Finnish Maritime Administration

BULLETIN No. 13/1.10.2002

FINNISH-SWEDISH ICE CLASS RULES

Pursuant to section 12 of the Act on Fairway Dues (708/2002) the Finnish Maritime Administration has, on 20 September 2002, adopted a regulation on the structural design and engine output required of ships for navigation in ice.

The regulation enters into force on 1 October 2002.

The form for the new Ice Class Certificate has been published in Bulletin No. 12/2002.

A list of ice classes of recognized classification societies equivalent to the ice classes of the Finnish-Swedish ice class rules will be published shortly.

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FINNISH MARITIME ADMINISTRATION	**REGULATION**	**Date: 20.9.2002** **No.: 5/30/2002**

Contents:	Regulations on the structural design and engine output required of ships for navigation in ice
Based on:	Act on Fairway Dues (708/2002) section 12
Period of validity:	October 1, 2002 – until further notice
Repeals:	Board of Navigation Ice Class Rules 1985 2.9.1985, No. 2575/85/307, as amended

FINNISH MARITIME ADMINISTRATION REGULATIONS ON THE STRUCTURAL DESIGN AND ENGINE OUTPUT REQUIRED OF SHIPS FOR NAVIGATION IN ICE

Adopted in Helsinki on 20 September 2002

Pursuant to section 12(3) of the Act of 16 August 2002 on Fairway Dues (708/2002) the Finnish Maritime Administration has decided the following:

Section 1

The Finnish Maritime Administration has adopted the following regulations, referred to in section 12 of the Act on Fairway Dues (708/2002), on the structural design and engine output required of ships for navigation in ice. The differences between the ice classes are defined in the Regulations.

Section 2

This Regulation enters into force on 1 October 2002.

This Regulation repeals the Board of Navigation Ice Class Rules of 2 September 1985 (No. 2575/85/307), as amended.

In determining the minimum engine output of ships of ice class IB or IC, the keels of which is laid or which is in a similar stage of construction before 1 September 2003, the Board of Navigation Ice Class Rules, 1985 (2.9.1985, No. 2575/85/307), as amended, still apply.

Helsinki, 20 September 2002

Director of Maritime Safety Jukka Häkämies

Head of Division Pertti Haatainen

FINNISH MARITIME ADMINISTRATION
REGULATIONS
ON THE STRUCTURAL DESIGN AND ENGINE OUTPUT REQUIRED OF SHIPS FOR NAVIGATION IN ICE

"FINNISH-SWEDISH ICE CLASS RULES"

Adopted in Helsinki on 20 September 2002

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1 GENERAL

1.1 Ice classes

Under section 12 of the Act on Fairway Dues (708/2002) ships are assigned to ice classes as follows:

1) special ice class IA Super, ships whose structural strength in essential areas affecting their ability to navigate in ice essentially exceeds the requirements of ice class IA and which as regards hull form and engine output are capable of navigation under difficult ice conditions;
2) ice class IA, IB or IC according to ice strengthening and engine output, ships which meet the requirements for navigation in ice as regards structural strength and engine output and are strengthened for navigation in ice;
3) ice class II, ships which have their own propulsion machinery, are built of steel and structurally fit for navigation on the high seas, but are not strengthened for navigation in ice;
4) ice class III, ships which do not belong to any of the ice classes referred to under 1) – 3) above.

2 ICE CLASS DRAUGHT

2.1 Maximum draught amidships

The maximum ice class draught amidships shall be the draught on the Fresh Water Load Line in Summer. If the ship has a timber load line, the Fresh Water Timber Load Line in Summer shall be used.

2.2 Maximum and minimum draught fore and aft

The maximum and minimum ice class draughts fore and aft shall be determined and stated in the classification certificate.

The line defined by the maximum draughts fore, amidship and aft will henceforth be referred to as LWL. The line may be a broken line. The line defined by the minimum draughts fore and aft will be referred to as BWL.

The draught and trim, limited by the LWL, 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 BWL when navigating in ice. Any ballast tank, situated above the BWL 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 BWL, 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 = displacement of the ship [t] on the maximum ice-class draught according to 2.1.

h_o = level ice thickness [m] according to 4.2.1.

3 ENGINE OUTPUT

3.1 Definition of engine output

The engine output P is the maximum output the propulsion machinery can continuously deliver to the propeller(s). If the output of the machinery is restricted by technical means or by any regulations applicable to the ship, P shall be taken as the restricted output.

3.2 Required engine output for ice classes IA Super, IA, IB and IC

The engine output shall not be less than that determined by the formula below and in no case less than 1000 kW for ice class IA, IB and IC, and not less than 2800 kW for IA Super.

3.2.1 Definitions

The dimensions of the ship and some other parameters are defined below:

L = length of the ship between the perpendiculars [m]

L_{BOW} = length of the bow [m]

L_{PAR} = length of the parallel midship body [m]

B = maximum breadth of the ship [m]

T = actual ice class draughts of the ship [m] according to 3.2.2

A_{wf} = area of the waterline of the bow [m^2]

α = the angle of the waterline at B/4 [degrees]

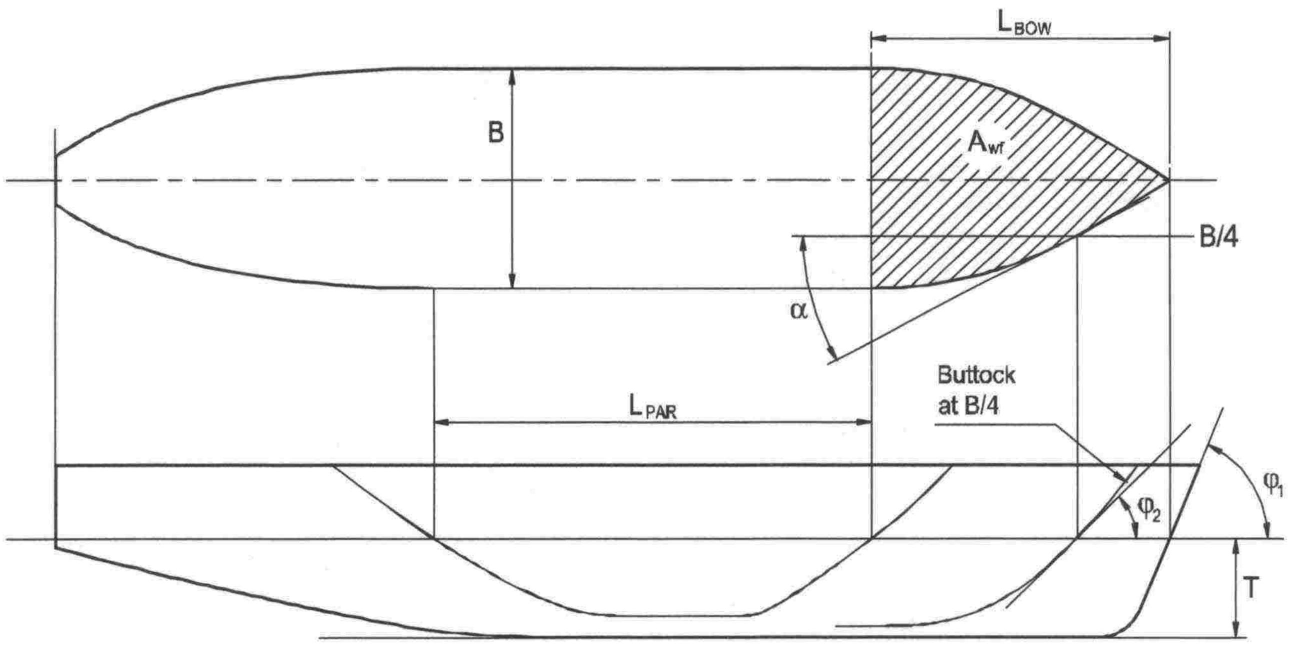
φ_1 = the rake of the stem at the centreline [degrees]

φ_2 = the rake of the bow at B/4 [degrees]

D_P = diameter of the propeller [m]

H_M = thickness of the brash ice in mid channel [m]

H_F = thickness of the brash ice layer displaced by the bow [m]



If bulb, then $\varphi_1 = 90°$

Figure 1

3.2.2 New Ships

To be entitled to ice class IA Super, IA, IB or IC, a ship the keel of which is laid or which is at a similar stage of construction on or after 1 September 2003 shall comply with the following requirements regarding its engine output. The engine output requirement shall be calculated for two draughts. Draughts to be used are the maximum draught amidship referred to as LWL and the minimum draught referred to as BWL, as defined in 2.2. In the calculations the ship's parameters which depend on the draught are to be determined at the appropriate draught, but L and B are to be determined only at the LWL. The engine output shall not be less than the greater of these two outputs.

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

where K_e shall be taken as follows:

Propeller type or machinery	CP 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

These K_e values apply for conventional propulsion systems. Other methods may be used for determining the required power for advanced propulsion systems (see 3.2.4).

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

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

$C_\mu = 0.15\cos\varphi_2 + \sin\psi\sin\alpha$, C_μ is to be taken equal or larger than 0.45

$C_\psi = 0.047 \cdot \psi - 2.115$, and $C_\psi = 0$ if $\psi \le 45°$

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

H_M = 1.0 for ice classes IA and IA Super
= 0.8 for ice class IB
= 0.6 for ice class IC

C_1 and C_2 take into account a consolidated upper layer of the brash ice and are to be taken as zero for ice classes IA, IB and IC.

For ice class IA Super:

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

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

For a ship with a bulbous bow, φ_1 shall be taken as 90°.

$f_1 = 23 \quad N/m^2$	$g_1 = 1530$ N
$f_2 = 45.8$ N/m	$g_2 = 170 \quad N/m$
$f_3 = 14.7$ N/m	$g_3 = 400 \quad N/m^{1.5}$
$f_4 = 29 \quad N/m^2$	

$C_3 = 845\ kg/(m^2s^2)$
$C_4 = 42\ kg/(m^2s^2)$
$C_5 = 825\ kg/s^2$

$$\psi = \arctan\left(\frac{\tan\varphi_2}{\sin\alpha}\right)$$

$\left(\frac{LT}{B^2}\right)^3$ is not to be taken as less than 5 and not to be taken as more than 20.

Further information on the validity of the above formulas can be found in Annex I together with sample data for the verification of powering calculations. If the ship's parameter values are beyond the ranges defined in Table 1 of Annex I, other methods for determining R_{CH} shall be used as defined in 3.2.5.

3.2.3 Existing ships of ice class IB or IC

To be entitled to retain ice class IB or IC a ship, the keel of which has been laid or which has been at a similar stage of construction before 1 September 2003, shall comply with the requirements in section 3.2.1 of the ice class regulations 1985 (2.9.1985, No. 2575/85/307), as amended. For ease of reference the provisions for ice classes IB and IC of section 3.2.1 of the ice class regulations 1985 are given in Annex II.

3.2.4 Existing ships of ice class IA Super or IA

To be entitled to retain ice class IA Super or IA a ship, the keel of which has been laid or which has been at a similar stage of construction before 1 September 2003, shall comply with the requirements in section 3.2.2 above at the following dates:

- 1 January 2005 or
- 1 January in the year when 20 years has elapsed since the year the ship was delivered, whichever occurs the latest.

When, for an existing ship, values for some of the hull form parameters required for the calculation method in section 3.2.2 are difficult to obtain, the following alternative formulae can be used:

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

For ice class IA, C_1 and C_2 shall be taken as zero.

For ice class IA Super, ship without a bulb, C_1 and C_2 shall be calculated as follows:

$$C_1 = f_1 \frac{BL}{2\frac{T}{B}+1} + 1.84(f_2 B + f_3 L + f_4 BL)$$

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

For ice class IA Super, ship with a bulb, C_1 and C_2 shall be calculated as follows:

$$C_1 = f_1 \frac{BL}{2\frac{T}{B}+1} + 2.89(f_2 B + f_3 L + f_4 BL)$$

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

$f_1 = 10.3\ N/m^2$	$g_1 = 1530\ N$
$f_2 = 45.8\ N/m$	$g_2 = 170\ N/m$
$f_3 = 2.94\ N/m$	$g_3 = 400\ N/m^{1.5}$
$f_4 = 5.8\ N/m^2$	

$C_3 = 460\ kg/(m^2s^2)$
$C_4 = 18.7\ kg/(m^2s^2)$
$C_5 = 825\ kg/s^2$

$\left(\frac{LT}{B^2}\right)^3$ is not to be taken as less than 5 and not to be taken as more than 20.

3.2.5 Other methods of determining K_e or R_{CH}

For an individual ship, in lieu of the K_e or R_{CH} values defined in 3.2.2 and 3.2.3, the use of K_e or R_{CH} values based on more exact calculations or values based on model tests may be approved. Such an approval will be given on the understanding that it can be revoked if experience of the ship's performance in practice motivates this.

The design requirement for ice classes is a minimum speed of 5 knots in the following brash ice channels:

IA Super	H_M = 1.0 m and a 0.1 m thick consolidated layer of ice
IA	= 1.0 m
IB	= 0.8 m
IC	= 0.6 m

4 HULL STRUCTURAL DESIGN

4.1 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.

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 2.

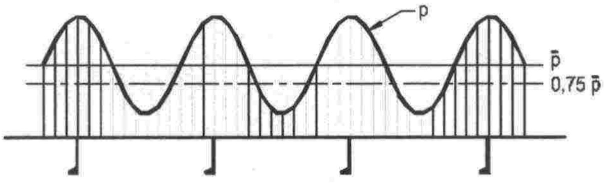


Figure 2
Ice load distribution on a ship's side

For the formulae and values given in this section for the determination of the hull scantlings more sophisticated methods may be substituted subject to approval by the administration or the classification society.

If scantlings derived from these regulations are less than those required by the classification society for an unstrengthened ship, the latter shall be used.

NB. The frame spacing and spans defined in the following text are normally assumed to be measured in a vertical plane parallel to the centreline of the ship. However, if the ship's side deviates more than 20° from this plane, the frame distances and spans shall be measured along the side of the ship.

4.1.1 Regions

For the purpose of this section, the ship's hull is divided into regions as follows (see also figure 3):

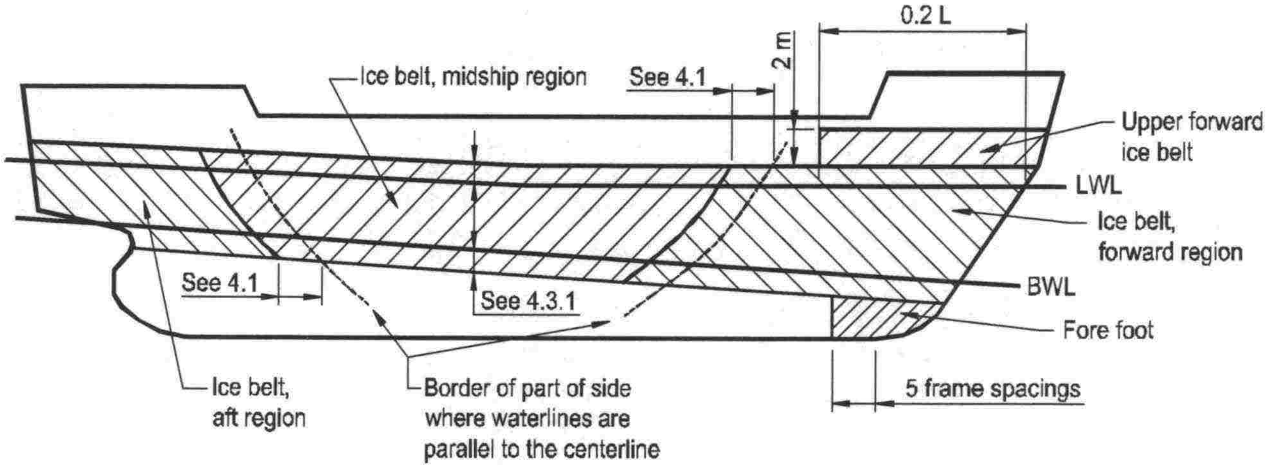
Forward region: From the stem to a line parallel to and 0.04·L aft of the forward borderline of the part of the hull where the waterlines run parallel to the centreline. For ice classes IA Super and IA the overlap over the borderline need not exceed 6 meters, for ice classes IB and IC this overlap need not exceed 5 meters.

Midship region: From the aft boundary of the Forward region to a line parallel to and 0.04·L aft of the aft borderline of the part of the hull where the waterlines run parallel to the centreline. For 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.

Aft region: From the aft boundary of the Midship region to the stern.

L shall be taken as the rule ship's length used by the classification society.

Figure 3



4.2 Ice load

4.2.1 Height of 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 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_o [m]	h [m]
IA Super	1.0	0.35
IA	0.8	0.30
IB	0.6	0.25
IC	0.4	0.22

4.2.2 Ice pressure

The design ice pressure is determined by the formula:

$p = c_d \cdot c_1 \cdot c_a \cdot p_o$ [MPa], where

c_d = a factor which takes account of the influence of the size and engine output of the ship.

It is calculated by the formula:

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

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

a and b are given in the following table:

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

Δ = the displacement of the ship at maximum ice class draught [t] (see 2.1).

P = the actual continuous engine output of the ship [kW] (see 3.1).

c_l = 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_l is given in the following table:

Ice Class	Region		
	Forward	Midship	Aft
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 = 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:

$$c_a = \frac{47 - 5l_a}{44}; \text{ maximum } 1.0; \text{ minimum } 0.6$$

l_a shall be taken as follows:

Structure	Type of framing	l_a [m]
Shell	Transverse	Frame spacing
	Longitudinal	$2 \cdot$ frame spacing
Frames	Transverse	Frame spacing
	Longitudinal	Span of frame
Ice stringer		Span of stringer
Web frame		$2 \cdot$ web frame spacing

p_o = the nominal ice pressure; the value 5.6 MPa shall be used.

4.3 Shell plating

4.3.1 Vertical extension of ice strengthening (ice belt) (see figure 3).

The vertical extension of the ice belt shall be as follows:

Ice Class	Above LWL [m]	Below BWL [m]
IA Super	0.6	0.75
IA	0.5	0.6
IB	0.4	0.5
IC	0.4	0.5

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 midship region.

Upper forward 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 plate from the upper limit of the ice belt to 2 m above it and from the stem to a position at least 0.2 L abaft the forward perpendicular, shall have at least the thickness required in the ice belt in the midship region. 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.

4.3.2 Plate thickness in the ice belt

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

$$t = 667\ s \sqrt{\frac{f_1 \cdot p_{PL}}{\sigma_y}} + t_c [mm]$$

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

$$t = 667\ s \sqrt{\frac{p_{PL}}{f_2 \cdot \sigma_y}} + t_c [mm]$$

S = the frame spacing [m]

p_{PL} = 0.75 p [MPa]

p = as given in 4.2.2

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

$f_2 \quad = 0.6 + \dfrac{0.4}{(h/s)}$; when $h/s \leq 1$

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

$h \quad$ = as given in 4.2.1

$\sigma_y \quad$ = yield stress of the material [N/mm^2]; the following values shall be used:

$\sigma_y \quad$ = 235 N/mm^2 for normal-strength hull structural steel

$\sigma_y \quad$ = 315 N/mm^2 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 classification society.

$t_c \quad$ = 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.

4.4 Frames

4.4.1 Vertical extension of ice strengthening

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

Ice Class	Region	Above LWL [m]	Below BWL [m]
IA Super	From stem to 0.3L abaft it	1.2	To double bottom or below top of floors
	Abaft 0.3L from stem	1.2	1.6
	midship	1.2	1.6
	aft	1.2	1.2
IA, IB, IC	From stem to 0.3L abaft it	1.0	1.6
	Abaft 0.3L from stem	1.0	1.3
	Midship	1.0	1.3
	Aft	1.0	1.0

Where an upper forward ice belt is required (see 4.3.1), 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 by no more than 250 mm, it can be terminated at that deck or tanktop.

4.4.2 Transverse frames

4.4.2.1 Section modulus

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

$$Z = \frac{p \cdot s \cdot h \cdot l}{m_t \cdot \sigma_y} 10^6 \left[cm^3\right]$$

p = ice pressure as given in 4.2.2 [MPa]

s = frame spacing [m]

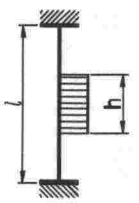
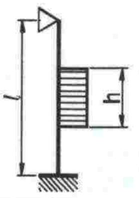
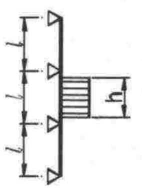
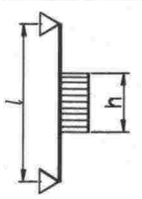
h = height of load area as given in 4.2.1 [m]

l = span of the frame [m]

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

σ_y = yield stress as in 4.3.2 [N/mm^2]

m_o = 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 as defined in 4.4.1, ordinary frame scantlings may be used.

4.4.2.2 Upper end of transverse framing

1. The upper end of the strengthened part of a main frame and of an intermediate ice frame shall be attached to a deck of an ice stringer (section 4.5).
2. Where a frame terminates above a deck or a stringer which is situated at or above the upper limit of the ice belt (section 4.3.1), the part above the deck or stringer may have the scantlings required by the classification society for an unstrengthened 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. Such an intermediate frame can also be extended to the deck above, and if this is situated more than 1.8 metre above the ice belt, the intermediate frame need not be attached to that deck, except in the Forward region.

4.4.2.3 Lower end of transverse framing

1. 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 ice stringer (section 4.5).
2. Where an intermediate frame terminates below a deck, tanktop or ice stringer which is situated at or below the lower limit of the ice belt (section 4.3.1), the lower end may be connected to the adjacent main frames by a horizontal member of the same scantlings as the frames.

4.4.3 Longitudinal frames

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

$$Z = \frac{f_3 \cdot f_4 \cdot p \cdot h \cdot l^2}{m \cdot \sigma_y} 10^6 \left[cm^3\right]$$

The shear area of a longitudinal frame shall be:

$$A = \frac{\sqrt{3} \cdot f_3 \cdot p \cdot h \cdot l}{2\sigma_y} 10^4 \left[cm^2\right]$$

This formula is valid only if the longitudinal frame is attached to supporting structure by brackets as required in 4.4.4.1.

f_3 = factor which takes account of the load distribution to adjacent frames

$f_3 = (1 - 0.2\ h/s)$

f_4 = factor which takes account of the concentration of load to the point of support,

$f_4 = 0.6$

p = ice pressure as given in 4.2.2 [MPa]

h = height of load area as given in 4.2.1 [m]

s = frame spacing [m]

The frame spacing shall not exeed 0.35 metre for ice class IA Super or IA and shall in no case exceed 0.45 metre.

l = span of frame [m]

m = 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.

σ_y = yield stress as in 4.3.2 [N/mm^2]

4.4.4 General on framing

4.4.4.1 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 is to be fitted. When a frame is running through the supporting structure, both sides of the web plate of the frame are to be connected to the structure (by direct welding, collar plate or lug). When a bracket is installed, it has to have at least the same thickness as the web plate of the frame and the edge has to be appropriately stiffened against buckling.

4.4.4.2 For ice class IA Super, for ice class IA in the forward and midship regions and for ice classes IB and IC in the forward region, the following shall apply in the ice-strengthened area:

1. Frames which are not at a straight angle to the shell shall be supported against tripping by brackets, intercostals, stringers or similar at a distance not exceeding 1300 mm.
2. The frames shall be attached to the shell by double continuous weld. No scalloping is allowed (except when crossing shell plate butts).
3. The web thickness of the frames shall be at least one half of the thickness of the shell plating and at least 9 mm. Where there is a deck, tanktop or bulkhead in lieu of a frame, the plate thickness of this shall be as above, to a depth corresponding to the height of adjacent frames.

4.5 Ice stringers

4.5.1 Stringers within the ice belt

The section modulus of a stringer situated within the ice belt (see 4.3.1) shall be calculated by the formula:

$$Z = \frac{f_5 \cdot p \cdot h \cdot l^2}{m \cdot \sigma_y} 10^6 \left[cm^3\right]$$

The shear area shall be:

$$A = \frac{\sqrt{3} \cdot f_5 \cdot p \cdot h \cdot l}{2\sigma_y} 10^4 \left[cm^2\right]$$

p = ice pressure as given in 4.2.2 [MPa]

h = height of load area as given in 4.2.1 [m]

The product $p \cdot h$ shall not be taken as less than 0.30.

l = span of the stringer [m]

m = boundary condition factor as defined in 4.4.3

f_5 = factor which takes account of the distribution of load to the transverse frames; to be taken as 0.9

σ_y = yield stress as in 4.3.2

4.5.2 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:

$$Z = \frac{f_6 \cdot p \cdot h \cdot l^2}{m \cdot \sigma_y} (1 - h_s/l_s) \cdot 10^6 \left[cm^3\right]$$

The shear area shall be:

$$A = \frac{\sqrt{3} \cdot f_6 \cdot p \cdot h \cdot l}{2\sigma_y} (1 - h_s/l_s) \cdot 10^4 \left[cm^2\right]$$

p = ice pressure as given in 4.2.2 [MPa]

h = height of load area as given in 4.2.1 [m]

The product $p \cdot h$ shall not be taken as less than 0.30.

l = span of stringer [m]

m = boundary condition factor as defined in 4.4.3

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

h_s = the distance to the ice belt [m]

f_6 = factor which takes account of load to the transverse frames; to be taken as 0.95

σ_y = yield stress of material as in 4.3.2

4.5.3 Deck strips

Narrow deck strips abreast of hatches and serving as ice stringers shall comply with the section modulus and shear area requirements in 4.5.1 and 4.5.2 respectively. In the case of very long hatches the classification society may permit the product $p \cdot h$ to be taken as less than 0.30 but in no case as less than 0.20.

Regard shall be paid to the deflection of the ship's sides due to ice pressure in way of very long hatch openings when designing weatherdeck hatch covers and their fittings.

4.6 Web frames

4.6.1 Load

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

$$F = p \cdot h \cdot S \text{ [MN]}$$

p = ice pressure as given in 4.2.2 [MPa], in calculating c_a however, l_a shall be taken as 2S.

h = height of load area as given in 4.2.1 [m]

The product $p \cdot h$ shall not be taken as less than 0.30

S = distance between web frames [m]

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 4.5.2.

4.6.2 Section modulus and shear area

If a web frame is represented by the structure model shown in figure 4, the section modulus and shear area shall be calculated by the formulae:

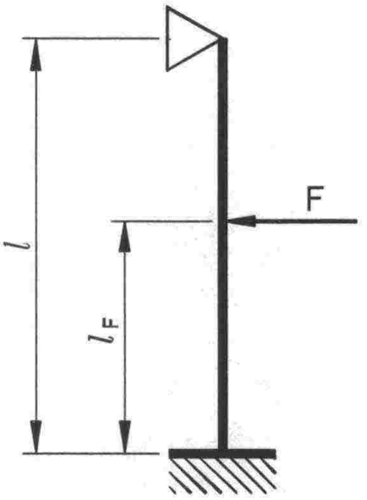


Figure 4

Shear area:

$$A = \frac{\sqrt{3} \cdot \alpha \cdot Q \cdot 10^4}{\sigma_y} \left[cm^2\right]$$

Q = maximum calculated shear force under the load F, as given in 4.6.1, or $k_1 \cdot F$.

$k_1 = 1 + 1/2\,(l_F/l)^3 - 3/2\,(l_F/l)^2$ or

$= 3/2\,(l_F/l)^2 - 1/2\,(l_F/l)^3$ whichever is greater

For the lower part of the web frame the smallest l_F within the ice belt shall be used. For the upper part the biggest l_F within the ice belt shall be taken.

α = as given in the table below

σ_y = yield stress of material as in 4.3.2

F = as in 4.6.1

Section modulus:

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

M = maximum calculated bending moment under the load F, as given in 4.6.1, or $k_2 \cdot F \cdot l$

$k_2 = 1/2\,(l_F/l)^3 - 3/2\,(l_F/l)^2 + (l_F/l)$

γ = as given in the table below

A = required shear area obtained by using

$k_1 = 1 + 1/2\ (l_F/l)^3 - 3/2\ (l_F/l)^2$

A_a = actual cross sectional area of the web frame

Factors α and γ

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

A_f = cross section area of free flange

A_w = cross section area of web plate

4.6.3 Direct calculations

For other web frame configurations and boundary conditions than those given in 4.6.2, a direct stress calculation shall be performed.

The concentrated load on the web frame is given in 4.6.1. The point of application is in each case to be chosen in relation to the arrangement of stringers and longitudinal frames so as to obtain the maximum shear and bending moments. Allowable stresses are as follows:

Shear stress:

$$\tau = \sigma_y / \sqrt{3}$$

Bending stress:

$$s_b = s_y$$

Equivalent stress:

$$\sigma_c = \sqrt{\sigma_b^{\ 2} + 3\tau^2} = \sigma_y$$

4.7 Bow

4.7.1 Stem

The stem shall be made of rolled, cast or forged steel or of shaped steel plates. A sharp edged stem (see figure 5) improves the manoeuvrability of the ship in ice and is recommended particularly for smaller ships with a length under 150 m.

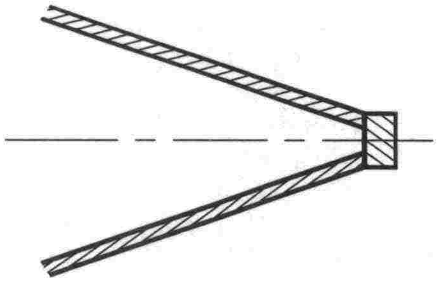


Figure 5
Example of a suitable stem

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, shall be calculated according to the formula in 4.3.2 assuming that:

s = spacing of elements supporting the plate [m]

p_{PL} = p [MPa] (see 4.3.2)

l_a = 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 LWL or, in case an upper forward ice belt is required (4.3.1), to the upper limit of this.

4.7.2 Arrangements for towing

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

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

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

It should be noted that fork towing is often the moste efficient way of assisting ships of moderate size (displacement not exceeding 30,000 tons) in ice. Ships with a bulb protruding more than 2.5 metres forward of the forward perpendicular are, however, often difficult to tow in this way.

4.8 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 aft region and the stern area. This fact should be considered in the design of the aft/stern structure.

4.8.1 An extremely narrow clearance between the propeller blade tip and the stern frame shall be avoided as a small clearance would cause very high loads on the blade tip.

4.8.2 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.

4.8.3 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.

4.8.4 A wide transom stern extending below the LWL will seriously impede the capability of the ship to back in ice, which is most essential. Therefore a transom stern shall not be extended below the LWL, if this can be avoided. If unavoidable, the part of the transom below the LWL shall be kept as narrow as possible. The part of a transom stern situated within the ice belt shall be strengthened as for the midship region.

4.9 Bilge keels

Bilge keels are often damaged or ripped off in ice. The connection of bilge keels to the hull shall be so designed that the risk of damage to the hull, in case a bilge keel is ripped off, is minimized. To limit damage when a bilge keel is partly ripped off, it is recommended that bilge keels are cut up into several shorter independent lengths.

5 RUDDER AND STEERING ARRANGEMENTS

5.1 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 rules of the Classification Society. 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.

5.2 For the ice classes IA Super and IA the rudder stock and the upper edge of the rudder shall be protected against ice pressure by an ice knife or equivalent means.

5.3 For the ice classes IA Super and IA due regard shall be paid to the excessive load caused by the rudder being forced out of the midship position when backing into an ice ridge.

5.4 Relief valves for hydraulic pressure shall be effective. The components of the steering gear shall be dimensioned to stand the yield torque of the rudder stock. Where possible, rudder stoppers working on the blade or rudder head shall be fitted.

6 PROPELLER, SHAFTS AND GEARS

6.1 Determination of ice torque

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

$M = m \cdot D^2$ tonmeters where:

D	= diameter of propeller in meters
m	= 2.15 for ice class IA Super
	= 1.60 " " " IA
	= 1.33 " " " IB
	= 1.22 " " " IC

If the propeller is not fully submerged when the ship is in ballast condition, the ice torque for ice class IA is to be used for ice classes IB and IC.

6.2 Propellers

6.2.1 The elongation of the material used is not to be less than 19%, preferably less than 22% for a test piece length = 5 d and the value for the Charpy V-notch test is not to be less than 2.1 kpm at –10°C.

6.2.2 Width c and thickness t of propeller blade sections are to be determined so that:

a) at the radius 0.25 D/2, for solid propellers

$$ct^2 = \frac{2.70}{\sigma_b \cdot (0.65 + 0.7H/D)}\left(20000\frac{P_S}{Z \cdot n} + 22000M\right)$$

b) at the radius 0.35 D/2 for cp-propellers

$$ct^2 = \frac{2.15}{\sigma_b \cdot (0.65 + 0.7H/D)}\left(20000\frac{P_S}{Z \cdot n} + 23000M\right)$$

c) at the radius 0.6 D/2

$$ct^2 = \frac{0.95}{\sigma_b \cdot (0.65 + 0.7H/D)}\left(20000\frac{P_S}{Z \cdot n} + 28000M\right)$$

where:

c = length in cm of the expanded cylindrical section of the blade, at the radius in question
t = the corresponding maximum blade thickness in cm
H = propeller pitch in meters at the radius in question.
(For controllable pitch propellers 0.7 $H_{nominal}$ is to be used.)
P_s = shaft engine output according to 3.1, *but expressed in horsepower [hp]*
n = propeller revolutions [rpm]
M = ice torque according to 6.1.
Z = number of blades
σ_b = tensile strength in kp/mm^2 of the material

6.2.3 The blade tip thickness t at the radius 1.0 D/2 is to be determined by the following formulae:

Ice Class IA Super

$$t = (20 + 2\ D)\sqrt{\frac{50}{\sigma_b}}\ \text{mm}$$

Ice Classes IA, IB and IC

$$t = (15 + 2\ D)\sqrt{\frac{50}{\sigma_b}}\ \text{mm}$$

where D and σ_b are as defined previously.

6.2.4 The thickness of other sections is governed by a smooth curve connecting the above section thicknesses.

6.2.5 Where the blade thickness derived is less than the class rule thickness, the latter is to be used.

6.2.6 The thickness of blade edges is not to be less than 50% of the derived tip thickness t, measured at 1.25 t from the edge. For controllable pitch propellers this applies only to the leading edge.

6.2.7 The strength of mechanisms in the boss of a controllable pitch propeller is to be 1.5 times that of the blade when a load is applied at the radius 0.9 D/2 in the weakest direction of the blade.

6.3 Screw shaft

The diameter of the screw shaft at the aft bearing is not to be less than:

$$d_S = 10.8\sqrt[3]{\frac{\sigma_b \cdot ct^2}{\sigma_y}}\ \text{mm}$$

where

σ_b = tensile strength of the blade in kp/mm^2
ct^2 = value derived by the formulae in 6.2.2 a).
σ_y = yield stress of the shaft in kp/mm^2
If the diameter of the propeller boss is greater than 0.25 D, the following formula is to be used:

$$d_S = 11.5 \sqrt[3]{\frac{\sigma_b \cdot ct^2}{\sigma_y}} \ \text{mm}$$

where σ_b and σ_y are as defined previously,
ct^2 = value derived by the formulae in 6.2.2 b).

If the shaft diameter derived is less than the class rule diameter, the latter is to be used. The shaft may be tapered in accordance with the rules.

6.4 Intermediate shafts

The diameter of intermediate shafts and thrust shafts in external bearings are not to be less than:

$d_i = 1.1 \cdot d_{rule}$, for ice class IA Super.

No strengthening is required for ice classes IA, IB and IC, i.e. class rule diameters are to be used.

6.5 Reduction gears

For calculation of the maximum permissible gear tooth load for maximum P_S according to 3.1, the following loading factor K_i is to be used:

$$K_i = K \frac{N}{N + \frac{M I_h R^2}{I_l + I_h R^2}}$$

where

K = the class rule loading factor
M = ice torque according to 6.1.
N = $0.716 \, P_S/n$
where: P_S = shaft engine output according to 3.1, *but expressed in horsepower [hp]*
n = corresponding engine rpm
R = gear ratio, pinion rpm/gear wheel rpm
I_h = mass moment of inertia of machinery components rotating at higher rpm
I_l = mass moment of inertia of machinery components rotating at lower rpm including propeller with an addition of 30% for water. (I_h and I_l are to be expressed in the same dimension)

7 MISCELLANEOUS MACHINERY REQUIREMENTS

7.1 Starting arrangements

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 has to be reversed for going astern, or 6 consecutive starts if the propulsion engine does not have to 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 has to be reversed for going astern, in which case the compressor shall be able to charge the receivers in half an hour.

7.2 Sea inlet and cooling water systems

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. Otherwise the arrangement and situation shall be as above.

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 inlet chest as described above.

ANNEX I

THE VALIDITY OF THE POWERING REQUIREMENT IN SECTION 3.2.2 FOR ICE CLASSES IA SUPER, IA, IB AND IC AND VERIFICATION OF CALCULATED POWERING REQUIREMENTS

1 Range of validity

The range of validity of the formulae for powering requirements in section 3.2.2 is presented in table 1. When calculating the parameter D_P/T, T shall be measured at LWL.

Table 1. The range of parameters used for validation of the powering requirement.

Parameter		Minimum	Maximum
α	[degrees]	15	55
φ_1	[degrees]	25	90
φ_2	[degrees]	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
$A_{wf}/(L*B)$		0.09	0.27

2 Verification of calculated powering requirements

To check the results of calculated powering requirements, table 2 is presented with input data for a number of sample ships.

Table 2. Parameters and calculated minimum engine power of sample ships.

		Sample ship No.								
		#1	#2	#3	#4	#5	#6	#7	#8	#9
Ice class		IAS	IA	IB	IC	IAS	IAS	IA	IA	IB
α	[degrees]	24	24	24	24	24	24	36	20	24
φ_1	[degrees]	90	90	90	90	30	90	30	30	90
φ_2	[degrees]	30	30	30	30	30	30	30	30	30
L	[m]	150	150	150	150	150	150	150	150	150
B	[m]	25	25	25	25	25	22	25	25	25
T	[m]	9	9	9	9	9	9	9	9	9
L_{BOW}	[m]	45	45	45	45	45	45	45	45	45
L_{PAR}	[m]	70	70	70	70	70	70	70	70	70
A_{wf}	[m^2]	500	500	500	500	500	500	500	500	500
D_P	[m]	5	5	5	5	5	5	5	5	5
Prop. No / type		1/CP	1/CP	1/CP	1/CP	1/CP	1/CP	1/CP	1/CP	1/FP
New ships	[kW]	7840	4941	3478	2253	6799	6406	5343	5017	3872
(see paragraph 3.2.2)										
Existing ships	[kW]	9192	6614			8466	7645	6614	6614	
(calculated according										
to the formula in 3.2.4)										

ANNEX II

REQUIRED ENGINE OUTPUT FOR A SHIP OF ICE CLASS IB OR IC THE KEEL OF WHICH HAS BEEN LAID OR WHICH HAS BEEN AT A SIMILAR STAGE OF CONSTRUCTION BEFORE 1 SEPTEMBER 2003

The engine output shall not be less than that determined by the formula below and in no case less than 740 kW for the ice classes IB and IC.

$$P = f_1 \cdot f_2 \cdot f_3 \cdot (f_4 \Delta + P_0) \text{ [kW], where}$$

$f_1 = 1.0$ for a fixed pitch propeller
$= 0.9$ for a controllable pitch propeller

$f_2 = \varphi_1 / 200 + 0.675$ but not more than 1.1.

$\varphi_1 =$ the rake of the stem at the centerline [degrees] (see figure 1)

The product $f_1\ f_2$ shall not be taken as less than 0.85.

$f_2 = 1.1$ for a bulbous bow

$f_3 = 1.2B / \Delta^{1/3}$ but not less than 1.0

f_4 and P_0 shall be taken as follows:

Ice class	IB	IC	IB	IC
Displacement	$\Delta < 30\,000$		$\Delta \geq 30\,000$	
f_4	0.22	0.18	0.13	0.11
P_0	370	0	3070	2100

$\Delta =$ displacement [t] of the ship on the maximum ice class draught according to 2.1. It needs not be taken as greater than 80 000 t.