RUSSIAN MARITIME REGISTER OF SHIPPING
HEAD OFFICE

CIRCULAR LETTER	No. 312-11-812c	dated 15.04.2015

Re:

Application of the requirements of the Finnish-Swedish Ice Class Rules, 2010, in the RS practice

Item of technical supervision:

ice class ships

Implementation	from the date of the Circular Letter publication
Valid: till	-
Validity period extended till	-
Cancels / Amends/ Supplements Circular Letter No.	-	dated -

Number of pages:	1 + 44
Appendices:	Amendments to the Rules for the Classification and Construction of Sea-Going Ships, 2015 — 44 pages

Chief Executive Officer S.N. Sedov

Amends	Rules for the Classification and Construction of Sea-Going Ships, 2015, ND No. 2-020101-82-E

Practice of application of the RS requirements for ice class ships operating in the northern parts of the Baltic Sea has revealed the necessity and feasibility of using, with the shipowners' consent, the requirements of the Finnish-Swedish Ice Class Rules, 2010 (23/11/2010 TRAFI/31298/03/04/01/00/2010).

To implement applicable requirements of the above mentioned Rules into the RS practice, the amendments given in Appendix to the Circular Letter shall be introduced into the Rules for the Classification and Construction of Sea-Going Ships.

The original text of the Finnish-Swedish Ice Class Rules, 2010, in English is posted on the RS internal website in Section "Normative Documents / External Normative Documents / ND No.1-0301-035-E".

It is necessary to do the following:

1. Where necessary (with the shipowners' consent), apply the amendments to the Rules for the Classification and Construction of Sea-Going Ships given in Appendix to the Circular Letter during technical supervision of ice class ships under construction / in service.

2. Bring the content of the Circular Letter to the notice of the RS surveyors, interested organizations and persons in the area of the RS Branch Offices' activity.

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No.   15-55159

Amendments

to the Rules for the Classification and Construction of Sea-Going Ships (2015)

PART I. CLASSIFICATION

2.2 CLASS NOTATION OF A SHIP

2.2.3 The Register ice category marks and IACS polar class notations.

Here and elsewhere throughout the RS Rules, where the term "ice category" is applied, this term shall be replaced by the term "ice class(es)".

Accordingly, the name of the paragraph shall be amended to read:

"2.2.3 The Register ice class, IACS polar class and the Baltic ice class notations."

2.2.3.1 Shall be amended to read:

"**2.2.3.1** Ice class notations are assigned to icebreakers and ice class ships in compliance with the requirements of paras. 2.2.3.2 to 2.2.3.6.

The IACS polar class notations are assigned to polar class ships in accordance with the requirements of Section 1, Part XVII "Distinguishing Marks and Descriptive Notations in the Class Notation Specifying Structural and Operational Particulars of Ships".

The Baltic ice class notations are assigned to ice class ships in compliance with the requirements of Section 10, Part XVII "Distinguishing Marks and Descriptive Notations in the Class Notation Specifying Structural and Operational Particulars of Ships".

The IACS polar class notations are assigned at the shipowner's discretion. At the same time, for the Register-classed ships intended for operation in Russian arctic seas as well as for ice breakers the Register Ice category marks are assigned in compliance with paras. 2.2.3.2 and 2.2.3.3.3.

At the shipowner's discretion the IACS polar class notations and the Baltic ice class notations may be applied simultaneously (double or triple ice class), provided such ships comply with the requirements for both the IACS polar class ships and the Register ice strengthened ships."

PART II. HULL

3.10 STRENGTHENING OF ICE SHIPS AND ICEBREAKERS

3.10.1.1.1 Shall be supplemented with the text reading as follows:
"The requirements to the Baltic ice class ships (refer to 2.2.3.1 of Part I "Classification") are given in Section 10, Part XVII "Distinguishing Marks and Descriptive Notations in the Class Notation Specifying Structural and Operational Particulars of Ships"."

PART VII. MACHINERY INSTALLATIONS

1.1 APPLICATION

1.1.1 Shall be supplemented with the text reading as follows:

"The requirements to machinery installations of the Baltic ice class ships (refer to 2.2.3.1, Part I "Classification") are given in Section 10, Part XVII "Distinguishing Marks and Descriptive Notations in the Class Notation Specifying Structural and Operational Particulars of Ships"."

PART XVII. DISTINGUISHING MARKS AND DESCRIPTIVE NOTATIONS IN THE CLASS NOTATION SPECIFYING STRUCTURAL AND OPERATIONAL PARTICULARS OF SHIPS

Shall be supplemented with Section 10 reading as follows:

"10 REQUIREMENTS TO SHIPS OF BALTIC ICE CLASSES

10.1 GENERAL

10.1.1 The requirements to ships of Baltic ice classes coincide with the requirements of the Finnish-Swedish Ice Class Rules, 2010 and apply to ships being in service in the Baltic Sea water area in winter.

10.2 BALTIC ICE CLASSES

The ships complying with the requirements of this Section may be assigned to Baltic ice class as follows:

.1 ice class **IA Super**; ships with such structure, engine output and other properties that they are normally capable of navigating in difficult ice conditions without the assistance of icebreakers;

.2 ice class **IA**; ships with such structure, engine output and other properties that they are capable of navigating in difficult ice conditions, with the assistance of icebreakers when necessary;

.3 ice class **IB**; ships with such structure, engine output and other properties that they are capable of navigating in moderate ice conditions, with the assistance of icebreakers when necessary;

.4 ice class **IC**; ships with such structure, engine output and other properties that they are capable of navigating in light ice conditions, with the assistance of icebreakers when necessary;

.5 ice class **II**; ships that have a steel hull and that are structurally fit for navigation in the open sea and that, despite not being strengthened for navigation in ice, are capable of navigating in very light ice conditions with their own propulsion machinery;

.6 ice class **III**; ships that do not belong to the ice classes referred to in paragraphs .1 - .5.

10.3 ICE CLASS DRAUGHT

10.3.1 Upper and lower ice waterlines.

The upper ice waterline (UIWL) shall be the envelope of the highest points of the waterlines at which the ship is intended to operate in ice. The line may be a broken line.

The lower ice waterline (LIWL) shall be the envelope of the lowest points of the waterlines at which the ship is intended to operate in ice. The line may be a broken line.

10.3.2 Maximum and minimum draught fore and aft.

The maximum and minimum ice class draughts at fore and aft perpendiculars shall be determined in accordance with the upper and lower ice waterlines.

Restrictions on draughts when operating in ice shall be documented and kept on board readily available to the master. The maximum and minimum ice class draughts fore, amidships and aft shall be indicated in the Annex to Classification Certificate (Form 3.1.2-1). If the summer load line in fresh water is anywhere located at a higher level than the UIWL, the ship's sides shall be provided with a warning triangle and with an ice class draught mark at the maximum permissible ice class draught

amidships (see Annex 1)., the availability of which shall be also specified in the Annex to Classification Certificate (Form 3.1.2-1).

The draught and trim, limited by the UIWL, must not be exceeded when the ship is navigating in ice. The salinity of the sea water along the intended route shall be taken into account when loading the ship.

The ship shall always be loaded down at least to the LIWL when navigating in ice. Any ballast tank, situated above the LIWL and needed to load down the ship to this water line, shall be equipped with devices to prevent the water from freezing. In determining the LIWL, regard shall be paid to the need for ensuring a reasonable degree of ice-going capability in ballast. The propeller shall be fully submerged, if possible entirely below the ice. The forward draught shall be at least:

$(2 + 0{,}00025 \, \Delta) \, h_o$ [m] but need not exceed $4h_o$,

where

Δ is displacement of the ship [t] on the maximum ice-class draught according to 10.3.1.

h_o is level ice thickness [m] according to 10.5.2.1.

10.4 ENGINE OUTPUT

10.4.1 Definitions and explanations.

The engine output P is the maximum output the propulsion machinery can continuously deliver to the propeller(s).

The definitions regarding the ship and some other parameters are given below:

|		
L	m	length of the ship between the perpendiculars
L_{BOW}	m	length of the bow
L_{PAR}	m	length of the parallel midship body
B	m	maximum breadth of the ship
T	m	actual ice class draughts of the ship according to 3.2.2
A_{wf}	m^2	area of the waterline of the bow
α	degree	the angle of the waterline at B/4
φ_1	degree	the rake of the stem at the centerline. If the ship has a bulbous bow, then $\varphi_1 = 90°$.
φ_2	degree	the rake of the bow at B/4
ψ	degree	flare angle calculated as $\psi = \arctan(\tan\varphi/\sin\alpha)$ using angles α and φ at each location. For 10.4.3 flare angle is calculated using $\varphi = \varphi_2$
D_P	m	diameter of the propeller
H_M	m	thickness of the brash ice in mid channel
H_F	m	thickness of the brash ice layer displaced by the bow
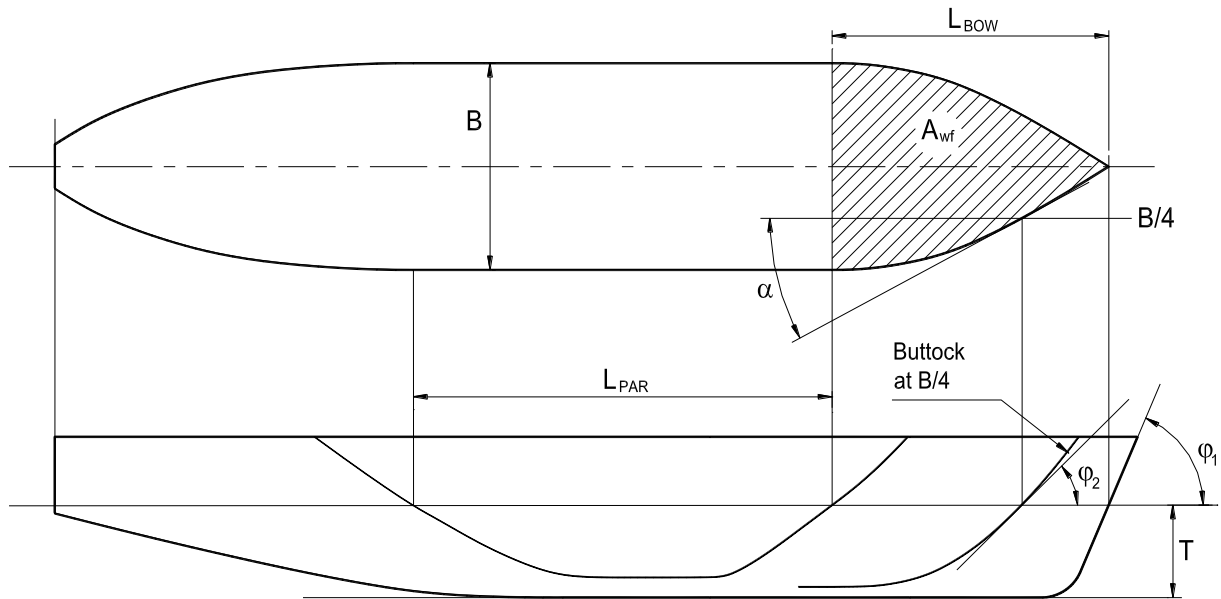
Fig. 10.4.1 Determination of the geometric quantities of the hull

10.4.2 The output of the main machinery shall not be less than the output calculated in accordance with 10.4.3.

Regardless the output calculated according to Formula (10.4.3-1), the output of the main machinery shall not be less than 1000 kW for ice class **IA, IB** and **IC** and less than 2800 kW for ice class **IA Super**.

10.4.3 The output shall be calculated for the UIWL and LIWL. The output of the main machinery shall be assumed equal to the maximum of the obtained values. In the calculations the ship's parameters stated in 10.4.1 which depend on the draught shall be determined at the appropriate draught, but L and B shall be determined only at the UIWL.

$$P = K_e \frac{(R_{CH}/1000)^{3/2}}{D_P} \quad [\text{kW}],$$

(10.4.3-1)

where K_e shall be taken as per the Table 10.4.3;

R_{CH} is the ice resistance in Newton of the ship in a channel with brash ice and a consolidated surface layer.

Table 10.4.3

Number of propellers	CP propeller or electric or hydraulic propulsion machinery	FP propeller
1 propeller	2.03	2.26
2 propellers	1.44	1.60
3 propellers	1.18	1.31

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

(10.4.3-2)

where

$C_\mu = 0{,}15\cos_{\varphi2} + \sin_\psi \sin_\alpha$, but not larger than 0.45;

$C_\psi = 0{,}047\psi - 2{,}115$, and $C_\psi = 0$, if $\psi < 45°$

$H_F = 0{,}26 + (H_M B)^{0,5}$

$H_M = 1{,}0$ m for ice classes **IA** and **IA Super**;

$H_M = 0{,}8$ m for ice class **IB**;

$H_M = 0{,}6$ m for ice class **IC**;

$C_1 = 0$ m for ice classes **IA**, **IB** и **IC**;

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

for ice class **IA Super**;

$f_1 = 23$ N/m²;

$f_2 = 45{,}8$ N/m;

$f_3 = 14{,}7$ N/m;

$f_4 = 29$ N/m²;

$C_2 = 0$ for ice classes **IA**, **IB** и **IC**;

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

for ice class **IA Super**;

$g_1 = 1530$ N;

$g_2 = 170$ N/m;

$g_3 = 400$ N/m^{1,5};

$C_3 = 845$ kg/(m²s²)
$C_4 = 42$ kg/(m²s²)
$C_5 = 825$ kg/s²

The value $\left(\dfrac{LT}{B^2}\right)^3$ in Formula (10.4.3-2) shall not be taken as less than 5 and shall not be taken as more than 20.

10.4.4 Formula (10.4.3.-2) may be used when the requirements given in Table 10.4.4 are complied with.

Failing to comply with the specified conditions, as well as when the results of model tests are available or based on more exact calculations or values based on sea trials tests, the use of K_e or R_{CH} values may be determined for the minimum speed of 5 knots in the following brash ice channels:

$H_M = 0{,}6$ m for ice class IC
$H_M = 0{,}8$ m for ice class IB
$H_M = 1{,}0$ m for ice class IA
$H_M = 1{,}0$ m and a 0,1 m thick consolidated layer of ice for ice class IA Super;

Table 10.4.4

Conditions of the formula application (10.4.3-2)

Parameter	The minimum value	The maximum value
α, degree	15	55
φ_1, degree	25	90
φ_2, degree	10	90
L, m	65,0	250,0
B, m	11,0	40,0
T, m	4,0	15,0
L_{BOW}/L	0,15	0,40
L_{PAR}/L	0,25	0,75
D_P/T^*	0,45	0,75
$A_{wf}/(L \cdot B)$	0,09	0,27
* - For calculating the parameter the value T amidships at the maximum draught shall be taken.		

10.5 HULL STRUCTURAL DESIGN

10.5.1 General.

The method for determining the hull scantlings is based on certain assumptions concerning the nature of the ice load on the structure. These assumptions are from full scale observations made in the northern Baltic.

It has thus been observed that the local ice pressure on small areas can reach rather high values. This pressure may be well in excess of the normal uniaxial crushing strength of sea ice. The explanation is that the stress field in fact is multiaxial (multicomponent).

Further, it has been observed that the ice pressure on a frame can be higher than on the shell plating at midspacing between frames. The explanation for this is the different flexural stiffness of frames and shell plating. The load distribution is assumed to be as shown in Figure 10.5.1-1.
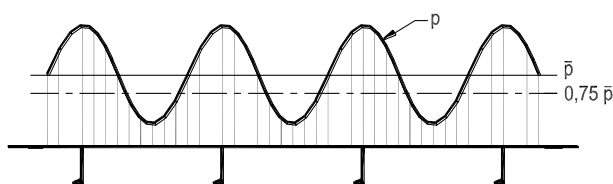

Fig. 10.5.1-1 Ice load distribution on a ship's side

The formulae and values given in these requirements may be substituted by direct analysis if they are deemed by the Register to be invalid or inapplicable for a given structural arrangement or detail. Otherwise, direct analysis shall not be utilized as an alternative to the analytical procedures prescribed by explicit requirements in 10.5.3 – 10.5.5.

Direct analyses shall be carried out using the load patch defined in 10.5.2 (p, h and l_a). The pressure to be used is $1.8p$ where p is determined according to 10.5.2.2. The load patch shall be applied at locations where the capacity of the structure under the combined effects of bending and shear are minimized. In particular, the structure shall be checked with load centred at the UIWL, $0.5h_0$ below the LIWL, and positioned several vertical locations in between. Several horizontal locations shall also be checked, especially the locations centred at the mid-span or –spacing. Further, if the load length

l_a cannot be determined directly from the arrangement of the structure, several values of l_a shall be checked using corresponding values for c_a.

The acceptance criterion for designs is that the combined stresses from bending and shear, using the von Mises yield criterion, are lower than the yield point σ_y. When the direct calculation is using beam theory, the allowable shear stress is not to be larger than $0,9 \cdot \tau_y$, where $\tau_y = \sigma_y/\sqrt{3}$.

If scantlings derived from these regulations are less than those required by the Register for not ice strengthened ship, the latter shall be used.

NOTE 1. The frame spacings and spans defined in the following text are normally (in accordance with the appropriate RS rules) assumed to be measured along the plate and perpendicular to the axis of the stiffener for plates, along the flange for members with a flange, and along the free edge for flat bar stiffeners. For curved members the span (or spacing) is defined as the chord length between span (or spacing) points. The span points are defined by the intersection between the flange or upper edge of the member and the supporting structural element (stringer, web frame, deck or bulkhead). Figure 10.5.1-2 illustrates the determination of span and spacing for curved members.
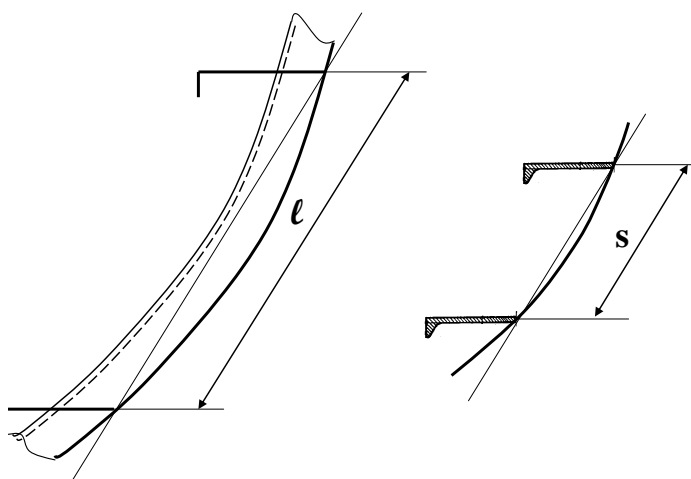

Fig. 10.5.1-2 Definition of the frame span (left) and frame spacing (right) for curved members

NOTE 2. The effective breadth of the attached plate to be used for calculating the combined section modulus of the stiffener, stringer and web frame and attached plate shall be taken in compliance with the applicable requirements of the RS normative documents. The effective breadth shall in no case be more than what is stated in the appropriate requirements of the RS normative documents.

NOTE 3. The requirements for the section modulus and shear area of the frames, stringers and web frames in 10.5.4, 10.5.5 and 10.5.6 are with respect to the effective member cross section. For such cases where the member is not normal to the plating, the section properties shall be calculated in accordance with the appropriate requirements of the RS normative documents.

### 10.5.1.1   Hull regions.

The ship's hull is divided into regions as follows (refer also to Fig. 10.5.1.1):

Bow region: From the stem to a line parallel to and $0,04 \cdot L$ aft of the forward borderline of the part of the hull where the waterlines run parallel to the centerline. For ice classes IA Super and IA the overlap over the borderline need not exceed 6 meters, for ice classes IB and IC this overlap need not exceed 5 meters.

Midbody region: From the aft boundary of the Bow region to a line parallel to and $0.04 \cdot L$ aft of the aft borderline of the part of the hull where the waterlines run parallel to the centerline. For ice classes IA Super and IA the overlap over the borderline need not exceed 6 meters, for ice classes IB and IC this overlap need not exceed 5 meters.

Stern region: From the aft boundary of the midbody region to the stern.

L shall be taken as the ship's rule length in compliance with the requirements of the RS normative documents.
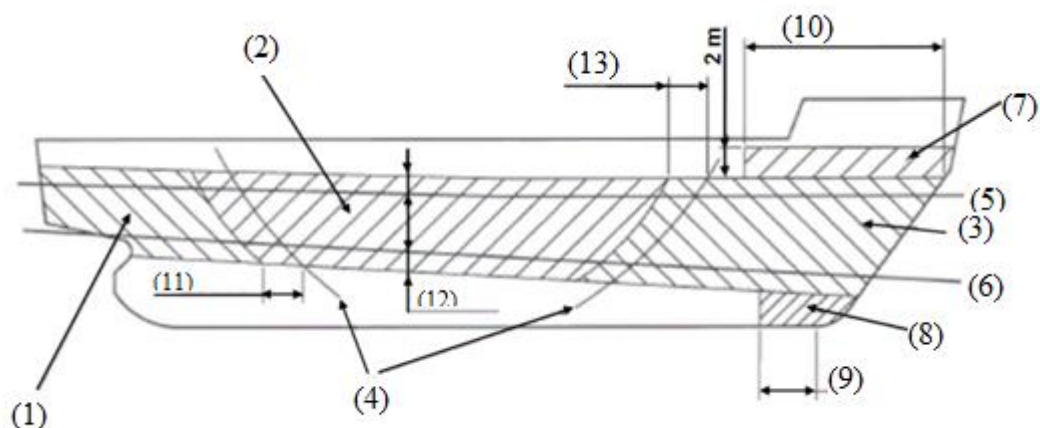
(1) – Ice belt, stern body
(2) – Midbody region
(3) – Bow region
(4) – Border of the part of the side where waterlines are parallel to the centrelines
(5) – UIWL
(6) – LIWL
(7) – Upper bow ice belt
(8) – Fore foot
(9) – 5 frame spacings
(10) - $0,2L$
(11) – refer to 10.5.1
(12) – refer to 10.5.3.1
(13) – refer to 10.5.1
Fig. 10.5.1.1 Ice strengthened regions of the hull

10.5.2 Ice load.

10.5.2.1 Height of the ice load area.

An ice-strengthened ship is assumed to operate in open sea conditions corresponding to a level ice thickness not exceeding h_o. The design ice load height (h) of the area actually under ice pressure at any particular point of time is, however, assumed to be only a fraction of the ice thickness. The values for h_o and h are given in the following table.

Ice class	h_0 [m]	h [m]
IA Super	1,0	0,35
IA	0,8	0,30
IB	0,6	0,25
IC	0,4	0,22

10.5.2.2 Ice pressure.

The design ice pressure is determined by the formula

$$p = c_d \cdot c_p \cdot c_a \cdot p_0 \ , \text{[MPa]},$$ (10.5.2.2)

where

c_d is a factor which takes account of the influence of the size and engine output of the ship. This factor is taken as maximum $c_d = 1{,}0$ and is calculated by the formula

$$c_d = \frac{a \cdot k + b}{1000},$$

where

$$k = \frac{\sqrt{\Delta \cdot P}}{1000},$$

the values of a and b are given in the following table:

	Hull region			
	Bow		Midbody and stern	
	$k \leq 12$	$k > 12$	$k \leq 12$	$k > 12$
a	30	6	8	2
b	230	518	214	286

Δ is the displacement of the ship at maximum ice class draught [t] (see 10.3.1);

P is the actual continuous engine output of the ship [kW] (see 10.4.2);

c_p is a factor which takes account of the probability that the design ice pressure occurs in a certain region of the hull for the ice class in question.

The value of c_p is given in the following table:

Ice class	Region		
	Bow	Midbody	Stern
IA Super	1,0	1,0	0,75
IA	1,0	0,85	0,65
IB	1,0	0,70	0,45
IC	1,0	0,50	0,25

c_a is a factor which takes account of the probability that the full length of the area under consideration will be under pressure at the same time. It is calculated by the formula

$$c_a = \sqrt{\frac{l_0}{l_a}}, \ 0{,}35 \leq c_a \leq 1{,}0$$

where
$l_0 = 0{,}6$ m,

where l_a shall be taken as follows:

Structure	Time of framing	l_a [m]
Shell	Transverse	Frame spacing
	Longitudinal	1,7 frame spacing
Frames	Transverse	Frame spacing
	Longitudinal	Span of frame
Ice stringer		Span of stringer
Web frame		2 web frame spacing

p_0 is the nominal ice pressure; the value 5,6 MPa shall be used.

10.5.3 Shell plating.

10.5.3.1 Vertical extension of ice strengthening for plating (ice belt).

The vertical extension of the ice belt shall be as follows (refer to Fig. 10.5.1.1):

Ice class	Hull region	Above UIWL	Below LIWL
IA Super	Bow	0.60 m	1.20 m
	Midbody		
	Stern		1.0 m
IA	Bow	0.50 m	0.90 m
	Midbody		0.75 m
	Stern		
IB and IC	Bow	0.40 m	0.70 m
	Midbody		0.60 m
	Stern		

In addition, the following areas shall be strengthened:

Fore foot: For ice class IA Super, the shell plating below the ice belt from the stem to a position five main frame spaces abaft the point where the bow profile departs from the keel line shall have at least the thickness required in the ice belt in the midbody region.

Upper bow ice belt: For ice classes IA Super and IA on ships with an open water service speed equal to or exceeding 18 knots, the shell plating shall have at least the thickness required in the ice belt in the midbody region.
heightwise - from the upper limit of the ice belt to 2 m above the ice belt;
lengthwise - from the stem to a position at least 0,2 L abaft the forward perpendicular.

A similar strengthening of the bow region is advisable also for a ship with a lower service speed, when it is, e.g. on the basis of the model tests, evident that the ship will have a high bow wave.

Sidescuttles shall not be situated in the ice belt. If the weather deck in any part of the ship is situated below the upper limit of the ice belt (e.g. in way of the well of a raised quarter decker), the bulwark

shall be given at least the same strength as is required for the shell in the ice belt. The strength of the construction of the freeing ports shall meet the same requirements.

10.5.3.2 Plate thickness in the ice belt.

For transverse framing the thickness of the shell plating shall be determined by the formula

$$t = 667\, s\, \sqrt{\frac{f_1 \cdot p_{PL}}{\sigma_y}} + t_c \quad , \text{[mm]}. \qquad (10.5.3.2\text{-}1)$$

For longitudinal framing the thickness of the shell plating shall be determined by the formula

$$t = 667 s \sqrt{\frac{p}{f_2 \cdot \sigma_y}} + t_c \quad , \text{[mm]}, \qquad (10.5.3.2\text{-}2)$$

where
  s is the frame spacing [m]

  $p_{PL} = 0.75\, p$ [MPa];

  where p is as given in 10.5.2.2

  $$f_1 = 1.3 - \frac{4.2}{(h/s + 1.8)^2}; \text{ maximum } 1.0$$

  $$f_2 = 0.6 + \frac{0.4}{(h/s)}; \text{ when } h/s \le 1$$

  $f_2 = 1.4 - 0.4\,(h/s)$; when $1 \le h/s < 1.8$

  where h is as given in 10.5.2.1

  σ_y is yield stress of the material [N/mm²], for which the following values shall be used:

    $\sigma_y = 235$ N/mm² for normal-strength hull structural steel;

    $\sigma_y = 315$ N/mm² or higher for high-strength hull structural steel

If steels with different yield stress are used, the actual values may be substituted for the above ones if accepted by the Register.

t_c is increment for abrasion and corrosion [mm]; normally t_c shall be 2 mm; if a special surface coating, by experience shown capable to withstand the abrasion of ice, is applied and maintained, lower values may be approved upon the agreement with the Register.

10.5.4 Frames.

10.5.4.1 Vertical extension of ice strengthening for framing.

The vertical extension of the ice strengthening of the framing shall be at least as follows:

Ice class	Hull region	Above UIWL	Below LIWL
IA Super	Bow	1.2 m	Down to double bottom or below top of the floors
	Midbody		2.0 m
	Stern		1.6 m
IA, IB and IC	Bow	1.0 m	1.6 m
	Midbody		1.3 m
	Stern		1.0 m

Where an upper bow ice belt is required (refer to 10.5.3.1), the ice-strengthened part of the framing shall be extended at least to the top of this ice belt.

Where the ice-strengthening would go beyond a deck or a tanktop (or tank bottom) by no more than 250 mm, it can be terminated at that deck or tanktop (or tank bottom).

10.5.4.2 Transverse frames.

10.5.4.2.1 Section modulus and shear area.

The section modulus of a main or intermediate transverse frame shall be calculated by the formula

$$Z = \frac{p \cdot s \cdot h \cdot l}{m_t \cdot \sigma_y} 10^6 \quad [\text{cm}^3]. \tag{10.5.4.2.1-1}$$

and the effective shear area is calculated from

$$A = \frac{\sqrt{3} \cdot f_3 \cdot p \cdot h \cdot s}{2\sigma_y} 10^4 \quad [\text{cm}^2], \tag{10.5.4.2.1-2}$$

where

  p is ice pressure as given in 10.5.2.2 [MPa]

  s is frame spacing [m]

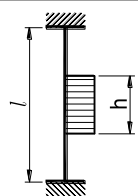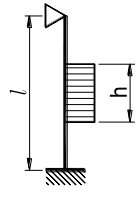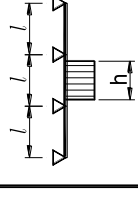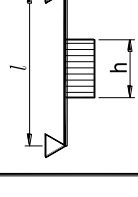 h is height of load area as given in 10.5.2.1 [m]

  l is span of the frame [m]

$$m_t = \frac{7 m_o}{7 - 5h/l}$$

  f_3 is a factor which takes into account the maximum shear force versus the load location and the shear stress distribution, $f_3 = 1.2$

  σ_y is yield stress as in 10.5.3.2 [MPa]

m_o takes the boundary conditions into account. The values are given in the following table:

Boundary Condition	m_o	Example
	7	Frames in a bulk carrier with top wing tanks
	6	Frames extending from the tank top to a single deck
	5.7	Continuous frames between several decks or stringers
	5	Frames extending between two decks only

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

Where less than 15% of the span, *l*, of the frame is situated within the ice-strengthening zone for frames, ordinary frame scantlings may be used.

10.5.4.2.2   Upper end of transverse framing

The upper end of the strengthened part of a main frame and of an intermediate ice frame shall be attached to a deck, tanktop (or tank bottom) or an ice stringer (refer to 10.5.5).

Where a frame terminates above a deck or a stringer which is situated at or above the upper limit of the ice belt, the part above the deck or stringer may have the scantlings required by the Register for an non ice-strengthened ship and the upper end of an intermediate frame may be connected to the adjacent frames by a horizontal member having the same scantlings as the main frame.

10.5.4.2.3   Lower end of transverse framing.

The lower end of the strengthened part of a main frame and of an intermediate ice frame shall be attached to a deck, tanktop (or tank bottom) or an ice stringer (refer to 10.5.5).

Where an intermediate frame terminates below a deck, tanktop (or tank bottom) or ice stringer which is situated at or below the lower limit of the ice belt, the lower end may be connected to the adjacent main frames by a horizontal member of the same scantlings as the main frames. Note that the main frames below the lower edge of ice belt must be ice strengthened, see 10.5.4.1.

10.5.4.3 Longitudinal frames.

The following requirements are intended for longitudinal frames with all end conditions.

10.5.4.3.1 Frames with and without brackets.

The section modulus of a longitudinal frame shall be calculated by the formula

$$Z = \frac{f_4 \cdot p \cdot h \cdot l^2}{m \cdot \sigma_y} 10^6 \quad \text{, [cm}^3\text{]},\qquad\qquad (10.5.4.3.1\text{-}1)$$

and effective shear area of a longitudinal frame shall be:

$$A = \frac{\sqrt{3} \cdot f_4 \cdot f_5 \cdot p \cdot h \cdot l}{2\sigma_y} 10^4 \quad \text{, [cm}^2\text{]}.\qquad\qquad (10.5.4.3.1\text{-}2)$$

In calculating the actual shear area of the frames, the shear area of the brackets is not to be taken into account.

In the formulae given above:

f_4 is a factor which takes account of the load distribution to adjacent frames:

$f_4 = (1 - 0{,}2\ h/s)$

f_5 is a factor which takes into account the maximum shear force versus load location and the shear stress distribution:

$f_5 = 2{,}16$

p is ice pressure as given in 10.5.2.2 [MPa]

h is height of load area as given in 10.5.2.1 [m]

s is frame spacing [m]

l is total span of frame [m]

m is a boundary condition factor; $m = 13{,}3$ for a continuous beam; where the boundary conditions deviate significantly from those of a continuous beam, e.g. in an end field, a smaller boundary factor may be required. For frames without brackets a value $m = 11.0$ shall be used.

σ_y is yield stress as in 10.5.3.2 [MPa].

10.5.4.4 General on framing.

10.5.4.4.1 The attachment of frames to supporting structures.

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

10.5.4.4.2 Support of frames against tripping for ice class IA Super, for ice class IA in the bow and midbody regions and for ice classes IB and IC in the bow region of the ice-strengthened area.

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

The web thickness of the frames shall be at least the maximum of the following:

- $\dfrac{h_w \sqrt{\sigma_y}}{C}$, h_w is the web height and $C = 805$ for profiles and $C = 282$ for flat bars;

- 2.5 % of the frame spacing for transverse frames;

- half of the net thickness of the shell plating, $t - t_c$. For the purpose of calculating the web thickness of frames, the required thickness of the shell plating shall be calculated according to 10.5.3.2 using the yield strength σ_y of the frames;

- 9 mm.

Where there is a deck, tanktop (or tank bottom) or bulkhead in lieu of a frame, the plate thickness of this shall be as above, to a depth corresponding to the height of the adjacent frames.

Frames that are not normal to the plating or the profile is unsymmetrical, and the span exceeds 4.0 m, shall be supported against tripping by brackets, intercostals, stringers or similar at a distance not exceeding 1,3 m. If the span is less than 4,0 m, the supports against tripping are required for unsymmetrical profiles and stiffeners the web of which is not normal to plating in the following regions:

IA Super	All hull regions
IA	Bow and midbody regions
IB and IC	Bow region.

10.5.5 Ice stringers.

10.5.5.1 Stringers within the ice belt.

The section modulus of a stringer situated within the ice belt (refer to 10.5.3.1) shall be calculated by the formula

$$Z = \frac{f_6 \cdot f_7 \cdot p \cdot h \cdot l^2}{m \cdot \sigma_y} 10^6 \text{ , [cm}^3\text{].} \qquad (10.5.5.1\text{-}1)$$

The effective shear area shall be:

$$A = \frac{\sqrt{3} \cdot f_6 \cdot f_7 \cdot f_8 \cdot p \cdot h \cdot l}{2 \cdot \sigma_y} 10^4 \text{ , [cm}^2\text{],} \qquad (10.5.5.1\text{-}2)$$

where

    p is ice pressure as given in 10.5.2.2 [MPa]

    h is height of load area as given in 10.5.2.1 [m]

    The product $p \cdot h$ shall not be taken as less than 0.15.

    l is span of the stringer [m]

    m is a boundary condition factor as defined in 10.5.4.3

f_6 is a factor which takes account of the distribution of load to the transverse frames; to be taken as 0.9

f_7 is the safety factor of stringers; to be taken as 1.8

f_8 is a factor that takes into account the maximum shear force versus load location and the shear stress distribution; $f_8 = 1.2$

σ_y is yield stress as in 10.5.3.2.

10.5.5.2 Stringers outside the ice belt.

The section modulus of a stringer situated outside the ice belt but supporting ice-strengthened frames shall be calculated by the formula

$$Z = \frac{f_9 \cdot f_{10} \cdot p \cdot h \cdot l^2}{m \cdot \sigma_y}(1 - h_s / l_s) \cdot 10^6 \quad , \quad [\text{cm}^3]. \tag{10.5.5.2-1}$$

The effective shear area shall be:

$$A = \frac{\sqrt{3} \cdot f_9 \cdot f_{10} \cdot f_{11} \cdot p \cdot h \cdot l}{2 \cdot \sigma_y}(1 - h_s / l_s) \cdot 10^4 \quad , \quad [\text{cm}^2], \tag{10.5.5.2-2}$$

where

p is ice pressure as given in 10.5.2.2 [MPa]

h is height of load area as given in 10.5.2.1 [m]

The product $p \cdot h$ shall not be taken as less than 0,15.

l is span of stringer [m]

m is boundary condition factor as defined in 10.5.4.3

l_s is the distance to the adjacent ice stringer [m]

h_s is the distance to the ice belt [m]

f_9 is a factor which takes account of the distribution of load to the transverse frames; to be taken as 0.80

f_{10} is the safety factor of stringers; to be taken as 1,8

f_{11} is a factor that takes into account the maximum shear force versus load location and the shear stress distribution; $f_{11} = 1,2$

σ_y is yield stress of material as in 10.5.3.2.

10.5.5.3   Deck strips.

Narrow deck strips abreast of hatches and serving as ice stringers shall comply with the section modulus and shear area requirements in 10.5.5.1 and 10.5.5.2 respectively. In the case of very long hatches the Register may permit the product $p \cdot h$ to be taken as less than 0.15 but in no case as less than 0.10.

Regard shall be paid to the deflection of the ship's sides due to ice pressure in way of very long (more than $B/2$) hatch openings when designing weatherdeck hatch covers and their fittings.

10.5.6 Web frames.

10.5.6.1 Ice load.

The ice load transferred to a web frame from an ice stringer or from longitudinal framing shall be calculated by the formula

$$F = f_{12} \cdot p \cdot h \cdot S \quad \text{, [MH],}$$

(10.5.6.1)

where

p is ice pressure as given in 10.5.2.2 [MPa], in calculating c_a however, l_a shall be taken as 2S.

h is height of load area as given in 10.5.2.1 [m]

The product $p \cdot h$ shall not be taken as less than 0,15

S is distance between web frames [m]

f_{12} is the safety factor of web frames; to be taken as 1,8.

In case the supported stringer is outside the ice belt, the force F shall be multiplied by $(1 - h_s/l_s)$, where h_s and l_s shall be taken as defined in 10.5.5.2.

10.5.6.2 Section modulus and shear area.

The section modulus and shear area of web frames shall be calculated by the formulae

The effective shear area:

$$A = \frac{\sqrt{3} \cdot \alpha \cdot f_{13} \cdot Q \cdot 10^4}{\sigma_y} \quad \text{, [cm}^2\text{],}$$

(10.5.6.2-1)

where

Q is maximum calculated shear force under the ice load F, as given in 10.5.6.1

f_{13} is a factor that takes into account the shear force distribution, $f_{13} = 1.1$

α is as given in the table below;

σ_y is yield stress of material as in 10.5.3.2.

Section modulus:

$$Z = \frac{M}{\sigma_y} \sqrt{\frac{1}{1 - (\gamma \cdot A / A_a)^2}} \cdot 10^6 \quad \text{, [cm}^3\text{],}$$

(10.5.6.2-2)

where

M is maximum calculated bending moment under the ice load F; this shall be taken as $M = 0.193 \cdot F \cdot l$.

γ is given in the table below

A is required shear area

A_a is actual cross sectional area of the web frame, $A_a = A_f + A_w$

Factors α and γ can be obtained from the table below

A_f/A_w	0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
α	1.5	1.23	1.16	1.11	1.09	1.07	1.06	1.05	1.05	1.04	1.04
γ	0	0.44	0.62	0.71	0.76	0.80	0.83	0.85	0.87	0.88	0.89

where

A_f is the actual cross section area of free flange

A_w is the actual effective cross section area of web plate.

10.5.7 Stem.

The stem shall be made of rolled, cast or forged steel or of shaped steel plates as shown in Fig. 10.5.7.
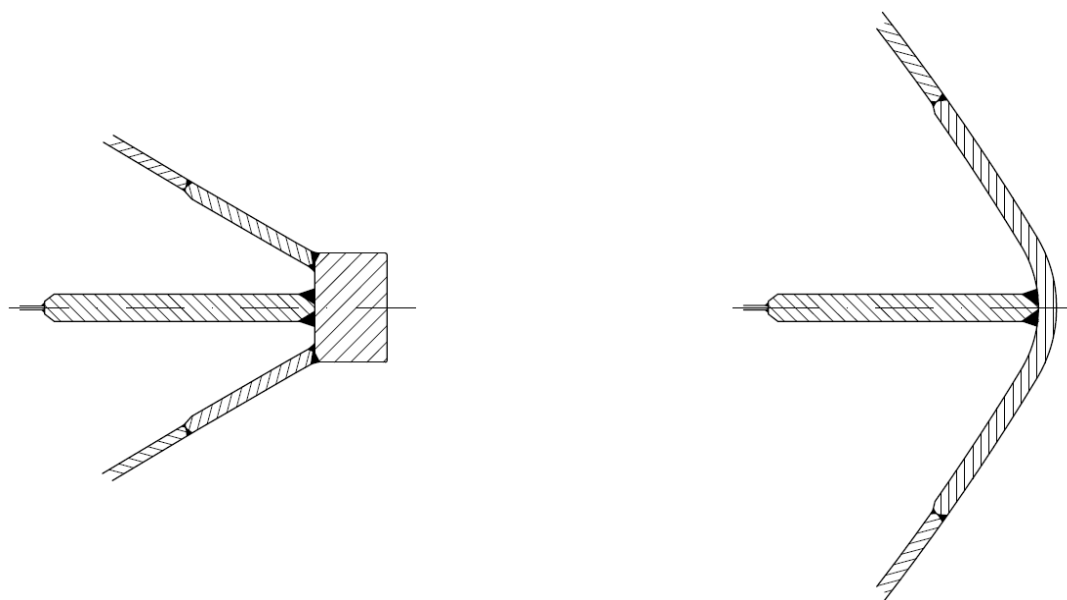

Fig. 10.5.7 Examples of suitable stems

The plate thickness of a shaped plate stem and in the case of a blunt bow, any part of the shell where $\alpha \geq 30^o$ and $\psi \geq 75^o$ (refer to 3.2.1 for angle definitions), shall be calculated according to Formula in 10.53.2 assuming that:

s is spacing of elements supporting the plate [m]

$p_{PL} = p$ [MPa] (refer to 10.5.3.2)

l_a is spacing of vertical supporting elements [m]

The stem and the part of a blunt bow defined above shall be supported by floors or brackets spaced not more than 0,6 m apart and having a thickness of at least half the plate thickness. The reinforcement of the stem shall extend from the keel to a point 0,75 m above UIWL or, in case an upper bow ice belt is required (10.5.3.1), to the upper limit of this.

10.5.8 Stern.

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

In order to avoid very high loads on propeller blade tips, the minimum distance between propeller(s) and hull (including stern frame) shall not be less than h_0 (refer to 10.5.2.1).

On twin and triple screw ships the ice strengthening of the shell and framing shall be extended to the double bottom for 1,5 metres forward and aft of the side propellers.

Shafting and stern tubes of side propellers shall normally be enclosed within plated bossings. If detached struts are used, their design, strength and attachments to the hull shall be duly considered.

10.6 RUDDER AND STEERING ARRANGEMENTS

The scantlings of rudder post, rudder stock, pintles, steering engine etc. as well as the capability of the steering engine shall be determined according to the applicable rules of the Register. The maximum service speed of the ship to be used in these calculations shall, however, not be taken as less than stated below:

IA Super   20 knots
IA   18 knots
IB   16 knots
IC   14 knots

If the actual maximum service speed of the ship is higher, that speed shall be used.

The local scantlings of rudders shall be determined assuming that the whole rudder belongs to the ice belt. Further, the rudder plating and frames shall be designed using the ice pressure *p* for the plating and frames in the midbody region.

For ice classes IA and IA Super, the rudder (rudder stock and the upper part of the rudder) shall be protected from direct contact with intact ice by an ice knife that extends below the LIWL, if practicable (or equivalent means). Special consideration shall be given to the design of the rudder and the ice knife for ships with flap-type rudders.

For ice classes IA and IA Super, due regard shall be paid to the large loads that arise when the rudder is forced out of the midship position while going astern in ice or into ice ridges. Suitable arrangement such as rudder stoppers shall be installed to absorb these loads.

Relief valves for hydraulic pressure in rudder turning mechanism(s) shall be installed. The components of the steering gear (e.g. rudder stock, rudder coupling, rudder horn etc.) shall be dimensioned to withstand loads causing yield stresses in the rudder stock.

10.7 PROPULSION MACHINERY

10.7.1 Scope.

These regulations apply to propulsion machinery covering open- and ducted-type propellers with controllable pitch or fixed pitch design for the ice classes **IA Super, IA, IB** and **IC.**

The given loads are the expected ice loads for the whole ship's service life under normal operational conditions, including loads resulting from the changing rotational direction of FP propellers. However, these loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice.

The regulations also apply to azimuthing and fixed thrusters for main propulsion, considering loads resulting from propeller/ice interaction. However, the load models of the regulations do not include propeller/ice interaction loads when ice enters the propeller of a turned azimuthing thruster from the side (radially) or load cases when ice block hits on the propeller hub of a pulling propeller. Ice loads

resulting from ice impacts on the body of thrusters shall be estimated, but ice load formulae are not available.

10.7.2 Definitions.

CP		controllable pitch
EAR		expanded blade area ratio
FP		fixed pitch
MCR		maximum continuous rating
LIWL	m	lower ice waterline
D	m	propeller diameter
R	m	propeller radius
c	m	chord length of blade section
$c_{0.7}$	m	chord length of blade section at 0.7R propeller radius
d	m	external diameter of propeller hub (at propeller plane)
D_{limit}	m	limit value for propeller diameter
F_b	kN	maximum backward blade force for the ship's service life
F_{ex}	kN	ultimate blade load resulting from blade loss through plastic bending
F_f	kN	maximum forward blade force for the ship's service life
F_{ice}	kN	ice load
$(F_{ice})_{max}$	kN	maximum ice load for the ship's service life
h_0	m	depth of the propeller centreline from lower ice waterline
H_{ice}	m	thickness of maximum design ice block entering to propeller
I	kgm^2	equivalent mass moment of inertia of all parts on engine side of component under consideration
I_t	kgm^2	equivalent mass moment of inertia of the whole propulsion system
k		shape parameter for Weibull distribution
m		slope for SN curve in log/log scale
M_{BL}	kNm	blade bending moment
n	rev./s	propeller rotational speed
n_n	rev./s	nominal propeller rotational speed at MCR in free running condition
N_{class}		reference number of impacts per propeller rotational speed per ice class
N_{ice}		total number of ice loads on propeller blade for the ship's service life
N_R		reference number of load for equivalent fatigue stress (10^8 cycles)
N_Q		number of propeller revolutions during a milling sequence
$P_{0.7}$	m	propeller pitch at 0.7R radius
$P_{0.7n}$	m	propeller pitch at 0.7R radius at MCR in free running condition
$P_{0.7b}$	m	propeller pitch at 0.7R radius at MCR in bollard condition
Q	kNm	torque
Q_{emax}	kNm	maximum engine torque
Q_{max}	kNm	maximum torque on the propeller resulting from propeller/ice interaction

Q_{motor}	kNm	electric motor peak torque
Q_n	kNm	nominal torque at MCR in free running condition
Q_r	kNm	maximum response torque along the propeller shaft line
Q_{smax}	kNm	maximum spindle torque of the blade for the ship's service life
r	m	blade section radius
T	kN	propeller thrust
T_b	kN	maximum backward propeller ice thrust for the ship's service life
T_f	kN	maximum forward propeller ice thrust for the ship's service life
T_n	kN	propeller thrust at MCR in free running condition
T_r	kN	maximum response thrust along the shaft line
t	m	maximum blade section thickness
Z		number of propeller blades
α_i	[deg]	duration of propeller blade/ice interaction expressed in rotation angle
γ_ε		the reduction factor for fatigue; scatter and test specimen size effect
γ_v		the reduction factor for fatigue; variable amplitude loading effect
γ_m		the reduction factor for fatigue; mean stress effect
ρ		a reduction factor for fatigue correlating the maximum stress amplitude to the equivalent fatigue stress for 10^8 stress cycles
$\sigma_{0.2}$	MPa	proof yield strength (at 0.2% offset) of blade material
σ_{exp}	MPa	mean fatigue strength of blade material at 10^8 cycles to failure in sea water
σ_{fat}	MPa	equivalent fatigue ice load stress amplitude for 10^8 stress cycles
σ_{fl}	MPa	characteristic fatigue strength for blade material
σ_{ref}	MPa	reference stress $\sigma_{ref} = 0.6 \cdot \sigma_{0.2} + 0.4 \cdot \sigma_u$
$\sigma_{ref\,2}$	MPa	reference stress $$\sigma_{ref\,2} = 0.7 \cdot \sigma_u \text{ or}$$ $$\sigma_{ref\,2} = 0.6 \cdot \sigma_{0.2} + 0.4 \cdot \sigma_u \text{ whichever is less}$$
σ_{st}	MPa	maximum stress resulting from F_b or F_f
σ_u	MPa	ultimate tensile strength of blade material
$(\sigma_{ice})_{bmax}$	MPa	principal stress caused by the maximum backward propeller ice load
$(\sigma_{ice})_{fmax}$	MPa	principal stress caused by the maximum forward propeller ice load
$(\sigma_{ice})_{max}$	MPa	maximum ice load stress amplitude

Table 10.7.2

Definition of loads

	Definition	Use of the load in design process
F_b	The maximum lifetime backward force on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade. The direction of the force is perpendicular to $0.7R$ chord line. See Figure 6-1.	Design force for strength calculation of the propeller blade.

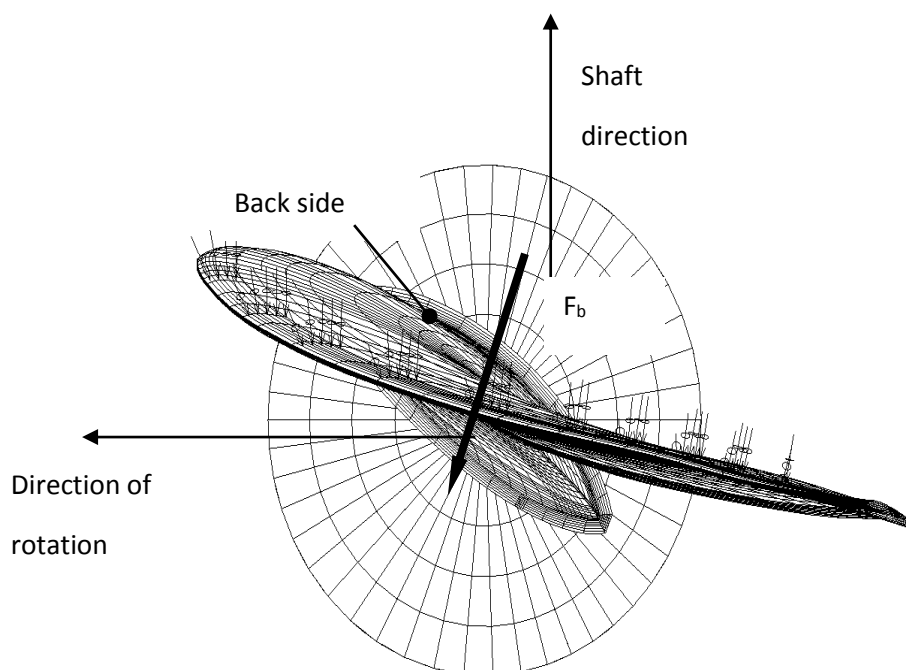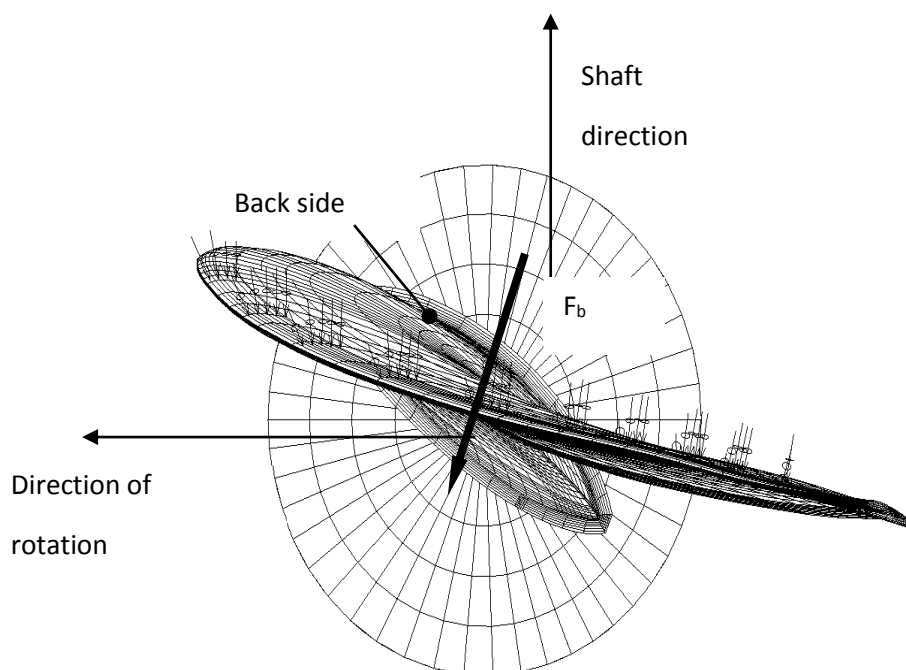| F_f	The maximum lifetime forward force on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade. The direction of the force is perpendicular to $0.7R$ chord line.	Design force for calculation of strength of the propeller blade.
Q_{smax}	The maximum lifetime spindle torque on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade.	In designing the propeller strength, the spindle torque is automatically taken into account because the propeller load is acting on the blade as distributed pressure on the leading edge or tip area.
T_b	The maximum lifetime thrust on propeller (all blades) resulting from propeller/ice interaction. The direction of the thrust is the propeller shaft direction and the force is opposite to the hydrodynamic thrust.	Is used for estimation of the response thrust T_r. T_b can be used as an estimate of excitation for axial vibration calculations. However, axial vibration calculations are not required in the rules.
T_f	The maximum lifetime thrust on propeller (all blades) resulting from propeller/ice interaction. The direction of the thrust is the propeller shaft direction acting in the direction of hydrodynamic thrust.	Is used for estimation of the response thrust T_r. T_f can be used as an estimate of excitation for axial vibration calculations. However, axial vibration calculations are not required in the rules.
Q_{max}	The maximum ice-induced torque resulting from propeller/ice interaction on one propeller blade, including hydrodynamic loads on that blade.	Is used for estimation of the response torque (Q_r) along the propulsion shaft line and as excitation for torsional vibration calculations.
F_{ex}	Ultimate blade load resulting from blade loss through plastic bending. The force that is needed to cause total failure of the blade so that plastic hinge is caused to the root area. The force is acting on $0.8R$. Spindle arm shall be taken as 2/3 of the distance between the axis of blade rotation and leading/trailing edge (whichever is the greater) at the $0.8R$ radius.	Blade failure load is used to dimension the blade bolts, pitch control mechanism, propeller shaft, propeller shaft bearing and trust bearing. The objective shall guarantee that total propeller blade failure shall not cause damage to other components.
Q_r	Maximum response torque along the propeller shaft line, taking into account the dynamic behavior of the shaft line for ice excitation (torsional vibration) and hydrodynamic mean torque on propeller.	Design torque for propeller shaft line components.
T_r	Maximum response thrust along shaft line, taking into account the dynamic behavior of the shaft line for ice excitation (axial vibration) and hydrodynamic mean thrust on propeller.	Design thrust for propeller shaft line components.

Fig. 10.7.2 F_b direction. Ice contact pressure at leading edge is shown with small arrows

10.7.3 Design ice conditions.

In estimating the ice loads of the propeller for ice classes, different types of operation as given in Table 10.7.3-1 were taken into account. For the estimation of design ice loads, a maximum ice block size is determined. The maximum design ice block entering the propeller is a rectangular ice block with the dimensions $H_{ice} \cdot 2H_{ice} \cdot 3H_{ice}$. The thickness of the ice block (H_{ice}) is given in Table 10.7.3-2.

Table 10.7.3-1

Operating characteristics

Ice class	Operation of the ship
IA Super	Operation in ice channels and in level ice
	The ship may proceed by ramming
IA, IB, IC	Operation in ice channels

Table 10.7.3-2

Ice class	**IA Super**	**IA**	**IB**	**IC**
H_{ice}	1,75 m	1,5 m	1,2 m	1,0 m

Fig. 10.7.2 F_b direction. Ice contact pressure at leading edge is shown with small arrows

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H_{ice}	1,75 m	1,5 m	1,2 m	1,0 m

10.7.4 Materials.

10.7.4.1 Materials exposed to sea water.

Materials of components exposed to sea water, such as propeller blades, propeller hubs, and thruster body, shall have an elongation of not less than 15% on a test specimen, the gauge length of which is five times the diameter.

A Charpy V impact test shall be carried out for materials other than bronze and austenitic steel. An average impact energy value of 20 J taken from three tests shall be obtained at minus 10 ºC.

10.7.4.2 Materials exposed to sea water temperature.

Materials exposed to sea water temperature shall be of steel or other ductile material. An average impact energy value of 20 J taken from three tests shall be obtained at minus 10 ºC.

This requirement applies to blade bolts, CP mechanisms, shaft bolts, strut-pod connecting bolts etc. This does not apply to surface hardened components, such as bearings and gear teeth.

10.7.5 Design loads.

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

The values of the parameters in the formulae shall comply with the units shown in 10.7.2.

If the propeller is not fully submerged when the ship is in ballast condition, the propulsion system shall be designed according to ice class IA for ice classes IB and IC.

10.7.5.1 Design loads on propeller blades.

F_b is the maximum force experienced during the lifetime of the ship that bends a propeller blade backwards when the propeller mills an ice block while rotating ahead.
F_f is the maximum force 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, not acting simultaneously. Hence they shall be applied to one blade separately.

10.7.5.1.1 Maximum backward blade force F_b for open propellers.

$$F_b = 27 \cdot [n \cdot D]^{0.7} \cdot \left[\frac{EAR}{Z} \right]^{0.3} \cdot D^2 \text{ [kN], при } D \leq D_{limit}$$

(10.7.5.1.1-1)

$$F_b = 23 \cdot [n \cdot D]^{0.7} \cdot \left[\frac{EAR}{Z} \right]^{0.3} \cdot D \cdot H_{ice}^{1.4} \text{ [kN], при } D > D_{limit},$$

(10.7.5.1.1-2)

where

$$D_{limit} = 0.85 \cdot H_{ice}^{1.4} \text{ [m]}$$

$n = n_n$ for a CP propeller;

$n = 0,85 \, n_n$ for an FP propeller.

10.7.5.1.2 Maximum forward blade force F_f for open propellers.

$$F_f = 250 \cdot \left[\frac{EAR}{Z}\right] D^2 \ [\text{kN}], \quad \text{при } D \le D_{limit}$$

(10.7.5.1.2-1)

$$F_f = 500 \cdot \left[\frac{EAR}{Z}\right] \cdot D \cdot \frac{1}{\left(1-\dfrac{d}{D}\right)} \cdot H_{ice} \ [\text{kN}], \quad \text{при } D > D_{limit}$$

(10.7.5.1.2-2)

where

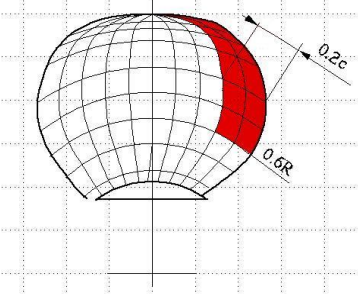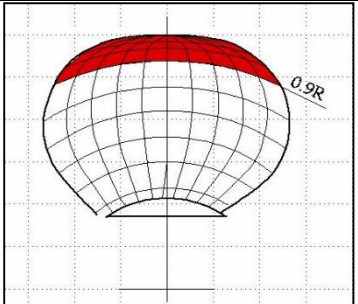$$D_{limit} = \frac{2}{\left(1-\dfrac{d}{D}\right)} \cdot H_{ice} \ [\text{m}].$$

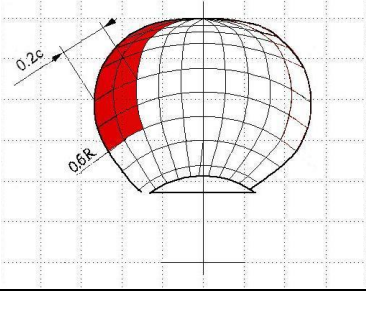**10.7.5.1.3 Loaded area on the blade for open propellers.**
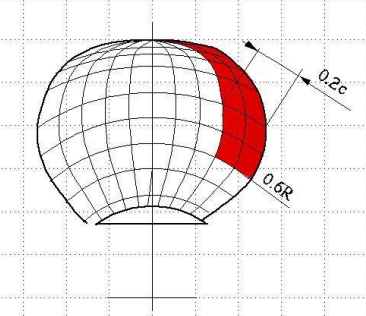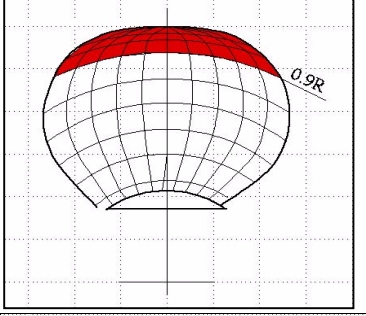
Load cases 1-4 shall be covered, as given in Table 10.7.5.1.3 below, for CP and FP propellers.

In order to obtain blade ice loads for a reversing propeller, load case 5 also shall be covered for FP propellers.

Table 10.7.5.1.3

Load cases for open propellers

Load case	Force	Loaded area	Right-handed propeller blade seen from behind
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0.6R to the tip and from the leading edge to 0.2 times the chord length.	
Load case 2	50% of F_b	Uniform pressure applied on the back of the blade (suction side) on the propeller tip area outside 0.9R radius.	

Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6R to the tip and from the leading edge to 0.2 times the chord length.	
Load case 4	50% of F_f	Uniform pressure applied on propeller face (pressure side) on the propeller tip area outside 0.9R radius.	
Load case 5	60% of F_f or F_b, whichever is greater	Uniform pressure applied on propeller face (pressure side) to an area from 0.6R to the tip and from the trailing edge to 0.2 times the chord length	

10.7.5.1.4 Maximum backward blade ice force F$_b$ for ducted propellers.

$$F_b = 9.5 \cdot [n \cdot D]^{0.7} \cdot \left[\frac{EAR}{Z}\right]^{0.3} \cdot D^2 \text{ [kN], при } D \le D_{limit}$$

(10.7.5.1.4-1)

$$F_b = 66 \cdot [n \cdot D]^{0.7} \cdot \left[\frac{EAR}{Z}\right]^{0.3} \cdot D^{0.6} \cdot H_{ice}^{1.4} \text{ [kN], при } D > D_{limit}$$

(10.7.5.1.4-2)

where

$$D_{limit} = 4 \cdot H_{ice} \text{ [m]}$$

$n = n_n$ for a CP propeller;

$n = 0.85\, n_n$ for an FP propeller.

10.7.5.1.5 Maximum forward blade ice force F_f for ducted propellers.

$$F_f = 250 \cdot \left[\frac{EAR}{Z}\right] \cdot D^2 \text{ [kN], при } D \le D_{limit}$$

(10.7.5.1.5-1)

$$F_f = 500 \cdot \left[\frac{EAR}{Z} \right] \cdot D \cdot \frac{1}{\left(1 - \dfrac{d}{D}\right)} \cdot H_{ice} \quad \text{[kN], when } D > D_{limit} \qquad (10.7.5.1.5\text{-}2)$$

where

$$D_{limit} = \frac{2}{\left(1 - \dfrac{d}{D}\right)} \cdot H_{ice} \quad \text{[m]}.$$
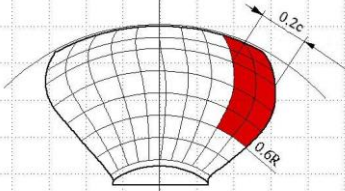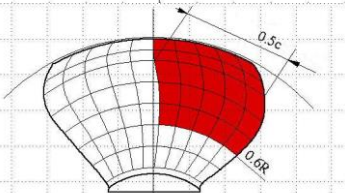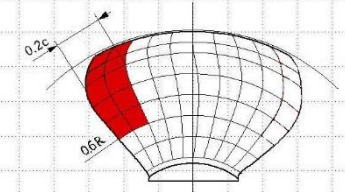
10.7.5.1.6 Loaded area on the blade for ducted propellers.

Load cases 1 and 3 shall be covered as given in Table 10.7.5.1.6 for all propellers.

Additional load case (load case 5) shall be considered for an FP propeller, to cover ice loads when the propeller is reversed.

Table 10.7.5.1.6

Load cases for ducted propellers

Load case	Force	Loaded area	Right handed propeller blade seen from behind
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0.6R to the tip and from the leading edge to 0.2 times the chord length.	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6R to the tip and from the leading edge to 0.5 times the chord length.	
Load case 5	60% of F_f or F_b, whichever is greater	Uniform pressure applied on propeller face (pressure side) to an area from 0.6R to the tip and from the trailing edge to 0.2 times the chord length.	

10.7.5.1.7 Torque Q_{smax}
The spindle torque Q_{smax} around the axis of the blade fitting shall be determined both for the maximum backward blade force F_b and forward blade force F_f, which are applied as in Table 10.7.5.1.3 and Table 10.7.5.16.

If the above method gives a value which is less than the default value given by Formula (10.7.5.1.7) below, the following Q_{smax} value shall be used:

$$Q_{smax} = 0.25 \cdot F \cdot c_{0.7} \ [\text{kNm}]$$

(10.7.5.1.7)

where F is either F_b or F_f, whichever has the greater absolute value.

10.7.5.1.8 Load distributions for blade loads

The Weibull-type distribution (probability that F_{ice} exceeds $(F_{ice})_{max}$) is used for the fatigue design of the blade.

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

(10.7.5.1.8)

where
$k=0,75$ shall be used for the ice force distribution of an open propeller
$k=1,0$ for that of a ducted propeller blade.
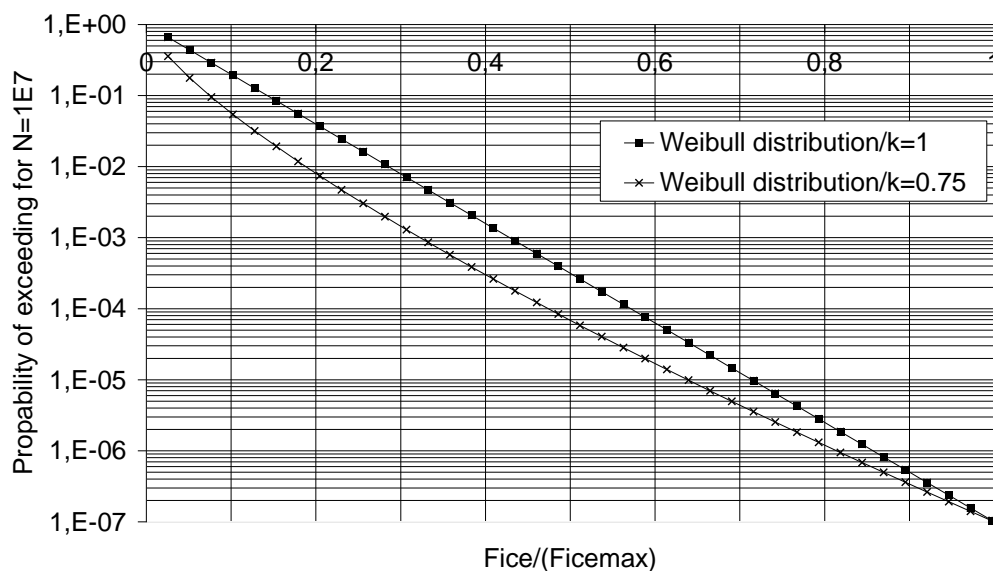F_{ice} is the random variable for ice loads on the blade $0 \leq F_{ice} \leq (F_{ice})_{max}$.

Fig.10.7.5.1.8 The Weibull-type distribution

10.7.5.1.9 Number of load cycles per propeller blade during the operational life of the ship.

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

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

(10.7.5.1.9)

where

Ice class	IA Super	IA	IB	IC
Impacts in life, n	$9 \cdot 10^6$	$6 \cdot 10^6$	$3,4 \cdot 10^6$	$2,1 \cdot 10^6$

Propeller location	Centre propeller	Wing propeller
Propeller location factor k_1	1	1,35

Propeller shroud availability	Non available	Available
Propeller type factor k_2	1	1,1

Type	Fixed	Azimuthing
Propulsion type factor k_3	1	1,2

The submersion factor k_4 is determined from the equation

$$
\begin{aligned}
k_4 &= 0.8 - f & \text{when} \quad f < 0 \\
&= 0.8 - 0.4 \cdot f & \text{when} \quad 0 \le f \le 1 \\
&= 0.6 - 0.2 \cdot f & \text{when} \quad 1 < f \le 2.5 \\
&= 0.1 & \text{when} \quad f > 2.5
\end{aligned}
$$

where the immersion function f is

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

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

10.7.5.2 Axial design loads for open and ducted propellers.

10.7.5.2.1 Maximum ice thrust T_f and T_b.

$$ T_f = 1.1 \cdot F_f \ [\text{kN}] $$
$$ T_b = 1.1 \cdot F_b \ [\text{kN}]. $$

10.7.5.2.2 Design thrust along the propulsion shaft line for open and ducted propellers.

The design thrust along the propeller shaft line shall be calculated with the formulae below. The greater shall be taken as the design load for both directions. The factors 2.2 and 1.5 take into account the dynamic magnification resulting from axial vibration.

$$ T_r = T + 2.2 \cdot T_f \ [\text{kN}], $$
$$ T_r = 1.5 \cdot T_b \ [\text{kN}]. $$

If the hydrodynamic bollard thrust, T, is not known, T shall be taken as follows:

Propeller type	T
CP propellers (open)	1,25 T_n
CP propellers (ducted)	1,1 T_n
FP propellers driven by turbine or electric motor	T_n
FP propellers driven by diesel engine (open)	0,85 T_n
FP propellers driven by diesel engine (ducted)	0,75 T_n

Here T_n is the nominal propeller thrust at MCR in the free running open water condition.

10.7.5.3 Torsional design loads.

10.7.5.3.1 Design ice torque on propeller Q_{max} for open propellers.

Q_{max} is the maximum torque on a propeller resulting from ice/propeller interaction.

$$Q_{max} = 10.9 \cdot \left[1 - \frac{d}{D} \right] \cdot \left[\frac{P_{0.7}}{D} \right]^{0.16} \cdot \left(nD \right)^{0.17} \cdot D^3 \text{ [kNm], when } D \le D_{\text{limit}}$$

$$Q_{max} = 20.7 \cdot \left[1 - \frac{d}{D} \right] \cdot \left[\frac{P_{0.7}}{D} \right]^{0.16} \cdot \left(nD \right)^{0.17} \cdot D^{1.9} \cdot H_{ice}^{1.1} \text{ [kNm], when } D > D_{limit},$$

where

$$D_{limit} = 1.8 \cdot H_{ice} \text{ [m].}$$

n is the rotational propeller speed in bollard condition. If not known, n shall be taken as follows:

Propeller type	Rotational speed n
CP propellers	n_n
FP propellers driven by turbine or electric motor	n_n
FP propellers driven by diesel engine	0.85 n_n

For CP propellers, the propeller pitch, $P_{0.7}$ shall correspond to MCR in bollard condition. If not known, $P_{0.7}$ shall be taken as $0{,}7 \cdot P_{0.7n}$, where $P_{0.7n}$ is the propeller pitch at MCR in free running condition.

10.7.5.3.2 Design ice torque on propeller Q_{max} for ducted propellers.

$$Q_{max} = 7.7 \cdot \left[1 - \frac{d}{D} \right] \cdot \left[\frac{P_{0.7}}{D} \right]^{0.16} \cdot \left(nD \right)^{0.17} \cdot D^3 \text{ [kNm] when } D \le D_{limit},$$

$$Q_{max} = 14.6 \cdot \left[1 - \frac{d}{D} \right] \cdot \left[\frac{P_{0.7}}{D} \right]^{0.16} \cdot \left(nD \right)^{0.17} \cdot D^{1.9} \cdot H_{ice}^{1.1} \text{ [kNm] when } D > D_{limit},$$

where

$$D_{limit} = 1.8 \cdot H_{ice} \cdot \text{[m]}$$

n is the rotational propeller speed in bollard condition. If not known, n shall be taken as follows:

Propeller type	n
CP propellers	n_n
FP propellers driven by turbine or electric motor	n_n
FP propellers driven by diesel engine	0.85 n_n

For CP propellers, the propeller pitch, $P_{0.7}$ shall correspond to MCR in bollard condition. If not known, $P_{0.7}$ shall be taken as $0.7 \cdot P_{0.7n}$, where $P_{0.7n}$ is the propeller pitch at MCR in free running condition.

10.7.5.3.3 Ice torque.

The propeller ice torque excitation for shaft line transient torsional vibration analysis shall be described by a sequence of blade impacts which are of a half sine shape (see Figure 10.7.5.3.3.)
The torque resulting from a single blade ice impact as a function of the propeller rotation angle is then

$$Q(\varphi) = C_q \cdot Q_{max} \cdot \sin\left(\varphi\left(180/\alpha_i\right)\right), \text{ when } \varphi = 0...\alpha_i$$

$$Q(\varphi) = 0, \text{ when } \varphi = \alpha_i...360$$

$C_{q \text{ and }} \alpha_i$ parameters are given in Table 10.7.5.3.3.

Table 10.7.5.3.3

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

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

The number of propeller revolutions during a milling sequence shall be obtained from the formula

$$N_Q = 2 \cdot H_{ice} \text{ .}$$
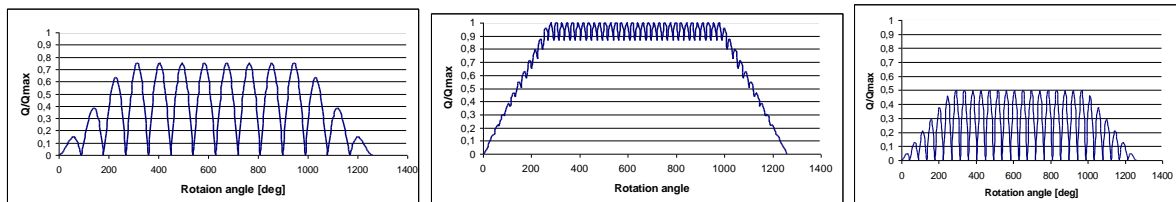
The number of impacts is $Z \cdot N_Q$.

Fig.10.7.5.3.3 The shape of ice torque excitation for 4 blades propeller for 90, and 135 degree single-blade impact sequences and 45 degree double blade impact sequence

10.7.5.3.4 Design torque along propeller shaft line.

If there is not any relevant first blade order torsional resonance within the designed operating rotational speed range extended 20% above the maximum and 20% below the minimum operating speeds, the following formula of the maximum torque can be used:

$$Q_r = Q_{e\,max} + Q_{max} \cdot \frac{I}{I_t} \text{ [kNm],}$$

If the maximum torque, Q_{emax}, is not known, it shall be taken as follows:

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

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

10.7.5.4 Blade failure load.

$$F_{ex} = \frac{300 \cdot c \cdot t^2 \cdot \sigma_{ref}}{0.8 \cdot D - 2 \cdot r} \ \text{[kN]},$$

where

  c, t, and *r* parameters shall be determined at the weakest section outside the root filet.

10.7.6 Design.

10.7.6.1 Design principle.

The strength of the propulsion line shall be designed according to the "pyramid strength" principle. This means that the loss of the propeller blade shall not cause any significant damage to other propeller shaft line components.

10.7.6.2 Propeller blade.

10.7.6.2.1 Calculation of blade stresses.

The blade stresses shall be calculated for the design loads given in 10.7.5.1. Finite element analysis shall be used for stress analysis for final approval for all propellers. The following simplified formulae can be used in estimating the blade stresses for all propellers at the root area ($r/R < 0.5$). The root area dimensions based on Formula (10.7.6.2.1) can be accepted even if the FEM analysis would show greater stresses at the root area.

$$\sigma_{st} = C_1 \frac{M_{BL}}{100 \cdot ct^2} \ \text{[MPa]}$$

                   (10.7.6.2.1)

where

  constant C_1 is the $\dfrac{\text{actual stress}}{\text{stress obtained with beam equation}}$. If the actual value is not available, C_1 shall be taken as 1.6.

  $M_{BL} = (0.75 - r/R) \cdot R \cdot F$, where

  F is the maximum of F_b and F_f.

10.7.6.2.2 Acceptability criterion.

The following criterion for calculated blade stresses shall be fulfilled:

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

If FEM analysis is used in estimating the stresses, von Mises stresses shall be used

10.6.6.2.3 Fatigue design of propeller blade.

The fatigue design of the propeller blade is based on an estimated load distribution for the service life of the ship and the S-N curve for the blade material. An equivalent stress that produces the same fatigue damage as the expected load distribution shall be calculated and the acceptability criterion for fatigue shall be fulfilled as given in this section. The equivalent stress is normalised for 10^8 cycles.

If the following criterion is fulfilled, fatigue calculations according to this chapter are not required:

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

where B_1, B_2 and B_3 coefficients for open and ducted propellers are given in the Table 10.7.6.2.3-1.

Table 10.7.6.2.3-1

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

For calculation of equivalent stress two types of S-N curves are available.

>   1. Two slope S-N curve (slopes 4.5 and 10), see Figure 10.7.6.2.3-1.
>   2. One slope S-N curve (the slope can be chosen), see Figure 10.7.6.2.3-2.

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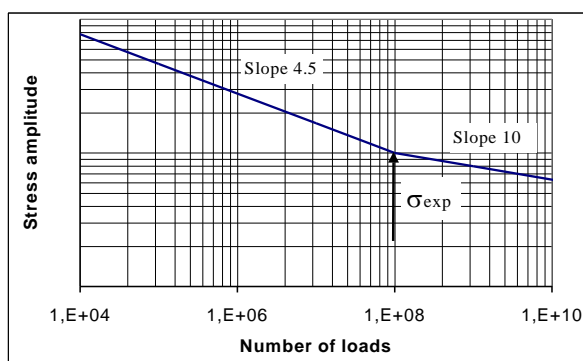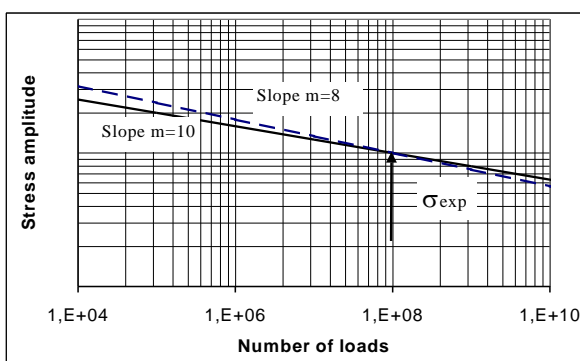

Fig. 10.7.6.2.3-1 Two-slope S-N curve   Fig/ 10.7.6.2.3-2 Constant-slope S-N curve

Equivalent fatigue stress

The equivalent fatigue stress for 10^8 stress cycles which produces the same fatigue damage as the load distribution is:

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

where

$$(\sigma_{ice})_{max} = 0.5 \cdot \left((\sigma_{ice})_{f\,max} - (\sigma_{ice})_{b\,max}\right)$$

In calculation of $(\sigma_{ice})_{max}$, case 1 and case 3 (or case 2 and case 4) given in 10.7.5.1 are considered. Case 5 is excluded from the fatigue analysis.

Calculation of parameter ρ for two-slope S-N curve

The parameter ρ relates the maximum ice load to the distribution of ice loads according to the regression formula

$$\rho = C_1 \cdot \left(\sigma_{ice}\right)_{max}^{C_2} \cdot \sigma_{fl}^{C_3} \cdot \log(N_{ice})^{C_4}$$

where

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

The following values shall be used for the reduction factors if actual values are not available: $\gamma_{\varepsilon} = 0.67$, $\gamma_v = 0.75$, and $\gamma_m = 0.75$.

The coefficients C_1, C_2, C_3, and C_4 are given in Table 10.7.6.2.3-2.

Table 10.7.6.2.3-2

	Open propeller	Ducted propeller
C_1	0.000711	0.000509
C_2	0.0645	0.0533
C_3	-0.0565	-0.0459
C_4	2.22	2.584

Calculation of parameter ρ for constant-slope S-N curve
For materials with a constant-slope S-N curve the factor ρ shall be calculated from the following formula

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

where

$k = 1.0$ for ducted propellers and $k = 0.75$ for open propellers;

values for the parameter G are given in Table 10.7.6.2.3-2. Linear interpolation may be used to calculate the value for other m/k ratios than given in the Table 10.7.6.2.3-2.

Table 10.7.6.2.3-2
Value for the parameter G for different m/k ratios

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

10.7.6.2.4 Acceptability criterion for fatigue.

The equivalent fatigue stress at all locations on the blade shall fulfil the following acceptability criterion:

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

where

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

The following values shall be used for the reduction factors if actual values are not available: γ_ε = 0.67, γ_v = 0.75, and γ_m = 0.75.

10.7.6.3 Propeller bossing and CP mechanism.

The blade bolts, the CP mechanism, the propeller boss, and the fitting of the propeller to the propeller shaft shall be designed to withstand the maximum and fatigue design loads, as defined in 10.7.5.

The safety factor against yielding shall be greater than 1.3 and that against fatigue greater than 1.5. In addition, the safety factor for loads resulting from loss of the propeller blade through plastic bending as defined in 10.7.5.4 shall be greater than 1.0 against yielding.

10.7.6.4 Propulsion shaft line.

The shafts and shafting components, such as the thrust and stern tube bearings, couplings, flanges and sealings, shall be designed to withstand the propeller/ice interaction loads as given in 10.7.5. The safety factor shall be at least 1.3.

10.7.6.4.1 Shafts and shafting components.

The ultimate load resulting from total blade failure as defined in 10.7.5.4 shall not cause yielding in shafts and shaft components. The loading shall consist of the combined axial, bending, and torsion loads, wherever this is significant. The minimum safety factor against yielding shall be 1.0 for bending and torsional stresses.

10.7.6.5 Main active means of ship's steering (AMSS).

In addition to the above requirements, special consideration shall be given to those loading cases which are extraordinary for propulsion units when compared with conventional propellers. The estimation of loading cases shall reflect the way of operation of active means of ship's steering. In this respect, for example, the loads caused by the impacts of ice blocks on the propeller hub of a pulling propeller shall be considered.

The steering mechanism, the fitting of the unit, and the body of the thruster shall be designed to withstand the loss of a blade without damage. The loss of a blade shall be considered for the propeller blade orientation which causes the maximum load on the component being studied. Typically, top-down blade orientation places the maximum bending loads on the AMSS body.

Azimuth thrusters shall also be designed for estimated loads caused by thruster body/ice interaction. The thruster body shall stand the loads obtained when the maximum ice blocks, which are given in 10.7.3, strike the thruster body when the ship is at a typical ice operating speed. In addition, the design situation in which an ice sheet glides along the ship's hull and presses against the thruster body shall be considered. The thickness of the sheet shall be taken as the thickness of the maximum ice block entering the propeller, as defined in 10.7.3.

10.7.6.6 Vibrations.

The propulsion system shall be designed in such a way that the complete dynamic system is free from harmful torsional, axial, and bending resonances at a 1-order blade frequency within the designed running speed range, extended by 20% above and below the maximum and minimum operating rotational speeds.

A detailed vibration analysis shall be carried out in order to determine that the acceptable strength of the components can be achieved.

10.7.7 Alternative design procedure.

10.7.7.1 Scope.

As an alternative to 10.7.5 and 10.7.6, a comprehensive design study may be carried out to the satisfaction of the Register. The study shall be based on ice conditions given for different ice classes in 6.3. It shall include both fatigue and maximum load design calculations and fulfil the pyramid strength principle, as given in 10.7.6.1.

10.7.7.2 Loading.

Loads on the propeller blade and propulsion system shall be based on an acceptable estimation of hydrodynamic and ice loads.

10.7.7.3 Design levels.

The analysis shall indicate that all components transmitting random (occasional) forces, excluding propeller blade, are not subjected to stress levels in excess of the yield stress of the component material, with a reasonable safety margin.

Cumulative fatigue damage calculations are to indicate a reasonable safety factor. Due account shall be taken of material properties, stress raisers, and fatigue enhancements.

Vibration analysis shall be carried out and shall indicate that the complete dynamic system is free from harmful torsional resonances resulting from propeller/ice interaction.

10.8 MISCELLANEOUS MACHINERY REQUIREMENTS

10.8.1 Compressed air system.

The capacity of the air receivers shall be sufficient to provide without reloading not less than 12 consecutive starts of the propulsion engine, if this shall be reversed for going astern, or 6 consecutive starts if the propulsion engine shall not be reversed for going astern.

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

The capacity of the air compressors shall be sufficient for charging the air receivers from atmospheric to full pressure in one (1) hour, except for a ship with the ice class IA Super, if its propulsion engine shall be reversed for going astern, in which case the compressor shall be able to charge the receivers in half an hour.

10.8.2 Cooling water system.

The cooling water system shall be designed to ensure supply of cooling water when navigating in ice.

For this purpose at least one cooling water inlet chest shall be arranged as follows:

1. The sea inlet shall be situated near the centreline of the ship and well aft if possible.
2. As guidance for design the volume of the chest shall be about one cubic metre for every 750 kW engine output of the ship including the output of auxiliary engines necessary for the ship's service.
3. The chest shall be sufficiently high to allow ice to accumulate above the inlet pipe.
4. A pipe for discharge cooling water, allowing full capacity discharge, shall be connected to the chest.
5. The open area of the strainer plates shall not be less than four (4) times the inlet pipe sectional area.

If there are difficulties to meet the requirements of paragraphs 2 and 3 above, two smaller chests may be arranged for alternating intake and discharge of cooling water, thus, the requirements of 1,4,5 shall be met.

Heating coils may be installed in the upper part of the sea chest.

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

Annex 1

Ice class draught marking

Subject to 10.3.2, the ship's sides shall be provided with a warning triangle and with a draught mark at the maximum permissible ice class draught amidships (see Figure 1). The purpose of the warning triangle shall provide information on the draught limitation of the ship when it is sailing in ice for masters of icebreakers and for inspection personnel in ports.
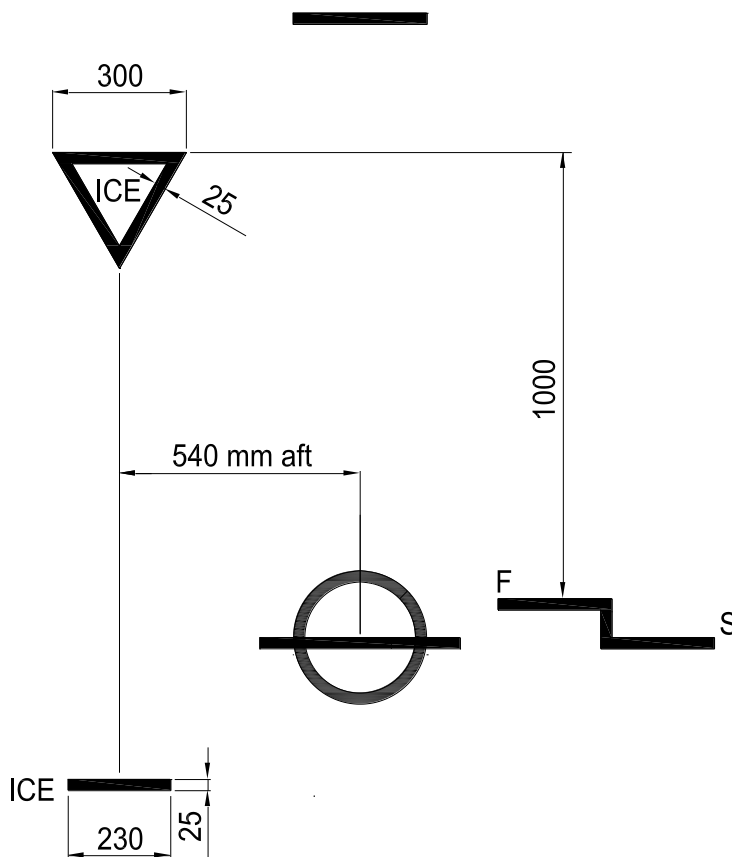

Fig. 1 Ice Class Draught Marking

Notes to Fig. 1

1. The upper edge of the warning triangle shall be located vertically above the "ICE" mark, 1000 mm higher than the Summer Load Line in fresh water but in no case higher than the deck line. The sides of the triangle shall be 300 mm in length.
2. The ice class draught mark shall be located 540 mm abaft the centre of the load line ring or 540 mm abaft the vertical line of the timber load line mark, if applicable.
3. The marks and figures shall be cut out of 5 - 8 mm plate and then welded to the ship's side. The marks and figures shall be painted in a red or yellow reflecting colour in order to make the marks and figures plainly visible even in ice conditions.
4. The dimensions of all letters shall be the same as those used in the load line mark.

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