

# I3 Machinery Requirements for Polar Class Ships

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## I3.1 Application \*

The contents of this Chapter apply to main propulsion, steering gear, emergency and essential auxiliary systems essential for the safety of the ship and the survivability of the crew.

## I3.2

### I3.2.1 Drawings and particulars to be submitted

I3.2.1.1 Details of the environmental conditions and the required ice class for the machinery, if different from ship's ice class.

I3.2.1.2 Detailed drawings of the main propulsion machinery. Description of the main propulsion, steering, emergency and essential auxiliaries are to include operational limitations. Information on essential main propulsion load control functions.

I3.2.1.3 Description detailing how main, emergency and auxiliary systems are located and protected to prevent problems from freezing, ice and snow and evidence of their capability to operate in intended environmental conditions.

I3.2.1.4 Calculations and documentation indicating compliance with the requirements of this chapter.

### I3.2.2 System Design

I3.2.2.1 Machinery and supporting auxiliary systems shall be designed, constructed and maintained to comply with the requirements of "periodically unmanned machinery spaces" with respect to fire safety. Any automation plant (i.e. control, alarm, safety and indication systems) for essential systems installed is to be maintained to the same standard.

I3.2.2.2 Systems, subject to damage by freezing, shall be drainable.

I3.2.2.3 Single screw vessels classed PC1 to PC5 inclusive shall have means provided to ensure sufficient vessel operation in the case of propeller damage including CP-mechanism.

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\* Note:

1. This UR is to be uniformly applied by IACS Societies on ships contracted for construction on and after 1 March 2008.
2. The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contract for construction", refer to IACS Procedural Requirement (PR) No. 29.

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## I3.3 Materials

### I3.3.1 Materials exposed to sea water

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

Charpy V impact test shall be carried out for other than bronze and austenitic steel materials. Test pieces taken from the propeller castings shall be representative of the thickest section of the blade. An average impact energy value of 20 J taken from three Charpy V tests is to be obtained at minus 10 °C.

### I3.3.2 Materials exposed to sea water temperature

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

An average impact energy value of 20 J taken from three tests is to be obtained at minus 10 °C.

### I3.3.3 Material exposed to low air temperature

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

An average impact energy value of 20 J taken from three Charpy V tests is to be obtained at 10 °C below the lowest design temperature.

## I3.4 Ice Interaction Load

### I3.4.1 Propeller Ice Interaction

These Rules cover open and ducted type propellers situated at the stern of a vessel having controllable pitch or fixed pitch blades. Ice loads on bow propellers and pulling type propellers shall receive special consideration. The given loads are expected, single occurrence, maximum values for the whole ships service life for normal operational conditions. These loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice. These Rules apply also for azimuthing (geared and podded) thrusters considering loads due to propeller ice interaction. However, ice loads due to ice impacts on the body of azimuthing thrusters are not covered by I3.

The loads given in section I3.4 are total loads (unless otherwise stated) during ice interaction and are to be applied separately (unless otherwise stated) and are intended for component strength calculations only. The different loads given here are to be applied separately.

$F_b$  is a force bending a propeller blade backwards when the propeller mills an ice block while rotating ahead.  $F_f$  is a force bending a propeller blade forwards when a propeller interacts with an ice block while rotating ahead.

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## 13.4.2 Ice Class Factors

The Table below lists the design ice thickness and ice strength index to be used for estimation of the propeller ice loads.

Ice Class	$H_{ice}$ [m]	$S_{ice}$ [-]	$S_{qice}$ [-]
PC1	4.0	1.2	1.15
PC2	3.5	1.1	1.15
PC3	3.0	1.1	1.15
PC4	2.5	1.1	1.15
PC5	2.0	1.1	1.15
PC6	1.75	1	1
PC7	1.5	1	1

$H_{ice}$  Ice thickness for machinery strength design

$S_{ice}$  Ice strength index for blade ice force

$S_{qice}$  Ice strength index for blade ice torque

## 13.4.3 Design Ice Loads for Open Propeller

13.4.3.1 Maximum Backward Blade Force,  $F_b$ 

when  $D < D_{limit}$ ,

$$F_b = -27 S_{ice} [nD]^{0.7} \left[ \frac{EAR}{Z} \right]^{0.3} [D] \quad \text{kN} \quad \text{[Equation 1]}$$

when  $D \geq D_{limit}$ ,

$$F_b = -23 S_{ice} [nD]^{0.7} \left[ \frac{EAR}{Z} \right]^{0.3} [H_{ice}]^{1.4} [D] \quad \text{kN} \quad \text{[Equation 2]}$$

where  $D_{limit} = 0.85 * (H_{ice})^{1.4}$

$n$  is the nominal rotational speed (at MCR free running condition) for CP-propeller and 85% of the nominal rotational speed (at MCR free running condition) for a FP-propeller (regardless driving engine type).

$F_b$  is to be applied as a uniform pressure distribution to an area on the back (suction) side of the blade for the following load cases:

- Load case 1: from 0.6R to the tip and from the blade leading edge to a value of 0.2 chord length.
- Load case 2: a load equal to 50% of the  $F_b$  is to be applied on the propeller tip area outside of 0.9R.

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c) Load case 5: for reversible propellers a load equal to 60% of the  $F_b$  is to be applied from 0.6R to the tip and from the blade trailing edge to a value of 0.2 chord length.

See load cases 1, 2 and 5 in Table 1 of Appendix.

### I3.4.3.2 Maximum Forward Blade Force, $F_f$

when  $D < D_{limit}$

$$F_f = 250 \left[ \frac{EAR}{Z} \right] [D]^2 \quad \text{kN} \quad \text{[Equation 3]}$$

when  $D \geq D_{limit}$

$$F_f = 500 \left( \frac{1}{1 - \frac{d}{D}} \right) H_{ice} \left[ \frac{EAR}{Z} \right] [D] \quad \text{kN} \quad \text{[Equation 4]}$$

where

$$D_{limit} = \left( \frac{2}{1 - \frac{d}{D}} \right) H_{ice} \quad \text{[Equation 5]}$$

$d$  = propeller hub diameter [m]

$D$  = propeller diameter [m]

EAR = expanded blade area ratio

$Z$  = number of propeller blades

$F_f$  is to be applied as a uniform pressure distribution to an area on the face (pressure) side of the blade for the following loads cases:

- Load case 3: from 0.6R to the tip and from the blade leading edge to a value of 0.2 chord length.
- Load case 4: a load equal to 50% of the  $F_f$  is to be applied on the propeller tip area outside of 0.9R.
- Load case 5: for reversible propellers a load equal to 60%  $F_f$  is to be applied from 0.6R to the tip and from the blade trailing edge to a value of 0.2 chord length.

See load cases 3, 4 and 5 in Table 1 of Appendix.

### I3.4.3.3 Maximum Blade Spindle Torque, $Q_{smax}$

Spindle torque  $Q_{smax}$  around the spindle axis of the blade fitting shall be calculated both for the load cases described in I3.4.3.1 & I3.4.3.2 for  $F_b$   $F_f$ . If these spindle torque values are less than the default value given below, the default minimum value shall be used.

$$\text{Default Value: } Q_{smax} = 0.25 \cdot F \cdot c_{0.7} \quad \text{[kNm]} \quad \text{[Equation 6]}$$

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where

$c_{0.7}$  = length of the blade chord at 0.7R radius [m]

F is either  $F_b$  or  $F_f$  which ever has the greater absolute value.

I3.4.3.4 Maximum Propeller Ice Torque applied to the propeller

When  $D < D_{limit}$

$$Q_{max} = 105 \times (1 - d / D) \times S_{qice} \times (P_{0.7} / D)^{0.16} \times (t_{0.7} / D)^{0.6} \times (nD)^{0.17} \times D^3 \quad \text{kNm} \quad \text{[Equation 7]}$$

When  $D \geq D_{limit}$

$$Q_{max} = 202 \times (1 - d / D) \times S_{qice} \times H_{ice}^{1.1} \times (P_{0.7} / D)^{0.16} \times (t_{0.7} / D)^{0.6} \times (nD)^{0.17} \times D^{1.9} \quad \text{kNm} \quad \text{[Equation 8]}$$

where

$D_{limit} = 1.81 H_{ice}$

$S_{qice}$  = Ice strength index for blade ice torque

$P_{0.7}$  = propeller pitch at 0.7 R [m]

$t_{0.7}$  = max thickness at 0.7 radius

$n$  is the rotational propeller speed, [rps], at bollard condition. If not known,  $n$  is to 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	$0.85 n_n$

Where  $n_n$  is the nominal rotational speed at MCR, free running condition.

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

I3.4.3.5 Maximum Propeller Ice Thrust applied to the shaft

$$T_f = 1.1 \cdot F_f \quad \text{kN} \quad \text{[Equation 9]}$$

$$T_b = 1.1 \cdot F_b \quad \text{kN} \quad \text{[Equation 10]}$$

I3.4.4 Design Ice Loads for Ducted Propeller

I3.4.4.1 Maximum Backward Blade Force,  $F_b$

when  $D < D_{limit}$

$$F_b = -9.5 S_{ice} \left[ \frac{EAR}{Z} \right]^{0.3} [nD]^{0.7} D^2 \quad \text{[Equation 11]}$$

## I3 (cont)

when  $D \geq D_{limit}$

$$F_b = -66 S_{ice} \left[ \frac{EAR}{Z} \right]^{0.3} [nD]^{0.7} D^{0.6} [H_{ice}]^4 \quad \text{[Equation 12]}$$

where  $D_{limit} = 4 H_{ice}$

$n$  shall be taken as in I3.4.3.1

$F_b$  is to be applied as a uniform pressure distribution to an area on the back side for the following load cases (see Table 2 of Appendix):

- a) Load case 1: On the back of the blade from 0.6R to the tip and from the blade leading edge to a value of 0.2 chord length.
- b) Load case 5: For reversible rotation propellers a load equal to 60% of  $F_b$  is applied on the blade face from 0.6R to the tip and from the blade trailing edge to a value of 0.2 chord length.

### I3.4.4.2 Maximum Forward Blade Force, $F_f$

when  $D \leq D_{limit}$

$$F_f = 250 \cdot \left[ \frac{EAR}{Z} \right] \cdot D^2 \quad \text{[kN]} \quad \text{[Equation 13]}$$

When  $D > D_{limit}$

$$F_f = 500 \cdot \left[ \frac{EAR}{Z} \right] \cdot D \cdot \frac{1}{\left(1 - \frac{d}{D}\right)} \cdot H_{ice} \quad \text{[kN]} \quad \text{[Equation 14]}$$

$$\text{where } D_{limit} = \frac{2}{\left(1 - \frac{d}{D}\right)} \cdot H_{ice} \quad \text{[m]} \quad \text{[Equation 15]}$$

$F_f$  is to be applied as a uniform pressure distribution to an area on the face (pressure) side for the following load case (see Table 2 Appendix):

- a) Load case 3: On the blade face from 0.6R to the tip and from the blade leading edge to a value of 0.5 chord length.
- b) Load case 5: A load equal to 60%  $F_f$  is to be applied from 0.6R to the tip and from the blade leading edge to a value of 0.2 chord length.

### I3.4.4.3 Maximum Propeller Ice Torque applied to the propeller

$Q_{max}$  is the maximum torque on a propeller due to ice-propeller interaction.

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$$Q_{max} = 74 \cdot \left[1 - \frac{d}{D}\right] \cdot \left[\frac{P_{0.7}}{D}\right]^{0.16} \cdot \left[\frac{t_{0.7}}{D}\right]^{0.6} \cdot (nD)^{0.17} \cdot S_{q_{ice}} \cdot D^3 \text{ [kNm]} \quad \text{[Equation 16]}$$

when  $D \leq D_{limit}$

$$Q_{max} = 141 \cdot \left[1 - \frac{d}{D}\right] \cdot \left[\frac{P_{0.7}}{D}\right]^{0.16} \cdot \left[\frac{t_{0.7}}{D}\right]^{0.6} \cdot (nD)^{0.17} \cdot S_{q_{ice}} \cdot D^{1.9} \cdot H_{ice}^{1.1} \text{ [kNm]} \quad \text{[Equation 17]}$$

when  $D > D_{limit}$

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

$n$  is the rotational propeller speed [rps] at bollard condition. If not known,  $n$  is to be taken as follows:

	<b>n</b>
CP propellers	$n_n$
FP propellers driven by turbine or electric motor	$n_n$
FP propellers driven by diesel engine	$0.85 n_n$

Where  $n_n$  is the nominal rotational speed at MCR, free running condition.

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

#### 13.4.4.4 Maximum Blade Spindle Torque for CP-mechanism Design, $Q_{smax}$

Spindle torque  $Q_{smax}$  around the spindle axis of the blade fitting shall be calculated for the load case described in 3.4.1. If these spindle torque values are less than the default value given below, the default value shall be used.

Default Value:  $Q_{smax} = 0.25 \cdot F \cdot c_{0.7}$  [kNm] [Equation 18]

Where  $c_{0.7}$  the length of the blade section at 0.7R radius and  $F$  is either  $F_b$  or  $F_f$  which ever has the greater absolute value.

#### 13.4.4.5 Maximum Propeller Ice Thrust (applied to the shaft at the location of the propeller)

$$T_f = 1.1 \cdot F_f \quad \text{[Equation 19]}$$

$$T_b = 1.1 \cdot F_b \quad \text{[Equation 20]}$$

#### 13.4.5 Reserved

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## 13.4.6 Design Loads on Propulsion Line

## 13.4.6.1 Torque

The propeller ice torque excitation for shaft line dynamic analysis shall be described by a sequence of blade impacts which are of half sine shape and occur at the blade. The torque due to a single blade ice impact as a function of the propeller rotation angle is then

$$Q(\varphi) = C_q * Q_{\max} * \sin(\varphi(180 / \alpha_i)) \quad \text{when } \varphi = 0 \dots \alpha_i \quad [\text{Equation 21}]$$

$$Q(\varphi) = 0 \quad \text{when } \varphi = \alpha_i \dots 360$$

where  $C_q$  and  $\alpha_i$  parameters are given in table below.

Torque excitation	Propeller-ice interaction	$C_q$	$\alpha_i$
Case 1	Single ice block	0.5	45
Case 2	Single ice block	0.75	90
Case 3	Single ice block	1.0	135
Case 4	Two ice blocks with 45 degree phase in rotation angle	0.5	45

The total ice torque is obtained by summing the torque of single blades taking into account the phase shift  $360\text{deg./Z}$ . The number of propeller revolutions during a milling sequence shall be obtained with the formula:

$$N_Q = 2 \cdot H_{ice} \quad [\text{Equation 22}]$$

The number of impacts is  $Z \cdot N_Q$ .

See Figure 1 in Appendix.

Milling torque sequence duration is not valid for pulling bow propellers, which are subject to special consideration.

The response torque at any shaft component shall be analysed considering excitation torque  $Q_{\square}$  at the propeller, actual engine torque  $Q_e$  and mass elastic system.

$Q_e$  = actual maximum engine torque at considered speed

Design torque along propeller shaft line

The design torque ( $Q_r$ ) of the shaft component shall be determined by means of torsional vibration analysis of the propulsion line. Calculations have to be carried out for all excitation cases given above and the response has to be applied on top of the mean hydrodynamic torque in bollard condition at considered propeller rotational speed.

## 13.4.6.2 Maximum Response Thrust

Maximum thrust along the propeller shaft line is to be calculated with the formulae below. The factors 2.2 and 1.5 take into account the dynamic magnification due to axial vibration. Alternatively the propeller thrust magnification factor may be calculated by dynamic analysis.

$$\text{Maximum Shaft Thrust Forwards: } T_r = T_n + 2.2 \times T_f \quad [\text{kN}] \quad [\text{Equation 24}]$$

$$\text{Maximum Shaft Thrust Backwards: } T_r = 1.5 \times T_b \quad [\text{kN}] \quad [\text{Equation 25}]$$

## I3 (cont)

$T_n$  = propeller bollard thrust [kN]  
 $T_f$  = maximum forward propeller ice thrust [kN]

If hydrodynamic bollard thrust,  $T_n$  is not known,  $T_n$  is to be taken as follows:

Propeller type	$T_n$
CP propellers (open)	1.25 T
CP propellers (ducted)	1.1 T
FP propellers driven by turbine or electric motor	T
FP propellers driven by diesel engine (open)	0.85 T
FP propellers driven by diesel engine (ducted)	0.75 T

T = nominal propeller thrust at MCR at free running open water conditions

### I3.4.6.3 Blade Failure Load for both Open and Nozzle Propeller

The force is acting at 0.8R in the weakest direction of the blade and at a spindle arm of 2/3 of the distance of axis of blade rotation of leading and trailing edge which ever is the greatest.

The blade failure load is:

$$F_{ex} = \frac{0.3 \cdot c \cdot t^2 \cdot \sigma_{ref}}{0.8 \cdot D - 2 \cdot r} 10^3 \quad [\text{kN}] \quad [\text{Equation 26}]$$

$$\text{where } \sigma_{ref} = 0.6 \cdot \sigma_{0.2} + 0.4 \cdot \sigma_u$$

Where  $\sigma_u$  and  $\sigma_{0.2}$  are representative values for the blade material.

$c$ ,  $t$  and  $r$  are respectively the actual chord length, thickness and radius of the cylindrical root section of the blade at the weakest section outside root fillet, and typically will be at the termination of the fillet into the blade profile.

## I3.5 Design

### I3.5.1 Design Principle

The strength of the propulsion line shall be designed

- for maximum loads in I3.4;
- such that the plastic bending of a propeller blade shall not cause damages in other propulsion line components;
- with sufficient fatigue strength.

### I3.5.2 Azimuthing Main Propulsors

In addition to the above requirements special consideration shall be given to the loading cases which are extraordinary for propulsion units when compared with conventional

## I3 (cont)

propellers. Estimation of the loading cases must reflect the operational realities of the ship and the thrusters. In this respect, for example, the loads caused by impacts of ice blocks on the propeller hub of a pulling propeller must be considered. Also loads due to thrusters operating in an oblique angle to the flow must 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 plastic bending of a blade shall be considered in the propeller blade position, which causes the maximum load on the studied component.

Azimuth thrusters shall also be designed for estimated loads due to thruster body / ice interaction as per I2.15

### I3.5.3 Blade Design

#### I3.5.3.1 Maximum Blade Stresses

Blade stresses are to be calculated using the backward and forward loads given in section 4.3 & 4.4. The stresses shall be calculated with recognised and well documented FE-analysis or other acceptable alternative method. The stresses on the blade shall not exceed the allowable stresses  $\sigma_{all}$  for the blade material given below.

Calculated blade stress for maximum ice load shall comply with the following:

$$\sigma_{calc} < \sigma_{all} = \sigma_{ref} / S$$

$$S = 1.5$$

$\sigma_{ref}$  = reference stress, defined as:

$$\sigma_{ref} = 0.7 \cdot \sigma_u \quad \text{or} \quad \sigma_{ref} = 0.6 \cdot \sigma_{0.2} + 0.4 \cdot \sigma_u \quad \text{whichever is less} \quad \begin{array}{l} \text{[Equation 27]} \\ \text{[Equation 28]} \end{array}$$

Where  $\sigma_u$  and  $\sigma_{0.2}$  are representative values for the blade material.

#### I3.5.3.2 Blade Edge Thickness

The blade edge thicknesses  $t_{ed}$  and tip thickness  $t_{tip}$  are to be greater than  $t_{edge}$  given by the following formula:

$$t_{edge} \geq x S S_{ice} \sqrt{\frac{3 P_{ice}}{\sigma_{ref}}} \quad \text{[Equation 29]}$$

$x$  = distance from the blade edge measured along the cylindrical sections from the edge and shall be 2.5% of chord length, however not to be taken greater than 45 mm. In the tip area (above 0.975R radius)  $x$  shall be taken as 2.5% of 0.975R section length and is to be measured perpendicularly to the edge, however not to be taken greater than 45 mm.

$S$  = safety factor  
 = 2.5 for trailing edges  
 = 3.5 for leading edges  
 = 5 for tip

$S_{ice}$  = according to Section I3.4.2

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$p_{ice}$  = ice pressure  
= 16 Mpa for leading edge and tip thickness

$\_ref$  = according 5.3.1

The requirement for edge thickness has to be applied for leading edge and in case of reversible rotation open propellers also for trailing edge. Tip thickness refers to the maximum measured thickness in the tip area above 0.975R radius. The edge thickness in the area between position of maximum tip thickness and edge thickness at 0.975 radius has to be interpolated between edge and tip thickness value and smoothly distributed.

I3.5.3.3 to I3.5.4.2 *Reserved*

I3.5.5 *Reserved*

I3.5.6 Prime Movers

I3.5.6.1 The Main engine is to be capable of being started and running the propeller with the CP in full pitch.

I3.5.6.2 Provisions shall be made for heating arrangements to ensure ready starting of the cold emergency power units at an ambient temperature applicable to the Polar class of the ship.

I3.5.6.3 Emergency power units shall be equipped with starting devices with a stored energy capability of at least three consecutive starts at the design temperature in I3.5.6.2 above. The source of stored energy shall be protected to preclude critical depletion by the automatic starting system, unless a second independent means of starting is provided. A second source of energy shall be provided for an additional three starts within 30 min., unless manual starting can be demonstrated to be effective.

## I3.6 Machinery fastening loading accelerations

I3.6.1 Essential equipment and main propulsion machinery supports shall be suitable for the accelerations as indicated in as follows. Accelerations are to be considered acting independently.

I3.6.2 Longitudinal Impact Accelerations,  $a_l$

Maximum longitudinal impact acceleration at any point along the hull girder

$$= (F_{IB}/\Delta) \{ [ 1.1 \tan(\gamma + \phi) ] + [ 7 \frac{H}{L} ] \} \quad [m/s^2] \quad \text{[Equation 31]}$$

I3.6.3 Vertical acceleration,  $a_v$

Combined vertical impact acceleration at any point along the hull girder

$$= 2.5 (F_{IB}/\Delta) F_x \quad [m/s^2] \quad \text{[Equation 32]}$$

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$F_x = 1.3$  at FP  
 $= 0.2$  at midships  
 $= 0.4$  at AP  
 $= 1.3$  at AP for vessels conducting ice breaking astern  
 Intermediate values to be interpolated linearly.

### I3.6.4. Transverse impact acceleration, $a_t$

Combined transverse impact acceleration at any point along hull girder

$$= 3 F_i \frac{F_x}{\Delta} \quad [\text{m/s}^2] \quad \text{[Equation 33]}$$

$F_x = 1.5$  at FP  
 $= 0.25$  at midships  
 $= 0.5$  at AP  
 $= 1.5$  at AP for vessels conducting ice breaking astern  
 Intermediate values to be interpolated linearly.

where

- $\phi$  = maximum friction angle between steel and ice, normally taken as  $10^\circ$  [deg.]
- $\gamma$  = bow stem angle at waterline [deg.]
- $\Delta$  = displacement
- $L$  = length between perpendiculars [m]
- $H$  = distance in meters from the waterline to the point being considered [m]

$F_{IB}$  = vertical impact force, defined in UR I2.13.2.1

$F_i$  = total force normal to shell plating in the bow area due to oblique ice impact, defined in UR I2.3.2.1

## I3.7 Auxiliary Systems

I3.7.1 Machinery shall be protected from the harmful effects of ingestion or accumulation of ice or snow. Where continuous operation is necessary, means should be provided to purge the system of accumulated ice or snow.

I3.7.2 Means should be provided to prevent damage due to freezing, to tanks containing liquids.

I3.7.3 Vent pipes, intake and discharge pipes and associated systems shall be designed to prevent blockage due to freezing or ice and snow accumulation.

## I3.8 Sea Inlets and cooling water systems

I3.8.1 Cooling water systems for machinery that are essential for the propulsion and safety of the vessel, including sea chests inlets, shall be designed for the environmental conditions applicable to the ice class.

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13.8.2 At least two sea chests are to be arranged as ice boxes for class PC1 to PC5 inclusive where. The calculated volume for each of the ice boxes shall be at least 1m<sup>3</sup> for every 750 kW of the total installed power. For PC6 and PC7 there shall be at least one ice box located preferably near centre line.

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

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

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

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

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

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

13.8.9 Openings in ship sides for ice boxes are to be fitted with gratings, or holes or slots in shell plates. The net area through these openings is to be not less than 5 times the area of the inlet pipe. The diameter of holes and width of slot in shell plating is to be not less than 20 mm. Gratings of the ice boxes are to be provided with a means of clearing. Clearing pipes are to be provided with screw-down type non return valves.

**13.9 Ballast tanks**

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

**13.10 Ventilation System**

13.10.1 The air intakes for machinery and accommodation ventilation are to be located on both sides of the ship.

13.10.2 Accommodation and ventilation air intakes shall be provided with means of heating.

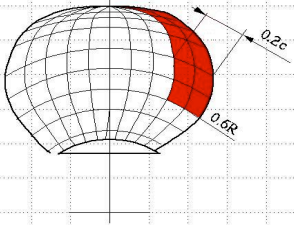
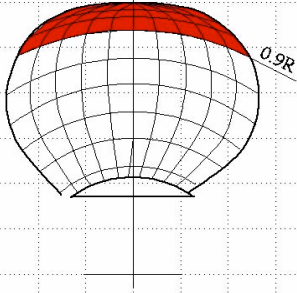
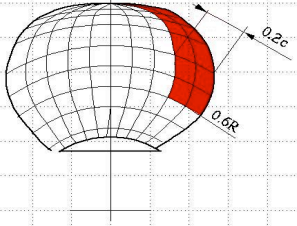
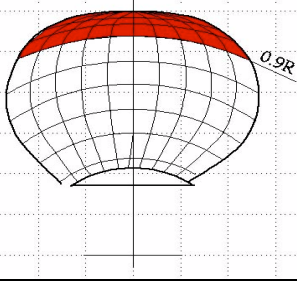
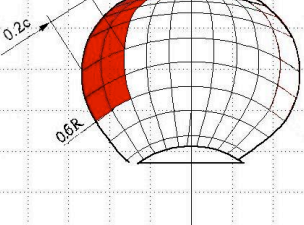
13.10.3 The temperature of inlet air provided to machinery from the air intakes shall be suitable for the safe operation of the machinery.

**13.11 Reserved****13.12 Alternative Design**

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

# APPENDIX

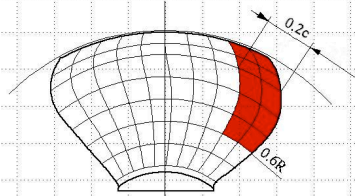
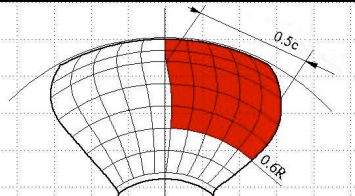
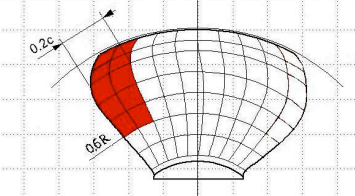
**Table 1 Load cases for open propeller**

	Force	Loaded area	Right handed propeller blade seen from back
Load case 1	$F_b$	Uniform pressure applied on the back of the blade (suction side) to an area from $0.6R$ to the tip and from the leading edge to $0.2$ times the chord length.	
Load case 2	50 % of $F_b$	Uniform pressure applied on the back of the blade (suction side) on the propeller tip area outside of $0.9R$ radius.	
Load case 3	$F_f$	Uniform pressure applied on the blade face (pressure side) to an area from $0.6R$ to the tip and from the leading edge to $0.2$ times the chord length.	
Load case 4	50 % of $F_f$	Uniform pressure applied on propeller face (pressure side) on the propeller tip area outside of $0.9R$ radius.	
Load case 5	60 % of $F_f$ or $F_b$ which one is greater	Uniform pressure applied on propeller face (pressure side) to an area from $0.6R$ to the tip and from the trailing edge to $0.2$ times the chord length.	 e

## 13

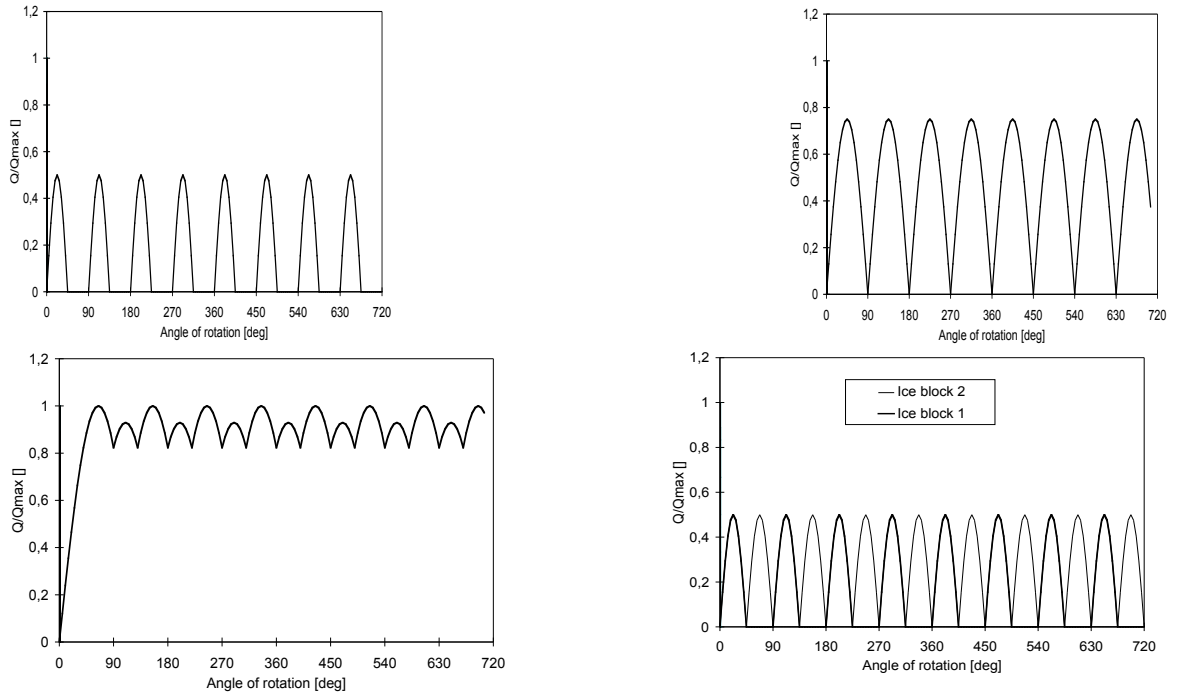
(cont)

Table 2 Load cases for ducted propeller

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

I3  
(cont)

**Figure 1** The shape of the propeller ice torque excitation for 45, 90, 135 degrees single blade impact sequences and 45 degrees double blade impact sequence (two ice pieces) on a four bladed propeller.



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