RESOLUTION MSC.168(79)
(adopted on 9 December 2004)

STANDARDS AND CRITERIA FOR SIDE STRUCTURES OF
BULK CARRIERS OF SINGLE-SIDE SKIN CONSTRUCTION

THE MARITIME SAFETY COMMITTEE,

RECALLING Article 28(b) of the Convention on the International Maritime Organization concerning the functions of the Committee,

RECALLING ALSO SOLAS chapter XII on Additional safety measures for bulk carriers, which the 1997 SOLAS Conference adopted with the aim of enhancing the safety of ships carrying solid bulk cargoes,

RECALLING FURTHER that, having recognized the need to further improve the safety of bulk carriers in all aspects of their design, construction, equipment and operation, it examined the results of various formal safety assessment (FSA) studies on bulk carrier safety,

RECOGNIZING that banning of alternate hold loading of heavy cargoes in full load condition for bulk carriers of single-side skin construction not meeting appropriate side structural strength requirements would contribute to improving the safety of these ships by reduction of shear forces and bending moments,

NOTING resolution MSC.170(79) by which it adopted, *inter alia*, the revised chapter XII of the 1974 SOLAS Convention, in particular regulation XII/14 – Restrictions from sailing with any hold empty, where reference is made to mandatory standards and criteria which a bulk carrier has to comply with in order to avoid the above-mentioned restrictions,

ACKNOWLEDGING that the International Association of Classification Societies (IACS) has issued the following relevant Unified Requirements:

S12 Rev.2.1 - Side structure in single side skin bulk carriers; and

S31 - Renewal criteria for side shell frames in single side skin bulk carriers not built in accordance with UR S12 Rev.1 or subsequent revisions,

CONSIDERING that the above IACS Unified Requirements embody respectively the standards and criteria necessary to ascertain whether regulation XII/14 of the Convention should apply to a particular bulk carrier, and, therefore, should form the basis of the said standards and criteria,

HAVING CONSIDERED the recommendation made by the Sub-Committee on Ship Design and Equipment at its forty-seventh session,

1.   ADOPTS, for the purposes of the application of regulation XII/14 of the Convention:

.1 the Standards for side structures in single-side skin bulk carriers, set out in Annex 1 to the present resolution; and

.2 the Renewal criteria for side shell frames and brackets in single-side skin bulk carriers not built in accordance with the Standards for side structures in single-side skin bulk carriers, set out in Annex 2 to the present resolution;

2. INVITES Contracting Governments to the Convention to note that the annexed Standards and Renewal criteria will take effect on 1 July 2006 upon the entry into force of the revised chapter XII of the Convention;

3. REQUESTS the Secretary-General to transmit certified copies of this resolution and the text of the annexed Standards and Renewal criteria to all Contracting Governments to the Convention;

4. FURTHER REQUESTS the Secretary-General to transmit certified copies of this resolution and the text of the annexed Standards and Renewal criteria to all Members of the Organization which are not Contracting Governments to the Convention.

ANNEX 1

STANDARDS FOR SIDE STRUCTURES IN SINGLE-SIDE SKIN BULK CARRIERS

1   Application

For the purpose of SOLAS regulation XII/14, these requirements define the minimum required standards for the side structures within the cargo area of single-side skin bulk carriers of 150 m in length and upwards carrying solid bulk cargoes having a density of 1,780 kg/m³ and above, for them not to be subject to restrictions from sailing with any hold empty.

2   Scantlings of side structures

2.1   The thickness of the side shell plating and the section modulus and shear area of side frames shall be determined according to the criteria of a classification society which is recognized by the Administration in accordance with the provisions of SOLAS regulation XI-1/1, or with applicable national standards of the Administration which provide an equivalent level of safety.

2.2   The scantlings of side hold frames immediately adjacent to the collision bulkhead shall be increased in order to prevent excessive imposed deformation on the shell plating.   As an alternative, supporting structures shall be fitted which maintain the continuity of forepeak stringers within the foremost hold.

3   Minimum thickness of frame webs

The thickness of frame webs within the cargo area shall not be less than $t_{w,min}$, in mm, given by:

$$t_{w,min} = C(7.0 + 0.03L)$$

where:

C = 1.15 for the frame webs in way of the foremost hold;
        1 for the frame webs in way of other holds.

L = the distance, in m, on the summer load waterline from the fore side of stem to the after side of the rudder post, or the centre of the rudder stock if there is no rudder post.   L shall not be less than 96%, and need not be greater than 97%, of the extreme length on the summer load waterline but need not be taken greater than 200 m.

4   Lower and upper brackets

4.1   The thickness of the frame lower brackets shall not be less than the greater of t_w and $t_{w,min} + 2$ mm, where t_w is the fitted thickness of the side frame web.   The thickness of the frame upper bracket shall not be less than the greater of t_w and $t_{w,min}$.

4.2   The section modulus SM of the frame and bracket or integral bracket, and associated shell plating, at the locations shown in figure 1, shall not be less than twice the section modulus SM_F required for the frame midspan area.

4.3   The dimensions of the lower and upper brackets shall not be less than those shown in figure 2.

4.4   Structural continuity with the upper and lower end connections of side frames shall be ensured within topside and hopper tanks by connecting brackets as shown in figure 3. The brackets shall be stiffened against buckling according to the criteria of a classification society which is recognized by the Administration in accordance with the provisions of SOLAS regulation XI-1/1, or with applicable national standards of the Administration which provide an equivalent level of safety.

4.5   The section moduli of the side longitudinals and sloping bulkhead longitudinals which support the connecting brackets shall be determined with the span taken between transverses according to the requirements of a classification society which is recognized by the Administration in accordance with the provisions of SOLAS regulation XI-1/1, or with applicable national standards of the Administration which provide an equivalent level of safety. Where other arrangements are adopted at the discretion of the Administration or a recognized classification society, the section moduli of the side longitudinals and sloping bulkhead longitudinals shall be determined according to the applicable criteria for the purpose of effectively supporting the brackets.

5   **Side frame sections**

5.1   Frames shall be fabricated symmetrical sections with integral upper and lower brackets and shall be arranged with soft toes.

5.2   The side frame flange shall be curved (not knuckled) at the connection with the end brackets. The radius of curvature shall not be less than r, in mm, given by:

$$r = \frac{0.4b_f^2}{t_f}$$

where b_f and t_f are the flange width and thickness of the brackets, respectively, in mm. The end of the flange shall be sniped.

5.3   In ships less than 190 m in length, mild steel frames may be asymmetric and fitted with separate brackets. The face plate or flange of the bracket shall be sniped at both ends. Brackets shall be arranged with soft toes.

5.4   The frame web thickness ratio of frames shall not exceed the following values:

.1 $60\,k^{0.5}$ for symmetrically flanged frames;

.2 $50\,k^{0.5}$ for asymmetrically flanged frames;

where:

k = 1 for ordinary hull structural steel;
k = 0.78 for steel with yield stress of 315 N/mm²; and
k = 0.72 for steel with yield stress of 355 N/mm².

The outstanding flange shall not exceed $10\,k^{0.5}$ times the net flange thickness.

6   Tripping brackets

In way of the foremost hold, side frames of asymmetrical section shall be fitted with tripping brackets at every two frames, as shown in figure 4.

7   Weld connections of frames and end brackets

7.1   Double continuous welding shall be adopted for the connections of frames and brackets to side shell and hopper and top-side tank plating and web to face plates.

7.2   For this purpose, the weld throat shall be (see figure 1):

.1   0.44 t in zone "a";

.2   0.4 t in zone "b";

where t is the thinner of the two connected members.

7.3   Where the hull form is such as to prohibit an effective fillet weld, edge preparation of the web of frame and bracket may be required, in order to ensure the same efficiency as the weld connection stated above.

8   Minimum net thickness of side shell plating

The thickness of side shell plating located between the hopper and top-side tank shall not be less than $t_{p,min}$, in mm, given by:
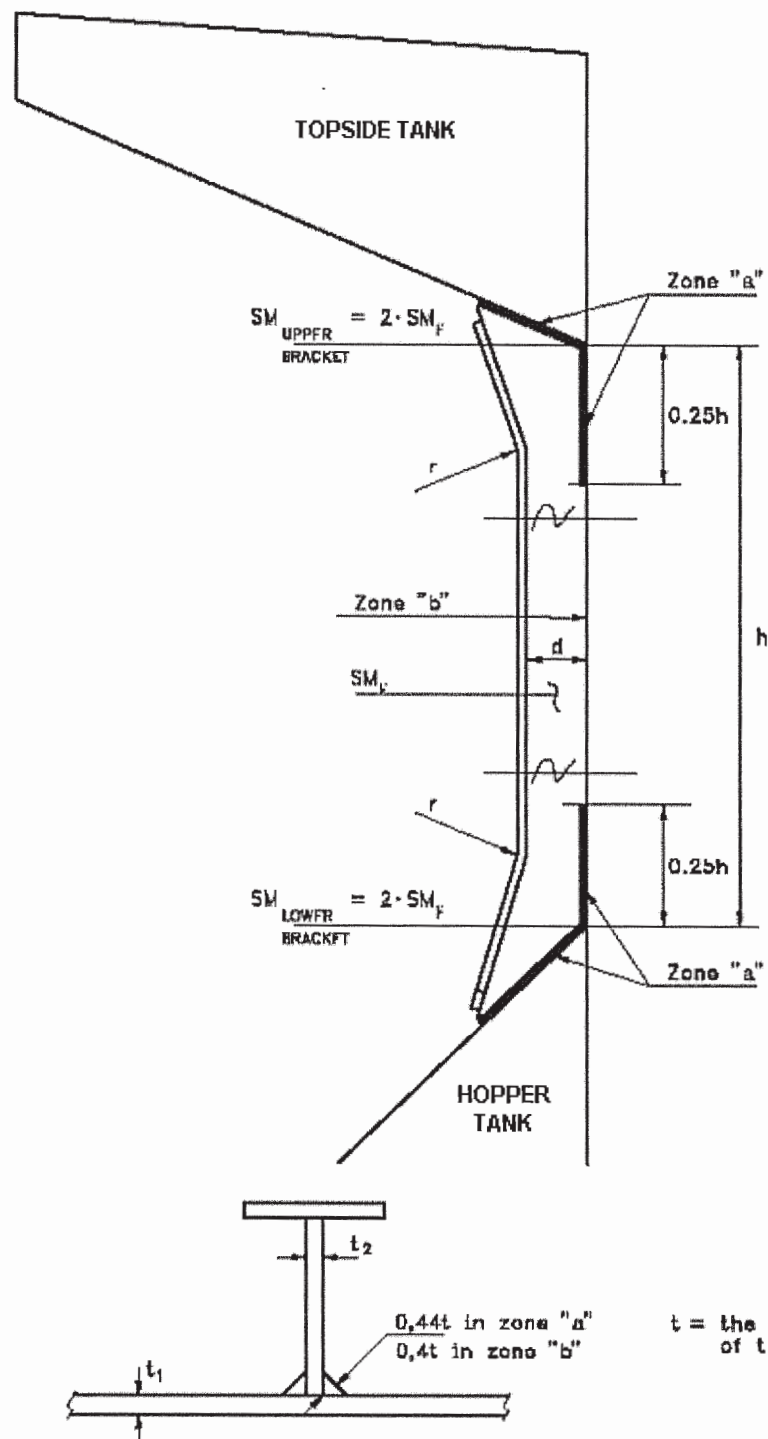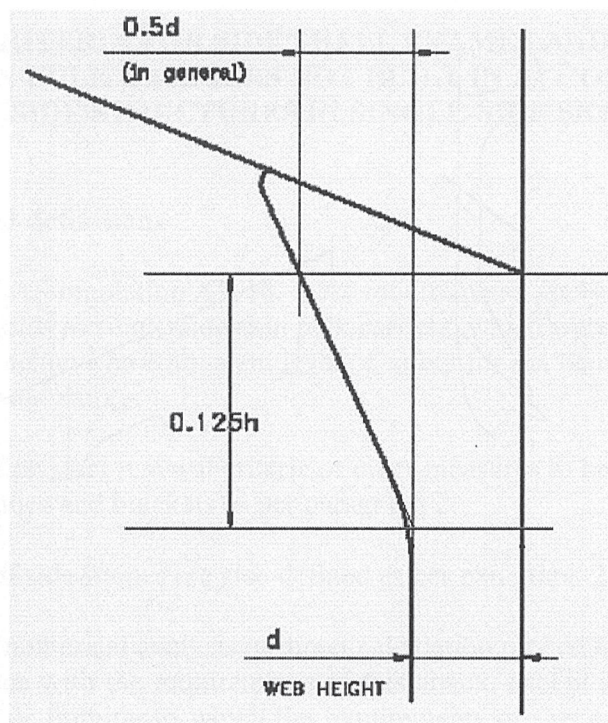
$$t_{p,min} = \sqrt{L}$$

Figure 1

TOPSIDE TANK

Zone "a"

$SM_{\substack{UPPER \\ BRACKET}} = 2 \cdot SM_F$

0.25h

r

Zone "b"

d

h

SM_F

r

0.25h

$SM_{\substack{LOWER \\ BRACKET}} = 2 \cdot SM_F$

Zone "a"

HOPPER TANK

t_2

0,44t in zone "a"
0,4t in zone "b"

$t = $ the lesser of t_1 or t_2

t_1

Figure 2

0.5d
(in general)

0.125h

d

WEB HEIGHT

Figure 3

90°

LOWER BRACKET
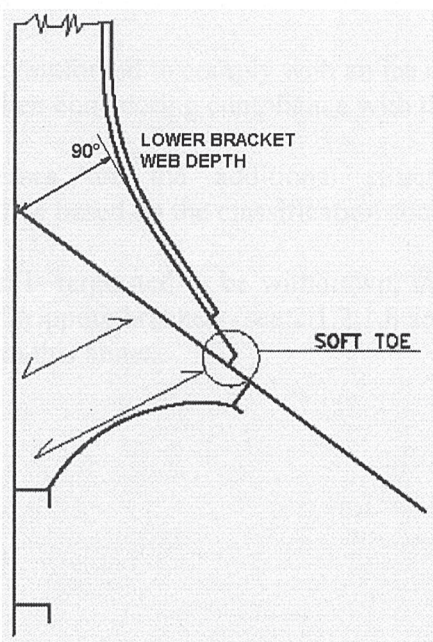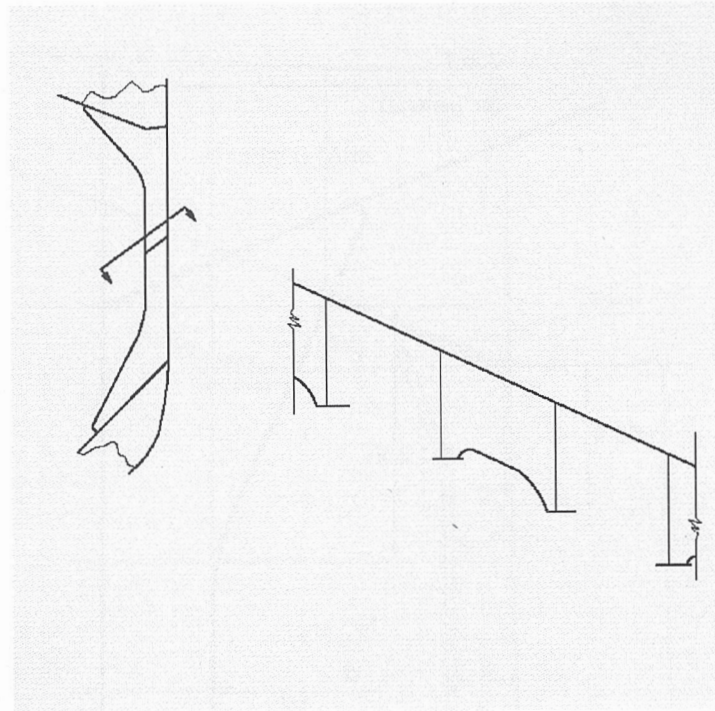WEB DEPTH

SOFT TOE

Figure 4 - Tripping brackets to be fitted in way of foremost hold

ANNEX 2

RENEWAL CRITERIA FOR SIDE SHELL FRAMES AND BRACKETS IN SINGLE-SIDE SKIN BULK CARRIERS NOT BUILT IN ACCORDANCE WITH THE STANDARDS FOR SIDE STRUCTURES IN SINGLE-SIDE SKIN BULK CARRIERS

1 Application and definitions

For the purpose of SOLAS regulation XII/14, these requirements apply to the side shell frames and brackets of cargo holds in single-side skin bulk carriers, which were not built in accordance with annex 1, but shall achieve an equivalent level of safety for not being subject to restrictions when sailing with any hold empty.

These requirements define steel renewal criteria or other measures to be taken for the webs and flanges of side shell frames and brackets as per paragraph 2.

Reinforcing measures of side frames are also defined as per paragraph 2.3.

Finite element or other numerical analysis or direct calculation procedures cannot be used as an alternative to compliance with the requirements of this annex, except in cases of unusual side structure arrangements or framing to which the requirements of this annex cannot be directly applied.

Assessment of compliance with these requirements is to be carried out by the date on which the ship reaches 10 years of age and at each subsequent intermediate and renewal survey.

1.1 Ice strengthened ships

1.1.1 Where bulk carriers are reinforced to comply with an ice class notation, the intermediate frames shall not be included when considering compliance with this annex.

1.1.2 The renewal thicknesses for the additional structure required to meet the ice strengthening notation shall be based on the classification society's requirements.

1.1.3 If the ice class notation is requested to be withdrawn, the additional ice strengthening structure, with the exception of tripping brackets (see 2.1.2.1.b and 2.3), shall not be considered to contribute to compliance with this annex.

2 Renewal or other measures

2.1 Criteria for renewal or other measures

2.1.1 Symbols used in 2.1

t_M = thickness as measured, in mm

t_{REN} = thickness at which renewal is required (2.1.2)

$t_{REN,d/t}$ = thickness criteria based on d/t ratio (2.1.2.1)

$t_{REN,S}$ = thickness criteria based on strength (2.1.2.2)

t_{COAT} = $0.75 t_{S12}$

t_{S12} = thickness, in mm, as required by annex 1 in paragraph 3 for frame webs and in paragraph 4 for upper and lower brackets

t_{AB} = thickness as built, in mm

t_C = See table 1 below

Table 1 - t_C values, in mm

Ship's length L, in m	Holds other than No.1		Hold No.1	
	Span and upper brackets	Lower brackets	Span and upper brackets	Lower brackets
≤100	2	2.5	2	3
150	2	3	3	3.5
≥ 200	2	3	3	4
Note: For intermediate ship lengths, t_C is obtained by linear interpolation between the above values.				

2.1.2 Criteria for webs (shear and other checks)

The webs of side shell frames and brackets shall be renewed when the measured thickness (t_M) is equal to, or less than, the thickness (t_{REN}) as defined below:

t_{REN} is the greatest of:

.1 $t_{COAT} - t_C$

.2 $0.75 t_{AB}$

.3 $t_{REN,d/t}$

.4 $t_{REN,S}$ (where required by 2.1.2.2)

2.1.2.1 Thickness criteria based on d/t ratio

Subject to b) and c) below, $t_{REN,d/t}$ is given by the following equation:

$$t_{REN,d/t} = \text{(web depth in mm)}/R$$

where:

R = for frames

65 $k^{0.5}$ for symmetrically flanged frames
55 $k^{0.5}$ for asymmetrically flanged frames

for lower brackets (see a) below):

87 $k^{0.5}$ for symmetrically flanged frames
73 $k^{0.5}$ for asymmetrically flanged frames

k = 1 for ordinary hull structural steel;
k = 0.78 for steel with yield stress of 315 N/mm²; and
k = 0.72 for steel with yield stress of 355 N/mm².

In no instance shall $t_{REN,d/t}$ for lower integral brackets be taken as less than $t_{REN,d/t}$ for the frames they support.

a) Lower brackets

In calculating the web depth of the lower brackets, the following shall apply:

.1 The web depth of lower bracket may be measured from the intersection of the sloped bulkhead of the hopper tank and the side shell plate, perpendicularly to the face plate of the lower bracket (see figure 3).

.2 Where stiffeners are fitted on the lower bracket plate, the web depth may be taken as the distance between the side shell and the stiffener, between the stiffeners or between the outermost stiffener and the face plate of the brackets, whichever is the greatest.

b) Tripping bracket alternative

When t_M is less than $t_{REN,d/t}$ at section b) of the side frames (see figure 2), tripping brackets in accordance with 2.3 may be fitted as an alternative to the requirements for the web depth to thickness ratio of side frames, in which case $t_{REN,d/t}$ may be disregarded in the determination of t_{REN} in accordance with 2.1.2.

c) Immediately abaft collision bulkhead

For the side frames located immediately abaft the collision bulkhead, whose scantlings are increased in order that their moment of inertia is such as to avoid undesirable flexibility of the side shell, when their web as built thickness t_{AB} is greater than $1.65t_{REN,S}$, the thickness $t_{REN,d/t}$ may be taken as the value $t'_{REN,d/t}$ obtained from the following equation:

$$t'_{REN,d/t} = \sqrt[3]{t_{REN,d/t}^2\ t_{REN,S}}$$

where $t_{REN,S}$ is obtained from 3.3.

2.1.2.2 Thickness criteria based on shear strength check

Where t_M in the lower part of side frames, as defined in figure 1, is equal to, or less than, t_{COAT}, $t_{REN,S}$ shall be determined in accordance with 3.3.

2.1.2.3 Thickness of renewed webs of frames and lower brackets

Where steel renewal is required, the renewed webs shall be of a thickness not less than t_{AB}, $1.2t_{COAT}$ or $1.2t_{REN}$, whichever is the greatest.

2.1.2.4 Criteria for other measures

When $t_{REN} < t_M \leq t_{COAT}$, measures shall be taken, consisting of all the following:

.1   sand blasting, or equivalent, and coating (see 2.2);

.2   fitting tripping brackets (see 2.3), when the above condition occurs for any of the side frame zones A, B, C and D, shown in figure 1; and

.3   maintaining the coating in "as new" condition (i.e. without breakdown or rusting) at renewal and intermediate surveys.

The above measures may be waived if the structural members show no thickness diminution with respect to the as-built thicknesses and coating is in "as new" condition (i.e. without breakdown or rusting).

2.1.3   Criteria for frames and brackets (bending check)

Where the length or depth of the lower bracket does not meet the requirements in annex 1, a bending strength check in accordance with 3.4 shall be carried out and renewals or reinforcements of frames and/or brackets effected as required therein.

2.2   Thickness measurements, steel renewal, sand blasting and coating

For the purpose of steel renewal, sand blasting and coating, four zones A, B, C and D are defined, as shown in figure 1.

Representative thickness measurements shall be taken for each zone and shall be assessed against the criteria in 2.1.

In case of integral brackets, when the criteria in 2.1 are not satisfied for zone A or B, steel renewal, sand blasting and coating, as applicable, shall be done for both zones A and B.

In case of separate brackets, when the criteria in 2.1 are not satisfied for zone A or B, steel renewal, sand blasting and coating shall be done for each one of these zones, as applicable.

When steel renewal is required for zone C according to 2.1, it shall be done for both zones B and C. When sand blasting and coating is required for zone C according to 2.1, it shall be done for zones B, C and D.

When steel renewal is required for zone D according to 2.1, it needs only to be done for this zone. When sand blasting and coating is required for zone D according to 2.1, it shall be done for both zones C and D.

Special consideration may be given to zones previously renewed or re-coated, if found in "as new" condition (i.e., without breakdown or rusting) by the Administration or a classification society which is recognized by the Administration in accordance with the provisions of SOLAS regulation XI-1/1.

When adopted, on the basis of the renewal thickness criteria in 2.1, in general coating shall be applied in compliance with the requirements of the organization, as applicable.

Where, according to the requirements in 2.1, a limited number of side frames and brackets are shown to require coating over part of their length, the following criteria apply:

.1   The part to be coated includes:

-       the web and the face plate of the side frames and brackets,

-       the hold surface of side shell, hopper tank and topside tank plating, as applicable, over a width not less than 100 mm from the web of the side frame.

.2   Epoxy coating or equivalent shall be applied.

In all cases, all the surfaces to be coated shall be sand blasted prior to coating application.

2.3   Reinforcing measures

Reinforcing measures are constituted by tripping brackets, located at the lower part and at midspan of side frames (see figure 4). Tripping brackets may be located at every two frames, but lower and midspan brackets shall be fitted in line between alternate pairs of frames.

The thickness of the tripping brackets shall be not less than the as-built thickness of the side frame webs to which they are connected.

Double continuous welding shall be adopted for the connections of tripping brackets to the side shell frames and shell plating.

2.4 Weld throat thickness

In case of steel renewal, the welded connections shall comply with paragraph 7 of annex 1.

2.5 Pitting and grooving

If pitting intensity is higher than 15% in area (see figure 5), thickness measurement shall be taken to check pitting corrosion.

The minimum acceptable remaining thickness in pits or grooves is equal to:

.1 75% of the as-built thickness, for pitting or grooving in the frame and brackets webs and flanges; and

.2 70% of the as-built thickness, for pitting or grooving in the side shell, hopper tank and topside tank plating attached to the side frame, over a width up to 30 mm from each side of it.

3 Strength check criteria

In general, loads shall be calculated and strength checks shall be carried out for the aft, middle and forward frames of each hold. The scantlings required for frames in intermediate positions shall be obtained by linear interpolation between the results obtained for the above frames.

When scantlings of side frames vary within a hold, the required scantlings shall also be calculated for the mid-frame of each group of frames having the same scantlings. The scantlings required for frames in intermediate positions shall be obtained by linear interpolation between the results obtained for the calculated frames.

3.1 Load model

3.1.1 Forces

The forces $P_{fr,a}$ and $P_{fr,b}$, in kN, to be considered for the strength checks at sections a) and b) of side frames (specified in figure 2; in the case of separate lower brackets, section b) is at the top of the lower bracket), are given by:

$$P_{fr,a} = P_S + \max(P_1, P_2)$$

$$P_{fr,b} = P_{fr,a}\frac{h - 2h_B}{h}$$

where:

P_s =   still water pressure force, in kN

$$P_s = s\,h\left(\frac{p_{S,U}+p_{S,L}}{2}\right)$$ when the upper end of the side frame span h (see figure 1)
is below the load water line

$$= s\,h'\left(\frac{p_{S,L}}{2}\right)$$ when the upper end of the side frame span h (see figure 1)
is at or above the load water line

P_1 =   wave pressure force, in kN, in head seas

$$= s\,h\left(\frac{p_{1,U}+p_{1,L}}{2}\right)$$

P_2 =   wave pressure force, in kN, in beam seas

$$= s\,h\left(\frac{p_{2,U}+p_{2,L}}{2}\right)$$

h, h_B =   side frame span and lower bracket length, in m, defined in figures 1 and 2, respectively

h' =   distance, in m, between the lower end of side frame span h (see figure 1) and the load waterline

s =   frame spacing, in m

$p_{S,U}, p_{S,L}$ =   still water pressure, in kN/m^2, at the upper and lower end of the side frame span h (see figure 1), respectively

$p_{1,U}, p_{1,L}$ =   wave pressure, in kN/m^2, as defined in 3.1.2.1, below for the upper and lower end of the side frame span h, respectively

$p_{2,U}, p_{2,L}$ =   wave pressure, in kN/m^2, as defined in 3.1.2.2, below for the upper and lower end of the side frame span h, respectively

3.1.2 Wave pressure

3.1.2.1 Wave pressure p_1

.1   The wave pressure p_1, in kN/m^2, at and below the waterline is given by:

$$p_1 = 1.50 \left[p_{11} + 135 \frac{B}{2\,(B+75)} - 1.2(T-z) \right]$$

$$p_{11} = 3\,k_s\,C + k_f$$

.2   The wave pressure p_1, in kN/m^2, above the water line is given by:

$$p_1 = p_{1wl} - 7.50\,(z-T)$$

3.1.2.2 Wave pressure p_2

.1   The wave pressure p_2, in kN/m^2, at and below the waterline is given by:

$$p_2 = 13.0 \left[0.5\,B \frac{50\,C_r}{2\,(B+75)} + C_B \frac{0.5\,B + k_f}{14} \left(0.7 + 2\frac{z}{T} \right) \right]$$

.2   The wave pressure p_2, in kN/m^2, above the water line is given by:

$$p_2 = p_{2wl} - 5.0\,(z-T)$$

where:

p_{1wl}	=	p_1 wave sea pressure at the waterline
p_{2wl}	=	p_2 wave sea pressure at the waterline
L	=	the distance, in m, on the summer load waterline from the fore side of stem to the after side of the rudder post, or the centre of the rudder stock if there is no rudder post. L shall not be less than 96%, and need not be greater than 97%, of the extreme length on the summer load waterline.
B	=	greatest moulded breadth, in m

C_B = moulded block coefficient at draught d corresponding to summer load waterline, based on length L and moulded breadth B, but not to be taken less than 0.6:

$$C_B = \frac{\text{moulded displacement [m}^3\text{] at draught d}}{LBd}$$

T = maximum design draught, in m

C = coefficient

= $10.75 - \left(\dfrac{300 - L}{100}\right)^{1.5}$ for $90 \leq L \leq 300$ m

= 10.75 for $300 < L$

C_r = $\left(1.25 - 0.025 \dfrac{2\,k_r}{\sqrt{GM}}\right) k$

k = 1.2   for ships without bilge keel

= 1   for ships with bilge keel

k_r = roll radius of gyration. If the actual value of k_r is not available

= 0.39 B for ships with even distribution of mass in transverse section (e.g. alternate heavy cargo loading or homogeneous light cargo loading)

= 0.25 B for ships with uneven distribution of mass in transverse section (e.g. homogenous heavy cargo distribution)

GM = 0.12 B if the actual value of GM is not available

z = vertical distance, in m, from the baseline to the load point

k_s = $C_B + \dfrac{0.83}{\sqrt{C_B}}$ at aft end of L

= C_B between 0.2 L and 0.6 L from aft end of L

= $C_B + \dfrac{1.33}{C_B}$ at forward end of L

Between the above specified points, k_s shall be varied linearly

k_f = 0.8 C

3.2 Allowable stresses

The allowable normal and shear stresses σ_a and τ_a, in N/mm^2, in the side shell frames are given by:

$$\sigma_a = 0.90\ \sigma_F$$

$$\tau_a = 0.40\ \sigma_F$$

where σ_F is the minimum upper yield stress, in N/mm^2, of the material.

3.3 Shear strength check

Where t_M in the lower part of side frames, as defined in figure 1, is equal to, or less than, t_{COAT}, shear strength check shall be carried out in accordance with the following.

The thickness $t_{REN,S}$, in mm, is the maximum between the thicknesses $t_{REN,Sa}$ and $t_{REN,Sb}$ obtained from the shear strength check at sections a) and b) (see figure 2 and 3.1) given by the following, but need not be taken in excess of $0.75t_{S12}$.

.1 at section a): $\quad t_{REN,Sa} = \dfrac{1,000\ k_s\ P_{fr,a}}{d_a\ \sin\phi\ \tau_a}$

.2 at section b): $\quad t_{REN,Sb} = \dfrac{1,000\ k_s\ P_{fr,b}}{d_b\ \sin\phi\ \tau_a}$

where:

k_s	=	shear force distribution factor, to be taken equal to 0.6
$P_{fr,a}$, $P_{fr,b}$	=	pressure forces defined in 3.1.1
d_a, d_b	=	bracket and frame web depth, in mm, at sections a) and b), respectively (see figure 2); in case of separate (non integral) brackets, d_b shall be taken as the minimum web depth deducting possible scallops
ϕ	=	angle between frame web and shell plate
τ_a	=	allowable shear stress, in N/mm^2, defined in 3.2.

3.4   Bending strength check

When the lower bracket length or depth do not comply with requirements in annex 1, the actual section modulus, in cm^3, of the brackets and side frames at sections a) and b) shall be not less than:

.1   at section a):

$$Z_a = \frac{1{,}000 \ P_{fr,a} \ h}{m_a \ \sigma_a}$$

.2   at section b):

$$Z_b = \frac{1{,}000 \ P_{fr,a} \ h}{m_b \ \sigma_a}$$

where:

$P_{fr,a}$ =   pressure force defined in 3.1.1

h =   side frame span, in m, defined in figure 1

σ_a =   allowable normal stress, in N/mm^2, defined in 3.2

m_a, m_b =   bending moment coefficients defined in table 2

The actual section modulus of the brackets and side frames shall be calculated about an axis parallel to the attached plate, based on the measured thicknesses. For pre-calculations, alternative thickness values may be used, provided they are not less than:

.1 t_{REN}, for the web thickness;

.2   the minimum thicknesses allowed by the renewal criteria for flange and attached plating of a classification society which is recognized by the Administration in accordance with the provisions of SOLAS regulation XI-1/1, or by applicable national standards of the Administration which provide an equivalent level of safety.

The attached plate breadth is equal to the frame spacing, measured along the shell at midspan h.

If the actual section moduli at sections a) and b) are less than the values Z_a and Z_b, the frames and brackets shall be renewed or reinforced in order to obtain actual section moduli not less than 1.2 Z_a and 1.2 Z_b, respectively.

In such a case, renewal or reinforcements of the flange shall be extended over the lower part of side frames, as defined in figure 1.

Table 2 – Bending moment coefficients m_a and m_b

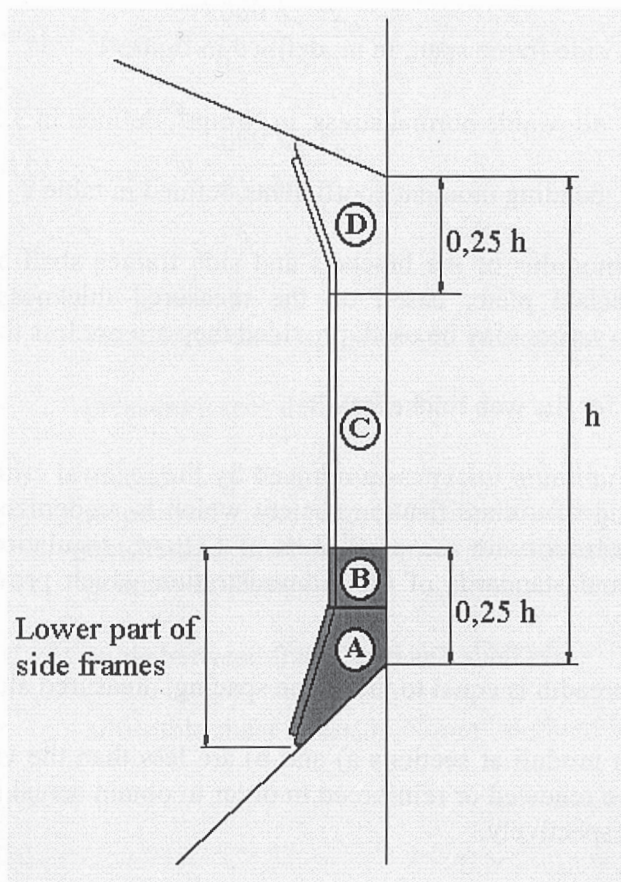|	m_a	m_b		
		$h_B = 0.08\ h$	$h_B = 0.1\ h$	$h_B = 0.125\ h$
Empty holds of ships approved to operate in non homogeneous loading conditions	10	17	19	22
Other cases	12	20	22	26
Note 1:	Non-homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling ratio, evaluated for each hold, exceeds 1.2 corrected for different cargo densities.			
Note 2:	For intermediate values of the bracket length h_B, the coefficient m_b is obtained by linear interpolation between the table values.			

Figure 1 – Lower part of side frames

Figure 1 – Lower part of side frames

Figure 2 – Sections a) and b)

d_a = lower bracket web depth

d_b = frame web depth

h_B = lower bracket length
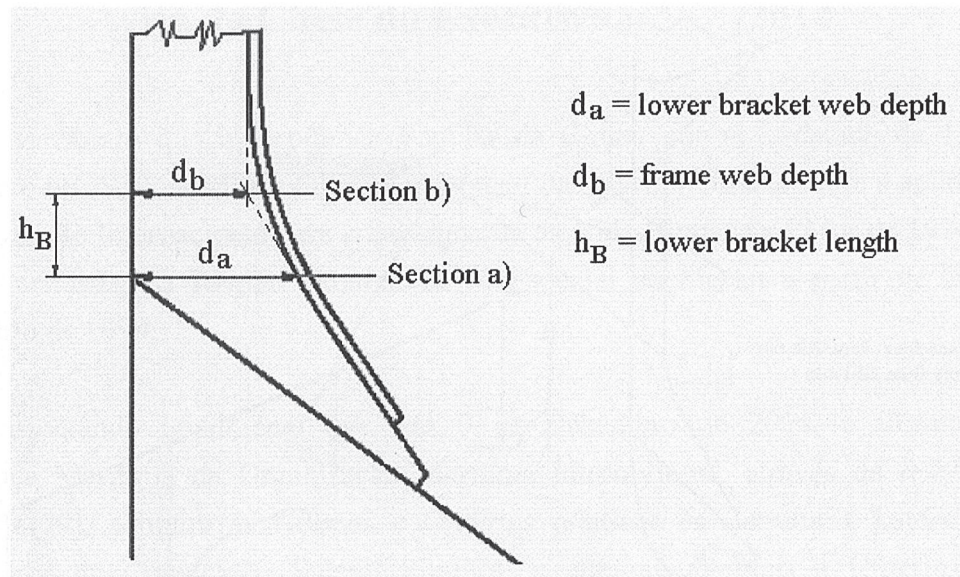
Figure 3 – Definition of the lower bracket web depth

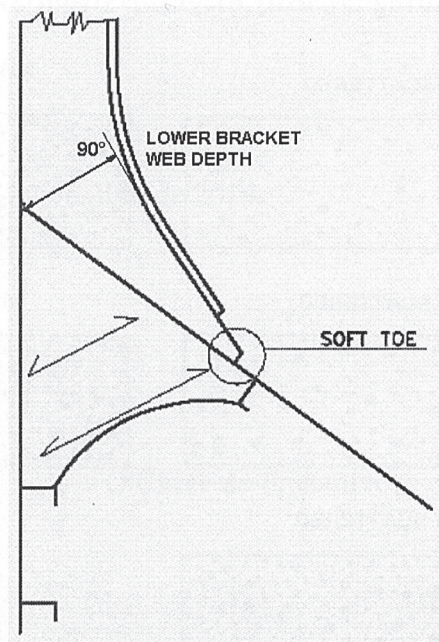## Figure 4 – Tripping brackets
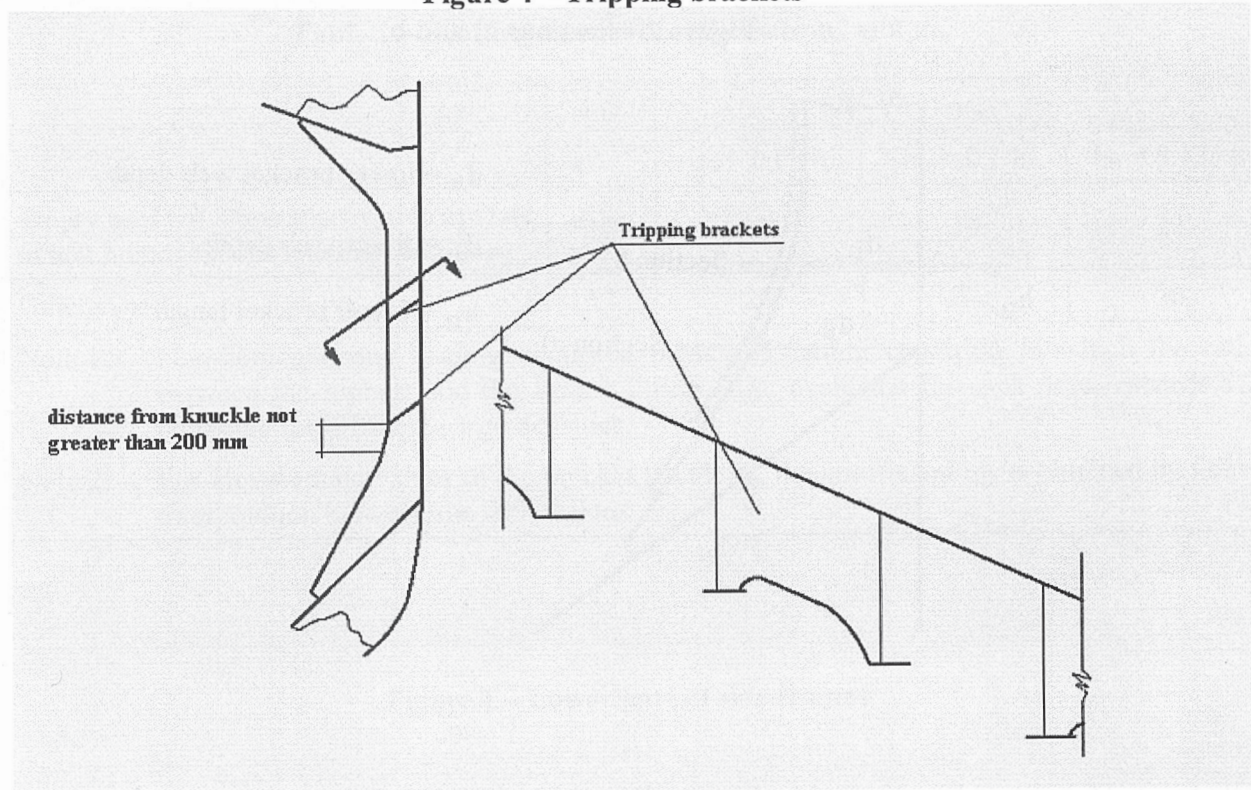

Figure 4 – Tripping brackets

Figure 5 - Pitting intensity diagrams (from 5% to 25% intensity)

Figure 5 - Pitting intensity diagrams (from 5% to 25% intensity)