1260/71/307), as amended, apply to ships the keels of which have been laid or which have been at a similar stage of construction before 1 November 1986. On the owner's request, the requirements of the 1985 Ice Class Rules or the 2008 Ice Class Regulations may, however, be applied to the engine output of such ships.

However, ships of ice class IA Super or IA the keels of which have been laid or which have been at a similar stage of construction before 1 September 2003 shall comply with the requirements in section 3.2.2 or 3.2.4 of the Ice Class Regulations of 2017 not later than 1 January in the year when twenty years have elapsed since the year the ship was delivered.

1.8 Ice classes

Under section 3 of the Act on the Ice Classes of Ships and Icebreaker Assistance (1121/2005), ships are assigned to ice classes as follows:

1. ice class IA Super; ships with such a 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 a 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 a 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 a 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 using their own propulsion machinery;
6. ice class III; ships that do not belong to the ice classes referred to in paragraphs 1-5.

2 ICE CLASS DRAUGHT

2.1 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.

2.2 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 and the draught of the ship at fore and aft perpendiculars, when ice conditions require the ship to be ice-strengthened, shall always be between 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 class certificate. For ships built on or after 1 July 2007, if the summer load line in fresh water is anywhere located at a higher level than the UIWL, the ship's sides are to be provided with a warning triangle and with an ice class draught mark at the maximum permissible ice class draught amidships (see Annex III). Ships built before 1 July 2007 shall be provided with such a marking, if the UIWL is below the summer load line, not later than the first scheduled dry docking after 1 July 2007.

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 draught of LIWL amidships 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 to ensure a reasonable degree of ice-going capability in ballast. The highest point of the propeller shall be submerged and if possible at a depth of at least h_i below the water surface in all loading conditions. The forward draught shall be at least:

$$(2 + 0.00025\,\Delta)h_i\,[\text{m}], \text{ but need not exceed } 4h_i, \qquad (2.1)$$

where

Δ is the displacement of the ship [t] determined from the waterline on the UIWL (see section 2.1). Where multiple waterlines are used for determining the UIWL, the displacement must be determined from the waterline corresponding to the greatest displacement.

h_i is the level ice thickness [m] according to section 4.2.1.

3 ENGINE OUTPUT

3.1 Definition of engine output

The engine output P is the total 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. If additional power sources are available for propulsion power (e.g. shaft motors), in addition to the power of the main engine(s), they shall also be included in the total engine 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 1,000 kW for ice class IA, IB and IC, and no less than 2,800 kW for IA Super.

3.2.1 Definitions

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

L	m	the length of the ship between the perpendiculars
L_{BOW}	m	the length of the bow
L_{PAR}	m	the length of the parallel midship body
B	m	the maximum breadth of the ship
T	m	the actual ice class draughts of the ship according to 3.2.2
A_{wf}	m^2	the 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
φ_2	degree	the rake of the bow at $B/4$
ψ	degree	the flare angle calculated as $\psi = \tan^{-1}\left(\frac{\tan\phi}{\sin\alpha}\right)$ using local angles α and φ at each location. For chapter 3, the flare angle is calculated using $\varphi = \varphi_2$
D_P	m	the diameter of the propeller
H_M	m	the thickness of the brash ice in mid channel
H_F	m	the thickness of the brash ice layer displaced by the bow

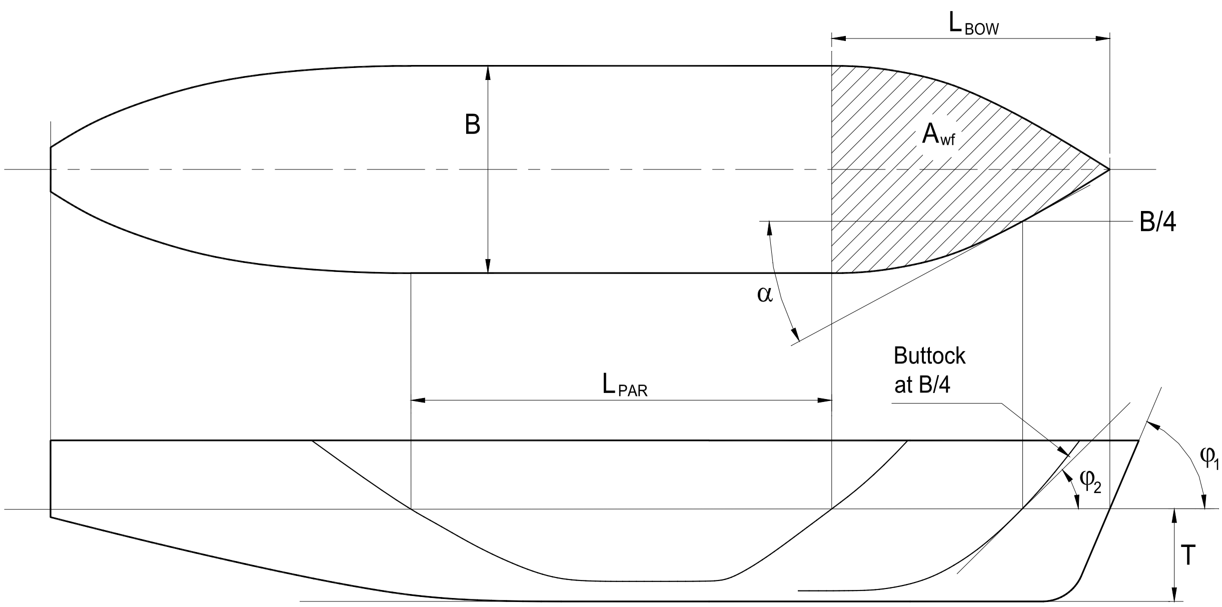

Figure 3-1. Determination of the geometric quantities of the hull. If the ship has a bulbous bow, then φ_1 = 90°.

3.2.2 New ships

To qualify for 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 re-quirements regarding its engine output. The engine output requirement shall be calculated for two draughts by formula 3.1. Draughts to be used are the maximum draught amidships referred to as UIWL and the minimum draught amidships referred to as LIWL, as defined in section 2.2. In the calculations, the ship's parameters which depend on the draught must be determined at the appropriate draught, but *L* and *B* must be determined only at the UIWL. The engine output shall be no less than the greater of these two outputs.

$$P_{min} = K_e \frac{(R_{CH}/1000)^{3/2}}{D_p} \text{ [kW]}, \tag{3.1}$$

where K_e shall be given a value according to Table 3-1.

Table 3-1: Values of K_e for conventional propulsion systems

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

These K_e values apply to conventional propulsion systems. Other methods may be used for determining the required power for advanced propulsion systems (see 3.2.5).

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

$$R_{CH} = C_1 + C_2 + C_3 C_\mu (H_F + H_M)^2 (B + C_\psi H_F) + C_4 L_{PAR} H_F^2 + C_5 \left(\frac{LT}{B^2}\right)^3 \frac{A_{wf}}{L}, \tag{3.2}$$

where

$C_\mu = 0.15 cos\varphi_2 + \sin\psi \sin\alpha$, C_μ has a value equal to or larger than 0.45

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

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

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

C_1 and C_2 take account of a consolidated upper layer of brash ice. C_1=0 and C_2=0 for ice classes IA, IB and IC.

For ice class IA Super:

$$C_1 = f_1 \frac{B L_{PAR}}{2\frac{T}{B} + 1} + (1 + 0.021\phi_1)(f_2 B + f_3 L_{BOW} + f_4 B L_{BOW}),$$

$$C_2 = (1 + 0.063\phi_1)(g_1 + g_2 B) + g_3 \left(1 + 1.2\frac{T}{B}\right)\frac{B^2}{\sqrt{L}}.$$

For a ship with a bulbous bow, φ_1 = 90°.

Coefficients f_1-f_4 and g_1-g_3 are given in Table 3-2.

Table 3-2: Values of coefficients f_1-f_4 and g_1-g_3 for the determination of C_1 and C_2

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

C_3 = 845 kg/(m^{2}s^2)

C_4 = 42 kg/(m^{2}s^2)

C_5 = 825 kg/s^2

$$\psi = \tan^{-1}\left(\frac{\tan\phi_2}{\sin\alpha}\right)$$

If the value of the term $\left(\frac{LT}{B^2}\right)^3$ is less than 5, the value 5 shall be used and if the value of the term is more than 20, the value 20 shall be used.

3.2.3 Existing ships of ice class IB or IC

In order to retain ice class IB or IC a ship, to which ice class regulations 1985 (2.9.1985, No. 2575/85/307, as amended) apply, shall comply with the required minimum engine output as defined in section 3.2.1 of the ice class regulations 1985. 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 of these regulations.

3.2.4 Existing ships of ice class IA Super or IA

In order 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 not later than 1 January in the year when twenty years have elapsed since the year the ship was delivered.

If the ship does not comply with the requirements in section 3.2.2 on the date given above, the highest lower ice class for which the engine output is sufficient can be confirmed for the ship.

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:

$$R_{CH} = C_1 + C_2 + C_3(H_F + H_M)^2(B + 0.658H_F) + C_4LH_F^2 + C_5\left(\frac{LT}{B^2}\right)^3\frac{B}{4}, \qquad (3.3)$$

where for ice class IA, C_1=0 and C_2=0.

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

$$C_1 = f_1\frac{BL}{2\frac{T}{B}+1} + 1{,}84(f_2B + f_3L + f_4BL),$$

$$C_2 = 3.52(g_1 + g_2B) + g_3\left(1 + 1{,}2\frac{T}{B}\right)\frac{B^2}{\sqrt{L}}.$$

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

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

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

Coefficients f_1-f_4 and g_1-g_3 are given in Table 3-3.

Table 3-3: Values of coefficients f_1-f_4 and g_1-g_3 for the determination of C_1 and C_2

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^{2}s^2)

C_4 = 18.7 kg/(m^{2}s^2)

C_5 = 825 kg/s^2

If the value of the term $\left(\frac{LT}{B^2}\right)^3$ is less than 5, the value 5 shall be used and if the value of the term is more than 20, the value 20 shall be used.

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 sections 3.2.2 and 3.2.3, the use of K_e or R_{CH} values based on more precise calculations or values based on model tests may be approved. Such approval will be given on the understanding that it can be revoked if experience of the ship's performance provides grounds for this in practice.

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 hull scantlings is based on certain assumptions concerning the nature of the ice load on the structure. These assumptions are based on 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 well be in excess of the normal uniaxial crushing strength of sea ice. This is explained by the fact that the stress field is in fact multiaxial.

Furthermore, it has been observed that the ice pressure on a frame can be higher than on the shell plating at the midspacing between frames. This is due to the different flexural stiffness of frames and shell plating. The load distribution is assumed to be as shown in Figure 4-1.