

Structural member		Peak pressure factor
Plating	• transversely-framed	$C_{PP} = (1,8 - s) \geq 1,2$
	• longitudinally-framed	$C_{PP} = (2,2 - 1,2\,s) \geq 1,5$
Frames in transverse framing systems	• with load distributing stringer(s)	$C_{PM} = (1,6 - s) \geq 1,0$
	• without load distributing stringer	$C_{PM} = (1,8 - s) \geq 1,2$
Frames in bottom structures		$C_{PS} = 1,0$
Load carrying stringers Side longitudinals Web frames		• if $S_w < 0,5\,w$: $C_{PS} = 2,0 - 2,0\,S_w / w$ **(1)** • if $S_w \geq 0,5\,w$: $C_{PS} = 1,0$ **(1)**
(1) S_w : Web frame spacing, in m.		

4.6 Hull area factor

4.6.1 The area factor C_{AF}, associated with each hull area, reflects the relative magnitude of the load expected in that area. The area factor C_{AF} for each hull area of **POLAR CLASS** ships is listed in Tab 11 and the area factor C_{AF} for each hull area of **icebreaker** ships is listed in Tab 12.

In the event that a structural member spans the boundary of a hull area, the largest hull area factor is to be used in the scantling determination of this member.

4.6.2 Stern icebelt and stern lower hull area factors are to be specially considered for ships having propulsion arrangements with azimuthing thruster(s) or “podded” propellers.

Table 11 : Hull area factor C_{AF} for POLAR CLASS ships

Hull area		POLAR CLASS						
		1	2	3	4	5	6	7
Bow	All	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Bow Intermediate	Icebelt	0,90	0,85	0,85	0,80	0,80	1,00	1,00
	Lower	0,70	0,65	0,65	0,60	0,55	0,55	0,50
	Bottom **(1)**	0,55	0,50	0,45	0,40	0,35	0,30	0,25
Midbody	Icebelt	0,70	0,65	0,55	0,55	0,50	0,45	0,45
	Lower	0,50	0,45	0,40	0,35	0,30	0,25	0,25
	Bottom **(1)**	0,30	0,30	0,25	N.A.	N.A.	N.A.	N.A.
Stern	Icebelt	0,75	0,70	0,65	0,60	0,50	0,40	0,35
	Lower	0,45	0,40	0,35	0,30	0,25	0,25	0,25
	Bottom **(1)**	0,35	0,30	0,30	0,25	0,15	N.A.	N.A.

(1) In case of navigation in shallow water and for bottom scantling requirement determined using F_{NonBow} defined in [4.4.2], C_{AF} is to be taken equal to 1,00 even if strengthening for ice load is not required (N.A.).
Note 1: N.A. indicates that strengthening for ice loads is not required in the hull area considered.

Table 12 : Hull area factor C_{AF} for icebreaker ships

Hull area		icebreaker						
		1	2	3	4	5	6	7
Bow	All	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Bow Intermediate	Icebelt	0,90	0,85	0,85	0,85	0,85	1,00	1,00
	Lower	0,70	0,65	0,65	0,65	0,65	0,65	0,65
	Bottom **(1)**	0,55	0,50	0,45	0,45	0,45	0,45	0,45
Midbody	Icebelt	0,70	0,65	0,55	0,55	0,55	0,55	0,55
	Lower	0,50	0,45	0,40	0,40	0,40	0,40	0,40
	Bottom **(1)**	0,30	0,30	0,25	0,25	0,25	0,25	0,25
Stern	Icebelt	0,95	0,90	0,80	0,80	0,80	0,80	0,80
	Lower	0,55	0,50	0,45	0,45	0,45	0,45	0,45
	Bottom **(1)**	0,35	0,30	0,30	0,30	0,30	0,30	0,30

(1) In case of navigation in shallow water and for bottom scantling requirement determined using F_{NonBow} defined in [4.4.2], C_{AF} is to be taken equal to 1,00.

5 Longitudinal strength

5.1 Application

5.1.1 A ramming impact on the bow is the design scenario for the evaluation of the longitudinal strength of the hull. Intentional ramming is not considered as a design scenario for ships with vertical or bulbous bows (see Sec 1, [1.4.1]). Hence the longitudinal strength is not to be considered for ships with buttock angle at the stem γ_{stem} greater than or equal to 80 degree.

5.1.2 Ice loads are to be combined with still water loads only. The combined stresses are to be compared against permissible bending and shear stresses at different locations along the ship length according to [5.3] and [5.4]. In addition, local buckling strength is to be verified according to [5.5].

5.2 Hull girder ice loads

5.2.1 Design vertical ice force at the bow

The design vertical ice force at the bow F_{IB}, in kN, is to be obtained from the following formula:

$F_{IB} = \text{Min}\ (F_{IB1}\ ;\ F_{IB2})$

where:

$$F_{IB1} = 1{,}505\ C_{I1}^{0{,}15}\ C_{I2}^{0{,}35}\ (\sin\gamma_{stem})^{0{,}2}\ \Delta_{ui}^{0{,}5}\ C_L$$

$$F_{IB2} = 1200\ C_F$$

with:

C_{I1} : Coefficient equal to:

- for a simple wedge bow form (c_{eb} = 1):

$$C_{I1} = \frac{\left[\frac{B_{ui}}{2L_B}\right]^{0{,}9}}{(\tan\gamma_{stem})^{1{,}8}}$$

- for a spoon bow form (0 < c_{eb} <1):

$$C_{I1} = \frac{\left[\frac{B_{ui}}{L_B^{c_{eb}}(1+c_{eb})}\right]^{0{,}9}}{(\tan\gamma_{stem})^{0{,}9\,(1+c_{eb})}}$$

- for a landing craft bow form (c_{eb} = 0):

$$C_{I1} = \frac{B_{ui}^{0{,}9}}{(\tan\gamma_{stem})^{0{,}9}}$$

C_{I2} : Coefficient, in kN/m, taken equal to:

$C_{I2} = 10\ A_{WP}$

Δ_{ui} : Displacement at the upper ice waterline (UIWL), in t, to be taken not less than 10000 t

A_{WP} : Ship waterplane area, in m^2, at the upper ice waterline (UIWL)

γ_{stem} : Buttock angle at the stem, in degree, to be measured between the horizontal axis and the stem tangent at the upper ice waterline (UIWL)

c_{eb} : Bow shape exponent that describes the waterplane at the upper ice waterline (UIWL), see Fig 5 and Fig 6

L_B : Bow length, in m, at the upper ice waterline (UIWL) as defined in Fig 6.

When the general arrangement plan of the ship is available, the way to find c_{eb} and L_B is to select two points on the bow. If the coordinates of the two points are (x_1, y_1) and (x_2, y_2), the shape parameters c_{eb} and L_B are to be obtained from the following formulae:

$$c_{eb} = \frac{\ln\left(\frac{y_2}{y_1}\right)}{\ln\left(\frac{L_{ui}-x_2}{L_{ui}-x_1}\right)}$$

$$L_B = (L_{ui}-x_2)\left(\frac{2y_2}{B_{ui}}\right)^{-1/c_{eb}}$$

Figure 5 : Examples of c_{eb} for B_{ui} = 20 and L_B = 16

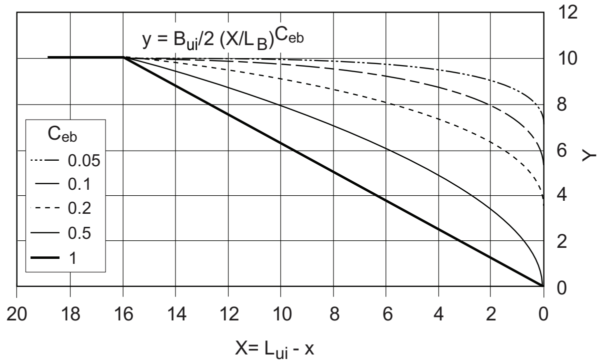
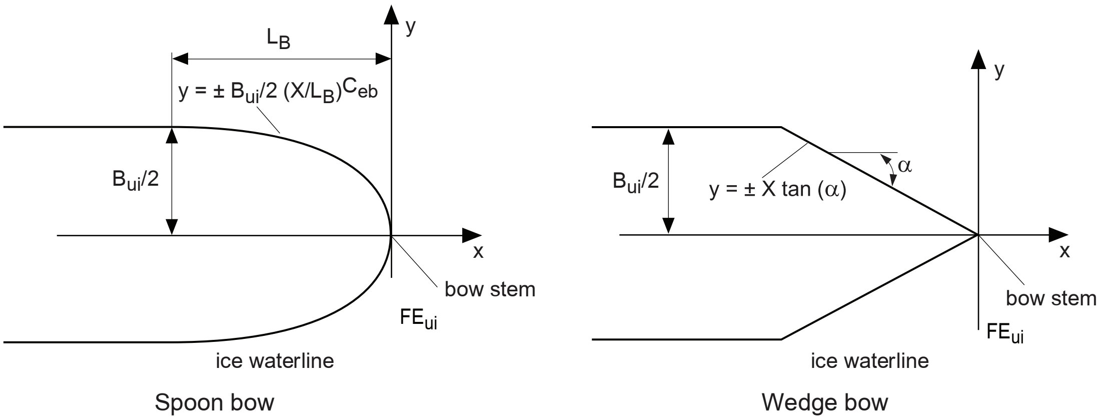


Figure 6 : Bow shape definition



5.2.2 Design vertical ice bending moment

The design vertical ice bending moment M_I , in kN·m, along the hull girder is to be obtained from the following formula:

$$M_I = -\frac{0,1\, C_{H1}\, L_{ui}\, F_{IB}}{(\sin\gamma_{stem})^{0,2}}$$

where:

γ_{stem} : Buttock angle at the stem, in degree, defined in [5.2.1]

F_{IB} : Design vertical ice force at the bow, in kN, defined in [5.2.1]

C_{H1} : Longitudinal distribution factor defined in Tab 13. To be reversed for double-ended ships.

Table 13 : Longitudinal distribution factor C_{H1}

Longitudinal position	C_{H1}
$0 \le x/L_{ui} < 0,50$	$2\ x/L_{ui}$
$0,50 \le x/L_{ui} \le 0,70$	1,0
$0,70 < x/L_{ui} < 0,95$	$-2,8\ x/L_{ui} + 2,96$
$0,95 \le x/L_{ui} \le 1,00$	$6\ (1 - x/L_{ui})$

5.2.3 Design vertical ice shear force

The design vertical ice shear force Q_I along the hull girder, in kN, is to be obtained from the following formula:

$Q_I = C_{H2}\ F_{IB}$

where:

C_{H2} : Longitudinal distribution factor defined in Tab 14

F_{IB} : Design vertical ice force at the bow, in kN, defined in [5.2.1].

Table 14 : Longitudinal distribution factor C_{H2}

Longitudinal position	C_{H2}	
	Positive shear force	Negative shear force
$0 \le x/L_{ui} < 0,2$	0,0	$-2,5\ \frac{x}{L_{ui}}$
$0,2 \le x/L_{ui} \le 0,6$		$-0,5$
$0,6 < x/L_{ui} < 0,8$	$\frac{10}{3}\ \frac{x}{L_{ui}} - 2$	$2,5\ \frac{x}{L_{ui}} - 2$
$0,8 \le x/L_{ui} < 0,9$		0,0
$0,9 \le x/L_{ui} \le 1,0$	1,0	

5.3 Normal stress

5.3.1 The normal stress σ, in N/mm², induced by the vertical bending moments is to be obtained from the following formulae:

- at any point of the hull transverse section:

$$\sigma = \frac{M_{SW-min} + M_I}{Z_A}\, 10^{-3}$$

- at bottom:

$$\sigma = \frac{M_{SW-min} + M_I}{Z_{AB}} 10^{-3}$$

- at deck:

$$\sigma = \frac{M_{SW-min} + M_I}{Z_{AD}} 10^{-3}$$

where:

Z_A : Net section modulus, in m^3, at any point of the hull transverse section, to be calculated according to NR467, Pt B, Ch 6, Sec 1, [1.4.1]

Z_{AB}, Z_{AD} : Net section moduli, in m^3, at bottom and deck respectively, to be calculated according to NR467, Pt B, Ch 6, Sec 1, [1.4.2].

5.3.2 The normal stress, in a structural member made in material other than steel with a Young's modulus E equal to 2,06·10^5 N/mm^2 and included in the hull girder transverse sections is obtained from the following formula:

$$\sigma_1 = \frac{E}{2{,}06\ 10^5}\sigma$$

where:

σ : Normal stress, in N/mm^2, in the structural member under consideration, calculated according to [5.3.1] considering this member as having the steel equivalent net sectional area A_{SE-n50} defined in NR467, Pt B, Ch 6, Sec 1, [1.2.8].

5.3.3 Checking criteria

It is to be checked that the normal stress σ or σ_1 calculated according to [5.3.1] or [5.3.2] is less than or equal to σ_{ALL} , with σ_{ALL} defined in Tab 15.

Table 15 : Allowable normal stress σ_{ALL}

	σ_{ALL} , in N/mm^2	
	POLAR CLASS	**icebreaker**
$R_{eH}/R_m \leq 0{,}7$	0,87 R_{eH}	0,65 R_{eH}
$R_{eH}/R_m > 0{,}7$	0,35 (R_{eH} + R_m)	0,26 (R_{eH} + R_m)

5.4 Shear stress

5.4.1 General

The hull girder shear stress τ, in N/mm^2, induced by vertical shear forces is to be determined, at the load calculation point under consideration, from the following formulae:

$$\tau = \frac{(Q_{SW} + Q_i) \cdot 10^3}{\frac{t_{n50}}{q_{vi}}}$$

where:

q_{vi} : Contribution ratio for hull girder shear force per mm, as defined in Pt B, Ch 6, Sec 1, [2.2.1]

t_{n50} : Net thickness with half corrosion reduction in mm.

5.4.2 Checking criteria

It is to be checked that the shear stress τ calculated according to [5.4.1] is less than or equal to τ_{ALL} , with τ_{ALL} defined in Tab 16.

Table 16 : Allowable shear stress τ_{ALL}

	τ_{ALL} , in N/mm^2	
	POLAR CLASS	**icebreaker**
$R_{eH}/R_m \leq 0{,}7$	0,50 R_{eH}	0,37 R_{eH}
$R_{eH}/R_m > 0{,}7$	0,20 (R_{eH} + R_m)	0,15 (R_{eH} + R_m)

5.5 Buckling

5.5.1 General

Plating and ordinary stiffeners contributing to the hull girder longitudinal strength are to be checked according to Pt B, Ch 9, Sec 1, considering:

- the ice load cases IHG1 and IHG2 associated hull girder loads combinations as defined in Tab 17
- a lateral pressure equal to zero
- allowable utilization factor n_{all} equal to 1,0 for plates, stiffeners and stiffened panels.

Table 17 : Hull girder loads combination

	Ice load cases	
Hull girder loads components	IHG1	IHG2
Vertical bending moment	$M_{sw-\mu\iota\nu} + M_I$	M_I
Horizontal bending moment	–	–
Vertical shear force	Q_I	$Q_{sw} + Q_I$
Horizontal shear force	0	0
Torsional moment	0	0

Note 1:
M_i : Ice bending moment as defined in [5.2.2]
Q_i : Ice shear force as defined in [5.2.3]

6 Shell plating

6.1 General

6.1.1 The shell plate thickness, in mm, is to be not less than the value obtained from the following formula:

$t = t_{net} + t_C$

6.2 Net thickness

6.2.1 Transversely-framed plating

The net thickness, in mm, of transversely-framed plating ($\alpha_1 \geq 70°$) is to be not less than the value obtained from the following formula:

$$t_{net} = 15{,}8\, s \sqrt{\frac{C_{AF}\, C_{PP}\, p_{avg}}{R_{eH}}} \; \frac{1}{1 + \dfrac{s}{2b}}$$

where:

b : Height of design load patch, in m, to be taken not greater than (ℓ – s/4)

α_1 : Smallest angle, in degree, between the chord of the waterline and the ordinary stiffeners (see Fig 7).

6.2.2 Longitudinally-framed plating

The net thickness, in mm, of longitudinally-framed plating ($\alpha_1 \leq 20°$) is to be not less than the value obtained from the following formulae:

- when b ≥ s:

$$t_{net} = 15{,}8\, s \sqrt{\frac{C_{AF}\, C_{PP}\, p_{avg}}{R_{eH}}} \; \frac{1}{1 + \dfrac{s}{2\ell}}$$

- when b < s:

$$t_{net} = 15{,}8\, s \sqrt{\frac{C_{AF}\, C_{PP}\, p_{avg}}{R_{eH}}} \sqrt{2\frac{b}{s} - \left(\frac{b}{s}\right)^2} \; \frac{1}{1 + \dfrac{s}{2\ell}}$$

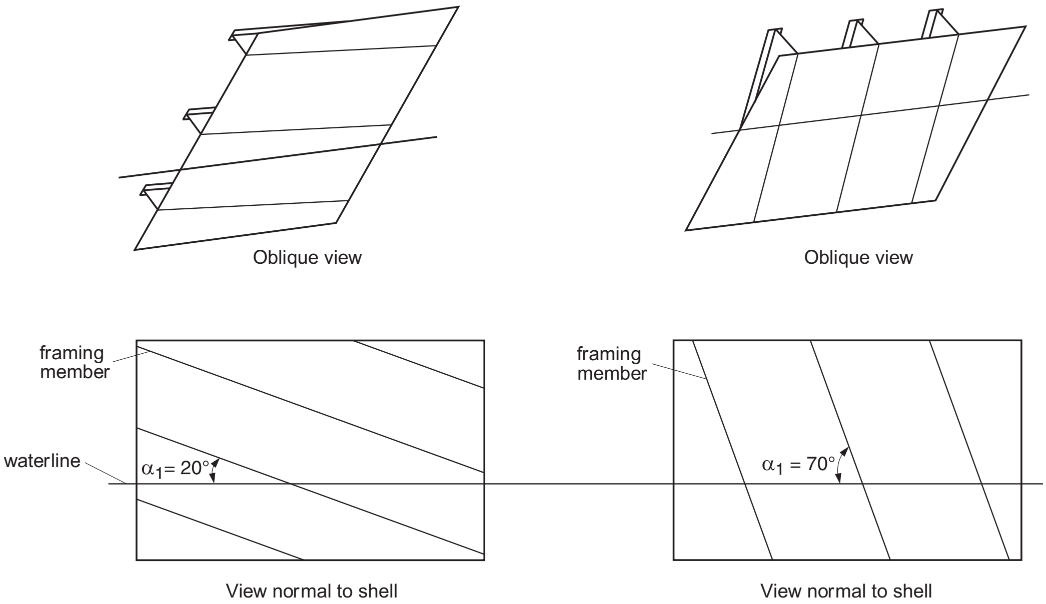
where:

ℓ : Distance between frame supports, in m, equal to the frame span as given in [7.1.4], 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.

6.2.3 Obliquely-framed plating

For obliquely-framed plating (70°> α_1 > 20°), the net thickness, in mm, is to be obtained by linear interpolation between the thicknesses from [6.2.1] and [6.2.2].

Figure 7 : Shell framing angle



7 Framing scantlings

7.1 General

7.1.1 The term “framing member” refers to transverse and longitudinal ordinary stiffeners, load-carrying stringers and web frames in the areas of the hull exposed to ice pressure. Where load-distributing stringers have been fitted, their arrangement is to be in accordance with the applicable requirements of NR467, Pt B, Ch 4 and their scantlings are to be in accordance with the applicable criteria defined in NR467, Pt B, Ch 7, Sec 3.

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

7.1.3 The details of framing member intersection with other framing members, including plated structures, as well as the details for securing the ends of framing members at supporting sections, are to be in accordance with the applicable requirements of NR467, Pt B, Ch 4.

7.1.4 The span of a framing member is to be determined in accordance with NR467, Pt B, Ch 4, Sec 6, [1.1]. Brackets are to be defined to ensure stability in the elastic and post-yield response regions.

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

7.2 Actual net effective shear area of ordinary stiffeners

7.2.1 The actual net effective shear area A_w , in cm², of a transverse or longitudinal ordinary stiffener is given by:

$$A_w = h t_w \frac{\sin(\varphi_w)}{100}$$

where (see Fig 8):

h : Height of the stiffener, in mm

φ_w : Angle, in degree, between the attached plate and the web of the stiffener, measured at midspan of the stiffener.

7.3 Actual net effective plastic section modulus of ordinary stiffeners

7.3.1 When the net cross-sectional area of the attached plate A_p exceeds the net cross-sectional area of the ordinary stiffener A_w' + A_f, the plastic neutral axis PNA is assumed to be tangent to the uppermost edge of the attached plate.

The actual net effective plastic section modulus w_p of such a transverse or longitudinal ordinary stiffener, in cm^3, is given by:

$$w_p = \frac{A_p' x_p + A_w' x_w + A_f x_f}{10}$$

where:

A_p' : Net cross-sectional area of the stiffener, in cm^2, taken equal to:

$A_p' = A_w' + A_f$

x_p : Distance, in mm, between the centre of gravity of area A_p and PNA, taken equal to:

$$x_p = \mathrm{Min}\left(\frac{A_w' + A_f}{20\ s}\ ;\ \frac{t_p}{2}\right)$$

A_w' : Net cross-sectional area of the stiffener web, in cm^2, taken equal to:

$$A_w' = \frac{h_w t_w}{100}$$

x_w : Distance, in mm, between the centre of gravity of area A_w' and PNA, taken equal to:

$$x_w = \frac{h_w \sin\varphi_w}{2}$$

A_f : Net cross-sectional area of the stiffener flange, in cm^2, taken equal to:

$$A_f = \frac{b_f\ t_f}{100}$$

x_f : Distance, in mm, between the centre of gravity of area A_f and PNA, taken equal to:

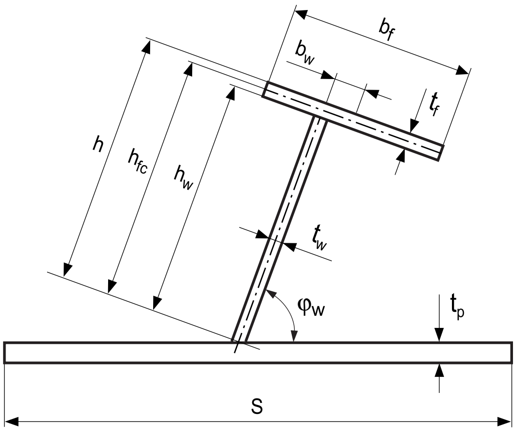
$x_f = h_{fc} \sin \varphi_w - b_w \cos \varphi_w$

h_{fc} : Height, in mm, of the stiffener, measured up to the centre of the flange area, see Fig 8

b_w : Distance, in mm, from the mid-thickness plane of the stiffener web to the centre of the flange area, see Fig 8

φ_w : As defined in [7.2.1].

Figure 8 : Dimensions of ordinary stiffeners



7.3.2 When the net cross-sectional area A_w' + A_f of the stiffener exceeds the net cross-sectional area of the attached plate A_p, the plastic neutral axis PNA is located at a distance z_a above the attached plate, in mm, given by:

$$z_a = \frac{(100\,A_f + h_w t_w - 1000\,t_p\,s)\ \sin\varphi_w}{2\ t_w}$$

The actual net effective plastic section modulus w_p of such a transverse or longitudinal ordinary stiffener, in cm^3, is given by:

$$w_p = \frac{(A_p x_p + A_{wa} x_{wa} + A_{wb} x_{wb} + A_f x_f)}{10}$$

where:

A_p : Net cross-sectional area of the attached plate, in cm^2, taken equal to:

$A_p = 10\ t_p\ s$

x_p : Distance, in mm, between the centre of gravity of area A_p and PNA, taken equal to:

$$x_p = z_a + \frac{t_p}{2}$$

A_{wa} : Net cross-sectional area, in cm², of the part of the stiffener located above PNA, taken equal to:

$$A_{wa} = \left(h_w - \frac{z_a}{\sin\varphi_w}\right)\frac{t_w}{100}$$

x_{wa} : Distance, in mm, between the centre of gravity of area A_{wa} and PNA, taken equal to:

$$x_{wa} = \left(h_w - \frac{z_a}{\sin\varphi_w}\right)\frac{\sin\varphi_w}{2}$$

A_{wb} : Net cross-sectional area, in cm², of the part of ordinary stiffener located below the PNA, taken equal to:

$$A_{wb} = \frac{t_w\ z_a}{100\ \sin\varphi_w}$$

x_{wb} : Distance, in mm, between the centre of gravity of area A_{wb} and PNA, taken equal to:

$$x_{wb} = \frac{z_a}{2}$$

x_f : Distance, in mm, between the centre of gravity of area A_f and PNA, taken equal to:

$x_f = h_{fc} \sin \varphi_w - b_w \cos \varphi_w - z_a$

h_{fc} , b_w : As defined in [7.3.1]

φ_w : As defined in [7.2.1].

7.4 Structural stability

7.4.1 The ratio of web height h_w to the net web thickness t_w of any framing member is to fulfil the following condition:

- for flat bar sections:

$$\frac{h_w}{t_w} \le \frac{282}{\sqrt{R_{eH}}}$$

- for bulb, tee and angle sections:

$$\frac{h_w}{t_w} \le \frac{805}{\sqrt{R_{eH}}}$$

7.4.2 The framing members for which it is not practicable to meet the requirements of [7.4.1] (e.g. load carrying stringers or deep web frames) are required to have effectively stiffened webs. The scantlings of the web stiffeners are to ensure the structural stability of the framing members.

For these framing members, the minimum net web thickness t_w , in mm, is given by the following formula:

$$t_w = \frac{2{,}63\ (h_w - 0{,}8\ h_f)\ \sqrt{R_{eH}}}{\sqrt{5{,}34 + 4\left(\frac{h_w - 0{,}8\ h_f}{s_1}10^{-3}\right)^2}}\ 10^{-3}$$

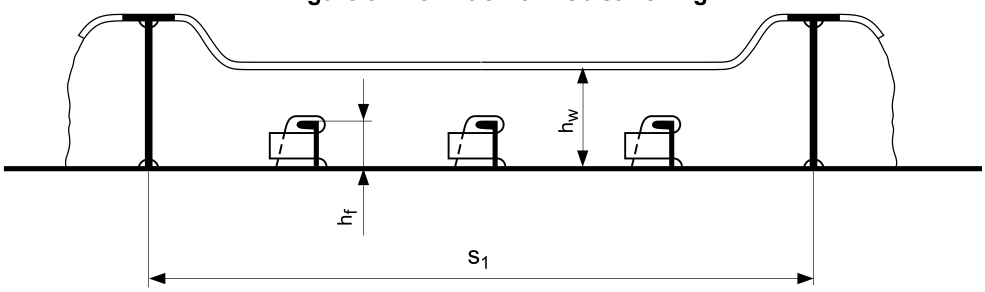
where (see Fig 9):

h_w : Web height, in mm, of the member under consideration

h_f : Height, in mm, of the framing members penetrating the member under consideration, taken equal to 0 in case of no penetration

s_1 : Spacing, in m, between the supporting structures oriented perpendicular to the member under consideration.

Figure 9 : Definition of web stiffening



7.4.3 In addition to [7.4.1] and [7.4.2], the following condition is to be satisfied:

$$t_w \ge 0{,}35\ t_{net}\sqrt{\frac{R_{eH}}{235}}$$

where:

t_{net} : Net thickness, in mm, of the attached plate in way of the framing member

R_{eH} : Minimum yield stress of the shell plate, in N/mm², in way of the framing member.

7.4.4 For the welded profiles, the following conditions are to be satisfied:

$$\frac{b_f}{t_w} \geq 5$$

$$\frac{b_{f-out}}{t_f} \leq \frac{155}{\sqrt{R_{eH}}}$$

where $b_{f\text{-}out}$ is the width of outstand of the flange, in mm (i.e. the maximum distance from the web including half the web thickness, to the flange edge, see NR615 Buckling assessment of plated structures, Sec 2, Fig 1.

7.5 Ordinary stiffeners in bottom structures and transverse ordinary stiffeners in side structures

7.5.1 The ordinary stiffeners in bottom structures (i.e. hull areas BIb, Mb and Sb) and the transverse ordinary stiffeners in side structures are to be designed such that the combined effects of shear and bending do not exceed the plastic strength of the stiffener. The plastic strength is defined by the magnitude of the midspan load that causes the development of a plastic collapse mechanism. For bottom structure the design load patch is to be applied with the height b parallel to the stiffener direction.

7.5.2 The net effective shear area A_w, in cm^2, of the ordinary stiffeners, as defined in [7.2], is to comply with the following condition:

$$A_w \geq A_\tau$$

where:

$$A_t = \frac{8{,}67\ \ell_{LP}\ s\ C_{AF}\ C_P\ p_{avg}}{R_{eH}}$$

ℓ_{LP} : Length of the span loaded portion, in m, taken equal to the lesser of ℓ and b

C_P : Peak pressure factor, to be taken equal to:

- C_{PM} for transverse stiffeners in side structures
- C_{PS} for stiffeners in bottom structures.

7.5.3 The net effective plastic section modulus w_p, in cm^3, of the ordinary stiffeners with their attached plating, as defined in [7.3], is to comply with the following condition:

$$w_p \geq \ell_{LP}\left(1 - 0{,}5\frac{\ell_{LP}}{\ell}\right) s\ \frac{C_{AF}\ C_P\ p_{avg}\ \ell\ A_1}{4\ R_{eH}}\ 10^3$$

where:

ℓ_{LP} : As defined in [7.5.2]

$A_1 = Max\ (A_{1A}\ ;\ A_{1B})$

A_{1A} : Coefficient taken equal to:

$$A_{1A} = \frac{1}{1 + \frac{j}{2} + k_w \frac{j}{2}\left[\sqrt{1 - \frac{A_t^2}{A_w^2}} - 1\right]}$$

j : Number of fixed supports (see [7.1.2]), to be taken equal to (see Fig 10):

- for stiffeners with two simple supports outside the ice-strengthened areas (see Fig 10, item a)):
  j = 0
- for stiffeners with only one simple support outside the ice-strengthened areas (see Fig 10, item b)):
  j = 1
- for stiffeners with no simple support outside the ice- strengthened area (see Fig 10, item c)):
  j = 2

A_{1B} : Coefficient taken equal to:

$$A_{1B} = \frac{\left[1 - \frac{1}{2\frac{A_t}{A_w}\left(1 - \frac{0{,}5\ \ell_{LP}}{\ell}\right)}\right]}{0{,}275 + 1{,}44\ k_z^{0,7}}$$

A_t : As defined in [7.5.2]

A_w : As defined in [7.2.1]

k_z : Sum of individual plastic section moduli of flange and attached plating as fitted, in cm^3, taken equal to:

- in general:

$$k_z = \frac{b_f\ t_f^2 + 500\ s t_p^2}{4000\ w_p}$$

- when the stiffener is arranged with end bracket(s):

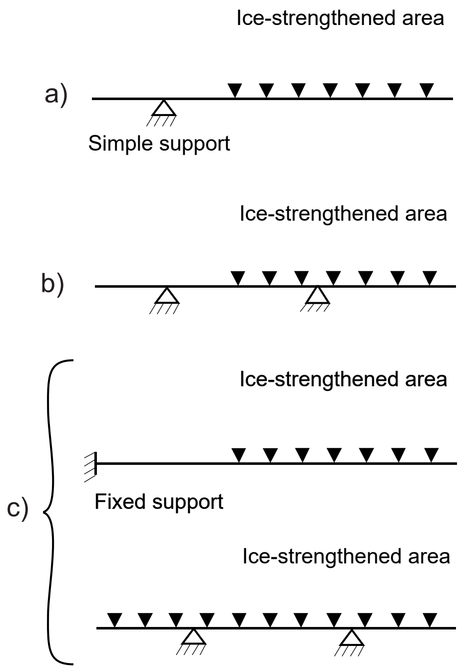
  $k_z = 0$

k_w : Coefficient taken equal to:

$$k_w = \frac{1}{1 + 2\frac{A_f}{A_w}}$$

A_f : As defined in [7.3.1].

Figure 10 : Framing supports arrangement



7.6 Longitudinal ordinary stiffeners in side structures

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

7.6.2 The net effective shear area A_w, in cm^2, of longitudinal ordinary stiffeners, as defined in [7.2], is to fulfil the following condition:

$A_w \geq A_L$

where:

$$A_L = \frac{8,67\,\ell\, b_1 C_{AF} C_{PS}\, p_{avg}}{R_{eH}}$$

with:

b_1 : Coefficient defined as follows:

- for b/s < 2:

$$b_1 = (b - 0,3\,s)\left(1 - 0,25\,\frac{b}{s}\right) \quad \text{with} \quad b_1 \geq 0$$

- for b/s ≥ 2:

$$b_1 = s\left(1 - 0,3\,\frac{s}{b}\right)$$

7.6.3 The net effective plastic section modulus w_p, in cm^3, of the longitudinal ordinary stiffeners with their attached plating, as defined in [7.3], is to fulfil the following condition:

$$w_p \geq \frac{\ell^2\, b_1\, C_{AF}\, C_{PS}\, p_{avg}\, A_2}{8\, R_{EH}}\, 10^3$$

where:

A_2 : Coefficient taken equal to:

$$A_2 = \frac{1}{2 + k_w\left[\sqrt{1 - \frac{A_L^2}{A_w^2}} - 1\right]}$$

k_w : As defined in [7.5.3]

A_L, b_1 : As defined in [7.6.2]

A_w : As defined in [7.2.1].

7.7 Oblique ordinary stiffeners

7.7.1 The net effective shear area, in cm², and the net effective plastic section modulus, in cm³, of the oblique ordinary stiffeners (70° > α_1 > 20°) are to be obtained by linear interpolation between the values obtained from [7.5] and [7.6].

7.8 Web frames and load-carrying stringers

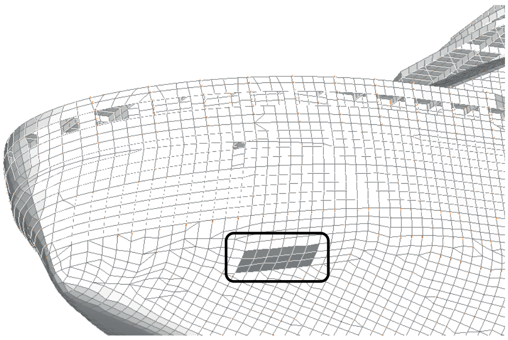
7.8.1 Web frames and load-carrying stringers are to be designed to withstand the ice load patch as defined in [4]. The load patch is to be applied parallel to the waterline and at locations where the capacity of these members, under the combined effects of bending and shear, is minimised. Special attention is to be paid to the shear capacity in way of lightening holes and of cut-outs at the intersection of structural members. A typical ice load patch location on a finite element model of a bow structure is illustrated on Fig 11.

7.8.2 For the scantling determination of load-carrying stringers, web frames supporting ordinary stiffeners, or web frames supporting load-carrying stringers that form part of a structural grillage system, direct structural calculations according to [7.9] are to be used. In that case, the peak pressure factors are not applied (see [4.5.2]). The scantlings of the members forming part of a grillage are to be defined so that the combined effects of shear and bending fulfil the criteria given in [7.9.6].

7.8.3 Where the structural configuration is such that the members do not form part of a grillage system, the appropriate peak pressure factor defined in Tab 10 is to be used.

7.8.4 The scantlings of web frames and load-carrying stringers are to meet the structural stability requirements of [7.4].

Figure 11 : Bow area with ice load patch location



7.9 Direct structural calculations

7.9.1 Direct structural calculations (beam or FE analysis) are not to be used as an alternative to the analytical procedures prescribed for the shell plating and the ordinary stiffener requirements given in this Section.

7.9.2 When direct structural calculations are used to check the strength of primary supporting members (such as load-carrying stringers or web frames), the design ice loads defined in [4] are to be applied without being combined with any other loads.

7.9.3 The corresponding design load patch is to be applied in accordance with [7.8.1]. The rectangular load patch is to be limited within the extent of hull areas and the hull area factor C_{AF} defined in [4.6]is to be applied.

7.9.4 Structural modelling

The structural modelling of primary supporting members with three dimensional models based on standard mesh from NR467, Pt B, Ch 8 or beams as defined in NR467, Pt B, Ch 7, Sec 6, [5], is to be used.

Net scantlings are to be used in accordance with the corrosion/abrasion margins defined in [3.1].

7.9.5 Boundary conditions

Models are to be constrained at model edges, in such way that realistic structural behaviour is obtained. Typical boundary conditions for a local model representing ice crushing loading condition are defined as follows:

- symmetry conditions at fore and aft end of the model
- displacements in Z direction are fixed for vertically continuous structures at upper deck level
- displacements in Y direction are fixed along one intermediate deck or transverse bulkhead on opposite side of the loading patch.

7.9.6 Criteria for direct structural calculations

When the scantlings are determined from direct structural calculations, the following criteria are to be considered:

- the web plates and flange elements in compression and shear are to comply with the relevant buckling criteria as required in NR467, Pt B, Ch 9, Sec 1.
- the nominal shear stress in web plates is to be less than the maximum values defined in Tab 18
- the nominal von Mises stress is to be less than the maximum values defined in Tab 18.

The finite element size for a standard mesh generally represents the spacing of ordinary stiffeners (s x s). In case of a finer mesh with individual elements exceeding the above von Mises criteria, the stresses obtained on an equivalent (s x s) area, using the averaging defined in NR467, Pt B, Ch 8, App 2, [4.1.2], are to satisfy the criteria.

Table 18 : Maximum stresses for direct calculations

Type of three dimensional model	Maximum shear stress	Maximum von Mises stress
Beam model	0,50 R_{eH}	R_{eH}
Finite element model with standard mesh	0,57 R_{eH}	1,15 R_{eH}

8 Plated structures

8.1 General

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

- web height of adjacent parallel web frame or stringer, and
- 2,5 times the depth of framing that intersects the plated structure.

8.1.2 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.

8.1.3 The stability of the plated structure is to adequately withstand the ice loads defined in [4] for the buckling check as required in NR615, Sec 5, [2.2].

9 Stem and stern arrangement

9.1 Fore part

9.1.1 Stem

The stem may be made of rolled, cast or forged steel or of shaped steel plates.

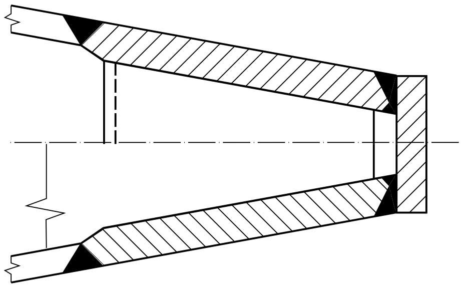
A sharp edged stem (see Fig 12) improves the manoeuvrability of the ship in ice and is particularly recommended for ships less than 150 m in length.

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° or more to the centreline in a horizontal plane, is to be not less than 1,3 times the thickness of the adjacent shell plating, calculated according to [6.2].

The stem and the part of a blunt bow defined above are to be supported by floors or brackets spaced not more than 600 mm apart and having a thickness at least equal to half the plate thickness.

The reinforcement of the stem is to be extending from the keel to the upper level of the Bow region.

Figure 12 : Sharp edged stem - Example



9.2 Aft part

9.2.1 An extremely narrow clearance between the propeller blade tip and the sternframe is to be avoided so as not to generate very high loads on the blade tip.

9.2.2 On twin and triple screw ships, the ice strengthening of the shell and framing is to be extended to the double bottom over at least 1,5 m forward and aft of the side propellers.

9.2.3 Shafting and sterntubes of side propellers are generally to be enclosed within plated bossings. If detached struts are used, their design, strength and attachment to the hull are to be examined by the Society on a case-by-case basis.

9.2.4 A wide transom stern extending below the UIWL seriously impedes the capability of the ship to run astern in ice, which is of paramount importance.

Consequently, a transom stern is normally not to be extended below the UIWL. Where this cannot be avoided, the part of the transom below the UIWL is to be kept as narrow as possible.

The part of a transom stern situated within the ice strengthened area is to be strengthened as required for the midship region.

9.2.5 Where azimuth propulsion systems are fitted, the increase in ice loading of the aft region and the stern area is to be considered, in the design of the aft/stern structure, on a case-by-case basis by the Society. This increase may be obtained by multiplying the hull area factors by the following coefficients:

- Midbody lower ($M\ell$): 1,10
- Stern icebelt (Si): 1,20
- Stern lower ($S\ell$): 1,30

The hull structure in the vicinity of the propulsor’s support is to be assessed according to NR584 Propulsors in ice, when ice loads are applied to the propulsor.

10 Hull outfittings

10.1 Rudders

10.1.1 The scantlings of the rudder post, rudder stock, pintles, steering gear, etc. as well as the capacity of the steering gear are to be determined according to NR467, Pt B, Ch 12, Sec 1.

The speed to be used in these calculations is the greater of the maximum ahead service speed and the speed indicated in Tab 19. When the speed indicated in Tab 19 is used, the coefficients r_1 and r_2, defined in NR467, Pt B, Ch 12, Sec 1, [2.1.2], are to be taken equal to, irrespective of the rudder type profile:

$r_1 = r_2 = 1,0$.

Within the ice-strengthened zone, the thickness of rudder plating and diaphragms is to be not less than that required for the shell plating of the stern region.

10.1.2 The rudder stock and the upper edge of the rudder are to be protected against ice pressure by an ice knife or equivalent means.

Table 19 : Minimum speed

POLAR CLASS or **icebreaker**	Speed (knots)
1	26
2	24
3	23
4	22
5	21
6	20
7	18

Section 3 Machinery Requirements for Polar Class Ships and Icebreakers

Symbols

α_i : Parameters for ice torque excitation of shaft line
F_{ex} : Blade failure load, in kN
F_{IB} : Vertical impact force, in kN, as defined in Sec 2, [5.2.1]
H : Distance from the waterline to the point being considered, in m
L_{ui} : Rule length, in m, as defined in Sec 2
T : Nominal propeller thrust at MCR at free running open water conditions, in kN
γ_{stem} : Buttock angle at the stem, in degree, to be measured between the horizontal axis and the stem tangent at the upper ice waterline (UIWL)
Δ_{ui} : Ship displacement at the upper ice waterline (UIWL), in t
ϕ : Maximum friction angle between steel and ice, in degree, normally taken equal to 10°.

1 General

1.1 Application

1.1.1 This Section applies to ships having one of the additional class notations **POLAR CLASS** or one of the service notations **icebreaker** and gives requirements for conventional main propulsion and steering gear, emergency and auxiliary systems essential for the safety of the ship.

1.1.2 This Section covers propulsion systems with open or ducted type propellers situated at the stern of the ship and having controllable pitch or fixed pitch blades.

1.1.3 For azimuth propulsion systems, refer to NR584.

1.1.4 For transverse thrusters, refer to [7.5.1].

1.2 Drawings and particulars to be submitted

1.2.1 The following drawings and particulars are to be submitted to the Society:

- details of the environmental conditions
- detailed drawings of the main propulsion and steering machinery. Description of the main propulsion, steering, emergency and essential auxiliaries are to include operational limitations. Information on essential main propulsion load control functions
- description detailing how main, emergency and auxiliary systems are located and protected to prevent problems from freezing, ice and snow and evidence of their capability to operate in intended environmental conditions
- calculations and documentation indicating compliance with the requirements of this Section.

1.3 Alternative design

1.3.1 As an alternative, a comprehensive design study may be submitted and may be requested to be validated by an agreed test programme.

2 Materials

2.1 Materials exposed to sea water

2.1.1 Materials exposed to sea water, such as propeller blades, propeller hub and blade bolts are to have an elongation not less than 15% on a test piece the length of which is five times the diameter.

Charpy V impact test is to be carried out for materials other than bronze and austenitic steel materials. Test pieces taken from the propeller castings are to be representative of the thickest section of the blade. An average impact energy value not to be less than 20 J taken from three Charpy V tests is to be obtained at –10ºC.

2.2 Materials exposed to sea water temperature

2.2.1 Materials exposed to sea water temperature are to be of steel or other approved ductile material.

An average impact energy value not to be less than 20 J taken from three tests is to be obtained at –10ºC.

2.3 Material exposed to low air temperature

2.3.1 Materials of essential components exposed to low air temperature are to be of steel or other approved ductile material.

An average impact energy value not to be less than 20 J taken from three Charpy V tests is to be obtained at 10ºC below the lowest design temperature.

3 Propulsion system

3.1 Design principle

3.1.1 The design ice loads are expected, single occurrence, maximum values for the whole ship's service life for normal operational conditions, including loads resulting from directional change of rotation where applicable. These loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice.

The design ice loads considered in [3.2.1] are total loads including ice-induced loads and hydrodynamic loads (unless otherwise stated) during ice interaction and are to be applied separately (unless otherwise stated) and are intended for strength calculations only. They are based on:

- the maximum backward blade force F_b experienced during the lifetime of the ship that bends a propeller blade backwards when the propeller mills an ice block while rotating ahead.
- the maximum forward blade force F_f experienced during the lifetime of the ship that bends a propeller blade forwards when the propeller mills an ice block while rotating ahead.

F_b and F_f originate from different propeller/ice interaction phenomena, which do not act simultaneously. Hence they are to be applied separately.

3.2 Design ice loads

3.2.1 The propulsion system components are to be designed taking into account the design ice loads given in NR584, as indicated in Tab 1.

3.3 Design of the propulsion system components

3.3.1 The propulsion system components other than those covered by [3.3.2] are to be designed taking into account the following requirements given in Tab 2.

3.3.2 Bearings

The aft stern tube bearing as well as the next shaft line bearing are to withstand the blade failure load F_{ex} (see Tab 1, item 5)), in such a way that the ship can maintain operational capability. Rolling bearings are to have an L10a lifetime of at least 40 000 hours according to ISO 281:2007. Thrust bearings and their housings are to be designed to withstand with a safety factor S = 1.0 the maximum response thrust (see Tab 1, item 6)) and the axial force resulting from the blade failure load F_{ex} (see Tab 1, item 5)). For the purpose of calculation, except for F_{ex}, the shafts are assumed to rotate at rated speed. For pulling propellers special consideration is to be given to loads from ice interaction on the propeller hub.

Table 1 : References to NR584 for design ice loads

No.	Subject	Reference to NR584
1	Ice load definition and propeller ice interaction	NR584, Sec 3, [2.1]
2	Ice class factors	NR584, Sec 3, [2.2]
3	Design ice load for open propeller	NR584, Sec 3, [2.3.1], [2.3.2] and [2.3.3] NR584, Sec 3, [2.3.7], [2.3.8] and [2.3.9]
4	Design ice load for ducted propeller	NR584, Sec 3, [2.3.4], [2.3.5] and [2.3.6] NR584, Sec 3, [2.3.7], [2.3.8] and [2.3.9]
5	Blade failure load for propeller	NR584, Sec 3, [2.4]
6	Axial design loads on propeller	NR584, Sec 3, [2.5]
7	Torsional design load on propeller	NR584, Sec 3, [2.6]

Table 2 : References to NR584 for the design of propulsion system components

No.	Subject	Reference to NR584
1	Design principle	NR584, Sec 3, [3.1]
2	Fatigue design criteria	NR584, Sec 3, [3.2]
3	Propeller blades	NR584, Sec 3, [3.3]
4	Blade bolts and pitch control mechanism	NR584, Sec 3, [3.4]
5	Propeller fitting to the shaft	NR584, Sec 3, [3.5]
6	Propulsion line components - general design principles	NR584, Sec 3, [3.6.1] and [3.6.2]
7	Propeller shaft	NR584, Sec 3, [3.6.3]
8	Intermediate shaft	NR584, Sec 3, [3.6.4]
9	Shaft connections	NR584, Sec 3, [3.6.5]
10	Gear transmissions	NR584, Sec 3, [3.6.5]
11	Clutches	NR584, Sec 3, [3.6.6]
12	Flexible couplings	NR584, Sec 3, [3.6.7]
12	Bracking devices	NR584, Sec 3, [3.6.8]
13	Seals	NR584, Sec 3, [3.6.9]

4 Steering system

4.1 Protection of the steering system

4.1.1 Rudder stops are to be provided. The design ice force on rudder is to be transmitted to the rudder stops without damage to the steering system.

4.2 Rudder actuator

4.2.1 The rudder actuator is to be designed for a holding torque obtained by multiplying the open water torque resulting from the application of NR467, Pt B, Ch 12, Sec 1 [2.1.3] (considering however a maximum speed of 18 knots) by the factors given in Tab 3.

Table 3 : Ice class factors for steering gear

	POLAR CLASS or **icebreaker**		
	1 and **2**	**3** to **5**	**6** and **7**
Factor	5	3	1,5

4.2.2 The design pressure for calculations to determine the scantlings of the rudder actuator is to be at least 1,25 times the maximum working pressure corresponding to the holding torque defined in [4.2.1] above.

4.2.3 The rudder actuator is to be protected by torque relief arrangements, assuming the turning speeds [deg/s] given in Tab 4, without an undue pressure rise (See NR467, Part C, Chapter 1, Section 11, [2.6.5]).

If the rudder and actuator design can withstand such rapid loads, this special relief arrangement is not necessary and a conventional one may be used instead.

Table 4 : Steering gear turning speeds

	POLAR CLASS or **icebreaker**		
	1 and **2**	**3** to **5**	**6** and **7**
Turning speed, in deg/s	10	7,5	6

4.2.4 Additionally, for ships with a notation Icebreaker, fast-acting torque relief arrangements are to be fitted in order to provide effective protection of the rudder actuator in case of the rudder being pushed rapidly hard over against the stops.

For hydraulically operated steering gear, the fast-acting torque relief arrangement is to be so designed that the pressure cannot exceed 115% of the set pressure of the safety valves when the rudder is being forced to move at the speed indicated in Table 5, also when taking into account the oil viscosity at the lowest expected ambient temperature in the steering gear compartment.

For alternative steering systems the fast fast-acting torque relief arrangement is to demonstrate an equivalent degree of protection to that required for hydraulically operated arrangements.

The turning speeds to be assumed for each ice class are shown in Tab 5.

The arrangement is to be designed such that steering capacity can be speedily regained.

Table 5 : Steering gear turning speeds for ships with a notation icebreaker

	icebreaker		
	1 and **2**	**3** to **5**	**6** and **7**
Turning speed, in deg/s	40	20	15

5 Prime movers

5.1 Propulsion engines

5.1.1 Engines are to be capable of being started and running the propeller in bollard condition.

5.1.2 Propulsion plants with CP propeller are to be capable of being operated even when the CP system is at full pitch as limited by mechanical stoppers.

5.2 Starting arrangements

5.2.1 The capacity of the air receivers is to be sufficient to provide, without recharging, not less than 12 consecutive starts of the propulsion engine, if this has to be reversed for going astern or 6 consecutive starts if the propulsion engine does not have to be reversed for going astern.

5.2.2 If the air receivers serve any other purposes than starting the propulsion engine, they are to have additional capacity sufficient for these purposes.

5.2.3 The capacity of the air compressors is to be sufficient for charging the air receivers from atmospheric to full pressure in one (1) hour, except for a ship with additional class notation **POLAR CLASS 1** to **POLAR CLASS 6** or the service notation **icebreaker 1** to **icebreaker 6**, if its propulsion engine has to be reversed for going astern, in which case the compressor is to be able to charge the receivers in half an hour.

5.3 Emergency power units

5.3.1 Provisions are to be made for heating arrangements to ensure ready starting of the cold emergency power units at an ambient temperature applicable to the additional class notations **POLAR CLASS** or the service notations **icebreaker**.

5.3.2 Emergency power units are to be equipped with starting devices with a stored energy capability of at least three consecutive starts at the design temperature in [5.3.1]. The source of stored energy is to be protected to preclude critical depletion by the automatic starting system, unless a second independent means of starting is provided. A second source of energy is to be provided for an additional three starts within 30 minutes, unless manual starting can be demonstrated to be effective.

6 Machinery fastening loading accelerations

6.1 General

6.1.1 Essential equipment and main propulsion machinery supports are to be suitable for the accelerations as indicated in [6.2]. Accelerations are to be considered acting independently.

6.2 Accelerations

6.2.1 Longitudinal impact accelerations a_ℓ

The maximum longitudinal impact acceleration at any point along the hull girder, in m/s², is equal to:

$$a_\ell = \frac{F_{IB}}{\Delta_{ui}}\left[1,1\tan(\gamma_{stem}+\phi)+7\frac{H}{L_{ui}}\right]$$

6.2.2 Vertical impact acceleration a_v

The combined vertical impact acceleration a_v at any point along the hull girder, in m/s², is equal to:

$$a_v = 2,5F_{IB}\frac{F_{xV}}{\Delta_{ui}}$$

where:

- F_{xV} = 1,30 at FE_{ui}
- F_{xV} = 0,20 at midship section
- F_{xV} = 0,40 at AE_{ui}
- F_{xV} = 1,30 at AE_{ui} for ships conducting ice breaking astern.

Intermediate values of F_x are to be interpolated linearly.

6.2.3 Transverse impact acceleration a_t

The combined transverse impact acceleration a_t at any point along hull girder, in m/s², is equal to:

$$a_t = 3\, F_{Bow} \frac{F_{xT}}{\Delta_{ui}}$$

where:

- F_{xT} = 1,50 at FE_{ui}
- F_{xT} = 0,25 at midship section
- F_{xT} = 0,50 at AE_{ui}
- F_{xT} = 1,50 at AE_{ui} for ships conducting ice breaking astern.

Intermediate values of F_x are to be interpolated linearly.

7 Other systems and equipment

7.1 Auxiliary systems

7.1.1 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.

7.1.2 Means are to be provided to prevent damage due to freezing, to tanks containing liquids due to freezing.

7.1.3 Vent pipes, intake and discharge pipes and associated systems are to be designed to prevent blockage due to freezing or ice and snow accumulation.

7.2 Sea inlets and cooling water systems

7.2.1 Cooling water systems for machinery that is essential for the propulsion and safety of the ship, including sea chests inlets, are to be designed for the environmental conditions applicable for the additional class notations **POLAR CLASS** and the service notations **icebreaker**.

7.2.2 At least two sea chests are to be arranged as ice boxes (sea chests for water intake in severe ice conditions) for the additional class notations **POLAR CLASS 1** to **5** inclusive and for the service notations Icebreaker 1 to 5 inclusive. The calculated volume for each ice box is to be at least 1 m³ for every 750 kW of the total installed power.

For the additional class notations **POLAR CLASS 6** and **7** and for the service notations **icebreaker 6** and **7**, there is to be at least one ice box, located preferably near the centreline.

7.2.3 Ice boxes are to be designed for an effective separation of ice and venting of air.

7.2.4 Sea inlet valves are to be secured directly to the ice boxes. The valve is to be a full bore type.

7.2.5 Ice boxes and sea bays are to have vent pipes and are to have shut off valves connected direct to the shell.

7.2.6 Means are to be provided to prevent freezing of sea bays, ice boxes, ship side valves and fittings above the load water line.

7.2.7 Efficient means are to be provided to re-circulate cooling seawater to the ice box. The total sectional area of the circulating pipes is not to be less than the area of the cooling water discharge pipe.

7.2.8 Detachable gratings or manholes are to be provided for ice boxes. Manholes are to be located above the deepest load line. Access is to be provided to the ice box from above.

7.2.9 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 slot in shell plating is to be not less than 20 mm. Gratings of the ice boxes are to be provided with a means of clearing. The means of clearing is to be of a type using low pressure steam. Clearing pipes are to be provided with screw-down type non return valves.

7.3 Ballast tanks

7.3.1 Efficient means are to be provided to prevent freezing in fore and after peak tanks and wing tanks located above the water line and where otherwise found necessary.

7.4 Ventilation system

7.4.1 The air intakes for machinery and accommodation ventilation are to be located on both sides of the ship at locations where manual de-icing is possible. Anti-icing protection of the air inlets may be accepted as an equivalent solution to location on both sides of the ship and manual de-icing at the Society's discretion. Notwithstanding the above, multiple air intakes are to be provided for the emergency generating set and are to be as far apart as possible.

7.4.2 The temperature of the inlet air is to be suitable for:

- the safe operation of the machinery; and
- the thermal comfort in the accommodation.

Accommodation and ventilation air intakes are to be provided with means of heating, if needed.

7.5 Transverse thrusters

7.5.1 Tunnels of transverse thrusters not ice-certified are to be fitted with grids for protection against ice impacts, except if the arrangement is made in order to:

a) when the thruster is not working during navigation, prevent ice block to impact the propeller blades or the propeller blades are designed to withstand ice impacts

b) when the thruster is working (e.g in harbour), prevent any ice accretion in the thruster (e.g. means of de-icing are available before starting the thruster).

Section 4 Ships Operating in Polar Waters (POLAR CAT)

1 General

1.1 Application

1.1.1 This Section applies to ships having one of the additional servi0e features **POLAR CAT-A, POLAR CAT-B** or **POLAR CAT-C**.

1.1.2 This Section includes:

a) the requirements of the IMO International Code for Ships Operating in Polar Waters (Polar Code), printed in Italic type when quoted in the Section; in the reproduction of the Polar Code applicable for the purpose of classification, the word "Administration", wherever mentioned, has been replaced by the word "Society". Exceptions are indicated in [1.1.3].

b) the additional classification requirements of the Society and the Society's interpretations of the Polar Code, printed in regular font.

The requirements of this Section are cross-referenced to the applicable Part, Chapter and paragraph of the Polar Code, as appropriate, under the wording "POLAR CODE REFERENCE".

1.1.3 The following requirements of the Polar Code are not within the scope of classification:

- Part I-A Safety measures, Chapter 11 - Voyage planning
- Part I-A Safety measures, Chapter 12 - Manning and training
- Operational requirements of Part II-A Pollution prevention measures.

1.2 Definitions

1.2.1 Ship operating in low air temperature

POLAR CODE REFERENCE: Part I-A, Chapter 1, 1.2.12

Ship intended to operate in low air temperature means a ship which is intended to undertake voyages to or through areas where the lowest Mean Daily Low Temperature (MDLT) is below -10°C.

1.2.2 Mean Daily Low Temperature (MDLT)

POLAR CODE REFERENCE: Part I-A, Chapter 1, 1.2.9

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

Guidance instructions for determining MDLT:

a) determine the daily low temperature for each day for a 10 year period,

b) determine the average of the values over the 10 year period each day,

c) plot the daily averages over the year,

d) pake the lowest of the averages for the season of operation.

1.2.3 Polar Service Temperature

POLAR CODE REFERENCE: Part I-A, Chapter 1, 1.2.11

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

1.2.4 Ship with the additional class notation COLD BASIC (H t_{DH} , E t_{DE}) or COLD (H t_{DH} , E t_{DE})

When the additional class notation **COLD BASIC (H t_{DH} , E t_{DE})** or **COLD (H t_{DH} , E t_{DE})** is assigned to the ship, the temperature t_{DE} and t_{DH} are defined as follows:

- the lowest design external air temperature t_{DE} , in °C, to be considered for the equipment exposed to low air temperature, is to be equal to the Polar Service Temperature (see [1.2.3])
- the lowest mean daily average air temperature t_{DH} , in °C, to be considered for the hull exposed to low air temperature, is to be taken not more than 13°C higher than the Polar Service Temperature (see [1.2.3]).

1.3 Documents to be submitted

1.3.1 Plans and documents to be submitted for approval

The following plans and documents are to be submitted to the Society for approval:

- midship section, shell expansion, transverse sections, construction profile and decks
- stability calculations in intact and damaged conditions when relevant
- machinery arrangement (particularly sea chest arrangement)
- winterization arrangement and systems (de-icing, anti-icing)
- list of communication and navigational equipment
- life saving and fire fighting arrangement
- sewage treatment plant arrangement when relevant
- the Polar Water Operational Manual (PWOM) (see [3.1]).

1.3.2 Documents to be submitted for information

The following documents are to be submitted to the Society for information:

- the operating profile describing area and season of operation, ice conditions, temperatures (see [2.2.2])
- the operational assessment methodology and outcome (see Article [2]).

2 Operational assessment

2.1 General

2.1.1 Purpose

POLAR CODE REFERENCE: Part I-A, Chapter 1, 1.5

In order to establish procedures or operational limitations, an assessment of the ship and its equipment shall be carried out, taking into consideration the following:

a) *the anticipated range of operating and environmental conditions, such as:*
   1) *operation in low air temperature,*
   2) *operation in ice*
   3) *operation in high latitude*
   4) *potential for abandonment onto ice or land*

b) *hazards, as listed in the* Polar Code*; and*

c) *additional hazards, if identified.*

The operating profile, the methodology and the outcome of the operational assessment are reviewed by the Society in order to issue the Polar Ship Certificate and to verify that all the requirements of the Polar Code are fulfilled according to the intended operations.

2.2 Methodology

2.2.1 Principles

The methodology may be based on the following steps:

a) to define operating profile (see [2.2.2])

b) to identify relevant hazards (see [2.2.3]) and any other hazards based on a review of the operating profile

c) to develop a model in order to analyse risks, considering:
   - development of accident scenarios
   - probability of events in each accident scenario, and
   - consequence of end states in each scenario

d) to assess risks and to determine acceptability:
   - to estimate risk levels in accordance with the selected modelling approach, and
   - to assess whether the risk levels are acceptable

e) in the event that risk levels determined in the previous steps are considered to be too high: to identify current or develop new risk control options that aim to achieve one or more of the following:
   - to reduce the frequency of failures through better design, procedures, training, etc.
   - to mitigate the effect of failures in order to prevent accidents
   - to limit the circumstances in which failures may occur, or
   - to mitigate consequences of accidents

f) to incorporate risk control options for design, procedures, training and limitations, as applicable.

2.2.2 Operating profile

The operating profile is used to describe the expected environmental and operational conditions in the area where the ship is intended to trade. The operating profile may be defined on the following relevant information and available documentation:

a) season and area of operation

b) ice charts covering the season and area and giving the most likely ice conditions

c) temperature data for the season and area, over at least 10 years

d) operation with icebreaker escort

e) description of Search And Rescue (SAR) availability.

Table 1 : Outcome of the operational assessment

Item	Main outcome	Additional outcome
Ice class selection	Ice class notation	Equivalency procedure when relevant
Ice accretion is likely to occur	yes / no	–
Snow accumulation is likely to occur	yes / no	–
Slush ice or ice ingestion are likely to occur	yes / no	–
Operating in low air temperature	yes / no	Polar Service Temperature (PST)
Freezing temperatures are likely to occur	yes / no	–
Operating at high latitude	yes / no	–
Operating during extended periods of darkness	yes / no	–
Operating during extended periods of daylight	yes / no	–
Scenario of abandonment	water / ice / land	Maximum Estimated Time of Rescue (ETR)
Operating with icebreaker escort	yes / no	–

2.2.3 Hazards

The hazards to be considered during the operational assessment may be taken as follows:

a) ice (sea ice regime, ice accretion, ice ingestion)

b) snow accumulation

c) low air and sea temperature

d) extended periods of darkness or daylight

e) high latitude

f) remoteness and possible lack of accurate and complete hydrographic data and information

g) lack of ship crew experience in polar operations

h) lack of suitable emergency response equipment

i) rapidly changing and severe weather conditions

j) environmental impacts.

Additional hazards may be considered if relevant.

2.2.4 Outcome of the assessment

As an outcome of the operational assessment, the information to be provided to the Society are summarized in Tab 1.

3 Safety

3.1 Polar Water Operational Manual (PWOM)

3.1.1 General

POLAR CODE REFERENCE: Part I-A, Chapter 2, 2.3.1

In order to provide the Owner, operator, master and crew with sufficient information regarding the ship's operational capabilities and limitations, to support their decision-making process, a Polar Water Operational Manual (PWOM) *shall be carried on board.*

3.1.2 Content of the PWOM

POLAR CODE REFERENCE: Part I-A, Chapter 2, 2.3.2 and 2.3.3

A table of contents is given as a guidance in App 1.

The PWOM shall contain the methodology used to determine capabilities and limitations in ice.

In order to avoid encountering conditions that exceed the ship's capabilities, the PWOM shall include or refer to specific risk-based procedures in normal operations for the following:

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

b) arrangements for receiving forecasts of the environmental conditions;

c) means of addressing any limitations of the hydrographic, meteorological and navigational information available;

d) operation of equipment; and

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

In the event of incidents in polar waters, the PWOM shall include risk-based procedures to be followed for:

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

*b) in the case of ship with an ice class notation or service notation **icebreaker**, procedures for maintaining life support and ship integrity in the event of prolonged entrapment by ice.*

The PWOM shall include risk-based procedures to be followed for measures to be taken in the event of encountering ice and/or temperatures which exceed the ship's design capabilities or limitations.

The PWOM shall include risk-based procedures for monitoring and maintaining safety during operations in ice, as applicable, including any requirements for escort operations or icebreaker assistance. Different operational limitations may apply depending on whether the ship is operating independently or with icebreaker escort. Where appropriate, the PWOM should specify both options.

3.2 Ship structure

3.2.1 Materials of exposed structures

POLAR CODE REFERENCE: Part I-A, Chapter 3, 3.3.1

For a ship operating in low air temperature and having the additional class notation **COLD BASIC (H t_{DH} , E t_{DE}) or COLD (H t_{DH} , E t_{DE})**, the materials for weather and sea exposed structural members and for members attached to the weather and sea exposed shell plating are to comply with the applicable requirements of NR467, Pt F, Ch 8, Sec 4.

When a ship is granted with an additional class notation **POLAR CLASS** or a service notation **icebreaker**, in case the material grades in Sec 2 and those of the additional class notation **COLD BASIC (H t_{DH} , E t_{DE})** or **COLD (H t_{DH} , E t_{DE})** differ, the higher material grade is to be selected.

3.2.2 Hull scantlings

POLAR CODE REFERENCE: Part I-A, Chapter 3, 3.3.2

When a ship is granted with the additional service feature **POLAR CAT-A**, the hull scantlings are to comply with at least the requirements of Sec 2, as applicable to the additional class notation **POLAR CLASS 5** or the service feature **icebreaker 5**.

When a ship is granted with the additional service feature **POLAR CAT-B**, the hull scantlings are to comply with at least the requirements of Sec 2 as applicable to the additional class notation **POLAR CLASS 7** or the service feature **icebreaker 7**.

When a ship is granted with the additional service feature **POLAR CAT-C**, the hull scantlings are to comply with the assigned ice class, as applicable.

When, according to the outcome of the operational assessment, ice strengthening is not required, typically for open water, the additional service feature **POLAR CAT-C** is to be granted.

3.3 Stability

3.3.1 Intact conditions

POLAR CODE REFERENCE: Part I-A, Chapter 4, 4.3.1

When, according to the outcome of the operational assessment, the ship is operating in areas and during periods where ice accretion is likely to occur, the stability in intact conditions is to take into account the weight of ice accretion on the full length of the ship, as follows:

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

b) 7,5 kg/m^2 for the projected lateral area of each side of the ship above the water plane; and

c) the projected lateral area of discontinuous surfaces of rail, sundry booms, spars (except masts) and rigging of ship having no sails and the projected lateral area of other small objects shall be computed by increasing the total projected area of continuous surfaces by 5% and the static moments of this area by 10%.

Ships operating in areas and during periods where ice accretion is likely to occur shall be:

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

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

Note 1: When the additional class notation **COLD DI** is assigned, the requirements above are fulfilled.

The PWOM is to include information about icing allowance used in the stability calculations and is to refer the appropriate measures to be taken to ensure that the ice accretion does not exceed this allowance (see Chapter 5 in the PWOM given in App 1, Tab 3).

3.3.2 Damaged conditions

POLAR CODE REFERENCE: Part I-A, Chapter 4, 4.3.2

The residual stability after ice damage is to be calculated for a ship having the additional service feature **POLAR CAT-A** or **POLAR CAT-B**.

When a probabilistic approach is required, the probability factor of survival after flooding s_i is to be taken equal to 1,0 for all the loading conditions used to calculate the attained subdivision index.

When a deterministic approach is required, the residual stability criteria are to be complied with for each loading condition.

The ice damage extents to be assumed for both probabilistic and deterministic approaches, regardless of the **SDS** notation, are defined as follows:

a) *the longitudinal extent is 4,5% of the upper ice waterline length if centred forward of the maximum breadth on the upper ice waterline, and 1,5% of upper ice waterline length otherwise, and shall be assumed at any longitudinal position along the ship's length;*

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

c) *the vertical extent is the lesser of 20% of the upper ice waterline draught or the longitudinal extent, and shall be assumed at any vertical position between the keel and 120% of the upper ice waterline draught.*

Note 1: When the additional class notation **COLD BASIC (H t_{DH} , E t_{DE})** or **COLD (H t_{DH} , E t_{DE})** is assigned, the damaged conditions not due to ice collision are to take into account the weight of ice accretion as specified in the additional class notation.

3.4 Watertight and weathertight integrity

3.4.1 General

POLAR CODE REFERENCE: Part I-A, Chapter 5, 5.3.1

When, according to the outcome of the operational assessment, the ship is operating in areas and during periods where ice accretion is likely to occur, means are to be provided to remove or prevent ice and snow accretion around hatches and doors.

Note 1: When the additional class notation **COLD DI** is assigned, the requirements above are fulfilled.

3.4.2 Ships with the additional class notation COLD BASIC (H t_{DH} , E t_{DE}) or COLD (H t_{DH} , E t_{DE}) operating in low air temperature

POLAR CODE REFERENCE: Part I-A, Chapter 5, 5.3.2

For a ship operating in low air temperature and having the additional class notation **COLD BASIC (H t_{DH} , E t_{DE})** or **COLD (H t_{DH} , E t_{DE})**, all the closing appliances and doors relevant to the watertight and weathertight integrity are to comply with the applicable requirements of NR467, Pt F, Ch 8, Sec 4.

3.5 Machinery installations

3.5.1 General

POLAR CODE REFERENCE: Part I-A, Chapter 6, 6.3.1

When, according to the outcome of the operational assessment, the ship is operating in areas and during periods where ice accretion and/or snow accumulation and/or slush ice conditions or freezing are likely to occur, the following applies:

a) *machinery installations and associated equipment are to be protected against the effect of ice accretion and/or snow accumulation, ice ingestion from sea water, freezing and increased viscosity of liquids, seawater intake temperature and snow ingestion;*

b) *working liquids shall be maintained in a viscosity range that ensures operation of the machinery; and*

c) *seawater supplies for machinery systems shall be designed to prevent ingestion of ice (Refer to MSC/Circ. 504, Guidance on design and construction of sea inlets under slush ice conditions), or otherwise arranged to ensure functionality.*

Note 1: When the additional class notation **COLD DI** is assigned, requirements a) and b) above are fulfilled.

3.5.2 Ships with the additional class notation COLD BASIC (H t_{DH} , E t_{DE}) or COLD (H t_{DH} , E t_{DE}) operating in low air temperature

POLAR CODE REFERENCE: Part I-A, Chapter 6, 6.3.2

For a ship operating in low air temperature and having the additional class notation **COLD BASIC (H t_{DH} , E t_{DE})** or **COLD (H t_{DH} , E t_{DE})**, the machinery installations are to comply with the applicable requirements of NR467, Pt F, Ch 8, Sec 4.

3.5.3 Propulsion and steering equipment

POLAR CODE REFERENCE: Part I-A, Chapter 6, 6.3.3

When a ship is granted with the additional service feature **POLAR CAT-A**, the scantlings of propeller blades, propulsion line, steering equipment and other appendages are to comply with at least the requirements of Sec 3, as applicable to the additional class notation **POLAR CLASS 5** or the service feature **icebreaker 5**.

When a ship is granted with the additional service feature **POLAR CAT-B**, the scantlings of propeller blades, propulsion line, steering equipment and other appendages are to comply with at least the requirements of Sec 3, as applicable to the additional class notation **POLAR CLASS 7** or the service feature **icebreaker 7**.

When a ship is granted with the additional service feature **POLAR CAT-C**, the scantlings of propeller blades, propulsion line, steering equipment and other appendages are to comply with the assigned ice class, if applicable.

3.6 Fire safety and protection

3.6.1 General

POLAR CODE REFERENCE: Part I-A, Chapter 7, 7.3.1 and 7.3.2

When, according to the outcome of the operational assessment, the ship is operating in areas and during periods where ice accretion and/or snow accumulation and/or slush ice conditions or freezing are likely to occur, the fire safety systems and appliances are to comply with the following requirements:

a) *isolating and pressure/vacuum valves in exposed locations are to be protected from ice accretion and remain accessible at all time;*

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

c) *the fire main shall be arranged so that exposed sections can be isolated and means of draining of exposed sections shall be provided. Fire hoses and nozzles need not be connected to the fire main at all times, and may be stored in protected locations near the hydrants;*

d) *firefighter's outfits shall be stored in warm locations on the ship; and*

e) *where fixed water-based fire-fighting systems are located in a space separate from the main fire pumps and use their own independent sea suction, this sea suction shall be also capable of being cleared of ice accumulation.*

Note 1: When the additional class notation **COLD DI** is assigned, requirements a) to d) above are fulfilled.

3.6.2 Ships with the additional class notation COLD BASIC (H t_{DH} , E t_{DE}) or COLD (H t_{DH} , E t_{DE}) operating in low air temperature

POLAR CODE REFERENCE: Part I-A, Chapter 7, 7.3.3

For a ship operating in low air temperature and having the additional class notation **COLD BASIC (H t_{DH} , E t_{DE})** or **COLD (H t_{DH} , E t_{DE})**, the exposed fire safety systems and appliances are to comply with the applicable requirements of NR467, Pt F, Ch 8, Sec 4.

3.7 Life-saving appliances

3.7.1 Escape

POLAR CODE REFERENCE: Part I-A, Chapter 8, 8.3.1

When, according to the outcome of the operational assessment, the ship is operating in areas and during periods where ice accretion is likely to occur*, means shall be provided to remove or prevent ice and snow accretion from escape routes, muster stations, embarkation areas, survival craft, its launching appliances and access to survival craft.*

Exposed escape routes shall be arranged so as not to hinder passage by persons wearing suitable polar clothing.

When a ship is operating in low air temperature*, adequacy of embarkation arrangements shall be assessed, having full regard to any effect of persons wearing additional polar clothing.*

3.7.2 Evacuation

POLAR CODE REFERENCE: Part I-A, Chapter 8, 8.3.2

Ships shall have means to ensure safe evacuation of persons, including safe deployment of survival equipment, when operating in ice-covered waters, or directly onto the ice, as applicable.

When means to ensure safe evacuation are requesting an additional source of power*, this source shall be able to operate independently of the ship's main source of power.*

3.7.3 Survival

POLAR CODE REFERENCE: Part I-A, Chapter 8, 8.3.3

For a ship assigned with the service notation **passenger ship** or **ro-ro passenger ship***, a proper sized immersion suit or a thermal protective aid shall be provided for each person on board.*

For any ship *where immersion suits are required, they shall be of the insulated type.*

When, according to the outcome of the operational assessment, the ship is operating in extended periods of darkness*, searchlights suitable for continuous use to facilitate identification of ice shall be provided for each lifeboat.*

No lifeboat shall be of any type other than partially or totally enclosed type.

Appropriate survival resources, which address both individual (personal survival equipment) and shared (group survival equipment) needs, shall be provided, as follows:

a) *life-saving appliances and group survival equipment that provide effective protection against direct wind chill for all persons on board;*

b) *personal survival equipment in combination with life-saving appliances or group survival equipment that provide sufficient thermal insulation to maintain the core temperature of persons; and*

c) *personal survival equipment that provide sufficient protection to prevent frostbite of all extremities.*

When, according to the outcome of the operational assessment, a potential of abandonment onto ice or land is identified, the following applies:

a) *group survival equipment shall be carried, unless an equivalent level of functionality for survival is provided by the ship's normal life-saving appliances;*

b) *when required, personal and group survival equipment sufficient for 110% of the persons on board shall be stowed in easily accessible locations, as close as practical to the muster or embarkation stations; and*

c) *containers for group survival equipment shall be designed to be easily movable over the ice and be floatable.*

When, according to the outcome of the operational assessment, the need to carry personal and group survival equipment is identified*, means shall be identified of ensuring that this equipment is accessible following abandonment.*

When carried in addition to persons, in the survival craft, the survival craft and launching appliances shall have sufficient capacity to accommodate the additional survival equipment.

Passengers shall be instructed in the use of the personal survival equipment and the action to take in an emergency.

The crew shall be trained in the use of the personal survival equipment and group survival equipment.

Adequate emergency rations shall be provided, for the maximum expected time of rescue (ETR).

3.8 Safety of navigation

3.8.1 Nautical information

POLAR CODE REFERENCE: Part I-A, Chapter 9, 9.3.1

Ships shall have means of receiving and displaying current information on ice conditions in the area of operation.

3.8.2 Navigational equipment functionality

POLAR CODE REFERENCE: Part I-A, Chapter 9, 9.3.2

Ships shall comply with SOLAS regulation V/22.1.9.4, irrespective of the size and, depending on the bridge configuration, have a clear view astern.

For a ship granted with an ice class or one of the service features **icebreaker**, the following applies:

a) either two independent echo-sounding devices or one echo-sounding device with two separate independent transducers are to be provided

b) where the required equipment has sensors that project below the hull, such sensors are to be protected against ice

c) when the ship is granted with the additional service feature **POLAR CAT-A** or **POLAR CAT-B**, the bridge wings are to be enclosed or designed to protect navigational equipment and operating personnel.

When, according to the outcome of the operational assessment, the ship is operating in areas and during periods where ice accretion is likely to occur, *means to prevent the accumulation of ice on antennas required for navigation and communication shall be provided.*

Ships shall have two non-magnetic means to determine and display their heading. Both means shall be independent and shall be connected to the ship's main and emergency source of power.

When, according to the outcome of the operational assessment, the ship is proceeding to latitudes over 80 degrees, the ship *shall be fitted with at least one GNSS compass or equivalent, which shall be connected to the ship's main and emergency source of power.*

3.8.3 Additional navigational equipment

POLAR CODE REFERENCE: Part I-A, Chapter 9, 9.3.3

When, according to the outcome of the operational assessment:

- the ship is not operating in areas with 24 hours daylight, the ship *shall be equipped with two remotely rotatable, narrow-beam search lights controllable from the bridge to provide lighting over an arc of 360 degrees, or other means to visually detect ice*
- the ship is involved in operations with an icebreaker escort, the ship *shall be equipped with a manually initiated flashing red light visible from astern to indicate when the ship is stopped. This light shall have a range of visibility of at least two nautical miles, and the horizontal and vertical arcs of visibility shall be conform to the stern light specifications required by the International Regulations for Preventing Collisions at Sea.*

3.9 Communication

3.9.1 Ship communication

POLAR CODE REFERENCE: Part I-A, Chapter 10, 10.3.1

Communication equipment on board shall have the capabilities for ship-to-ship and ship-to-shore communication, taking into account the limitations of communications systems in high latitudes and the anticipated low temperature.

Note 1: When a ship is navigating above latitudes of 76°N or 76°S, the GMDSS equipment is to be compliant with the requirements for sea areas A1 to A4 (refer to COMSAR/Circ. 32 Harmonization of GMDSS requirements for radio installations on board SOLAS ships).

Two-way on-scene and Search And Rescue (SAR) coordination communication capability in ship shall include:

a) voice and/or data communications with relevant rescue coordination centres; and

b) equipment for voice communications with aircraft on 121,5 MHz and 123,1 MHz.

The communication equipment shall provide for two-way voice and data communication with a TeleMedical Assistance Service (TMAS).

A ship with one of the additional service notations **icebreaker** *shall be equipped with a sound signalling system mounted to face astern to indicate escort and emergency manoeuvres to following ships as described in the International Code of Signals.*

3.9.2 Survival craft and rescue boat communication capabilities

POLAR CODE REFERENCE: Part I-A, Chapter 10, 10.3.2

All rescue boats, all lifeboats and all other survival crafts carried by the ship, notwithstanding the redundancy in aggregate capacity of survival crafts required by SOLAS Regulation III/21 and Regulation III/31, and taking into account the different possible distress scenarios, are considered able to be released for evacuation simultaneously and are to be provided with mandatory communication equipment.

When a ship is operating in low air temperature*, all rescue boats and lifeboats, whenever released for evacuation, shall:*

a) for distress alerting, carry one device for transmitting ship to shore alerts,

b) in order to be located, carry one device for transmitting signals for location,

c) for on-scene communications, carry one device for transmitting and receiving on-scene communications.

Note 1: Requirements above are fulfilled when, on each rescue boat and lifeboat, the following communication devices are carried:

- one equipment of EPIRB type for ship to shore communications
- one equipment of SART type for transmitting signals for location
- one equipment of VHF type (portable or fixed) for on-scene communications.

When a ship is operating in low air temperature*, all other survival craft shall:*

a) in order to be located, carry one device for transmitting signals for location,

b) for on-scene communications, carry one device for transmitting and receiving on-scene communications.

Note 2: Requirements above are fulfilled when the following communication devices are stored on board in order to be carried on each survival craft:

- one equipment of SART type for transmitting signals for location
- one equipment of VHF type for on-scene communications.

Recognizing the limitations arising from battery life, procedures shall be developed and implemented such that mandatory communication equipment for use in survival craft, including liferafts, and rescue boats are available for operation during the maximum expected time of rescue.

Procedures can include both operational requirements and any other means including technical solutions i.e. thermal insulation, chemical heat sources, additional batteries, rechargeable batteries with respective chargers, etc., and are to be documented in the PWOM.

The mandatory communication equipment are to be able to maintain the ready-for-operation state within the maximum expected time of rescue at the PST and after that to be capable to perform its functions at the PST with the operating time not less than specified in respective existing performance standards:

- for EPIRB: Res. A.810(19) and MSC.471(101)
- for Radar transponder: Res. A 802(19)
- for AIS-SART: Res. MSC.246 (83)
- for two-way VHF: Res. MSC. 149(77).

Note 3: For example, it is not required that an EPIRB being used for distress alerting continues distress messaging for maximum expected time of rescue, and two-way VHF radiotelephone apparatus being used for transmitting and receiving on-scene communications does not need to be technically in operation at its highest rated power with a duty cycle of 1:9 for maximum expected time of rescue.

4 Pollution prevention

4.1 Pollution by oil

4.1.1 Application

POLAR CODE REFERENCE: Part II-A, Chapter 1, 1.2

The requirements of [4.1.2] to [4.1.5] apply only to ships granted with the additional service feature **POLAR CAT-A** or **POLAR CAT-B**.

4.1.2 Fuel oil tanks

POLAR CODE REFERENCE: Part II-A, Chapter 1, 1.2.1

A ship with an aggregate oil fuel capacity of less than 600 m^3 is to be assigned with the additional class notation **PROTECTED FO TANKS**, as defined in NR467, Part A, except if all fuel oil tanks have a maximum individual capacity not greater than 30 m^3.

4.1.3 Cargo oil tanks of oil tankers less than 5000 tons deadweight

POLAR CODE REFERENCE: Part II-A, Chapter 1, 1.2.3

A ship assigned with one of the following service notations:

- **oil tanker**
- **FLS tanker**
- **Combination carrier/OBO ESP**
- **Combination carrier/OOC ESP**,

and with a deadweight less than 5000 tons, is to have the entire cargo length protected with double bottom tanks, wing tanks or spaces other than cargo and fuel oil tanks, arranged in accordance with the applicable requirements given in NR467, Pt D, Ch 7, Sec 2, [3.2.4].

4.1.4 Cargo tanks of ships other than oil tankers

POLAR CODE REFERENCE: Part II-A, Chapter 1, 1.2.2

A ship not assigned with one of the service notations listed in [4.1.3] *shall have all cargo tanks constructed and utilized to carry oil separated from the outer shell by a distance of not less than 0,76 m.*

4.1.5 Oil residue tanks

POLAR CODE REFERENCE: Part II-A, Chapter 1, 1.2.4

All oil residue (sludge) tanks and oily bilge water holding tanks shall be separated from the outer shell by a distance of not less than 0,76 m. This requirement does not apply to small tanks with a maximum individual capacity not greater than 30 m^3.

4.2 Pollution by sewage

4.2.1 Sewage treatment plant

POLAR CODE REFERENCE: Part II-A, Chapter 4, 4.2.1

A sewage treatment plant is not required when the ship has a sufficient onboard storage capacity for liquid effluent allowing the fully loaded ship to operate without discharging any sewage substances into the sea during the expected time of operation.

Note 1: When the additional class notation **NDO-x** days is assigned, requirement above is fulfilled and a sewage treatment plant is not required.

When the ship operates in areas of ice concentrations less than 1/10 and is assigned with:

- the service notation **passenger ship** or **ro-ro passenger ship**, and/or
- the additional service feature **POLAR CAT-A** or **POLAR CAT-B**,

the discharge of sewage into the sea is allowed only with an approved sewage treatment plant certified by the Society to meet the operational requirements in regulation either 9.1.1 or 9.2.1 of MARPOL Annex IV.

When the ship operates in areas of ice concentrations exceeding 1/10 for extended periods of time, the discharge of sewage into the sea is allowed only for a ship having the additional service feature **POLAR CAT-A** or **POLAR CAT-B** and using an approved sewage treatment plant certified by the Society to meet the operational requirements in regulation either 9.1.1 or 9.2.1 of MARPOL Annex IV.

Appendix 1 Polar Water Operational Manual (PWOM)

1 General

1.1 Application

1.1.1 The Polar Water Operational Manual (PWOM) is intended to address all aspects of operations. When appropriate information, procedures or plans exist elsewhere in a ship's documentation, the PWOM itself does not need to replicate this material but may, instead, cross-reference the relevant document.

As a guidance, a table of contents is given in this Appendix.

Not every section will be applicable to every polar ship. For instance **POLAR CAT-C** ships that undertake occasional or limit polar voyages will not need to have procedures for situations with a very low probability of occurrence.

Noting an aspect as ‘not applicable’ also indicates that this aspect has been considered and not merely omitted.

1.2 Table of contents

1.2.1 A detailed table of contents with guidances are given in Tab 2 to Tab 5 for each division of the PWOM listed in Tab 1.

Table 1 : Contents of PWOM

Division	Title
1	Operational capabilities and limitations
2	Ship operations
3	Risk management
4	Joint operations

Table 2 : Contents for operational capabilities and limitations

<table>
<tr><th colspan="2">1 - OPERATIONAL CAPABILITIES AND LIMITATIONS</th></tr>
<tr><td colspan="2">Chapter 1 - Operation in ice</td></tr>
<tr><td>1.1 - Operator guidance for safe operation</td><td>The PWOM should establish the means by which decisions as to whether ice conditions exceed the ship's design limits should be made, taking into account the operational limitations on the Polar Ship Certificate. An appropriate decision support system, such as the Canada's Arctic Ice Regime Shipping System, and/or the Russian Ice Certificate as described in the Rules of Navigation on the water area of the Northern Sea Route, can be used (1).
Bridge personnel should be trained in the proper use of the system to be utilized. For ships that will operate only in ice-free waters, procedures to ensure that will keep the ship from encountering ice should be established.</td></tr>
<tr><td>1.2 - Icebreaking capabilities</td><td>The PWOM should provide information on the ice conditions in which the ship can be expected to make continuous progress. This may be drawn, for example from numerical analysis, model test or from ice trials. Information on the influence of ice strength for new or decayed ice and of snow cover may be included.</td></tr>
<tr><td>1.3 - Manoeuvring in ice</td><td>No guidance.</td></tr>
<tr><td>1.4 - Special features</td><td>Where applicable, the PWOM should include the results of any equivalency analyses made to determine Polar Ship category/ice class. The manual should also provide information on the use of any specialized systems fitted to assist in ice operations.</td></tr>
<tr><td colspan="2">Chapter 2 - Operation in low air temperatures</td></tr>
<tr><td>2.1 - System design</td><td>The PWOM should list all ship systems susceptible to damage or loss of functionality by exposure to low temperatures, and the measures to be adopted to avoid malfunction.</td></tr>
<tr><td colspan="2">Chapter 3 - Communication navigation capabilities in high latitudes</td></tr>
<tr><td colspan="2">The PWOM should identify any restrictions to operational effectiveness of communications and navigational equipment that may result from operating in high latitudes.</td></tr>
<tr><td colspan="2">Chapter 4 - Voyage duration</td></tr>
<tr><td colspan="2">The PWOM should provide information on any limitations on ship endurance such as fuel tankage, fresh water capacity, provision stores, etc. This will normally only be a significant consideration for smaller ships, or for ships planning to spend extended periods in ice.</td></tr>
<tr><td colspan="2">(1) Guidance on methodologies for assessing operational capabilities and limitations in ice (POLARIS) as described in IMO Circular MSC.1/Circ.1519, can also be used.</td></tr>
</table>

Table 3 : Contents for ship operations

2 - SHIP OPERATIONS		
Chapter 1 - Strategic planning		
Assumptions used in conducting the analyses referred to below should be included in the Manual.		
1.1 -	Avoidance of hazardous ice	For ships operating frequently in polar waters, the PWOM should provide information with respect to periods during which the ship should be able to operate for intended areas of operation. Areas that pose particular problems, e.g. chokepoints, ridging, as well as worst recorded ice conditions should be noted. Where the available information is limited or of uncertain quality, this should be recognized and noted as a risk for voyage planning.
1.2 -	Avoidance of hazardous temperatures	For ships operating frequently in polar waters, the PWOM should provide information with respect to, the daily mean daily low temperature as well as the minimum recorded temperature for each of the days during the intended operating period. Where the available information is limited or of uncertain quality, this should be recognized as a risk for voyage planning.
1.3 -	Voyage duration and endurance	Procedures to establish requirements for supplies should be established, and appropriate safety levels for safety margins determined taking into account various scenarios, e.g. slower than expected steaming, course alterations, adverse ice conditions, places of refuge and access to provisions. Sources for and availability of fuel types should be established, taking into account long lead times required for deliveries.
1.4 -	Human resources management	The PWOM should provide guidance for the human resources management, taking into account the anticipated ice conditions and requirements for ice navigation, increased levels of watch keeping, hours of rest, fatigue and a process that ensures that these requirements will be met.
Chapter 2 - Arrangements for receiving forecasts of environmental conditions		
The PWOM should set out the means and frequency for provision of ice and weather information. Where a ship is intended to operate in or in the presence of ice, the manual should set out when weather and ice information is required and the format for the information. When available, the information should include both global and localized forecasts that will identify weather and ice patterns/ regimes that could expose the ship to adverse conditions. The frequency of updates should provide enough advance notice that the ship can take refuge or use other methods of avoiding the hazard if the conditions are forecast to exceed its capabilities. The PWOM may include use of a land-based support information provider an effective method of sorting through available information, thereby providing the ship only with information that is relevant, reducing demands on the ship's communications systems. The manual may also indicate instances in which additional images should be obtained and analysed, as well as where such additional information may be obtained.		
2.1 -	Ice information	The PWOM should include or refer to guidance on how radar should be used to identify ice floes, how to tune the radar to be most effective, instructions on how to interpret radar images, etc. If other technologies are to be used to provide ice information, their use should also be described.
2.2 -	Meteorological information	No guidance.
Chapter 3 - Verification of hydrographic, meteorological and navigational information		
The PWOM should provide guidance on the use of hydrographic information.		
Chapter 4 - Operation of Special Equipment		
4.1 -	Navigation systems	No guidance.
4.2 -	Communication systems	No guidance.
Chapter 5 - Procedures to maintain equipment and system functionality		
5.1 -	Icing prevention and de-icing	The PWOM should provide guidance on how to prevent or mitigate icing by operational means, how to monitor and assess ice accretion, how to conduct de-icing using equipment available on the ship, and how to maintain the safety of the ship and its crew during all of these aspects of the operation.
5.2 -	Operation of seawater systems	The PWOM should provide guidance on how to monitor, prevent or mitigate ice ingestion by seawater systems when operating in ice or in low water temperatures. This may include recirculation, use of low rather than high suctions, etc.
5.3 -	Procedures for low temperature operations	The PWOM should provide guidance on maintaining and monitoring any systems and equipment that are required to be kept active in order to ensure functionality; e.g. by trace heating or continuous working fluid circulation.

Table 4 : Contents for risk management

3 - RISK MANAGEMENT		
Chapter 1 - Risk mitigation in limiting environmental condition		
1.1 -	Measures to be considered in adverse ice conditions	The PWOM should contain guidance for the use of low speeds in the presence of hazardous ice. Procedures should also be set for enhanced watchkeeping and lookout manning in situations with high risks from ice, e.g. in proximity to icebergs, operation at night, and other situations of low visibility. When possibilities for contact with hazardous ice exist, procedures should address regular monitoring, e.g. soundings/inspections of compartments and tanks below the waterline.
1.2 -	Measures to be considered in adverse temperature conditions	The PWOM should contain guidance on operational restrictions in the event that temperatures below the ships polar service temperature are encountered or forecast. These may include delaying the ship, postponing the conduct of certain types of operation, using temporary heating, and other risk mitigation measures.
Chapter 2 - Emergency response		
In general, where the possibility of encountering low air temperatures, sea ice, and other hazards is present, the PWOM should provide guidance on procedures that will increase the effectiveness of emergency response measures.		
2.1 -	Damage control	The PWOM should consider damage control measures arrangements for emergency transfer of liquids and access to tanks and spaces during salvage operations.
2.2 -	Fire-fighting	No guidance.
2.3 -	Escape and evacuation	Where supplementary or specialized lifesaving equipment is carried to address the possibilities of prolonged durations prior to rescue, abandonment onto ice or adjacent land, or other aspects specific to polar operations, the PWOM should contain guidance on the use of the equipment and provision for appropriate training and drills.
Chapter 3 - Coordination with emergency response services		
3.1 -	Ship emergency response	The PWOM should include procedures to be followed in preparing for a voyage and in the event of an incident arising.
3.2 -	Salvage	The PWOM should include procedures to be followed in preparing for a voyage and in the event of an incident arising.
3.3 -	Search and rescue	The PWOM should contain information on identifying relevant Rescue Coordination Centres for any intended routes, and should require that contact information and procedures be verified and updated as required as part of any voyage plan.
Chapter 4 - Procedures for maintaining life support and ship integrity in the event of prolonged entrapment by ice		
Where any ship incorporates special features to mitigate safety or environmental risks due to prolonged entrapment by ice, the PWOM should provide information on how these are to be set up and operated. This may include, for example, adding additional equipment to be run from emergency switchboards, draining systems at risk of damage through freezing, isolating parts of HVAC systems, etc.		
4.1 -	System configuration	No guidance.
4.2 -	System operation	No guidance.

Table 5 : Contents for joint operations

4 - JOINT OPERATIONS	
Chapter 1 - Escorted operations	
The PWOM should contain or reference information on the rules and procedures set out by coastal States who require or offer icebreaking escort services. The manual should also emphasize the need for the master to take account of the ship's limitations in agreeing on the conduct of escort operations.	
Chapter 2 - Convoy operations	No guidance.

BUREAU VERITAS MARINE & OFFSHORE

Tour Alto
4 place des Saisons
92400 Courbevoie - France
+33 (0)1 55 24 70 00

marine-offshore.bureauveritas.com/rules-guidelines

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