

I2 Structural Requirements for Polar Class Ships

(August 2006)
(Rev.1 Jan 2007)
(Corr.1 Oct 2007)
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(Rev.3 Apr 2016)

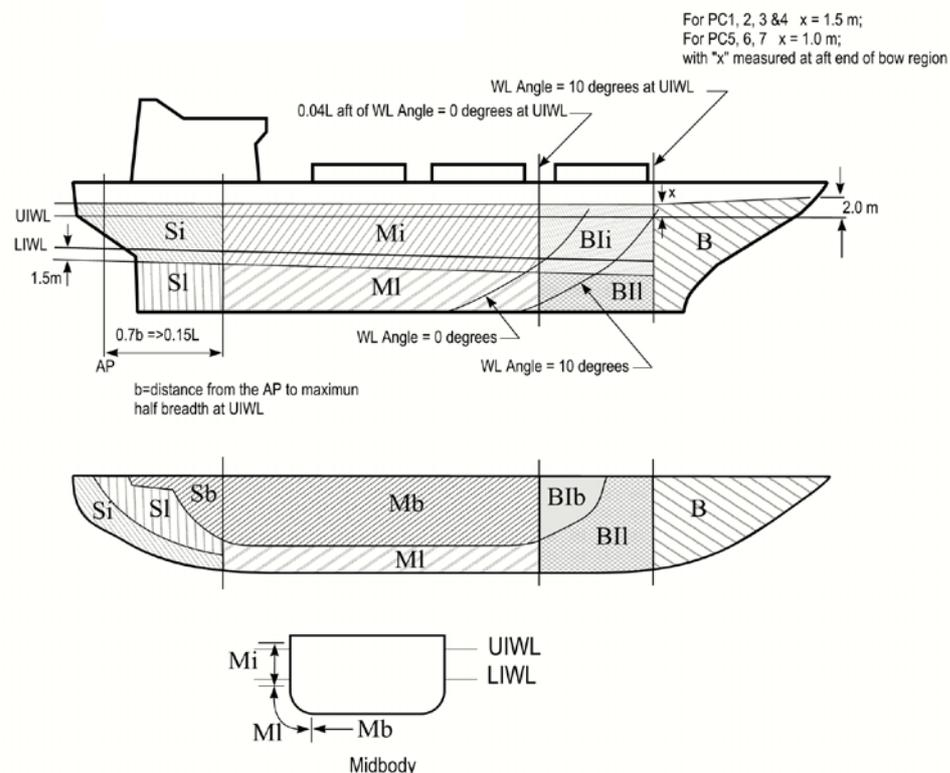
I2.1 Application *

I2.1.1 ~~These requirements are to be applied~~ This UR applies to polar class Polar Class ships according to IACS UR I1.

I2.2 Hull areas Areas

I2.2.1 The hull of all ~~polar class~~ Polar Class ships is divided into areas reflecting the magnitude of the loads that are expected to act upon them. In the longitudinal direction, there are four regions: Bow, Bow Intermediate, Midbody and Stern. The Bow Intermediate, Midbody and Stern regions are further divided in the vertical direction into the Bottom, Lower and Icebelt regions. The extent of each ~~Hull Area~~ hull area is illustrated in Figure 1.

Figure 1 - ~~Hull area extents~~ Area Extents



* Note:

1. UR I2 applies to ships contracted for construction on or after 1 July 2007.
42. This Rev.1 of this UR is to be uniformly applied by IACS Societies on ships contracted for construction on and after 1 March 2008.
23. Rev.2 of this UR is to be uniformly implemented by the IACS Societies on ships contracted for construction on or after 1 January 2012.
4. Rev.3 of this UR is to be uniformly implemented by the IACS Societies on ships contracted for construction on or after 1 July 2017.
35. 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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12.2.2 The upper ice waterline (UIWL) and lower ice waterline (LIWL) are as defined in UR 11.3.

12.2.3 Figure 1 notwithstanding, at no time is the boundary between the Bow and Bow Intermediate regions to be forward of the intersection point of the line of the stem and the ship baseline.

12.2.4 Figure 1 notwithstanding, the aft boundary of the Bow region need not be more than 0.45 L aft of the forward perpendicular (FP).

12.2.5 The boundary between the bottom and lower regions is to be taken at the point where the shell is inclined 7° from horizontal.

12.2.6 If a ship is intended to operate astern in ice regions, the aft section of the ship is to be designed using the Bow and Bow Intermediate hull area requirements.

12.2.7 Figure 1 notwithstanding, if the ship is assigned the additional notation "Icebreaker", the forward boundary of the stern region is to be at least 0.04 L forward of the section where the parallel ship side at the upper ice waterline (UIWL) ends.

12.3 Design ice loads ~~Ice Loads~~

12.3.1 General

(i) ~~For ships of all Polar Classes, a~~ A glancing impact on the bow is the design scenario for determining the scantlings required to resist ice loads.

(ii) The design ice load is characterized by an average pressure (P_{avg}) uniformly distributed over a rectangular load patch of height (b) and width (w).

(iii) ~~Within the Bow area of all polar classes~~ Polar Class ships, and within the Bow Intermediate Icebelt area of ~~polar classes~~ Polar Class PC6 and PC7, the ice load parameters are functions of the actual bow shape. To determine the ice load parameters (P_{avg} , b and w), it is required to calculate the following ice load characteristics for sub-regions of the bow area; shape coefficient (f_{a_i}), total glancing impact force (F_i), line load (Q_i) and pressure (P_i).

(iv) In other ice-strengthened areas, the ice load parameters (P_{avg} , b_{NonBow} and w_{NonBow}) are determined independently of the hull shape and based on a fixed load patch aspect ratio, $AR = 3.6$.

~~(v) Design ice forces calculated according to 12.3.2.1 (iii) are only valid for vessels with icebreaking forms. Design ice forces for any other bow forms are to be specially considered by the member society. applicable for bow forms where the buttock angle γ at the stem is positive and less than 80 deg, and the normal frame angle β' at the centre of the foremost sub-region, as defined in 12.3.2.1 (i), is greater than 10 deg.~~

(vi) Design ice forces calculated according to 12.3.2.1 (iv) are applicable for ships which are assigned the Polar Class PC6 or PC7 and have a bow form with vertical sides. This includes bows where the normal frame angles β' at the considered sub-regions, as defined in 12.3.2.1 (i), are between 0 and 10 deg.

(vii) For ships which are assigned the Polar Class PC6 or PC7, and equipped with bulbous bows, the design ice forces on the bow are to be determined according to 12.3.2.1 (iv). In

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addition, the design forces are not to be taken less than those given in I2.3.2.1 (iii), assuming $f_a = 0.6$ and $AR = 1.3$.

(viii) For ships with bow forms other than those defined in (v) to (vii), design forces are to be specially considered by the Classification Society.

(vix) Ship structures that are not directly subjected to ice loads may still experience inertial loads of stowed cargo and equipment resulting from ship/ice interaction. These inertial loads, based on accelerations determined by the Classification Society ~~each member society~~, are to be considered in the design of these structures.

I2.3.2 Glancing impact load characteristics ~~Impact Load Characteristics~~

(†) The parameters defining the glancing impact load characteristics are reflected in the Class Factors listed in Table 1 and Table 2.

Table 1 - Class factors to be used in I2.3.2.1 (iii) Factors

Polar Class	Crushing Failure Class Factor (CF_C)	Flexural Failure Class Factor (CF_F)	Load Patch Dimensions patch dimensions Class Factor (CF_D)	Displacement Class Factor (CF_{DIS})	Longitudinal Strength strength Class Factor (CF_L)
PC1	17.69	68.60	2.01	250	7.46
PC2	9.89	46.80	1.75	210	5.46
PC3	6.06	21.17	1.53	180	4.17
PC4	4.50	13.48	1.42	130	3.15
PC5	3.10	9.00	1.31	70	2.50
PC6	2.40	5.49	1.17	40	2.37
PC7	1.80	4.06	1.11	22	1.81

Table 2 - Class factors to be used in I2.3.2.1 (iv)

Polar Class	Crushing failure Class Factor (CF_{CV})	Line load Class Factor (CF_{QV})	Pressure Class Factor (CF_{PV})
PC6	3.43	2.82	0.65
PC7	2.60	2.33	0.65

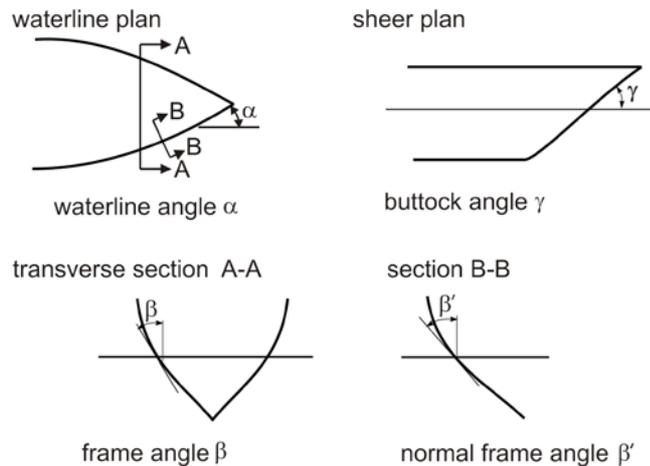
I2.3.2.1 Bow area Area

(i) In the Bow area, the force (F), line load (Q), pressure (P) and load patch aspect ratio (AR) associated with the glancing impact load scenario are functions of the hull angles measured at the upper ice waterline (UIWL). The influence of the hull angles is captured through calculation of a bow shape coefficient (f_a). The hull angles are defined in Figure 2.

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Figure 2 - Definition of hull angles Hull Angles



Note: β' = normal frame angle at upper ice waterline [deg]

α = upper ice waterline angle [deg]

γ = buttock angle at upper ice waterline (angle of buttock line measured from horizontal) [deg]

$\tan(\beta) = \tan(\alpha)/\tan(\gamma)$

$\tan(\beta') = \tan(\beta) \cdot \cos(\alpha)$

(ii) The waterline length of the bow region is generally to be divided into 4 sub-regions of equal length. The force (F), line load (Q), pressure (P) and load patch aspect ratio (AR) are to be calculated with respect to the mid-length position of each sub-region (each maximum of F, Q and P is to be used in the calculation of the ice load parameters P_{avg} , b and w).

(iii) The Bow area load characteristics for bow forms defined in I2.3.1 (v) are determined as follows:

(a) Shape coefficient, fa_i , is to be taken as

$$fa_i = \text{minimum}(fa_{i,1}; fa_{i,2}; fa_{i,3}) \quad \text{[Equation 1]}$$

$$\text{where } fa_{i,1} = (0.097 - 0.68 \cdot (x/L - 0.15)^2) \cdot \alpha_i / (\beta'_i)^{0.5} \quad \text{[Equation 2]}$$

$$fa_{i,2} = 1.2 \cdot CF_F / (\sin(\beta'_i) \cdot CF_C \cdot D^{0.64}) \quad \text{[Equation 3]}$$

$$fa_{i,3} = 0.60 \quad \text{[Equation 4]}$$

i = sub-region considered

L = ship length as defined in UR S2.1, but measured on the upper ice waterline (UIWL) [m]

x = distance from the forward perpendicular (FP) to station under consideration [m]

α = waterline angle [deg], see Figure 2

β' = normal frame angle [deg], see Figure 2

D = ship displacement [kt], not to be taken less than 5 kt

CF_C = Crushing Failure Class Factor from Table 4

CF_F = Flexural Failure Class Factor from Table 4

(b) Force, F_i :

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$$F_i = f_{a_i} \cdot CF_C \cdot D^{0.64} \text{ [MN]} \quad \text{[Equation 5]}$$

where i = sub-region considered
 f_{a_i} = shape coefficient of sub-region i
 CF_C = Crushing Failure Class Factor from Table 1
 D = ship displacement [kt], not to be taken less than 5 kt

(c) Load patch aspect ratio, AR_i :

$$AR_i = 7.46 \cdot \sin(\beta'_i) \geq 1.3 \quad \text{[Equation 6]}$$

where i = sub-region considered
 β'_i = normal frame angle of sub-region i [deg]

(d) Line load, Q_i :

$$Q_i = F_i^{0.61} \cdot CF_D / AR_i^{0.35} \text{ [MN/m]} \quad \text{[Equation 7]}$$

where i = sub-region considered
 F_i = force of sub-region i [MN]
 CF_D = Load Patch Dimensions Class Factor from Table 1
 AR_i = load patch aspect ratio of sub-region i

(e) Pressure, P_i :

$$P_i = F_i^{0.22} \cdot CF_D^2 \cdot AR_i^{0.3} \text{ [MPa]} \quad \text{[Equation 8]}$$

where i = sub-region considered
 F_i = force of sub-region i [MN]
 CF_D = load patch dimensions class factor from Table 1
 AR_i = load patch aspect ratio of sub-region i

where i = sub-region considered

L = ship length as defined in UR S2.1, but measured on the upper ice waterline (UIWL) [m]

x = distance from the forward perpendicular (FP) to station under consideration [m]

α = waterline angle [deg], see Figure 2

β' = normal frame angle [deg], see Figure 2

D = ship displacement [kt], not to be taken less than 5 kt

CF_C = Crushing failure Class Factor from Table 1

CF_F = Flexural failure Class Factor from Table 1

CF_D = Load patch dimensions Class Factor from Table 1

(iv) The Bow area load characteristics for bow forms defined in I2.3.1 (vi) are determined as follows:

(a) Shape coefficient, f_{a_i} , is to be taken as

$$f_{a_i} = \alpha_i / 30$$

(b) Force, F_i :

$$F_i = f_{a_i} \cdot CF_{CV} \cdot D^{0.47} \text{ [MN]}$$

I2 (cont)

(c) Line load, Q_i :

$$Q_i = F_i^{0.22} \cdot CF_{QV} \text{ [MN/m]}$$

(d) Pressure, P_i :

$$P_i = F^{0.56} \cdot CF_{PV} \text{ [MPa]}$$

where i = sub-region considered

α = waterline angle [deg], see Figure 2

D = ship displacement [kt], not to be taken less than 5 kt

CF_{CV} = Crushing failure Class Factor from Table 2

CF_{QV} = Line load Class Factor from Table 2

CF_{PV} = Pressure Class Factor from Table 2

12.3.2.2 Hull areas other than the bow ~~Areas Other Than the Bow~~

(i) In the hull areas other than the bow, the force (F_{NonBow}) and line load (Q_{NonBow}) used in the determination of the load patch dimensions (b_{NonBow} , w_{NonBow}) and design pressure (P_{avg}) are determined as follows:

(a) Force, F_{NonBow} :

$$F_{\text{NonBow}} = 0.36 \cdot CF_C \cdot DF \text{ [MN]} \quad \text{[Equation 9]}$$

(b) Line Load, Q_{NonBow} :

$$Q_{\text{NonBow}} = 0.639 \cdot F_{\text{NonBow}}^{0.61} \cdot CF_D \text{ [MN/m]}$$

where CF_C = Crushing Force ~~failure~~ Class Factor from Table 1

DF = ship displacement factor

$$= D^{0.64} \quad \text{if } D \leq CF_{DIS}$$

$$= CF_{DIS}^{0.64} + 0.10 \cdot (D - CF_{DIS}) \quad \text{if } D > CF_{DIS}$$

D = ship displacement [kt], not to be taken less than 10 kt

CF_{DIS} = Displacement Class Factor from Table 1

CF_D = Load patch dimensions Class Factor from Table 1

~~(b) Line Load, Q_{NonBow} :~~

$$Q_{\text{NonBow}} = 0.639 \cdot F_{\text{NonBow}}^{0.61} \cdot CF_D \text{ [MN/m]} \quad \text{[Equation 10]}$$

where F_{NonBow} = force from Equation 9 [MN]

CF_D = Load Patch Dimensions Class Factor from Table 1

12.3.3 Design load patch ~~Load Patch~~

(i) In the Bow area, and the Bow Intermediate Icebelt area for ships with class notation PC6 and PC7, the design load patch has dimensions of width, w_{Bow} , and height, b_{Bow} , defined as follows:

$$w_{\text{Bow}} = F_{\text{Bow}} / Q_{\text{Bow}} \text{ [m]} \quad \text{[Equation 11]}$$

$$b_{\text{Bow}} = Q_{\text{Bow}} / P_{\text{Bow}} \text{ [m]} \quad \text{[Equation 12]}$$

I2 (cont)

where F_{Bow} = maximum force F_i in the Bow area from Equation 5 [MN]
 Q_{Bow} = maximum line load Q_i in the Bow area from Equation 7 [MN/m]
 P_{Bow} = maximum pressure P_i in the Bow area from Equation 8 [MPa]

(ii) In hull areas other than those covered by I2.3.3 (i), the design load patch has dimensions of width, W_{NonBow} , and height, b_{NonBow} , defined as follows:

$$W_{NonBow} = F_{NonBow} / Q_{NonBow} \text{ [m]} \quad \text{[Equation 13]}$$

$$b_{NonBow} = W_{NonBow} / 3.6 \text{ [m]} \quad \text{[Equation 14]}$$

where F_{NonBow} = force as defined in I2.3.2.2 (i) (a) determined using Equation 9 [MN]
 Q_{NonBow} = line load as defined in I2.3.2.2 (i) (b) determined using Equation 10 [MN/m]

I2.3.4 Pressure within the design load patch ~~Within the Design Load Patch~~

(i) The average pressure, P_{avg} , within a design load patch is determined as follows:

$$P_{avg} = F / (b \cdot w) \text{ [MPa]} \quad \text{[Equation 15]}$$

where $F = F_{Bow}$ or F_{NonBow} as appropriate for the hull area under consideration [MN]
 $b = b_{Bow}$ or b_{NonBow} as appropriate for the hull area under consideration [m]
 $w = W_{Bow}$ or W_{NonBow} as appropriate for the hull area under consideration [m]

(ii) Areas of higher, concentrated pressure exist within the load patch. In general, smaller areas have higher local pressures. Accordingly, the peak pressure factors listed in Table 23 are used to account for the pressure concentration on localized structural members.

Table 23 - Peak Pressure Factors

Structural member		Peak Pressure Factor (PPF _i)
Plating	Transversely-Framed framed	$PPF_p = (1.8 - s) \geq 1.2$
	Longitudinally-Framed framed	$PPF_p = (2.2 - 1.2 \cdot s) \geq 1.5$
Frames in <u>transverse framing systems</u>	With Load-Distributing Stringers <u>load distributing stringers</u>	$PPF_t = (1.6 - s) \geq 1.0$
	Transverse Framing Systems <u>With No Load-Distributing Stringers no load distributing stringers</u>	$PPF_t = (1.8 - s) \geq 1.2$
<u>Frames in bottom structures</u>		$PPF_s = 1.0$
<u>Load Carrying Stringers carrying stringers</u>		$PPF_s = 1.0$, if $S_w \geq 0.5 \cdot w$
<u>Side and Bottom Longitudinals longitudinals</u>		$PPF_s = 2.0 - 2.0 \cdot S_w / w$,
<u>Web Frames frames</u>		if $S_w < (0.5 \cdot w)$
where: s = frame or longitudinal spacing [m] S_w = web frame spacing [m] w = ice load patch width [m]		

I2.3.5 Hull area factors ~~Area Factors~~

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(cont)

(i) Associated with each hull area is an Area Factor that reflects the relative magnitude of the load expected in that area. The Area Factor (AF) for each hull area is listed in Table 34.

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

(iii) Due to their increased manoeuvrability, ships having propulsion arrangements with azimuthing thruster(s) or “podded” propellers shall are to have specially considered Stern Icebelt (S_i) and Stern Lower (S_l) hull area factors.

(iv) For ships assigned the additional notation “Icebreaker”, the Area Factor (AF) for each hull area is listed in Table 5.

Table 34 - Hull Area Factors (AF)

Hull area Area		Area	Polar Class						
			PC1	PC2	PC3	PC4	PC5	PC6	PC7
Bow (B)	All	B	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bow Intermediate (BI)	Icebelt	BI _i	0.90	0.85	0.85	0.80	0.80	1.00*	1.00*
	Lower	BI _l	0.70	0.65	0.65	0.60	0.55	0.55	0.50
	Bottom	BI _b	0.55	0.50	0.45	0.40	0.35	0.30	0.25
Midbody (M)	Icebelt	M _i	0.70	0.65	0.55	0.55	0.50	0.45	0.45
	Lower	M _l	0.50	0.45	0.40	0.35	0.30	0.25	0.25
	Bottom	M _b	0.30	0.30	0.25	**	**	**	**
Stern (S)	Icebelt	S _i	0.75	0.70	0.65	0.60	0.50	0.40	0.35
	Lower	S _l	0.45	0.40	0.35	0.30	0.25	0.25	0.25
	Bottom	S _b	0.35	0.30	0.30	0.25	0.15	**	**

Note to Table 34: * See I2.3.1 (iii).
** Indicates that strengthening for ice loads is not necessary.

Table 5 - Hull Area Factors (AF) for ships with additional notation “Icebreaker”

Hull area		Area	Polar Class						
			PC1	PC2	PC3	PC4	PC5	PC6	PC7
Bow (B)	All	B	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bow Intermediate (BI)	Icebelt	BI _i	0.90	0.85	0.85	0.85	0.85	1.00	1.00
	Lower	BI _l	0.70	0.65	0.65	0.65	0.65	0.65	0.65
	Bottom	BI _b	0.55	0.50	0.45	0.45	0.45	0.45	0.45
Midbody (M)	Icebelt	M _i	0.70	0.65	0.55	0.55	0.55	0.55	0.55
	Lower	M _l	0.50	0.45	0.40	0.40	0.40	0.40	0.40
	Bottom	M _b	0.30	0.30	0.25	0.25	0.25	0.25	0.25
Stern (S)	Icebelt	S _i	0.95	0.90	0.80	0.80	0.80	0.80	0.80
	Lower	S _l	0.55	0.50	0.45	0.45	0.45	0.45	0.45
	Bottom	S _b	0.35	0.30	0.30	0.30	0.30	0.30	0.30

I2.4 Shell plate requirements Plate Requirements

I2.4.1 The required minimum shell plate thickness, t, is given by:

$$t = t_{net} + t_s \text{ [mm]} \tag{Equation 16}$$

where t_{net} = plate thickness required to resist ice loads according to I2.4.2 [mm]
 t_s = corrosion and abrasion allowance according to I2.11 [mm]

I2 (cont)

I2.4.2 The thickness of shell plating required to resist the design ice load, t_{net} , depends on the orientation of the framing.

In the case of transversely-framed plating ($\Omega \geq 70$ deg), including all bottom plating, i.e. plating in hull areas B_{lb} , M_b and S_b , the net thickness is given by:

$$t_{net} = 500 \cdot s \cdot ((AF \cdot PPF_p \cdot P_{avg}) / \sigma_y)^{0.5} / (1 + s / (2 \cdot b)) \text{ [mm]} \quad \text{[Equation 17a]}$$

In the case of longitudinally-framed plating ($\Omega \leq 20$ deg), when $b \geq s$, the net thickness is given by:

$$t_{net} = 500 \cdot s \cdot ((AF \cdot PPF_p \cdot P_{avg}) / \sigma_y)^{0.5} / (1 + s / (2 \cdot l)) \text{ [mm]} \quad \text{[Equation 17b]}$$

In the case of longitudinally-framed plating ($\Omega \leq 20$ deg), when $b < s$, the net thickness is given by:

$$t_{net} = 500 \cdot s \cdot ((AF \cdot PPF_p \cdot P_{avg}) / \sigma_y)^{0.5} \cdot (2 \cdot b / s - (b / s)^2)^{0.5} / (1 + s / (2 \cdot l)) \text{ [mm]} \quad \text{[Equation 17c]}$$

In the case of obliquely-framed plating ($70 \text{ deg} > \Omega > 20 \text{ deg}$), linear interpolation is to be used.

where Ω = smallest angle between the chord of the waterline and the line of the first level framing as illustrated in Figure 3 [deg].

s = transverse frame spacing in transversely-framed ships or longitudinal frame spacing in longitudinally-framed ships [m]

AF = Hull Area Factor from Table 3 or Table 5

PPF_p = Peak Pressure Factor from Table 23

P_{avg} = average patch pressure as defined in I2.3.4 according to Equation 15 [MPa]

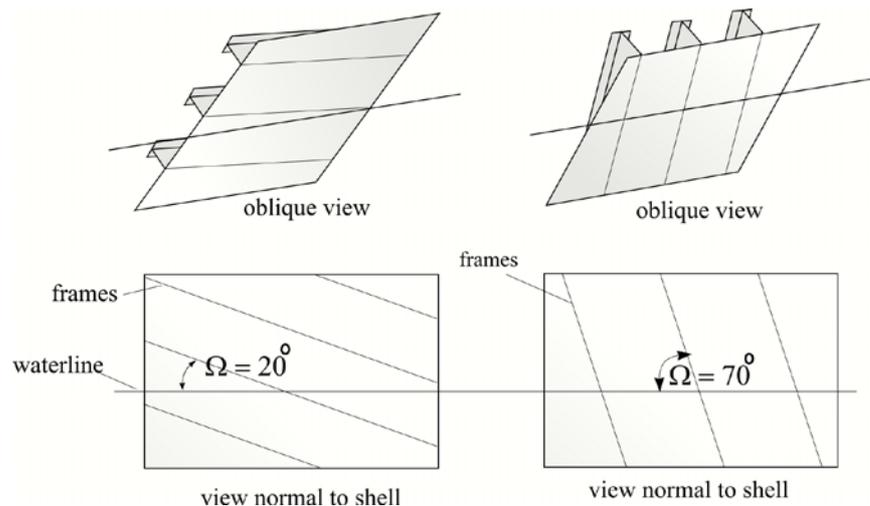
σ_y = minimum upper yield stress of the material [N/mm²]

b = height of design load patch [m], where $b \leq$ is to be taken not greater than ($l - s/4$) in the case of Equation 17a determination of the net thickness for transversely framed plating

l = distance between frame supports, i.e. equal to the frame span as given in I2.5.5, but not reduced for any fitted end brackets [m]. When a load-distributing stringer is fitted, the length l need not be taken larger than the distance from the stringer to the most distant frame support.

Figure 3 - Shell framing angle Framing Angle Ω

I2 (cont)



I2.5 Framing - General

I2.5.1 Framing members of Polar Class ~~class~~ ships are to be designed to withstand the ice loads defined in I2.3.

I2.5.2 The term “framing member” refers to transverse and longitudinal local frames, load-carrying stringers and web frames in the areas of the hull exposed to ice pressure, see Figure 1. Where load-distributing stringers have been fitted, the arrangement and scantlings of these are to be in accordance with the requirements of ~~each member society~~ the Classification Society.

I2.5.3 The strength of a framing member is dependent upon the fixity that is provided at its supports. Fixity can be assumed where framing members are either continuous through the support or attached to a supporting section with a connection bracket. In other cases, simple support is to be assumed unless the connection can be demonstrated to provide significant rotational restraint. Fixity is to be ensured at the support of any framing which terminates within an ice-strengthened area.

I2.5.4 The details of framing member intersection with other framing members, including plated structures, as well as the details for securing the ends of framing members at supporting sections, are to be in accordance with the requirements of ~~each member society~~ the Classification Society.

I2.5.5 The design effective span of a framing member is to be determined on the basis of its moulded length. If brackets are fitted, the design effective span may be reduced in accordance with the usual practice of ~~each member society~~ the Classification Society. Brackets are to be configured to ensure stability in the elastic and post-yield response regions.

I2.5.6 When calculating the section modulus and shear area of a framing member, net thicknesses of the web, flange (if fitted) and attached shell plating are to be used. The shear area of a framing member may include that material contained over the full depth of the member, i.e. web area including portion of flange, if fitted, but excluding attached shell plating.

I2.5.7 The actual net effective shear area, A_w , of a transverse or longitudinal local frame ~~framing member~~ is given by:

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$$A_w = h \cdot t_{wn} \cdot \sin \varphi_w / 100 \text{ [cm}^2\text{]}$$

[Equation 18]

where

h = height of stiffener [mm], see Figure 4

t_{wn} = net web thickness [mm]

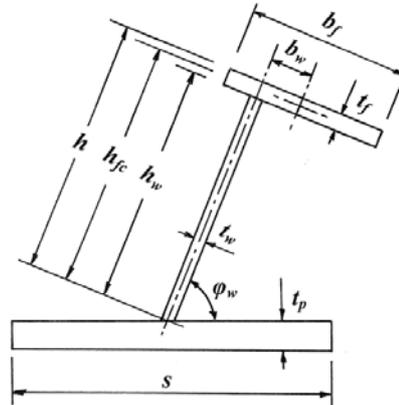
$$= t_w - t_c$$

t_w = as built web thickness [mm], see Figure 4

t_c = corrosion deduction [mm] to be subtracted from the web and flange thickness (as specified by the Classification Society each member society, but not less than t_s as required by I2.11.3).

φ_w = smallest angle between shell plate and stiffener web, measured at the midspan of the stiffener, see Figure 4. The angle φ_w may be taken as 90 degrees provided the smallest angle is not less than 75 degrees.

Figure 4 - Stiffener geometry



I2.5.8 When the cross-sectional area of the attached plate flange exceeds the cross-sectional area of the local frame, the actual net effective plastic section modulus, Z_p , of a transverse or longitudinal frame is given by:

$$Z_p = A_{pn} \cdot t_{pn} / 20 + \frac{h_w^2 \cdot t_{wn} \cdot \sin \varphi_w}{2000} + A_{fn} \cdot (h_{fc} \cdot \sin \varphi_w - b_w \cdot \cos \varphi_w) / 10 \text{ [cm}^3\text{]} \quad \text{[Equation 19]}$$

where

h , t_{wn} , t_c , and φ_w are as given in I2.5.7 and s as given in I2.4.2.

A_{pn} = net cross-sectional area of the local frame [cm²]

t_{pn} = fitted net shell plate thickness [mm] (~~shall comply~~ complying with t_{net} as required by I2.4.2)

h_w = height of local frame web [mm], see Figure 4

A_{fn} = net cross-sectional area of local frame flange [cm²]

h_{fc} = height of local frame measured to centre of the flange area [mm], see Figure 4

b_w = distance from mid thickness plane of local frame web to the centre of the flange area [mm], see Figure 4

When the cross-sectional area of the local frame exceeds the cross-sectional area of the attached plate flange, the plastic neutral axis is located a distance z_{na} above the attached shell plate, given by:

$$z_{na} = (100 \cdot A_{fn} + h_w \cdot t_{wn} - 1000 \cdot t_{pn} \cdot s) / (2 \cdot t_{wn}) \text{ [mm]} \quad \text{[Equation 20]}$$

I2 (cont)

and the net effective plastic section modulus, Z_p , of a transverse or longitudinal frame is given by:

$$Z_p = t_{pn} \cdot s \cdot (z_{na} + t_{pn} / 2) \cdot \sin \varphi_w + \left(\frac{((h_w - z_{na})^2 + z_{na}^2) \cdot t_{wn} \cdot \sin \varphi_w}{2000} + A_{fn} \cdot ((h_{fc} - z_{na}) \cdot \sin \varphi_w - b_w \cdot \cos \varphi_w) / 10 \right) \text{ [cm}^3\text{]}$$

[Equation 21]

I2.5.9 In the case of oblique framing arrangement ($70 \text{ deg} > \Omega > 20 \text{ deg}$, where Ω is defined as given in I2.4.2), linear interpolation is to be used.

I2.6 Framing - Transversely-Framed Side Structures and Bottom Structures Local frames in bottom structures and transverse local frames in side structures

I2.6.1 The local frames in bottom structures (i.e. hull areas B_b , M_b and S_b) and transverse local frames in transversely-framed side structures and in bottom structures (i.e. hull areas B_b , M_b and S_b) are to be dimensioned such that the combined effects of shear and bending do not exceed the plastic strength of the member. The plastic strength is defined by the magnitude of midspan load that causes the development of a plastic collapse mechanism. For bottom structure the patch load shall be applied with the dimension (b) parallel with the frame direction.

I2.6.2 The actual net effective shear area of the frame, A_w , as defined in I2.5.7, is to comply with the following condition: $A_w \geq A_t$, where:

$$A_t = 100^2 \cdot 0.5 \cdot LL \cdot s \cdot (AF \cdot PPF_t \cdot P_{avg}) / (0.577 \cdot \sigma_y) \text{ [cm}^2\text{]} \quad \text{[Equation 22]}$$

where LL = length of loaded portion of span
= lesser of a and b [m]

a = local frame span as defined in I2.5.5 [m]

b = height of design ice load patch as defined in I2.3.3 (i) or I2.3.3 (ii) according to Equation 12 or 14 [m]

s = transverse spacing of local frame spacing [m]

AF = Hull Area Factor from Table 3 or Table 5

PPF_t = Peak Pressure Factor, PPF_t or PPF_s as appropriate from Table 23

P_{avg} = average pressure within load patch according to Equation 15 as defined in I2.3.4 [MPa]

σ_y = minimum upper yield stress of the material [N/mm²]

I2.6.3 The actual net effective plastic section modulus of the plate/stiffener combination, Z_p , as defined in I2.5.8, is to comply with the following condition: $Z_p \geq Z_{pt}$, where Z_{pt} is to be the greater calculated on the basis of two load conditions: a) ice load acting at the midspan of the transverse local frame, and b) the ice load acting near a support. The A_1 parameter in Equation 23 defined below reflects these two conditions:

$$Z_{pt} = 100^3 \cdot LL \cdot Y \cdot s \cdot (AF \cdot PPF_t \cdot P_{avg}) \cdot a \cdot A_1 / (4 \cdot \sigma_y) \text{ [cm}^3\text{]} \quad \text{[Equation 23]}$$

where AF, PPF_t, P_{avg}, LL, b, s, a and σ_y are as given in I2.6.2

$Y = 1 - 0.5 \cdot (LL / a)$

$A_1 = \text{maximum of}$

$A_{1A} = 1 / (1 + j / 2 + k_w \cdot j / 2 \cdot [(1 - a_1^2)^{0.5} - 1])$

$A_{1B} = (1 - 1 / (2 \cdot a_1 \cdot Y)) / (0.275 + 1.44 \cdot k_z^{0.7})$

I2 (cont)

$j = 1$ for framing a local frame with one simple support outside the ice-strengthened areas

$= 2$ for framing a local frame without any simple supports

$$a_1 = A_t / A_w$$

A_t = minimum shear area of transverse the local frame as given in I2.6.2 [cm²]

A_w = effective net shear area of transverse the local frame (calculated according to I2.5.7) [cm²]

$k_w = 1 / (1 + 2 \cdot A_{fn} / A_w)$ with A_{fn} as given in I2.5.8

$k_z = z_p / Z_p$ in general

$= 0.0$ when the frame is arranged with end bracket

z_p = sum of individual plastic section moduli of flange and shell plate as fitted [cm³]

$$= (b_f \cdot t_{fn}^2 / 4 + b_{eff} \cdot t_{pn}^2 / 4) / 1000$$

b_f = flange breadth [mm], see Figure 4

t_{fn} = net flange thickness [mm]

$= t_f - t_c$ (t_c as given in I2.5.7)

t_f = as-built flange thickness [mm], see Figure 4

t_{pn} = the fitted net shell plate thickness [mm] (not to be less than t_{net} as given in I2.4)

b_{eff} = effective width of shell plate flange [mm]

$= 500 \cdot s$

Z_p = net effective plastic section modulus of transverse the local frame (calculated according to I2.5.8) [cm³]

I2.6.4 The scantlings of the local frame are to meet the structural stability requirements of I2.9.

I2.7 Framing - Side Longitudinals (Longitudinally-Framed Ships) Longitudinal local frames in side structures

I2.7.1 ~~Side longitudinal~~ Longitudinal local frames in side structures are to be dimensioned such that the combined effects of shear and bending do not exceed the plastic strength of the member. The plastic strength is defined by the magnitude of midspan load that causes the development of a plastic collapse mechanism.

I2.7.2 The actual net effective shear area of the frame, A_w , as defined in I2.5.7, is to comply with the following condition: $A_w \geq A_L$, where:

$$A_L = 100^2 \cdot (AF \cdot PPF_s \cdot P_{avg}) \cdot 0.5 \cdot b_1 \cdot a / (0.577 \cdot \sigma_y) \text{ [cm}^2\text{]} \quad \text{[Equation 24]}$$

where AF = Hull Area Factor from Table 3 4 or Table 5

PPF_s = Peak Pressure Factor from Table 23

P_{avg} = average pressure within load patch ~~according to Equation 15~~ as defined in I2.3.4 [MPa]

$$b_1 = k_o \cdot b_2 \text{ [m]}$$

$$k_o = 1 - 0.3 / b'$$

$$b' = b / s$$

b = height of design ice load patch ~~from Equation 12 or 14~~ as defined in I2.3.3 (i) or I2.3.3 (ii) [m]

s = spacing of longitudinal frames [m]

$$b_2 = b \cdot (1 - 0.25 \cdot b') \text{ [m], if } b' < 2$$

$$= s \text{ [m], if } b' \geq 2$$

a = longitudinal design effective span of longitudinal local frame as given in I2.5.5 [m]

I2**(cont)**

σ_y = minimum upper yield stress of the material [N/mm²]

I2.7.3 The actual net effective plastic section modulus of the plate/stiffener combination, Z_p , as defined in I2.5.8, is to comply with the following condition: $Z_p \geq Z_{pL}$, where:

$$Z_{pL} = 100^3 \cdot (AF \cdot PPF_s \cdot P_{avg}) \cdot b_1 \cdot a^2 \cdot A_4 / (8 \cdot \sigma_y) \text{ [cm}^3\text{]} \quad \text{[Equation 25]}$$

where AF, PPF_s, P_{avg}, b₁, a and σ_y are as given in I2.7.2

$$A_4 = 1 / (2 + k_{wl} \cdot [(1 - a_4^2)^{0.5} - 1])$$

$$a_4 = A_L / A_w$$

A_L = minimum shear area for longitudinal as given in I2.7.2 [cm²]

A_w = net effective shear area of longitudinal (calculated according to I2.5.7) [cm²]

$k_{wl} = 1 / (1 + 2 \cdot A_{fn} / A_w)$ with A_{fn} as given in I2.5.8

I2.7.4 The scantlings of the longitudinals are to meet the structural stability requirements of I2.9.

I2.8 Framing - Web Frame and Load-Carrying Stringers frames and load carrying stringers

I2.8.1 Web frames and load-carrying stringers are to be designed to withstand the ice load patch as defined in I2.3. The load patch is to be applied at locations where the capacity of these members under the combined effects of bending and shear is minimised.

I2.8.2 Web frames and load-carrying stringers are to be dimensioned such that the combined effects of shear and bending do not exceed the limit state(s) defined by each member society the Classification Society. ~~Where these members form part of a structural grillage system, appropriate methods of analysis are to be used.~~ Where the structural configuration is such that members do not form part of a grillage system, the appropriate peak pressure factor (PPF) from Table 23 is to be used. Special attention is to be paid to the shear capacity in way of lightening holes and cut-outs in way of intersecting members.

I2.8.3 For determination of scantlings of load carrying stringers, web frames supporting local frames, or web frames supporting load carrying stringers forming part of a structural grillage system, appropriate methods as outlined in I2.17 are normally to be used.

~~I2.8.34~~ I2.8.34 The scantlings of web frames and load-carrying stringers are to meet the structural stability requirements of I2.9.

I2.9 Framing - Structural Stability stability

I2.9.1 To prevent local buckling in the web, the ratio of web height (h_w) to net web thickness (t_{wn}) of any framing member is not to exceed:

For flat bar sections: $h_w / t_{wn} \leq 282 / (\sigma_y)^{0.5}$

For bulb, tee and angle sections: $h_w / t_{wn} \leq 805 / (\sigma_y)^{0.5}$

where h_w = web height

t_{wn} = net web thickness

σ_y = minimum upper yield stress of the material [N/mm²]

I2.9.2 Framing members for which it is not practicable to meet the requirements of I2.9.1 (e.g. load carrying stringers or deep web frames) are required to have their webs effectively

I2 (cont)

stiffened. The scantlings of the web stiffeners are to ensure the structural stability of the framing member. The minimum net web thickness for these framing members is given by:

$$t_{wn} = 2.63 \times 10^{-3} \cdot c_1 \sqrt{\sigma_y / (5.34 + 4 \cdot (c_1 / c_2)^2)} \quad [\text{mm}] \quad \text{[Equation 26]}$$

$$t_{wn} = 2.63 \cdot 10^{-3} \cdot c_1 \cdot (\sigma_y / (5.34 + 4 \cdot (c_1 / c_2)^2))^{0.5} \quad [\text{mm}]$$

where $c_1 = h_w - 0.8 \cdot h$ [mm]

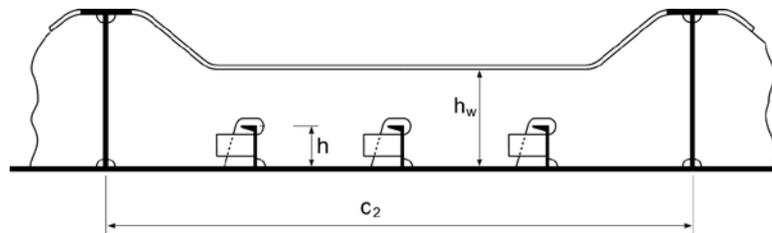
h_w = web height of stringer / web frame [mm] (see Figure 5)

h = height of framing member penetrating the member under consideration (0 if no such framing member) [mm] (see Figure 5)

c_2 = spacing between supporting structure oriented perpendicular to the member under consideration [mm] (see Figure 5)

σ_y = minimum upper yield stress of the material [N/mm²]

Figure 5 - Parameter Definition for Web Stiffening definition of web stiffening



I2.9.3 In addition, the following is to be satisfied:

$$t_{wn} \geq 0.35 \cdot t_{pn} \cdot (\sigma_y / 235)^{0.5}$$

where σ_y = minimum upper yield stress of the shell plate in way of the framing member [N/mm²]

t_{wn} = net thickness of the web [mm]

t_{pn} = net thickness of the shell plate in way of the framing member [mm]

I2.9.4 To prevent local flange buckling of welded profiles, the following are to be satisfied:

(i) The flange width, b_f [mm], shall is not to be less than five times the net thickness of the web, t_{wn} .

(ii) The flange outstand, b_{out} [mm], shall is to meet the following requirement:

$$b_{out} / t_{fn} \leq 155 / (\sigma_y)^{0.5}$$

where t_{fn} = net thickness of flange [mm]

σ_y = minimum upper yield stress of the material [N/mm²]

I2.10 Plated Structures structures

I2.10.1 Plated structures are those stiffened plate elements in contact with the hull and subject to ice loads. These requirements are applicable to an inboard extent which is the lesser of:

(i) web height of adjacent parallel web frame or stringer; or

I2 (cont)

(ii) 2.5 times the depth of framing that intersects the plated structure

I2.10.2 The thickness of the plating and the scantlings of attached stiffeners are to be such that the degree of end fixity necessary for the shell framing is ensured.

I2.10.3 The stability of the plated structure is to adequately withstand the ice loads defined in I2.3.

I2.11 Corrosion/Abrasion Additions ~~abrasion additions and steel renewal and Steel Renewal~~

I2.11.1 Effective protection against corrosion and ice-induced abrasion is recommended for all external surfaces of the shell plating for all Polar Class ships.

I2.11.2 The values of corrosion/abrasion additions, t_s , to be used in determining the shell plate thickness for each Polar Class are listed in Table 46.

I2.11.3 Polar Class ships are to have a minimum corrosion/abrasion addition of $t_s = 1.0$ mm applied to all internal structures within the ice-strengthened hull areas, including plated members adjacent to the shell, as well as stiffener webs and flanges.

Table 46 - Corrosion/Abrasion Additions for Shell Plating ~~abrasion additions for shell plating~~

Hull <u>area</u> Area	t_s [mm]					
	<u>With Effective Protection</u> <u>effective protection</u>			<u>Without Effective Protection</u> <u>effective protection</u>		
	PC1 - PC3	PC4 & PC5	PC6 & PC7	PC1 - PC3	PC4 & PC5	PC6 & PC7
Bow; Bow Intermediate Icebelt	3.5	2.5	2.0	7.0	5.0	4.0
Bow Intermediate Lower; Midbody & Stern Icebelt	2.5	2.0	2.0	5.0	4.0	3.0
Midbody & Stern Lower; Bottom	2.0	2.0	2.0	4.0	3.0	2.5

I2.11.4 Steel renewal for ice strengthened structures is required when the gauged thickness is less than $t_{net} + 0.5$ mm.

I2.12 Materials

I2.12.1 Steel grades of plating ~~Plating materials~~ for hull structures are to be not less than those given in Tables 68 and 7 based on the as-built thickness of the material, the Polar Class ~~ice class notation assigned to the ship~~ and the Material-Class ~~material class~~ of structural members according to I2.12.2.

I2
(cont)

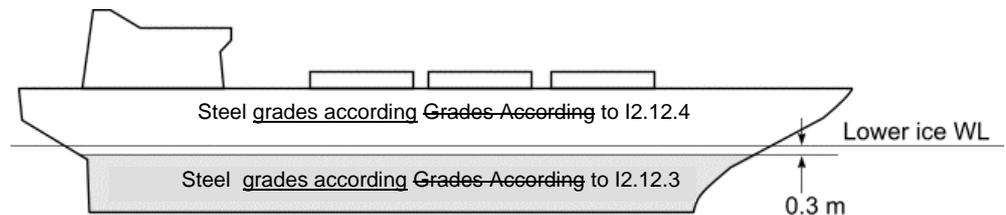
Table 57 - Material Classes for Structural Members of Polar Ships classes for structural members

Structural Members members	Material Class class
Shell plating within the bow and bow intermediate icebelt hull areas (B, B _{ii})	II
All weather and sea exposed SECONDARY and PRIMARY, as defined in Table 1 of UR S6.1, structural members outside 0.4L amidships	I
Plating materials for stem and stern frames, rudder horn, rudder, propeller nozzle, shaft brackets, ice skeg, ice knife and other appendages subject to ice impact loads	II
All inboard framing members attached to the weather and sea-exposed plating, including any contiguous inboard member within 600 mm of the plating	I
Weather-exposed plating and attached framing in cargo holds of ships which by nature of their trade have their cargo hold hatches open during cold weather operations	I
All weather and sea exposed SPECIAL, as defined in Table 1 of UR S6.1, structural members within 0.2L from FP	II

I2.12.2 Material classes specified in Table 1 of UR S6.1 are applicable to ~~polar~~ Polar Class ships regardless of the ship's length. In addition, material classes for weather and sea exposed structural members and for members attached to the weather and sea exposed plating are given in Table 57. Where the material classes in Table 57 and those in Table 1 of UR S6.1 differ, the higher material class is to be applied.

I2.12.3 Steel grades for all plating and attached framing of hull structures and appendages situated below the level of 0.3 m below the lower waterline, as shown in Figure 6, are to be obtained from Table 6 and Table 7 of UR S6 based on the Material Class material class for Structural Members structural members in Table 57 above, regardless of Polar Class.

Figure 6 - Steel Grade Requirements for Submerged and Weather Exposed Shell Plating grade requirements for submerged and weather exposed shell plating



I2.12.4 Steel grades for all weather exposed plating of hull structures and appendages situated above the level of 0.3 m below the lower ice waterline, as shown in Figure 6, are to be not less than given in Table 68.

12 (cont)

Table 68 - Steel Grades for Weather Exposed Plating grades for weather exposed plating¹⁾

Thickness, t [mm]	Material Class class I				Material Class class II				Material Class class III					
	PC1-5		PC6&7		PC1-5		PC6&7		PC1-3		PC4&5		PC6&7	
	MS	HT	MS	HT	MS	HT	MS	HT	MS	HT	MS	HT	MS	HT
t ≤ 10	B	AH	B	AH	B	AH	B	AH	E	EH	E	EH	B	AH
10 < t ≤ 15	B	AH	B	AH	D	DH	B	AH	E	EH	E	EH	D	DH
15 < t ≤ 20	D	DH	B	AH	D	DH	B	AH	E	EH	E	EH	D	DH
20 < t ≤ 25	D	DH	B	AH	D	DH	B	AH	E	EH	E	EH	D	DH
25 < t ≤ 30	D	DH	B	AH	E	EH ²⁾	D	DH	E	EH	E	EH	E	EH
30 < t ≤ 35	D	DH	B	AH	E	EH	D	DH	E	EH	E	EH	E	EH
35 < t ≤ 40	D	DH	D	DH	E	EH	D	DH	F	FH	E	EH	E	EH
40 < t ≤ 45	E	EH	D	DH	E	EH	D	DH	F	FH	E	EH	E	EH
45 < t ≤ 50	E	EH	D	DH	E	EH	D	DH	F	FH	F	FH	E	EH

Notes to Table 68:

- 1) Includes weather-exposed plating of hull structures and appendages, as well as their outboard framing members, situated above a level of 0.3 m below the lowest ice waterline.
- 2) Grades D, DH are allowed for a single strake of side shell plating not more than 1.8 m wide from 0.3 m below the lowest ice waterline.

~~12.12.5 Steel grades for all inboard framing members attached to weather exposed plating are to be not less than given in Table 7. This applies to all inboard framing members as well as to other contiguous inboard members (e.g. bulkheads, decks) within 600 mm of the exposed plating.~~

Table 7 - Steel Grades for Inboard Framing Members Attached to Weather Exposed Plating

Thickness t, mm	PC1 - PC5		PC6 & PC7	
	MS	HT	MS	HT
t ≤ 20	B	AH	B	AH
20 < t ≤ 35	D	DH	B	AH
35 < t ≤ 45	D	DH	D	DH
45 < t ≤ 50	E	EH	D	DH

12.12.65 Castings are to have specified properties consistent with the expected service temperature for the cast component.

12.13 Longitudinal Strength strength

12.13.1 Application

12.13.1.1 A ramming impact on the bow is the design scenario for the evaluation of the longitudinal strength of the hull.

12.13.1.2 Intentional ramming is not considered as a design scenario for ships which are designed with vertical or bulbous bows, see I1.1.6. Hence the longitudinal strength

I2 (cont)

requirements given in I2.13 is not to be considered for ships with stem angle γ_{stem} equal to or larger than 80 deg.

I2.13.1.43 Ice loads need are only to be combined with still water loads. The combined stresses are to be compared against permissible bending and shear stresses at different locations along the ship's length. In addition, sufficient local buckling strength is also to be verified.

I2.13.2 Design ~~Vertical Ice Force at the Bow~~ vertical ice force at the bow

I2.13.2.1 The design vertical ice force at the bow, F_{IB} , is to be taken as

$$F_{\text{IB}} = \text{minimum} (F_{\text{IB},1}; F_{\text{IB},2}) \text{ [MN]} \quad \text{[Equation 27]}$$

$$\text{where } F_{\text{IB},1} = 0.534 \cdot K_1^{0.15} \cdot \sin^{0.2}(\gamma_{\text{stem}}) \cdot (D \cdot K_h)^{0.5} \cdot CF_L \text{ [MN]} \quad \text{[Equation 28]}$$

$$F_{\text{IB},2} = 1.20 \cdot CF_F \text{ [MN]} \quad \text{[Equation 29]}$$

K_1 = indentation parameter = K_f / K_h

a) for the case of a blunt bow form

$$K_f = (2 \cdot C \cdot B^{1-e_b} / (1 + e_b))^{0.9} \cdot \tan(\gamma_{\text{stem}})^{-0.9 \cdot (1 + e_b)}$$

b) for the case of wedge bow form ($\alpha_{\text{stem}} < 80$ deg), $e_b = 1$ and the above simplifies to

$$K_f = (\tan(\alpha_{\text{stem}}) / \tan^2(\gamma_{\text{stem}}))^{0.9}$$

$$K_h = 0.01 \cdot A_{\text{wp}} \text{ [MN/m]}$$

CF_L = Longitudinal Strength Class Factor from Table 1

e_b = bow shape exponent which best describes the waterplane (see Figures 7 and 8)

= 1.0 for a simple wedge bow form

= 0.4 to 0.6 for a spoon bow form

= 0 for a landing craft bow form

An approximate e_b determined by a simple fit is acceptable

γ_{stem} = stem angle to be measured between the horizontal axis and the stem tangent at the upper ice waterline [deg] (buttock angle as per Figure 2 measured on the centreline)

α_{stem} = waterline angle measured in way of the stem at the upper ice waterline (UIWL) [deg] (see Figure 7)

$$C = 1 / (2 \cdot (L_B / B)^{e_b})$$

B = ship moulded breadth [m]

L_B = bow length used in the equation $y = B / 2 \cdot (x/L_B)^{e_b}$ [m] (see Figures 7 and 8)

D = ship displacement [kt], not to be taken less than 10 kt

A_{wp} = ship waterplane area [m²]

CF_F = Flexural Failure Class Factor from Table 1

Where applicable, draught dependent quantities are to be determined at the waterline corresponding to the loading condition under consideration.

I2
(cont)

Figure 7 - Bow Shape Definition

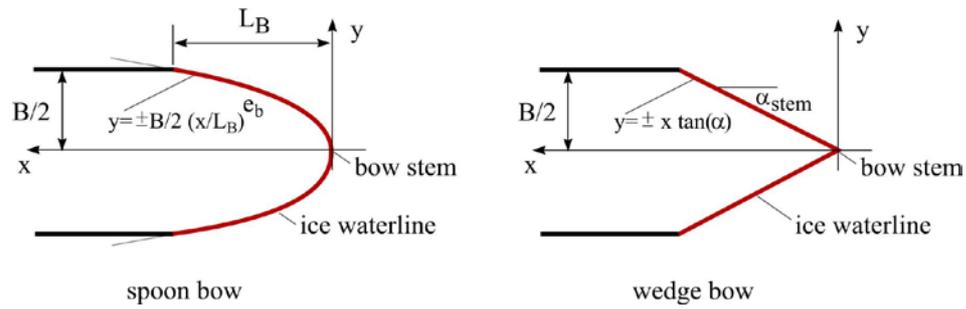
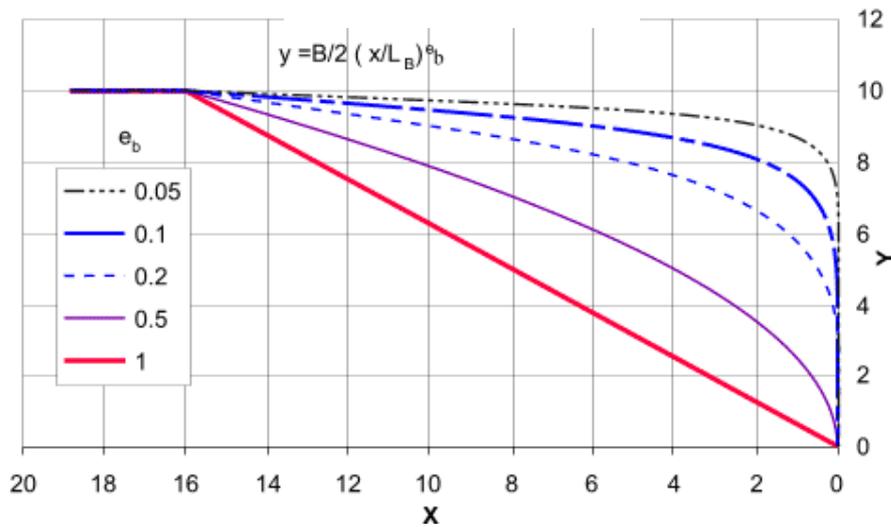


Figure 8 - Illustration of e_b Effect on the Bow Shape for $B = 20$ and $L_B = 16$



I2.13.3 Design Vertical Shear Force

I2.13.3.1 The design vertical ice shear force, F_I , along the hull girder is to be taken as:

$$F_I = C_f \cdot F_{IB} \text{ [MN]} \quad \text{[Equation 30]}$$

where C_f = longitudinal distribution factor to be taken as follows:

- (a) Positive shear force
 - $C_f = 0.0$ between the aft end of L and $0.6L$ from aft
 - $C_f = 1.0$ between $0.9L$ from aft and the forward end of L
- (b) Negative shear force
 - $C_f = 0.0$ at the aft end of L
 - $C_f = -0.5$ between $0.2L$ and $0.6L$ from aft
 - $C_f = 0.0$ between $0.8L$ from aft and the forward end of L

Intermediate values are to be determined by linear interpolation

I2.13.3.2 The applied vertical shear stress, τ_a , is to be determined along the hull girder in a similar manner as in UR S11.5.4.2 by substituting the design vertical ice shear force for the design vertical wave shear force.

12

(cont)

12.13.4 Design ~~Vertical Ice Bending Moment~~ vertical ice bending moment12.13.4.1 The design vertical ice bending moment, M_I , along the hull girder is to be taken as:

$$M_I = 0.1 \cdot C_m \cdot L \cdot \sin^{-0.2}(\gamma_{\text{stem}}) \cdot F_{IB} \text{ [MNm]} \quad \text{[Equation 31]}$$

where L = ship length as defined in UR S2.1, but measured on the upper ice waterline [UIWL] [m]

γ_{stem} is as given in I2.13.2.1

F_{IB} = design vertical ice force at the bow [MN]

C_m = longitudinal distribution factor for design vertical ice bending moment to be taken as follows:

$C_m = 0.0$ at the aft end of L

$C_m = 1.0$ between $0.5L$ and $0.7L$ from aft

$C_m = 0.3$ at $0.95L$ from aft

$C_m = 0.0$ at the forward end of L

Intermediate values are to be determined by linear interpolation

Where applicable, draught dependent quantities are to be determined at the waterline corresponding to the loading condition under consideration.

12.13.4.2 The applied vertical bending stress, σ_a , is to be determined along the hull girder in a similar manner as in UR S11.5.4.1, by substituting the design vertical ice bending moment for the design vertical wave bending moment. The ship still water bending moment is to be taken as the maximum sagging moment.

12.13.5 Longitudinal ~~Strength Criteria~~ strength criteria

12.13.5.1 The strength criteria provided in Table 89 are to be satisfied. The design stress is not to exceed the permissible stress.

Table 89 - Longitudinal ~~Strength Criteria~~ strength criteria

<u>Failure Mode</u>	<u>Applied Stress</u>	<u>Permissible Stress</u> when $\sigma_y / \sigma_u \leq 0.7$	<u>Permissible Stress</u> when $\sigma_y / \sigma_u > 0.7$
Tension	σ_a	$\eta \cdot \sigma_y$	$\eta \cdot 0.41 (\sigma_u + \sigma_y)$
Shear	τ_a	$\eta \cdot \sigma_y / (3)^{0.5}$	$\eta \cdot 0.41 (\sigma_u + \sigma_y) / (3)^{0.5}$
Buckling	σ_a	σ_c for plating and for web plating of stiffeners $\sigma_c / 1.1$ for stiffeners	
	τ_a	τ_c	

where σ_a = applied vertical bending stress [N/mm²]

τ_a = applied vertical shear stress [N/mm²]

σ_y = minimum upper yield stress of the material [N/mm²]

σ_u = ultimate tensile strength of material [N/mm²]

σ_c = critical buckling stress in compression, according to UR S11.5 [N/mm²]

τ_c = critical buckling stress in shear, according to UR S11.5 [N/mm²]

$\eta = 0.8$

$\eta = 0.6$ for ships which are assigned the additional notation "Icebreaker"

I2 (cont)

I2.14 ~~Stem and Stern Frames~~ stern frames

I2.14.1 The stem and stern frame are to be designed according to the requirements of ~~each member society~~ the Classification Society. For PC6/PC7 ~~vessels~~ ships requiring 1AS/1A IAS/IA equivalency, the stem and stern requirements of the Finnish-Swedish Ice Class Rules may need to be additionally considered.

I2.15 Appendages

I2.15.1 All appendages are to be designed to withstand forces appropriate for the location of their attachment to the hull structure or their position within a hull area.

I2.15.2 Load definition and response criteria are to be determined by ~~each member society~~ the Classification Society.

I2.16 ~~Local Details~~ details

I2.16.1 For the purpose of transferring ice-induced loads to supporting structure (bending moments and shear forces), local design details are to comply with the requirements of ~~each member society~~ the Classification Society.

I2.16.2 The loads carried by a member in way of cut-outs are not to cause instability. Where necessary, the structure is to be stiffened.

I2.17 ~~Direct Calculations~~ calculations

I2.17.1 Direct calculations are not to be utilised as an alternative to the analytical procedures prescribed in ~~this unified requirement for the shell plating and local frame requirements given in I2.4, I2.6, and I2.7.~~

I2.17.2 Direct calculations are to be used for load carrying stringers and web frames forming part of a grillage system.

I2.17.23 Where direct calculation is used to check the strength of structural systems, the load patch specified in I2.3 is to be applied, without being combined with any other loads. The load patch is to be applied at locations where the capacity of these members under the combined effects of bending and shear is minimised. Special attention is to be paid to the shear capacity in way of lightening holes and cut-outs in way of intersecting members.

I2.17.4 The strength evaluation of web frames and stringers may be performed based on linear or non-linear analysis. Recognized structural idealisation and calculation methods are to be applied, but the detailed requirements are to be specified by the Classification Society. In the strength evaluation, the guidance given in I2.17.5 and I2.17.6 may generally be considered.

I2.17.5 If the structure is evaluated based on linear calculation methods, the following are to be considered:

- (1) Web plates and flange elements in compression and shear to fulfil relevant buckling criteria as specified by the Classification Society
- (2) Nominal shear stresses in member web plates to be less than $\sigma_y / \sqrt{3}$
- (3) Nominal von Mises stresses in member flanges to be less than $1.15 \sigma_y$

I2 (cont)

I2.17.6 If the structure is evaluated based on non-linear calculation methods, the following are to be considered:

- (1) The analysis is to reliably capture buckling and plastic deformation of the structure
- (2) The acceptance criteria are to ensure a suitable margin against fracture and major buckling and yielding causing significant loss of stiffness
- (3) Permanent lateral and out-of plane deformation of considered member are to be minor relative to the relevant structural dimensions
- (4) Detailed acceptance criteria to be decided by the Classification Society

I2.18 Welding

I2.18.1 All welding within ice-strengthened areas is to be of the double continuous type.

I2.18.2 Continuity of strength is to be ensured at all structural connections.

End of Document
