RULES FOR CLASSIFICATION

Ships

Edition January 2017

Part 3 Hull

Chapter 10 Special requirements
FOREWORD

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**CHANGES – CURRENT**

This document supersedes the July 2016 edition.
Changes in this document are highlighted in red colour. However, if the changes involve a whole chapter, section or sub-section, normally only the title will be in red colour.

**Main changes January 2017, entering into force as from date of publication**

- **Sec.6 Special hull structures**
  - **Sec.6 [3]:** Blow out by air may be used to open sea chests and this design load shall be accounted for. The rules are however simplified so that 2 bar may be used and there is no need to request information about actual pressure from the designer.

**Editorial corrections**

In addition to the above stated changes, editorial corrections may have been made.
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SECTION 1 BOW IMPACT

Symbols

For symbols not defined in this section, refer to Ch.1 Sec.4.

\[ f_{pl} = \text{bending moment factor taken as:} \]
\[ f_{pl} = 8 \left( 1 + \frac{n_s}{2} \right) \]
\[ n_s = \text{end fixation factor taken as:} \]
\[ n_s = 0 \text{ for both ends simply supported} \]
\[ n_s = 1 \text{ for one end fixed in and one end simply supported} \]
\[ n_s = 2 \text{ for continuous members and members with both ends fixed}. \]

1 General

1.1 Application

1.1.1 The requirements given in this section apply to all ships, and cover the strengthening requirements for local impact pressure that may occur in the bow area.

1.1.2 The bow impact pressure given in [2.1] applies to areas away from knuckles, anchor bolster etc. that may obstruct the water flow during wave impacts. In way of such obstructions, additional reinforcement of the shell plating by fitting carlings or similar shall generally be considered.

1.1.3 Extent of strengthening

The strengthening shall extend forward of 0.1 \( L \) from the F.E. and vertically from the minimum design ballast draught, \( T_{BAL} \), defined in Ch.1 Sec.4 [3.1.6] and to forecastle deck if any. See Figure 1.

Outside the bow impact area the requirements given in [3], shall be gradually tapered to the ordinary requirements at 0.15 \( L \) from F.E.

However, if the flare angle, \( \alpha \) as defined in [2.1.1], is greater than 40° at 0.15 \( L \) from F.E., the bow impact area shall be extended to 0.15 \( L \) from F.E. with gradual tapering to 0.2 \( L \) from F.E.

Figure 1 Extent of strengthening against bow impact
2 Bow impact pressure

2.1 Design bow impact pressure

2.1.1 The design bow impact pressure, in kN/m², shall be taken as:

\[ P_{PB} = C \left(2.2 + C_f\right) \left(0.4V\sin\beta + 0.6\sqrt{L}\right)^2 \]

where:

- \( C = 0.18 (f_r C_W - 0.5 h_o), \) maximum 1.0
- \( f_r = \) reduction factor related to service restrictions as given in Ch.4 Sec.3
  - \( f_r = 1.0, \) unless otherwise specified
- \( C_W = \) wave coefficient as given in Ch.4 Sec.4
- \( h_o = \) vertical distance (positive upwards), in m, from the waterline at draught \( T_{SC} \) to the point considered
  - \( h_o = 0 \) for points between \( T_{BAL} \) and \( T_{SC} \)
- \( C_f = 1.5 \tan (\alpha + \gamma), \) maximum 4.0
- \( \alpha = \) flare angle in degrees between a vertical line and a tangential plane of side plating, measured at the point considered. With reference to Figure 2, the flare angle \( \alpha \) may normally be taken in accordance with:
  \[ \tan \alpha = \frac{a_1 + a_2}{h_d} \]
  - If there is significant difference between \( a_1 \) and \( a_2 \), more than one plane between the design waterline and upper deck (forecastle deck if any) may have to be considered.
  - \( \beta = \) angle in degrees between a longitudinal line and a tangential line of side plating measured at the point considered in plan view, see Figure 2
  - \( \gamma = 0.4 (\theta_r \cos \beta + \phi_r \sin \beta) \cdot 180/\pi \)
  - \( \theta_r = \theta \cdot \pi/180 \)
  - \( \phi_r = \phi \cdot \pi/180 \)
  - \( \theta, \phi = \) as given in Ch.4 Sec.3 [2.1] in degrees.
3 Scantling requirements

3.1 Plating

3.1.1 Side shell plating
The net thickness of the side shell plating, in mm, shall not be less than:

\[ t = 0.0158k_a b \sqrt{\frac{P_{pl} \ell}{C_d R e H}} \]

where:

- \( P_{pl} = P_{FB} \)
- \( C_d \) = plastic capacity coefficient taken as: \( C_d = 1.5 \)
- \( k_a = (k_{a1} - 0.25k_{a2})^2 \)
- \( k_{a1} = 1.1 \) in general
  \[ = 1.95\left(\frac{b}{1000R}\right)^{0.25} \]
- \( k_{a2} = b/a \), but need not to be taken less than 0.4, and shall not be taken greater than 1.0
- \( R \) = radius of curvature of shell plating in m
- \( P_{FB} \) = design bow impact pressure, in kN/m², as given in [2.1.1].
3.2 Stiffeners

3.2.1 Side shell stiffeners
The side shell stiffeners within the strengthening area defined in [1.1.3] shall comply with the following criteria:

a) The net web thickness, in mm, shall not be less than:

\[ t_w = \frac{f_{shr} P_{st}}{d_{shr} t_e H} \]

b) The effective net plastic section modulus, in cm³ calculated in accordance with Ch.3 Sec.7 [1.4.5], shall not be less than:

\[ Z_{pl} = \frac{1.2 P_{st} s \ell_{bdq}^2}{f_{pl} R_{eH}} + \frac{n_2 [1 - \sqrt{1 - (t_w/t_{wa})}] h_w t_w (h_w + t_p)}{8000} \]

where:

- \( P_{st} \) = effective pressure acting on the stiffener, in kN/m²
  = 0.5 \( P_{FB} \)
- \( P_{FB} \) = design bow impact pressure, in kN/m², as given in [2.1.1]
- \( f_{shr} \) = shear force distribution factor taken as:
  \( f_{shr} = 0.7 \)
- \( d_{shr} \) = effective web depth of stiffener, in mm, as defined in Ch.3 Sec.7 [1.4.3]
- \( t_w \) = net required web thickness in mm, according to a)
- \( t_{wa} \) = net actual web thickness in mm
- \( h_w \) = depth of stiffener web, in mm, as defined in Ch.3 Sec.7 [1.4.5]
- \( t_p \) = net thickness of stiffener attached plating, in mm, as defined in Ch.3 Sec.2 Figure 1

c) The slenderness ratio of the stiffeners shall comply with Ch.8 Sec.2.

3.2.2 Design of bulwarks against bow impact
In case of bulwarks in the bow impact area, the plating and stiffeners shall be in accordance with [3.1.1] and [3.2.2], respectively applying a linear varying pressure from 0.5\( P_{pl} \) or 0.5\( P_{st} \) at deck level to 0 at the top of the bulwark.

For bulwark stay, the effective net plastic section modulus, in cm³, calculated in accordance with Ch.3 Sec.7 [1.4.5], shall not be less than:

\[ Z_{pl} = \frac{P_{st} \ell_{st}^2}{6 R_{eH}} \]

where:

- \( \ell_{st} \) = length of stay in m, measured from deck.

3.2.3 Connection area
Shell stiffeners shall be connected to supports, e.g. stringers, web frames, decks or bulkheads. The connection area is generally obtained through fitting supporting members such as collar plate, lugs, end brackets or web stiffeners.
The load, in kN, transmitted through the primary support member web stiffener shall comply with the following criteria:

\[ W \leq \frac{A_I T e_H + A_w R e_H}{10} \]

where:
- \( W \) = load, in kN, as defined in Ch.6 Sec.7 [1.2.3], with \( P = 0.5 P_{FB} \)
- \( A_I \) = effective net shear area, in cm\(^2\), as defined in Ch.6 Sec.7 [1.2.3]
- \( A_w \) = effective net cross-sectional area, in cm\(^2\), as defined in Ch.6 Sec.7 [1.2.3].

The welding size at the connection between stiffener and primary supporting member shall be calculated according to Ch.13 Sec.1 [2.5.7].

End brackets of shell stiffeners shall be in accordance with slenderness criteria given in Ch.8 Sec.2 [5.2].

### 3.3 Primary supporting members

#### 3.3.1 General structural requirements

The section modulus requirements for the primary supporting member shall apply along the bending span clear of end brackets. The cross sectional area requirement for the primary supporting member shall be applied at the ends/supports.

The primary supporting members in the bow impact region shall be configured to ensure effective continuity of strength and the avoidance of hard spots.

As far as possible, web frames and stringers shall be fitted in the fore peak. However, the spacing of primary supporting members shall not be more than 4 times the stiffener spacing. Other structural arrangement may be accepted upon direct analysis.

In way of end supports of primary supporting members, i.e. stringers and web frames, which support shell stiffeners, web stiffening parallel to the flange shall be provided as necessary for ensuring the buckling strength of the member, as outlined in [3.3.2].

End brackets of primary supporting members shall be suitably stiffened along their edge. Consideration shall be given to the design of bracket toes to minimize abrupt changes of cross section.

In case of curved flange, the effective flange shall be taken according to Ch.3 Sec.7 [1.3.4].

#### 3.3.2 Bending and shear capacity of local girders

The net elastic section modulus of each primary supporting member, i.e. stringer and web frames, in cm\(^3\), calculated in accordance with Ch.3 Sec.7 [1.4.6] shall not to be less than:

\[ Z_{n50} = \frac{1000 f_{PSM} S f_{bdg}^2}{f_{bdg}^2 e_H} \]

where:
- \( f_{bdg} \) = bending moment distribution factor, as given in Ch.6 Sec.6 Table 1, but not to be taken less than 10
- \( S \) = primary supporting member spacing, in m, as defined in Ch.3 Sec.7 [1.2.2], see also Figure 3.
The net effective shear area of the web, in cm², of each primary supporting member at the supports, calculated in accordance with Ch.3 Sec.7 [1.4.6] shall not be less than:

\[ A_{shr} = \frac{10 f_{shr} P_{PSM} S_{shr}}{t_{ehl}} \]

where:

\[ f_{shr} = \text{shear force distribution factor taken as:} \]

\[ f_{shr} = 0.7 \]

\[ P_{PSM} = \text{effective pressure, in kN/m}^2, \text{acting on primary supporting member, taken as:} \]

\[ P_{PSM} = 0.4 P_{FB} \]

\[ P_{FB} = \text{design bow impact pressure, in kN/m}^2, \text{as given in [2.1.1].} \]

Figure 3 Primary member supporting shell stiffeners
3.3.3 Local buckling requirements

Close to shell the stiffening direction of primary supporting members, decks and bulkheads supporting shell stiffeners shall be arranged parallel to the web direction of the supported shell stiffeners, to protect against buckling.

The net plate thickness of primary supporting members, which support shell stiffeners, e.g. decks or bulkheads fitted in lieu of a stringer or a web frame, in mm, shall not be less than:

\[
t = \frac{f_p f_s P bw h}{\sin \phi_w \sigma} 10^{-3} - t_s
\]

where:

- \(f_p = (h - h_p)/h\)
- \(f_s = \cos \phi_s\) with respect to the stress component perpendicular to the stiffening direction of the elementary plate panel (EPP) considered
- \(f_s = \sin \phi_s\) with respect to the stress component parallel to the stiffening direction of the elementary plate panel (EPP) considered
- \(t_s = \frac{900 \rho_e h^4}{E_s \sigma}\)
- \(A_{ns} = \text{net cross-sectional area, in cm}^2\), of the stiffening members which are parallel to the stress component considered
- \(A\) = 0 if such stiffening members are not fitted
- \(h = \text{depth, in mm, of primary supporting member, and deck or bulkhead fitted in lieu of a primary supporting member, measured at right angle to its line of intersection with the shell. In case of a deck or bulkhead the depth need not be measured further than to the ship's centreline and need not be taken larger than the length, } h_m. \text{ See Figure 5 for illustration}\)
- \(h_m = \text{distance, in mm, measured along the side shell between the members which support the deck or the bulkhead}\)
- \(h_p = \text{distance, in mm, measured in the plane of the member, from the side shell to the mid point of the elementary plate panel (EPP) considered. In way of elementary plate panel (EPP) adjacent to the shell, with stiffening aligned with the shell frames, the length } h_p \text{ shall not be taken larger than the}\)
depth of the shell frames plus half the arm length of any bracket fitted on the shell frames. See Figure 5 for illustration

\[ s_w = \text{spacing, in mm, of the stiffening members parallel with the stress component considered} \]

\[ \sigma = 0.9 \sigma_{cr} \]

\[ \sigma_{cr} = \text{the critical buckling stress, in N/mm}^2, \text{as given in DNVGL-CG-0128 Sec.3, of the supporting plate member} \]

\[ \sigma_{cr} = \sigma_{crx}' \text{ for stress component parallel to the stiffeners} \]

\[ \sigma_{cr} = \sigma_{cry}' \text{ for stress component perpendicular to the stiffeners} \]

with the following assumption

- \( \sigma_x \geq 0 \) and \( \sigma_y \geq 0 \)
- \( \psi = 1.0 \)
- SP-A assessment method

\[ P_{bu} = \text{effective pressure, in kN/m}^2, \text{acting considered primary supporting member, deck or bulkhead} \]

\[ P_{bu} = 0.5P_{FB} \]

\[ s_b = \text{load breadth of shell, in mm, supported by considered primary supporting member, deck or bulkhead} \]

\[ \phi_w = \text{angle, in degrees, between the primary supporting member, deck or bulkhead and the shell plate} \]

\[ \phi_s = \text{angle, in degrees, measured in the plane of the member considered, between the side shell and the direction of the stiffeners of the elementary plate panel (EPP) considered.} \]

**Figure 5 Deck supporting shell frames**

**3.3.4 Direct calculation**

Alternative to the requirements given in [3.3.2] and [3.3.3], for complex girder system of primary stiffening system, the scantling requirements may be based on direct strength analysis. When direct calculation of the bow structure subjected to bow impact pressure is undertaken, a mean bow impact pressure = 0.375 \( P_{FB} \) is applicable. This pressure shall be applied on one or both sides of the bow. In the structure analysis, the nominal equivalent stress, \( \sigma_{vm} \), as given in Ch.7 Sec.3 [4.2] shall not exceed the yield stress, \( R_{y_{TH}} \), as given in
Ch.1 Sec.4 [2.2.1]. In case of beam assessment the nominal shear stress shall not exceed 90% of the shear yield stress $\tau_{yH}$.

In the buckling control, the utilisation factor, $\eta_{all}$, as given in Ch.8 Sec.1 [3.4], shall be taken equal to 1.0.

$$P_{FB} = \text{design bow impact pressure, in kN/m}^2,$$ as given in [2.1.1].

Guidance note:
When direct calculation is undertaken for the scantling assessment of a stringer or an equivalent PSM which is supporting shell stiffeners, the structure model should preferably extend from the stringer or equivalent PSM below to the stringer or equivalent PSM above the member to be considered by the assessment.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

4 Structural details

4.1 Tripping brackets

Tripping arrangements shall comply with Ch.8 Sec.2 [5.1]. In addition, tripping brackets shall be fitted at locations where the primary supporting member flange is knuckled or curved.

For side shell stiffeners, located in the area of strengthening as defined in [1.1.3], tripping brackets/intercoastals spaced not more than 4 times the stiffener spacing, see Figure 6.

The as-built thickness of the tripping brackets shall not be less than 75% of the as-built thickness of the side frame webs to which they are connected.

![Figure 6 Tripping brackets/intercoastals](image-url)
SECTION 2 BOTTOM SLAMMING

Symbols
For symbols not defined in this section, refer to Ch.1 Sec.4.

1 General

1.1 Application

1.1.1 The requirements given in this section, apply to ships with length $L > 65$ m where the minimum draughts forward, $T_{F-f}$ or $T_{F-e}$ as specified in [2.1.1], are less than 0.045 $L$, and cover the strengthening requirements for local impact pressure that may occur in the forward bottom structure. For ships with service restriction, the strengthening will be specially considered.

1.1.2 Local scantling increases due to bottom slamming pressure shall be made with due consideration given to details and avoidance of hard spots, notches and other harmful stress concentrations.

1.1.3 The draughts for which the bottom has been strengthened shall be indicated on the shell expansion plan and loading guidance information, as required in Ch.1 Sec.5.

1.1.4 Extent of strengthening
The strengthening shall extend forward of 0.3 $L$ from the F.E. over the flat bottom and adjacent plating with attached stiffeners up to a height of 0.05 $T_{F}$ but need not be taken greater than 500 mm above the baseline, see Figure 1.

![Figure 1 Extent of strengthening against bottom slamming](image)

Figure 1 Extent of strengthening against bottom slamming

Outside the region strengthened to resist bottom slamming the scantlings shall be tapered to maintain continuity of longitudinal and/or transverse strength.

For vessels with rise of floor, however, reduction will not be accepted below the bilge curvature.

2 Bottom slamming pressure

2.1 Design bottom slamming pressure

2.1.1 The bottom slamming pressure, in kN/m², shall be taken as:

$$P_{SL} = \frac{c_1 c_2}{T_{FL}} B (0.56 \frac{L}{1250} - \frac{x}{L})$$
where:

\[ c_1 = \text{coefficient to be taken as:} \]
\[ c_1 = \frac{L}{3} \text{ for } L \leq 150 \text{ m} \]
\[ c_1 = (225 - 0.5L)^{1/3} \text{ for } L > 150 \text{ m} \]

\[ c_2 = \text{coefficient to be taken as:} \]
\[ c_2 = 1675 \left(1 - \frac{20T_F}{L}\right) \]

\[ x = \text{longitudinal distance in m from F.E. to cross section considered, but need not to be taken smaller than } x_1: \]
\[ x_1 = [1.2 - \frac{c_1^{1/3} - L}{2500}]L \]

\[ B_B = \text{the breadth of bottom in m at the height } 0.15 \ T_F \text{ above the baseline measured at the cross section considered. } B_B \text{ shall not be taken greater than the smaller of } 1.35 \ T_F \text{ and } 0.55\sqrt{L} \]

\[ T_F = \text{design bottom slamming draught in m at the FE taken as:} \]
\[ T_{F-f} = \text{for normal ballast condition} \]
\[ T_{F-e} = \text{for seagoing condition with any ballast tanks empty in bottom slamming region} \]

Shall not be taken greater than \(1.15 \frac{L}{3}\) for vessels with \(C_B > 0.75\)

\[ T_{F-f} = \text{design bottom slamming draught in m at FE to be provided by the designer. } T_{F-f} \text{ shall be based on the minimum forward draught in normal ballast condition where ballast is carried in dedicated ballast tanks only} \]

\[ T_{F-e} = \text{design bottom slamming draught in m at FE to be provided by the designer. } T_{F-e} \text{ shall not be greater than the minimum draught at the FE indicated in the loading manual for all seagoing conditions where any of the ballast tanks within the bottom slamming region are empty.} \]

The assumed variation in design bottom slamming pressure is shown in Figure 2.
2.1.2 If the ship on the design ballast draught $T_{F-f}$ is intended to have full ballast tanks in the forebody and the load from the ballast will act on the bottom panel, the design bottom slamming pressure $P_{SL}$ may be reduced by $14 \ h \ \text{kN/m}^2$ where $h$ is the height, in m, of the ballast tank.

For strength assessment of double bottom floors and girders, $h$ shall not be taken greater than the double bottom height.

2.1.3 Loading manual information
The loading guidance information shall clearly state the design bottom slamming draughts $T_{F-f}$ and $T_{F-e}$.

3 Scantling requirements

3.1 Plating
The strengthening of plates against bottom slamming shall be according to Sec.1 [3.1] using:

$$P_{PL} = P_{SL}$$
where:

\[ P_{SL} = \text{shall be taken according to [2.1.1].} \]

### 3.2 Stiffeners

**3.2.1** The strengthening of stiffeners against bottom slamming shall be according to Sec.1 [3.2] using:

\[ P_{st} = 0.5 P_{SL} \]

where:

\[ P_{SL} = \text{shall be taken according to [2.1.1].} \]

**3.2.2 Connection area**

Bottom stiffeners shall be connected to supports, e.g. floors, girders or bulkheads. The connection area is generally obtained through fitting supporting members such as collar plate, end bracket or web stiffener. The requirements for net connection area of the supporting members and its welding size shall be according to Sec.1 [3.2.3] using:

\[ P = 0.5 P_{SL} \]

where:

\[ P_{SL} = \text{shall be taken according to [2.1.1].} \]

### 3.3 Primary supporting members

**3.3.1 Shear area**

The net effective shear area, in cm\(^2\), of each floor at the supports, calculated in accordance with Ch.3 Sec.7 [1.4.6] shall not be less than:

\[ A_{shr - n50} = \frac{10 f_{shr} P_{PSM} s_{shr}}{t_{eH}} \]

where:

\[ f_{shr} = \text{shear force distribution factor taken as:} \]

\[ f_{shr} = 0.5 \]

\[ P_{PSM} = \text{effective pressure, in kN/m}^2, \text{acting on PSM, taken as:} \]

\[ P_{PSM} = 0.4 P_{SL} \]

\[ P_{SL} = \text{shall be taken according to [2.1.1].} \]

The size and number of openings in web plating of the floors and girders shall be minimised considering the required shear area.

**3.3.2 Web thickness**

The net web thickness, in mm, of primary supporting members adjacent to the shell shall not be less than:

\[ t_w = \frac{s_w}{90} \sqrt{R_{235}} \]
where:

\[ s_W = \text{plate breadth, in mm, taken as the spacing between the web stiffening.} \]

### 3.3.3 Direct strength calculations

Alternative to the requirement given in [3.3.1], for complex arrangements, the scantling requirements may be based on direct strength assessment with a mean bottom slamming pressure = 0.375 \( P_{SL} \) at any location within the area of strengthening as defined in [1.1.4]. This pressure shall be applied on an area equal 0.03 \( L \) times the breadth of the bottom at the considered location. In case of FE analysis, the nominal equivalent stress \( \sigma_{vm} \), given in Ch.7 Sec.3 [4.2], shall not exceed \( R_{eh} \). For beam element assessment the nominal shear stress shall not exceed 0.9\( \tau_{eh} \).

**Guidance note:**

For direct calculation of primary supporting structure, the model should extend between effective supports longitudinally and transversely where fixed boundary conditions may be assumed. Otherwise, the model extent and boundary conditions will be specially considered.

---end---of---g-u-i-d-a-n-c-e---n-o-t-e---
SECTION 3 STERN SLAMMING

Symbols
For symbols not defined in this section, refer to Ch.1 Sec.4.

1 General

1.1 Application

1.1.1 The requirements given in this section, apply to ships with length \( L \) > 150 m, and cover the strengthening requirements for local impact pressure that may occur in the stern bottom structure.

1.1.2 Vessels where the flare angle of the lower shell is larger than 60º, typically container ships, passenger ships, ro-ro vessels, car carriers, offshore construction vessels and ships with twin skeg, shall be strengthened according to [3.1], [3.2.1] and [3.3.1].

1.1.3 The stern slamming requirements are in general applicable aft of 0.1 \( L \) forward of A.E.

2 Stern slamming pressure

2.1 Design stern slamming pressure

The design stern slamming pressure, in kN/m², shall be taken as:

\[
P_{SS} = 2.2C \left(0.6 + \frac{1.65a_0(0.55L - X) \sin^3 \alpha}{CB^3} \right)^2
\]

Shall not be taken greater than:

\[
P_{SS} = 2.2C \left(0.6 + \frac{1.65a_0 \sin^3 \alpha}{2CB} \right)^2
\]

where:

\[
C = 0.18 \left(C_W - 2h_o\right), \text{ maximum } 1.0 \text{ (minimum } 0.0)\

a_0 = \text{ acceleration parameter to be taken as:} \\
(3C_W/L) + 0.16
\]

\[
C_W = \text{ wave coefficient as given in Ch.4 Sec.4}\

h_o = \text{ vertical distance (positive downwards) in m from the waterline } T_{BA} \text{ to the shell at the position considered}\

T_{BA} = \text{ design minimum ballast draught in m at A.E.}\

X = \text{ distance from A.E. to position considered, in m}\

\alpha = \text{ flare angle in degrees as defined in Sec.1 [1].}


3 Scantling requirements

3.1 Plating
The strengthening of plates against stern slamming shall be according to Sec.1 [3.1] using:

\[ P_{pl} = P_{SS} \]

where:
\[ P_{SS} = \text{ster}

3.2 Stiffeners

3.2.1 The strengthening of stiffeners against stern slamming shall be according to Sec.1 [3.2] using:

\[ P_{st} = 0.5 P_{SS} \]

where:
\[ P_{SS} = \text{stern slamming pressure in kN/m}^2 \text{ as given in [2.1].} \]

3.2.2 Connection area
Stiffeners shall be connected to supports, e.g. floors, girders or bulkheads. The connection area is generally obtained through fitting supporting members such as collar plate, end bracket or web stiffener. The requirements for net connection area of the supporting members and its welding size shall be according to Sec.1 [3.2.3] using:

\[ P = 0.5 P_{SS} \]

where:
\[ P_{SS} = \text{stern slamming pressure in kN/m}^2 \text{ as given in [2.1].} \]

3.3 Primary supporting members

3.3.1 Shear area and section modulus
The shear area and the section modulus of the girders or and web frames supporting shell stiffeners shall be strengthened in accordance with Sec.1 [3.3] using:

\[ P_{PSM} = 0.4 P_{SS} \]

where:
\[ P_{SSL} = \text{shall be taken according to [2.1].} \]

3.3.2 Direct strength calculations
For complex arrangements of primary supporting members, the scantling requirements given in [3.3.1] may be based on direct strength analysis in accordance with Sec.1 [3.3.4] with a mean stern slamming pressure = 0.375 \( P_{SS} \).
3.4 Tripping brackets

Stiffeners and primary supporting members shall be supported by tripping brackets in accordance with Sec.1 [4.1].
SECTION 4 SLOSHING AND LIQUID IMPACT IN TANKS

Symbols

For symbols not defined in this section, refer to Ch.1 Sec.4.

\[ f_{bdg} = \text{bending moment factor as given in Sec.1} \]

\[ \alpha_p = \text{correction factor for the panel aspect ratio as defined in Ch.6 Sec.4 to be taken as:} \]

\[ \alpha_p = 1.2 - \frac{b}{2.1a} \]

but not to be taken as greater than 1.0

\[ \ell_{slh} = \text{effective sloshing length, in m, as defined in [2.2.2]} \]

\[ P_{slh-l} = \text{sloshing pressure in kN/m}^2 \text{ due to longitudinal liquid motion as defined in [2.2.3]} \]

\[ P_{slh-t} = \text{sloshing pressure in kN/m}^2 \text{ due to transverse liquid motion as defined in [2.3.3]} \]

\[ b_{slh} = \text{effective sloshing breadth, in m, as defined in [2.3.2]} \]

1 General

1.1 Application

1.1.1 The sloshing requirements given in this section cover the strengthening requirements for localised sloshing loads that may occur in tanks carrying liquid.

1.1.2 Where the effective sloshing length, \( \ell_{slh} \) is less than 0.03 \( L \), calculations involving \( P_{slh-l} \) are not required and where the effective sloshing breadth \( b_{slh} \) is less than 0.32 \( B \), calculations involving \( P_{slh-t} \) are not required.

1.1.3 The minimum sloshing pressure, \( P_{slh-min} \), for small tanks with volume less than 100 \( m^3 \) and for tanks of cellular construction, i.e. double hull construction with internal structures restricting the fluid motion, shall be taken equal to 12 kN/m\(^2\). This pressure is only applicable to plates, stiffeners and tripping brackets at internal surfaces such as web frames, girders and stringers and shall be verified in accordance with [3.1]. No other sloshing requirements are applicable to such tanks.

1.1.4 The minimum sloshing pressure, \( P_{slh-min} \), for other tanks than those defined in [1.1.3], shall be taken equal to 20 kN/m\(^2\). This pressure is only applicable to plates, stiffeners and tripping brackets at all internal surfaces as web frames, girders, stringers and wash bulkheads and shall be verified in accordance with [3.1].

1.1.5 For larger tanks with an effective sloshing breadth, \( b_{slh} \), as defined in [2.3.2], greater than 0.56 \( B \) or an effective sloshing length, \( \ell_{slh} \), as defined in [2.2.2], greater than 0.13 \( L \) at any filling level from 0.05 \( h_{max} \) to 0.95 \( h_{max} \), see [2.2.3], an additional assessment shall be carried out with liquid impact loads in accordance with [2.4], in addition to the sloshing loads as defined in [2.1] to [2.3].

1.1.6 Dry bulk cargo holds intended for carriage of ballast water are assumed either full or empty in seagoing condition and are not required to be assessed for sloshing or liquid impact loads.

1.2 General requirements

1.2.1 Filling heights of tanks

The scantlings of all tanks shall comply with the sloshing requirements given in this section for the following cases:

— unrestricted filling height for all tanks, except for cargo tanks,
— unrestricted filling height for cargo tanks with cargo density equal to \( \rho_c \), as defined in Ch.4 Sec.6,
all filling levels up to $h_{\text{part}}$ for cargo tanks with cargo density equal to $\rho_{\text{part}}$ taken as:

$$h_{\text{part}} = \frac{h_{tk} \rho_L f_{cd}}{\rho_{\text{part}}}$$

where:

- $h_{\text{part}}$ = maximum permissible filling height, in m, associated with a partial filling of the considered cargo tank with a high liquid density equal to $\rho_{\text{part}}$
- $h_{tk}$ = maximum tank height, in m
- $\rho_L$ = cargo density as defined in Ch.4 Sec.6
- $f_{cd}$ = factor defined in Ch.4 Sec.6
- $\rho_{\text{part}}$ = maximum permissible high liquid density as defined in Ch.4 Sec.6.

1.2.2 Structural details
Local scantling increases due to sloshing loads shall be made with due consideration given to details and avoidance of hard spots, notches and other harmful stress concentrations.

1.3 Application of sloshing pressure

1.3.1 General
The structural members of the following tanks shall be assessed for the design sloshing pressures $P_{slh-lng}$ and $P_{slh-t}$ in accordance with [1.3.3] and [1.3.4]:

- a) cargo and slop tanks
- b) fore peak and aft peak ballast tanks
- c) other tanks which allow free movement of liquid, e.g. ballast tanks, fuel oil bunkering tanks and fresh water tanks, etc.

1.3.2 Structural members to be assessed
The following structural members shall be assessed:

- a) plates and stiffeners forming boundaries of tanks
- b) plates and stiffeners on wash bulkheads
- c) web plates and web stiffeners of primary supporting members located in tanks
- d) tripping brackets supporting primary supporting members in tanks.

1.3.3 Application of design sloshing pressure due to longitudinal liquid motion
The design sloshing pressure due to longitudinal liquid motion, $P_{slh-l}$ as defined in [2] shall be applied to the following members as shown in Figure 1:

- a) transverse tight bulkheads
- b) transverse wash bulkheads
- c) stringers on transverse tight and wash bulkheads
- d) plating and stiffeners on the longitudinal bulkhead, deck and inner hull within a distance from the transverse bulkhead taken as:
  - $0.25 \ell_{slh}$
  - the distance between the transverse bulkhead and the first web frame if located inside the tank at the considered level,

  whichever is less.
In addition, the first web frame next to a transverse tight or wash bulkhead if the web frame is located within 0.25 $l_{slh}$ from the bulkhead, as shown in Figure 1, shall be assessed for the web frame reflected sloshing pressure, $P_{slh-wf}$, as defined in [2].

The sloshing pressure applied on internal members such as transverse web frames, horizontal stringers and wash transverse bulkheads shall not be taken less than the minimum sloshing pressure, $P_{slh-min}$, as given in [1.1].

**Figure 1 Application of sloshing loads due to longitudinal liquid motion**

1.3.4 Application of design sloshing pressure due to transverse liquid motion

The design sloshing pressure due to transverse liquid motion, $P_{shl-t}$, as defined in [2], shall be applied to the following members as shown in Figure 2.

a) Longitudinal tight bulkhead.

b) Longitudinal wash bulkhead and longitudinal girders.

c) Horizontal stringers on longitudinal tight and wash bulkheads, and vertical webs on transverse tight and wash bulkhead.

d) Plating and stiffeners on the transverse tight bulkheads including stringers and deck within a distance from the longitudinal bulkhead taken as:
— 0.25 \( b_{slh} \)
— the distance between the longitudinal bulkhead and the first girder if located inside the tank at the considered level, whichever is less.

In addition, the first girder next to the longitudinal tight or wash bulkhead if the girder is located within 0.25 \( b_{slh} \) from the longitudinal bulkhead, as shown in Figure 2, shall be assessed for the reflected sloshing pressure, where \( P_{slh-grd} \) as defined in [2].

The sloshing pressure applied on internal members as longitudinal stringers and girders shall not be taken less than the minimum sloshing pressure, \( P_{slh-min} \) as given in [1.1].

**Figure 2 Application of sloshing loads due to transverse liquid motion**

1.3.5 Combination of transverse and longitudinal fluid motion

The sloshing pressures due to transverse and longitudinal fluid motion are assumed to act independently. Structural members shall therefore be evaluated based on the greatest sloshing pressure due to longitudinal or transverse fluid motion.
2 Sloshing and liquid impact loads

2.1 General

2.1.1 Sloshing pressure on tank boundaries and internal divisions

The sloshing pressure due to liquid motions in a tank $P_{slh}$ acting on any load point of a tank boundary or internal divisions, in kN/m$^2$, for the sloshing design load scenario, given in [3.1.1], shall be taken as follows:

- $P_{slh} = P_{slh-l}$ for transverse bulkheads, as defined in [2.2]
- $P_{slh} = P_{slh-wf}$ for web frames and transverse stringers, as defined in [2.2]
- $P_{slh} = P_{slh-t}$ for longitudinal bulkheads, as defined in [2.3]
- $P_{slh} = P_{slh-grd}$ for longitudinal girders and stringers, see [2.3].

2.2 Sloshing pressure due to longitudinal liquid motion

2.2.1 Application

The sloshing pressure due to longitudinal liquid motion, $P_{slh-l}$, shall be taken as a constant value over the full tank depth and shall be taken as the greater of the sloshing pressures calculated for filling levels from 0.05 $h_{max}$ to 0.95 $h_{max}$, in 0.05 $h_{max}$ increments.

2.2.2 Effective sloshing length

The effective sloshing length, $\ell$ in m, shall be taken as defined in Table 1.

**Table 1 Effective sloshing length $\ell_{slh}$**

<table>
<thead>
<tr>
<th>Type of transverse bulkhead</th>
<th>$\ell_{slh}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transverse tight bulkheads</td>
<td>$\ell_{slh} = \frac{1 + n_{WT} \alpha_{WT} (1 + f_{wf} \alpha_{wf})}{1 + n_{WT}} \ell_{tk} - h$</td>
</tr>
<tr>
<td>Transverse wash bulkheads</td>
<td>$\ell_{slh} = \frac{1 + (n_{WT} - 1) \alpha_{WT} (1 + f_{wf} \alpha_{wf})}{1 + n_{WT}} \ell_{tk} - h$</td>
</tr>
</tbody>
</table>

where:

- $n_{WT}$ = number of transverse wash bulkheads in the tank
- $\alpha_{WT}$ = transverse wash bulkhead coefficient, to be taken as (see Figure 3):
  
  $\alpha_{WT} = \frac{A_{0WT}}{A_{tk-t-h}}$

- $\alpha_{wf}$ = transverse web frame coefficient, to be taken as (see Figure 4):
  
  $\alpha_{wf} = \frac{A_{0-wf-h}}{A_{tk-t-h}}$
For tanks with changing shape along the length and/or with web frames of different shape the transverse web frame coefficient, $\alpha_{wf}$, may be taken as the weighted average of all web frame locations in the tank given as:

$$\alpha_{wf} = \frac{\sum_{i=1}^{n_{wf}} A_{O-wf-h_i}}{n_{wf}}$$

- $A_{OWT}$ = total area of openings, in m$^2$, in the transverse section in way of the wash bulkhead below the considered filling height
- $A_{tk-h}$ = total transverse cross sectional area, in m$^2$, of the tank below the considered filling height
- $A_{O-wf-h}$ = total area of openings, in m$^2$, in the transverse section in way of the web frame below the considered filling height
- $f_{wf}$ = factor to account for number of transverse web frames and transverse wash bulkheads in the tank, to be taken as:

$$f_{wf} = \frac{n_{wf}}{1 + n_{WT}}$$

- $n_{wf}$ = number of transverse web frames, excluding wash bulkheads, in the tank
- $\ell_{tk-h}$ = length of tank, in m, at considered filling height.

Figure 3 Transverse wash bulkhead coefficient
2.2.3 Sloshing pressure in way of transverse bulkheads

The sloshing pressure in way of transverse bulkheads including wash bulkheads due to longitudinal liquid motion, in kN/m², for a particular filling level, shall be taken as:

\[ P_{slh} = \rho_{slh} g \cdot \ell_{slh} \cdot F_{slh} \left[ 0.4 - \left( 0.39 - \frac{1.7 \ell_{slh}}{L} \right) \frac{L}{350} \right] \]

where:

- \( F_{slh} = \) coefficient taken as:
  \[ f_{slh} = 1 - 2 \left( 0.7 - \frac{h_{fill}}{h_{max}} \right)^2 \]

- \( h_{fill} = \) filling height, measured from tank bottom, in m, see Figure 3.

2.2.4 Sloshing pressure on internal web frames or transverse stringers adjacent to a transverse bulkhead

For tanks with internal web frames the sloshing pressure acting on a web frame or transverse stringer adjacent to transverse bulkheads or transverse wash bulkheads due to longitudinal liquid motion, in kN/m², provided it is located within 0.25 \( \ell_{slh} \) from the bulkhead, shall be taken as:

\[ P_{slh-wf} = P_{slh} - \left( 1 - \frac{s_{wf}}{\ell_{slh}} \right)^2 \]

where:

- \( s_{wf} = \) distance from transverse bulkhead to web frame under consideration, in m.

The distribution of pressure across web frames and transverse stringers is given in Figure 5.
2.3 Sloshing pressure due to transverse liquid motion

2.3.1 Application
The sloshing pressure due to transverse liquid motion, $P_{slh-t}$, shall be taken as a constant value over the full tank depth and shall be taken as the greater of the sloshing pressures calculated for filling levels from 0.05 $h_{max}$ to 0.95 $h_{max}$, in 0.05 $h_{max}$ increments.
2.3.2 Effective sloshing breadth
The effective sloshing breadth, in m, shall be taken as in Table 1, but not less than 0.3 B.

<table>
<thead>
<tr>
<th>Table 2 Effective sloshing breadth $b_{slh}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of longitudinal bulkhead</strong></td>
</tr>
<tr>
<td>Longitudinal tight bulkheads</td>
</tr>
<tr>
<td>Longitudinal wash bulkheads</td>
</tr>
</tbody>
</table>

where:

- $n_{WL} = \text{number of longitudinal wash bulkheads in the tank}$
- $\alpha_{WL} = \text{longitudinal wash bulkhead coefficient}$:
  $$\alpha_{WL} = \frac{A_{OWL}}{A_{tk-L-h}}$$
- $\alpha_{grd} = \text{girder coefficient, to be taken as}$:
  $$\alpha_{grd} = \frac{A_{O-grd-h}}{A_{tk-L-h}}$$
- $A_{OWL} = \text{total area of openings, in m}^2, \text{in the longitudinal section in way of the wash bulkhead below the considered filling height}$
- $A_{tk-L-h} = \text{total longitudinal cross sectional area, in m}^2, \text{of the tank below the considered filling height}$
- $A_{O-grd-h} = \text{total area of openings, in m}^2, \text{in the longitudinal section in way of the web frame below the considered filling height}$
- $f_{grd} = \text{factor to account for number of longitudinal girders and longitudinal wash bulkheads in the tank, to be taken as}$:
  $$f_{grd} = \frac{n_{grd}}{1 + n_{WL}}$$
- $n_{grd} = \text{number of longitudinal girders, excluding longitudinal wash bulkheads, in the tank}$
- $b_{tk-h} = \text{breadth of tank, in m, at considered filling height}$

2.3.3 Sloshing pressure in way of longitudinal bulkheads
The sloshing pressure in way of longitudinal bulkheads including wash bulkheads due to transverse liquid motion, in kN/m$^2$, for a particular filling level, shall be taken as:

$$P_{slh-t} = 7 p_{slh} g f_{slh} \left(\frac{b_{slh}}{B} - 0.3\right)GM^{0.75}$$

where:

- $b_{slh} = \text{effective sloshing breadth defined in [2.3.2]}$
- $GM = \text{metacentric height, given in Ch.4 Sec.3 [2.1.1]}$

For the calculation of sloshing pressure in ballast tanks the "normal ballast condition" shall be used.
For the calculations of sloshing pressure in cargo tanks, the "partial load condition" shall be used.

2.3.4 Sloshing pressure on internal girders or longitudinal stringers adjacent to longitudinal bulkheads
For tanks with internal girders or stringers, the sloshing pressure acting on the girder/web frame adjacent to longitudinal bulkheads and longitudinal wash bulkhead, in kN/m, provided it is located within 0.25 \( b_{slh} \) from the bulkhead, shall be taken as:

\[
P_{sthl-grd} = P_{stl} - r \left( 1 - \frac{s_{grd}}{b_{slh}} \right)^2
\]

where:

\[s_{grd} = \text{distance from longitudinal bulkhead to girder under consideration, in m.}\]

The distribution of pressure across stringers is given in Figure 6. The distribution of pressure across longitudinal girders is similar to the deck web frame shown in Figure 5.

![Figure 6 Sloshing pressure distribution on longitudinal stringers and girders](image)

2.4 Impact pressure in larger tanks

2.4.1 Application
The requirements given in this article apply to ships with length \( L > 100 \text{ m} \) and for tanks with effective sloshing length \( \ell_{slh} > 0.13 L \) and/or effective sloshing breadth \( b_{slh} > 0.56 B \), and cover the strengthening requirements for localised impact loads that may occur in larger tanks carrying liquids.

2.4.2 Restrictions on GM
Tanks with free sloshing breadth \( b_{slh} > 0.56 B \) will be subject to specified restrictions on maximum metacentric height (\( GM \)). In addition, for such tanks or tanks with a sloshing length \( \ell_{slh} > 0.13 L \) filling
height will be restricted to avoid resonance between the liquid motion and the pitch roll motion of the ship. For this, the ship’s periods of pitch and roll motion shall be determined as given in Ch.4 Sec.3 [2.1]. The natural periods of the liquid in the tank, in s, shall be determined by the following formula:

\[ T_{t,b} = 1.132 \cdot \sqrt{\frac{e_t}{f}} \]

where:

- \( f \) = hyperbolic function, defined as:
  \[ f = \tanh\left(\frac{n-h}{e_t}\right) \]
- \( e_t \) = sloshing length \( \ell_{slh} \) for longitudinal liquid motion; sloshing breadth \( b_{slh} \) for transverse liquid motion, in m
- \( h \) = maximum allowable filling height in m.

### 2.4.3 Impact pressure in upper part of tanks

Tanks with free sloshing length \( \ell_{slh} > 0.13 \ L \) or with free sloshing breadth \( b_{slh} > 0.56 \ B \) will generate an impact pressure on horizontal and inclined surfaces adjacent to vertical surfaces in upper part of the tank due to high liquid velocities meeting these surfaces.

For horizontal or inclined panels (deck, horizontal stringers etc.) the impact pressure \( P_i \) in kN/m² on upper parts of the tank may be taken as:

Within 0.15 \( \ell_{slh} \) from transverse wash or end bulkheads:

\[ P_{i-t} = \rho \ g \ k_f \left( 220 \ \frac{\ell_{slh}}{L} - 7.5 \right) \sin^2 \gamma \quad \text{for} \quad \frac{\ell_{slh}}{L} < \frac{350 + L}{3350} \]

\[ = \rho \ g \ k_f \left( 25 + \frac{L}{13} \right) \left( 0.5 + \frac{\ell_{slh}}{L} \right) \sin^2 \gamma \quad \text{for} \quad \frac{\ell_{slh}}{L} > \frac{350 + L}{3350} \]

Within 0.15 \( b_{slh} \) from longitudinal wash bulkheads and tank sides:

\[ P_{i-l} = \frac{240 \rho \ g \ k_f \left( b_{slh} \ / \ B - 0.3 \right)}{B} \ GM^{1.5} \sin^2 \gamma \]

Outside 0.15 \( \ell_{slh} \) and 0.15 \( b_{slh} \) the pressure may be reduced to zero at 0.3 \( \ell_{slh} \) and 0.3 \( b_{slh} \), respectively, see Figure 7. In tank corners within 0.15 \( \ell_{slh} \) and 0.15 \( b_{slh} \) the impact pressure shall not be taken smaller than \( P_{i-t} \) (transversely) or \( P_{i-l} \) (longitudinally) + 0.4 \( P_{i-t} \) (transversely).

The reflected impact pressure on vertical surfaces adjacent to horizontal or inclined surfaces above will have an impact pressure linearly reduced to 50% of the pressure above, 0.1 \( \ell_{slh} \) or 0.1 \( b_{slh} \) m below.

\( \ell_{slh}, b_{slh} \) and \( GM \) are as given in [2.2.2], [2.3.2] and Ch.4 Sec.3 [2.1.1], respectively.

\[ k_f = 1 - 4 \left( 0.6 - \frac{h}{H} \right)^2 \], maximum = 1.0

\( h \) = maximum allowable filling height, in m
$H$ = tank height, in m, within 0.15 $t_{slh}$ or 0.15 $b_{slh}$, see Figure 7

$\gamma$ = angle between considered panel and the vertical, in degree.

Figure 7 Pressure distribution

2.4.4 For tanks with upper panels higher than $L/20$ in m above lowest seagoing waterline the impact pressures given in [2.4.3] shall be multiplied by the following magnification factors:

$$k_m = 1 + 18 \frac{z_c}{L}$$

for longitudinal impact

$$k_m = 1 + 17 \left( \frac{z_c \cdot GM}{L^2} \right)$$

for transverse impact

where:

$z_c = z - T_s - L/20$, in m

$T_s = T_{LC}$

$0.50 T_{SC}$ may normally be used.

2.4.5 Impact pressure in lower part of smooth tanks

In larger tanks ($t_{slh} > 0.13 L$ or $b_{slh} > 0.56 B$) with double bottom and which have no internal transverse or longitudinal girders restraining the liquid movement at low minimum filling heights ($2 < h < 0.2 t_{slh}$ or $2 < h < 0.2 b_{slh}$) the impact pressure $P_{i-l}$ and $P_{i-t}$ in kN/m$^2$ on vertical and inclined tank surfaces shall not be taken less than:

$$P_{i-l} = 1.42 \rho g_0 k t_{slh} \sin^2 \delta$$

on transverse bulkheads up to a height of 0.2 $t_{slh}$
\[ P_{i-t} = 1.5 \rho g_0 b_{slh} \sin^2 \delta \]
on longitudinal bulkheads up to a height of 0.2 \( b_{slh} \)

The impact pressure may be reduced to zero 1 metre above the heights given, see Figure 7.

In tank corners at outermost side of transverse bulkheads the impact pressure within 0.15 \( b_{slh} \) shall not be taken smaller than:

\[ P_i = P_{i-l} \text{ (longitudinally)} + 0.4 P_{i-t} \text{ (transversely)} \]

If the tank is arranged with a horizontal stringer within the height \( h < 0.2 \ell_{slh} \) or \( h < 0.2 b_{slh} \) a reflected impact pressure of the same magnitude as on adjacent transverse or longitudinal bulkhead shall be used on the under side of the stringer panel.

\( \ell_{slh} \) and \( b_{slh} \) are free sloshing length and breadth in m at height considered, as given in [2.2.2] and [2.3.2], respectively.

\( k \)
= 1 for \( L < 200 \)
= 1.4 – 0.002 \( L \) for \( L \geq 200 \)

\( \delta \)
= angle, in degree, between the lower boundary panel and the horizontal.

2.4.6 For tanks with smooth boundaries (no internal structural members) with tank bottom higher than the \( D/2 \), the low filling impact pressure as given in [2.4.5] shall be multiplied by the following magnification factor:

\[ \left( 1 + \frac{2z_i \theta}{\ell_{slh}} \right)^2 \text{ in longitudinal direction} \]
\[ \left( 1 + \frac{2z_i \varphi}{b_{slh}} \right)^2 \text{ in transverse direction} \]

where:

\( \theta \) and \( \varphi \)
= roll and pitch angle given in degrees Ch.4 Sec.3 [2.1.1] and Ch.4 Sec.3 [2.1.2]

\( z_i \)
= distance from panel considered to \( D/2 \), in m.

3 Scantling requirements

3.1 Scantling requirements due to sloshing pressure

3.1.1 Plating

The net thickness of plating, in mm shall not be less than:

\[ t = 0.0158 a_p b \sqrt{ \frac{P_{slh}}{C_a R_{elH}} } \]

where:

\( C_a \)
= permissible bending stress coefficient for acceptance criteria AC-I as defined in Ch.6 Sec.4 [1.1.1]
\( P_{slh} \) = sloshing pressure in kN/m² taken as the greater of \( P_{slh-l} \) or \( P_{slh-t} \) as specified in [2.2] and [2.3]. For internal members like wash bulkheads the sloshing pressure shall not be taken less than \( P_{slh-min} \) as given in [1.1].

### 3.1.2 Stiffeners

The net section modulus, in cm³, of stiffeners shall not be less than:

\[
Z = \frac{f_u \cdot P_{slh} \cdot s \cdot f_{bdg}^2}{f_{bdg} \cdot C_s \cdot R_{ell}}
\]

where:

- \( f_u \) = factor for unsymmetrical profiles as defined in Ch.6 Sec.5 [1.1.2]
- \( f_{bdg} \) = bending moment factor as defined in Ch.6 Sec.5 [1.1.2]
- \( C_s \) = permissible bending stress coefficient for acceptance criteria AC-I as defined in Ch.6 Sec.5 [1.1.2]
- \( P_{slh} \) = sloshing pressure in kN/m² taken as the greater of \( P_{slh-l} \) or \( P_{slh-t} \) as specified in [2.2] and [2.3]. For internal members like wash bulkheads the sloshing pressure shall not be taken less than \( P_{slh-min} \) as given in [1.1].

### 3.1.3 Tripping brackets supporting primary supporting members

The net section modulus, in cm³ in way of the base within the effective length, \( d \), of tripping brackets and net shear area, in cm², after deduction of cut-outs and slots, of tripping brackets supporting primary supporting members shall not be less than:

\[
Z = \frac{1000 \cdot P_{slh} \cdot s_{trip} \cdot h^2}{2 \cdot C_s \cdot R_{ell}}
\]

\[
A_{shr} = \frac{10 \cdot P_{slh} \cdot s_{trip} \cdot h}{C_t \cdot R_{ell}}
\]

where:

- \( P_{slh} \) = sloshing pressure in kN/m² taken as the greater of \( P_{slh-lng} \), \( P_{slh-tr} \), \( P_{slh-wf} \) or \( P_{slh-grd} \) as specified in [2.1.1]. The average pressure may be calculated at mid point of the tripping bracket taking into account the distribution as shown Figure 1 and Figure 2. The sloshing pressure shall not be taken less than \( P_{slh-min} \) as given in [1.1]
- \( s_{trip} \) = mean spacing, between tripping brackets or other primary supporting members or bulkheads, in m
- \( h \) = height of tripping bracket, see Figure 8, in m
- \( C_s \) = permissible bending stress coefficient for tripping brackets to be taken as 0.75
- \( C_t \) = permissible shear stress coefficient for tripping brackets to be taken as 0.75.

The effective breadth of the attached plate to be used for calculating the section modulus of the tripping bracket shall be taken equal to \( h/3 \).
3.2 Scantling requirements due to liquid impact pressure

3.2.1 Design impact pressure
Design impact pressure $P_i$ in kN/m$^2$ shall be taken as the maximum applicable value of $P_{i-f}$ and $P_{i-t}$ as given in [2.4.3] and [2.4.5].

3.2.2 Plating
The strengthening of plates against liquid impact pressure shall be according to Sec.1 [3.1] using:
$$P_{pl} = P_i$$

3.2.3 Stiffeners
The strengthening of stiffeners against liquid impact pressure shall be according to Sec.1 [3.2] using:
$$P_{st} = 0.5 P_i$$

3.2.4 Connection area and welding of stiffeners due to impact pressure
The requirements for net connection area given in Sec.1 [3.2.3] shall be based on liquid impact pressure $P_i$ as defined in [3.2.1].
The leg length, in mm, of continuous fillet welding of the stiffener to the plating when impact pressure is acting on the stiffener side shall not be less than:
$$t_{leg} = 1.2 s P_i 10^{-5}$$

3.2.5 Bending and shear capacity of local girders
The net section modulus of each primary supporting member subjected to impact pressures, i.e. stringers and web frames, in cm$^3$, which is supporting stiffeners shall not to be less than:
$$Z_{n50} = \frac{1000 P_{sk} \ell_p \ell_{bdg}}{\ell_{bdg}^2 \ell_{el}^2}$$
where:

\[ f_{bdg} = \text{bending moment factor, as given in Ch.6 Sec.6 Table 1} \]

\[ \ell_p = \text{loaded length of girder in m, maximum } \ell_{bdg}, \text{ but need not be taken greater than } 0.1 \ell_{slh} \text{ or } 0.1 b_{slh}, \text{ respectively, for longitudinal or transverse impact pressure} \]

\[ k_p = \text{area reduction factor for impact pressure} \]

\[ = 1.1 - 10 \frac{b}{\ell_{slh}}, \text{ minimum 0.25 for horizontals} \]

\[ = 1.1 - 10 \frac{b}{\ell_{bdg}}, \text{ minimum 0.25 for verticals} \]

\[ \ell'_s = \ell_{slh} \text{ or } b_{slh} \text{ as defined in [2.2.2] and [2.3.2].} \]

The net shear area of the web, in cm², of each primary supporting member at the support/toe of end brackets subjected to impact pressures shall not be less than:

\[ A_{shr - n50} = \frac{10f_{shr}P_i \ell_{shr} K_p}{t_{eff}} \]

where:

\[ f_{shr} = \text{shear force distribution factor taken as: } f_{shr} = 0.63 \]

The leg length, in mm, of continuous fillet welding of the web to the plating when impact pressure is acting on the web side shall not be less than:

\[ t_{leg} = 1.2 s P_i 10^{-5} \]
SECTION 5 WHEEL LOADING

Symbols

For symbols not defined in this section, refer to Ch.1 Sec.4.

\( \sigma_{hg} \) = hull girder bending stress, in N/mm\(^2\), for load component S + D shall be taken as defined in Ch.5 Sec.3 [2] for ships without large deck openings and in Ch.5 Sec.3 [3] for ships with large deck openings as maximum from HSM-1, HSM-2, OST-1S, OST-2S, OST-1P and OST-2P only

\( Q \) = maximum axle load in t

\( a_{z-env} \) = vertical envelop acceleration in m/s\(^2\) as defined in Ch.4 Sec.3 [3.3] using \( y = B/2 \).

1 General

1.1 Application

1.1.1 These requirements cover wheel loads from cargo handling vehicles and from cargo transporting vehicles kept onboard and supported on their wheels when the ship is at sea. Vehicles supported by crutches, horses etc. will be specially considered.

1.1.2 Scantling for stiffeners of decks intended for carrying MAFI trailers or other vehicles carrying more than one tier of container, shall be specially considered in a heeled condition.

1.1.3 The strength requirements are based on the assumption that the considered element (plating or stiffener) is subjected to one load area only, and that the element is continuous in both directions across several evenly spaced supports. Requirements for other loads and or boundary conditions will be specially considered.

1.1.4 Signboards stating the maximum permissible axle load, the maximum tyre pressure of pneumatic tyres, wheel arrangement on axles, and specially approved vehicles shall be fitted in suitable positions onboard.

1.1.5 Other types and combinations of car decks and materials may be approved after special considerations in the individual case.

1.1.6 For decks covered with protection plates, such as wooden plating, an increased footprint area may be considered for the scantling requirements for plates and stiffeners, taking into account the load spreading through the cover plate. A spreading of 30 degrees may be assumed.

2 Wheel loads

2.1 Design deck pressure

2.1.1 For individual vehicles with specified arrangement and dimensions of footprints, the design pressure, in kN/m\(^2\), shall be taken as:

- Normal operation at harbour

\[ P_{wl-1} = \frac{Q}{h_0^{0.811} \cdot b_1} \left( g + \frac{3}{\sqrt{Q}} \right) 10^6 \]

- Normal operation at seas
\[ P_{wl-2} = \frac{q}{n_\theta a_1 b_1} (g + a_{z-e_{nw}}) 10^6 \]

- \( n_\theta \) = number of loads areas on the axle
- \( a_1 \) = extent in mm of the load area parallel to the stiffeners (see Figure 1)
- \( b_1 \) = extent in mm of the load area perpendicular to the stiffeners (see Figure 1).

The load area as indicated in Figure 1 is defined as:
- the footprint area of individual wheels or
- the rectangular enveloped area of footprints of a wheel group.

\begin{table}
\centering
\begin{tabular}{|c|c|c|c|}
\hline
Number of wheels in a group & Footprint dimensions (real contact areas between the tyres and the deck) & Design load area for axle perpendicular to the stiffeners & Design load area for axle parallel to the stiffeners \\
\hline
Single wheel & \includegraphics{single_wheel_diagram} & \includegraphics{single_wheel_diagram} & \includegraphics{single_wheel_diagram} \\
\hline
Double wheels & \includegraphics{double_wheels_diagram} & \includegraphics{double_wheels_diagram} & \includegraphics{double_wheels_diagram} \\
\hline
Triple wheels & \includegraphics{triple_wheels_diagram} & \includegraphics{triple_wheels_diagram} & \includegraphics{triple_wheels_diagram} \\
\hline
\end{tabular}
\end{table}

Figure 1 Definition of load area
In general the scantlings shall be checked according to both definitions. If, however, the distance \( e \) between individual footprints is less than the breadth \( b_2 \) of the prints, the load area may normally be calculated for the group of wheels only.

2.1.2 If the arrangement and dimensions of footprints are not available for vehicles with pneumatic tyres, the design pressure, in kN/m\(^2\), may normally be taken as:

- Normal operation at harbour
  \[ P_{wl-1} = \frac{P_0}{w} \left( 1 + \frac{3}{g\sqrt{Q}} \right) \]

- Normal operation at seas
  \[ P_{wl-2} = \frac{P_0}{w} \left( 1 + \frac{a - enw}{g} \right) \]

where:

- \( P_0 \) = maximum tyre pressure in kN/m\(^2\)
  - = 1000 for cargo handling vehicles unless otherwise specified
  - = 120(\( \sqrt{Q} + 3 \)) for road transporters unless otherwise specified
- \( w \) = 1.0 in general
  - = 1.20 when double wheels are specified
  - = 1.27 when triple wheels are specified.

The load area dimensions, in mm, shall in general be taken as:

\[ a_1 = \sqrt{kA} \cdot 10^3 \]
\[ b_1 = \sqrt{A/k} \cdot 10^3 \]

where:

- \( k \) = \( k_1 \) in general
  - = \( k_2 \) for plating when \( k_2 < k_1 \) and:
  \[ \frac{wQ}{n_0 b^2} 10^6 \geq 100 \]
- \( k_1 \) = 2.0 for single wheel
  = 2.0 for multiple wheels with axle parallel to stiffeners
  = 0.8 for double wheels with axle perpendicular to stiffeners
  = 0.5 for triple wheels with axle perpendicular to stiffeners
- \( k_2 \) = \( \frac{\sqrt{A}}{2b} \cdot 1000 \)
- \( A \) = load area in m\(^2\)
  \[ A = \frac{gQ}{n_0 P_0} \]
- \( n_o \) = number of axle areas on the axle
  \( n_0 = 2 \) otherwise specified.
2.1.3 For heavy vehicles where the stowing and lashing arrangement may significantly affect the load distribution at sea, the design pressure for individual load areas will be specially considered.

2.1.4 Deck areas for wheel loads from cargo handling vehicles, which are frequently operating in all directions, shall be checked for design loads with axle parallel and perpendicular to stiffeners.

# 3 Scantling requirements

## 3.1 Plating

### 3.1.1 Net thickness

The net thickness, in mm, of deck plating subjected to wheel loading shall not be less than:

\[
t = \frac{\frac{774}{\alpha_p} \sqrt{\frac{k_w c b P}{m C_a R_{eH}}}}{10^{-3}}
\]

where:

\[
\alpha_p = \text{coefficient as defined in Ch.6 Sec.4}
\]

\[
k_w = \text{coefficient taken as:}
\]

\[
k_w = 1.3 - \frac{4.2}{\left(\frac{a_1}{b} + 1.8\right)^2}
\]

not to be greater than 1.0 for \(a_1 \geq 1.94 b\)

\[
c = \text{coefficient taken as:}
\]

\[
c = b_1 \quad \text{for } b_1 \leq b
\]

\[
c = b \quad \text{for } b_1 > b
\]

\[
a_1, b_1 = \text{extents, in mm, of the load area as defined in [2.1.1]}
\]

\[
P = \text{design pressure in kN/m}^2, \text{as defined in [2.1.1] and [2.1.2] considering design load set being defined in Ch.6 Sec.2}
\]

\[
m = \text{bending moment factor taken as (see Figure 2)}:
\]

\[
m = \left(\frac{b_1}{b}\right)^2 \frac{38}{4.7 \frac{b_1}{b} + 6.5} \quad \text{for } b_1 \leq b
\]

\[
m = 13.57 \quad \text{for } b_1 > b
\]

\[
C_a = \text{permissible bending stress coefficient for plate taken as:}
\]

\[
C_a = \beta_a - \frac{\sigma_{kg}}{R_{eH}}
\]

not to be taken greater than \(C_{a-max}\)

\[
\alpha_a = \text{coefficient as defined in Table 1}
\]

\[
\beta_a = \text{coefficient as defined in Table 1}
\]

\[
C_{a-max} = \text{maximum permissible bending stress coefficient for AC-I and AC-II as defined in Table 1.}
\]
### Table 1 Plating definition of $\beta_a$, $\alpha_a$ and $C_{a\text{-}max}$

<table>
<thead>
<tr>
<th>Acceptance criteria</th>
<th>Structural member</th>
<th>$\beta_a$</th>
<th>$\alpha_a$</th>
<th>$C_{a\text{-}max}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC-I</td>
<td>Longitudinal member</td>
<td>1.9</td>
<td>0.50</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>Longitudinal stiffened plating</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transverse stiffened plating</td>
<td>1.9</td>
<td>1.0</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>Other member</td>
<td>1.8</td>
<td>0</td>
<td>1.8</td>
</tr>
<tr>
<td>AC-II</td>
<td>Longitudinal member</td>
<td>2.1</td>
<td>0.5</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Longitudinal stiffened plating</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transverse stiffened plating</td>
<td>2.1</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Other member</td>
<td>2.0</td>
<td>0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

### Figure 2 Bending factor for plates

#### 3.2 Stiffeners

#### 3.2.1 Net section modulus

The net section modulus, in cm$^3$, for deck beams and longitudinals subjected to wheel loading shall not be less than:

$$Z = \frac{P k_2 c d}{m} \frac{\ell}{b d_g} R_{eH} 10^{-3}$$
where:

\( P \) = design pressure in kN/m\(^2\) as defined in [2.1.1] and [2.1.2] considering design load set being defined in Ch.6 Sec.2

\( k_Z \) = coefficient taken as:

\[
\begin{align*}
  k_Z &= 1.0 & \text{for } b_1/b \leq 0.6 \\
  k_Z &= (1.15 - 0.25 \frac{b_1}{b}) & \text{for } 0.6 < b_1/b \leq 1.0 \\
  k_Z &= (1.15 - 0.25 \frac{b_1}{b})^{\frac{b_1}{b}} & \text{for } 1.0 < b_1/b < 3.4 \\
  k_Z &= 1.0 & \text{for } b_1/b \geq 3.4
\end{align*}
\]

\( a_1, b_1 \) = extents, in mm, of the load area as defined in [2.1.1]

\( c \) = coefficient as defined in [3.1.1]

\( d \) = coefficient taken as:

\[
\begin{align*}
  d &= a_1 & \text{for } a_1 \leq \ell \\
  d &= \ell & \text{for } a_1 > \ell
\end{align*}
\]

\( m \) = bending moment factor taken as:

\[
\begin{align*}
  m &= \frac{a_1}{1000 \ell} - 4.7 \frac{a_1}{1000 \ell} + 6.5 & \text{for } \frac{a_1}{1000 \ell} \leq 1.0 \\
  m &= \frac{a_1}{1000 \ell} \left( \frac{a_1}{1000 \ell} \right)^2 - 6.3 \frac{a_1}{1000 \ell} + 10.9 & \text{for } 1.2 < \frac{a_1}{1000 \ell} \leq 2.5 \\
  m &= 12 & \text{for } \frac{a_1}{1000 \ell} \geq 3.5
\end{align*}
\]

Between specified values of \( a_1/\ell \) the \( m \)-value may be varied linearly. The \( m \)-value may also be obtained from Figure 3

\( r \) = factor depending on the rigidity of girders supporting continuous stiffeners

\( r = 38 \) for stiffeners with rigid support at each girder, otherwise \( r = 29 \) to be applied as illustrated in Figure 3

\( C_s \) = permissible bending stress coefficient as defined in Ch.6 Sec.1 [1.1.2] for the design load set being considered

\( \alpha_s \) = coefficient for AC-I and AC-II as defined in Ch.6 Sec.1 [1.1.2]

\( \beta_s \) = coefficient for AC-I and AC-II as defined in Ch.6 Sec.1 [1.1.2]

\( C_{s-max} \) = coefficient for AC-I and AC-II as defined in Ch.6 Sec.1 [1.1.2].
3.2.2 Web plating

The net web thickness, in mm, of stiffeners subjected to wheel loading shall not be taken less than:

\[
t_w = \frac{f_{shr} P k_z c d}{d_{shr} c \ell' e H} \times 10^{-3}
\]

where:

- \( f_{shr} \) = shear force distribution factor taken as:
  
  \[
  f_{shr} = \begin{cases} 
  1 - 0.5 \frac{a_1}{1000 \ell} & \text{for } a_1 \leq 1000 \ell \\
  0.5 - 0.25 \left( \frac{a_1}{1000 \ell} - 1 \right) & \text{for } a_1 > 1000 \ell, \text{ Minimum } 0.25
  \end{cases}
  \]

- \( P \) = design pressure in kN/m² as defined in [2.1.1] and [2.1.2] considering design load set being defined in Ch.6 Sec.2

- \( k_z \) = coefficient as defined in [3.2.1]

- \( c \) = coefficient as defined in [3.1.1]

- \( d \) = coefficient as defined in [3.2.1]

- \( d_{shr} \) = effective web depth of stiffener, in mm, as defined in Ch.3 Sec.7 [1.4.3]
$C_t = \text{permissible shear stress coefficient as defined in Ch.6 Sec.5 Table 2 for the design load set being considered.}$

3.2.3 If more than one load area can be positioned simultaneously on the same stiffener span or adjacent spans, the sections modulus will be specially considered, based on direct stress analysis.

3.3 Primary supporting members

3.3.1 Vehicle load
The scantlings of girders shall be specially considered based on the most severe condition of moving or stowed vehicles. Allowable stresses are as given in Ch.6 Sec.6 [2.3].

The vehicle loads, in kN, shall be taken as concentrated force according to Ch.4 Sec.5 [2.3.2]. Alternatively, it is acceptable to use the envelop vertical acceleration, $a_{z-env}$, for design concentrated force calculation in combination with maximum hull girder stress, $\sigma_{hg}$.

3.3.2 The girder structure shall be based on Ch.4 Sec.5 [2.3.1] corresponding to the most severe of the uniform deck load, UDL (evenly and unevenly distributed) and the vehicle axle load (cargo handling vehicle and vehicles to be carried). The position of the vehicles shall be taken as the most unfavourable for the girder strength. Reference is made to Pt.5 Ch.3 Sec.2 [3.3] for further details.

3.3.3 The scantlings of girders shall also be considered based on the most severe condition of cargo handling or stowed vehicles. Unless otherwise specified, the girder system shall be designed for a condition were the axles of several trailers side by side are acting on the same transverse girder (see LC 6 in Pt.5 Ch.3 Sec.2 Table 1).
SECTION 6 SPECIAL HULL STRUCTURES

Symbols
For symbols not defined in this section, refer to Ch.1 Sec.4.

1 Plate stem, breasthooks and diaphragm plating

1.1 Stem

1.1.1 Plate stem
The net thickness, in mm, shall not be less than:

\[ t = (0.6 + 0.4S_B)(0.08L + 2.7)\sqrt{k} \]

but need not be greater than:

\[ 22\sqrt{k} - 1 \]

where:

\[ S_B = \text{spacing, in m, between horizontal stringers (partial or not), breasthooks, or equivalent horizontal stiffening members.} \]

The extension in mm of the stem plate from its leading edge and aftwards shall not be smaller than determined by the following formula:

\[ \ell = 70\sqrt{L} \]

From \( T_{SC} + 0.6 \text{ m} \) up to \( T_{SC} + C_w \), the net thickness may gradually be reduced to 0.8 \( t \).

1.1.2 Bar stem
The cross sectional area, in cm\(^2\), of a bar stem below \( T_{SC} \) shall not be less than:

\[ A_B = 1.25L \]

Starting from \( T_{SC} \), the sectional area of the bar stem may be reduced towards the upper end to 0.75 \( A_B \).

1.2 Breasthooks and diaphragm plating

1.2.1 The net thickness of breasthooks/diaphragm plates, in mm, shall not be less than:

\[ t_w = \frac{s}{70} \sqrt{\frac{R_{eH}}{235}} \]

where:

\[ s = \text{spacing of stiffeners on the web, as defined in Ch.1 Sec.4 Table 5, in mm. Where no stiffeners are fitted, } s \text{ shall be taken as the depth of the web.} \]
2 Stern frames and propeller posts

2.1 Scantlings and structural arrangement

2.1.1 Stern frames may be fabricated from steel plates or made of cast steel with a hollow section. For applicable material specifications and steel grades, see Ch.3 Sec.1. Stern frames of other material or construction will be specially considered.

2.1.2 Cast steel and fabricated stern frames shall be strengthened by adequately spaced plates with gross thickness not less than 80% of required thickness for stern frames. Abrupt changes of section shall be avoided in castings; all sections shall have adequate tapering radius.

2.1.3 In the upper part of the propeller aperture, where the hull form is full and centerline supports are provided, the thickness of stern frames may be reduced to 80% of the applicable requirement given in [2.1.4].

Table 1 Gross scantlings of propeller posts

<table>
<thead>
<tr>
<th>Gross scantlings of propeller posts, in mm</th>
<th>Fabricated propeller post</th>
<th>Cast propeller post</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>50 (L^{1/2})</td>
<td>40 (L^{1/2})</td>
</tr>
<tr>
<td>b</td>
<td>36 (L^{1/2})</td>
<td>30 (L^{1/2})</td>
</tr>
<tr>
<td>(t_1)</td>
<td>2.4 (L^{1/2})</td>
<td>3.0 (L^{1/2})</td>
</tr>
<tr>
<td>(t_2)</td>
<td>-</td>
<td>3.7 (L^{1/2})</td>
</tr>
<tr>
<td>(t_d)</td>
<td>1.2 (L^{1/2})</td>
<td>1.5 (L^{1/2})</td>
</tr>
<tr>
<td>(R)</td>
<td>-</td>
<td>40 mm</td>
</tr>
<tr>
<td>(Zx)</td>
<td>1.35 (L^{3/2})</td>
<td>1.3 (L^{3/2})</td>
</tr>
</tbody>
</table>

2.1.4 Gross scantlings of propeller posts

The gross scantlings of propeller posts shall not be less than those obtained from the formulae in Table 1. Scantlings and proportions for the special shape of the propeller post which differ from the case specified in Table 1 may be considered acceptable provided that the section modulus of the propeller post section about its longitudinal axis is not less the section modulus requirement given in Table 1 if applicable.

2.1.5 Section modulus below the propeller shaft bossing

In the case of a propeller post without a sole piece, the section modulus of the propeller post may be gradually reduced below the propeller shaft bossing down to 85% of the value calculated with the scantlings in Table 1, as applicable.
In any case, the thicknesses of the propeller posts shall not be less than those obtained from the formulae in the Table 1.

2.1.6 Propeller shaft bossing
The boss gross thickness, in mm, at the bore for the stern tube shall not be less than:

\[ t = 5 \sqrt{d_p - 60} \]

where:
\[ d_p = \text{diameter of propeller shaft in mm.} \]

3 Sea chest

3.1 General

3.1.1 Application
The requirements given in Ch.3, Ch.6 and Ch.13 apply in addition to the requirements below.

3.1.2 Gratings
The sea water inlet openings in the shell shall be protected by gratings.

3.2 Scantlings

3.2.1 Plate thickness
The net thickness, in mm, of sea chest boundaries shall not be less than determined by the following formula:

\[ t = 0.012b \sqrt{P_o \cdot k} \]

where:
\[ P_o = \text{blow out pressure, in bar} \]
\[ = 2 \text{ bar, unless a higher pressure is specified.} \]

3.2.2 Stiffener section modulus
The net section modulus, in cm\(^3\), of sea chest stiffeners shall not be less than determined by the following formula:

\[ Z = 0.048s_b \cdot b_{dg}^2 P_o k \]

where:
\[ P_o = \text{blow out pressure, in bar} \]
\[ = 2 \text{ bar, unless a higher pressure is specified.} \]
4 Thruster tunnel

4.1 General

4.1.1 Application
Following requirements apply to transverse thrusters for manoeuvring, which are integrated in the ship structure and which are able to produce transverse thrust at very slow ship speeds. Retractable rudder propellers are not transverse thrusters in the context of these requirements.

4.2 Structural principles

4.2.1 Tunnel plate thickness
Transverse thruster tunnels shall be completely integrated in the ship structure and welded to it.

The net thickness of the tunnel plating, in mm, shall not be less than the net required thickness for the shell plating in the vicinity of the bow thruster.

In addition the net thickness, in mm, shall not be less than:

\[ t = 0.008d + 1.8 \]

where:

\[ d = \text{inside diameter of the tunnel, in mm, but not to be taken less than 970 mm.} \]

In addition, for ships with \( L \leq 200 \text{ m} \), \( t \) shall not be taken less than:

\[ t = \sqrt{L/k} + 2.5 \]

4.2.2 Housing structure
Thrust element housing structures holding fixtures for propulsion units shall be effectively connected to the tunnel structure.

4.2.3 Propulsion engine support
If a propulsion engine is as well directly supported by the ship structure, it shall be ensured that the engine housing and the supporting elements are able to withstand the loading by the propulsion excitation without damage.

4.2.4 Welding
All welding of structural elements which are part of the watertight integrity of the ship hull shall generally be carried out as welds with full penetration welding, see Figure 1.
Figure 1 Single- and double bevel welds with full penetration welding

Upon special consideration, partial penetration welding according to Figure 2 may be accepted for structural elements where the stress level is low.

Figure 2 Single- and double bevel welds with partial penetration weld (incomplete root penetration)

4.2.5 Gear housing support
If the gear housing is supported in the vicinity of the propeller hub, the support bracket shall be connected to the tunnel by full penetration welding. The transition shall be carried out as shown in Figure 3 and be grinded notch-free. The radius, in mm, shall not be less than determined by the following formula:

\[ R = 3 + 0.7 t_{s-gr} \cos(\alpha_W - 45°) \]
where:

\[ t_{s-gr} = \text{gross thickness of the gear housing support bracket, in mm} \]

\[ \alpha_W = \text{angle between tunnel and the gear housing support bracket, in degrees.} \]

**Figure 3** Connection between gear housing support bracket and thruster tunnel

### 4.2.6 Bars and grids
Where the outboard ends of the tunnel are provided with bars or grids, the bars or grids shall be effectively secured.

### 4.3 Special designs

#### 4.3.1 Suction and drainage ducts
If suction or draining ducts are arranged in the ship's bottom the bottom slamming loads according to Sec.2 shall be considered.

**Guidance note:**
From a vibration point of view it is recommended that shell and tank structures in the vicinity of transverse thrusters should be designed such that the following design criteria are fulfilled:

\[ f_{\text{plate}} > 1.2 f_{\text{blade}} \]

\[ f_{\text{stiff}} < 0.8 f_{\text{blade}} \text{ or } f_{\text{stiff}} > 1.2 f_{\text{blade}} \]

where:

- \( f_{\text{plate}} \) = lowest natural frequency, in Hz, of isotropic plate field under consideration of additional outfitting and hydrodynamic masses
- \( f_{\text{stiff}} \) = lowest natural frequency, in Hz, of stiffener under consideration of additional outfitting and hydrodynamic masses
- \( f_{\text{blade}} \) = propeller blade passage excitation frequency, in Hz, at \( n \)

\[ f_{\text{blade}} = \frac{1}{60} nz \]

- \( n \) = maximum revolution speed, in 1/min, of transverse thruster
- \( z \) = number of propeller blades.

---end---of---guidance---note---
5 Machinery foundations

5.1 General

5.1.1 Main engines and thrust bearings shall be effectively secured to the hull structure by foundations of strength that is sufficient to resist the various gravitational, thrust, torque, dynamic, and vibratory forces which may be imposed on them.

5.1.2 In the case of higher power internal combustion engines or turbine installations, the foundations shall generally be integral with the double bottom structure. Consideration shall be given to substantially increase the inner bottom plating thickness in way of the engine foundation plate or the turbine gear case and the thrust bearing, see type 1 of Figure 4.

5.1.3 For main machinery supported on foundations of type 2, as shown in Figure 5, the forces from the engine into the adjacent structure shall be distributed as uniformly as possible. Longitudinal members supporting the foundation shall be aligned with girders in the double bottom, and transverse stiffening shall be arranged in line with the floors, see type 2 of Figure 5.

![Figure 4 Machinery foundations type 1](image)

![Figure 5 Machinery foundations type 2](image)
5.2 Foundations for internal combustion engines and thrust bearings

5.2.1 In determining the scantlings of foundations for internal combustion engines and thrust bearings, consideration shall be given to the general rigidity of the engine and to its design characteristics with regard to out of balance forces.

5.2.2 Generally, two girders shall be fitted in way of the foundation for internal combustion engines and thrust bearings.

5.2.3 Inner bottom plating and seating plate

Where main engines or thrust bearings are bolted directly to the inner bottom, the net thickness of the inner bottom plating shall be not less than twice the minimum requirement for inner bottom plating in Ch.6 Sec.3 Table 1. Hold-down bolts shall be arranged as close as possible to floors and longitudinal girders. Plating thickness and the arrangements of hold-down bolts shall also consider the manufacturer’s recommendations.

Guidance note:
The gross thickness of the top plate of seatings for main engine and reduction gear should preferably not be less than:

<table>
<thead>
<tr>
<th>$P_s$ in kW&lt;sup&gt;1)&lt;/sup&gt;</th>
<th>$t_{gr}$ in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\leq 1000$</td>
<td>25</td>
</tr>
<tr>
<td>$1000 &lt; P_s \leq 1750$</td>
<td>30</td>
</tr>
<tr>
<td>$1750 &lt; P_s \leq 2500$</td>
<td>35</td>
</tr>
<tr>
<td>$2500 &lt; P_s \leq 3500$</td>
<td>40</td>
</tr>
<tr>
<td>$P_s &gt; 3500$</td>
<td>45</td>
</tr>
</tbody>
</table>

1) $P_s$ = maximum continuous output of propulsion machinery.

5.2.4 Heavy equipment

Where heavy equipment is mounted directly on the inner bottom, the thickness of the floors and girders shall be increased.

5.3 Foundations for auxiliary machinery

Auxiliary machinery shall be secured on foundations that are of suitable size and arrangement to distribute the loads from the machinery evenly into the supporting structure.

6 Retractable bottom equipment

6.1 Introduction

6.1.1 The requirements below are valid for ships fitted with bottom equipment (e.g. hydro acoustic equipment, retractable thrusters, etc.) that is lowered through the bottom of the ship below the lower turn of the bilge.
6.2 Arrangement

6.2.1 Equipment that shall be lowered through the bottom of the ship shall be fitted in a separate watertight compartment of limited volume to reduce the impact in case of flooding.
Alternatively floatability and stability calculations showing that, with the ship fully loaded to summer draught on even keel, flooding of the compartment in which the bottom equipment is fitted will not result in:
— any other compartments being flooded
— an unacceptable loss of stability
— damage to equipment vital for safe operation of the ship.

6.2.2 The compartment where the bottom equipment is located shall have a bilge system and an audible high water level alarm being set off in the engine control room.

6.2.3 Doors leading into the compartment shall be watertight. A watertight sliding door shall normally be fitted. A hinged door is however normally accepted if opening into the compartment where the bottom equipment is located. A signboard stipulating that the door shall not be left open shall be fitted.

6.3 Design loads and allowable stresses

6.3.1 The strength of the supporting structure for retractable thrusters shall be based on resulting loads acting during operation of the thrusters in various positions and in stowed position.

6.3.2 The supporting structure for retractable hydro acoustic equipment shall be able to resist maximum bending moment from the shaft, to which the equipment is mounted. Maximum bending moment from the shaft shall be taken as the moment causing local yield stress in the shaft.
Arrangements other than based on retractable shaft will be specially considered, based on loads specified by the designer.

6.3.3 For the above load conditions the allowable stresses are the following:
— normal stress: $0.67 R_{eH}$
— shear stress: $0.67 \tau_{eH}$

7 Box coolers

7.1 Introduction

7.1.1 The requirements below are valid for ships fitted with box coolers. The box coolers are normally installed between the tank top and the shell plating of the ship.

7.2 Arrangement

7.2.1 As far as practical the box coolers shall be fitted in separate watertight compartments. If not, the requirements given in item [7.2.2] to [7.2.7] shall be complied with.

7.2.2 When the box coolers can be dismounted inwards, into the ship hull, an independent securing device for the box coolers shall be arranged, in addition to the bolt arrangement.

7.2.3 The box cooler shall be bolted to a separate mounting flange. The thickness of the flange shall be at least 1.25 times the depth of the bolt hole in the flange.
**Guidance note:**
The bolt grade is normally not to be higher than 8.8.

---end-of-guidance-note---

7.2.4 The mounting flange shall be welded to the hull with double continuous fillet weld with a minimum throat thickness of 10 mm.

7.2.5 Gaskets shall be of a quality suitable for sea water exposure.

7.2.6 The dimension of the bolts shall be minimum M16.

7.2.7 Longitudinal strength shall be specially considered in way of cut outs for box coolers.

Detail design of cut outs for box coolers shall be specially considered in order to reduce stress concentrations, typically the shell and inner bottom plating. For corners of the cut-outs the radius, in m, shall not be less than:

\[ r = 0.1 \cdot b_o \]

where:

\[ b_o \] = the greatest dimension of the opening in m.

However, the radius needs not to be taken greater than 0.2 m.

7.2.8 An insert plate shall be fitted in way of cut outs in shell plating. The net thickness, in mm, of the insert plate shall not be less than:

\[ t = 1.25 \cdot t_s \]

where:

\[ t_s \] = net thickness in mm of shell plate.

7.2.9 The breadth of the remaining plate strip between adjacent cut outs in shell shall not be less than 100 mm. The length of the opening is subject to special consideration based on the actual structural arrangement and hull girder stress level. The hull girder stress in N/mm² shall normally not exceed 120/k.

7.2.10 The net thickness, in mm, of the plate to which the box coolers are fitted shall not be less than:

\[ t = 9 + \sqrt{d} \]

where:

\[ d \] = distance from free edge of plate, in mm, to the nearest floor or support.

This net thickness shall extend 100 mm beyond nearest floor or support.

7.2.11 The net thickness, in mm, of the dividing plates between the box coolers shall not be less than:

\[ t = 0.018 \cdot s \]

7.2.12 Boundaries of structure holding box coolers shall have scantlings as required in Ch.6 Sec.1 to Sec.5.
8 Strengthening against berthing impact

8.1 General

8.1.1 Application
This requirement applies to ships with length \( L > 90 \) m.
Where a steel fender integrated to side shell structure is provided, the requirements given in [8.1.2], [8.2.1] and [8.2.2] shall be specially considered.

8.1.2 Extent of strengthening
Side shell longitudinals and webs of side transverses shall be strengthened against berthing impact within the range from ballast draught to 0.25 \( T_{SC} \), maximum 2.0 m above \( T_{SC} \) where the breadth is exceeding 0.9 \( B \).

8.1.3 Impact loads
The force in kN, included by a fender into the side shell shall be determined by the following formulae:

\[
P_f = \begin{cases} 
0.08 \cdot \Delta & \text{for } 0 < \Delta \leq 2100 \\
170 & \text{for } 2100 < \Delta \leq 17000 \\
\Delta/100 & \text{for } 17000 < \Delta 
\end{cases}
\]

where:
\( \Delta \) = displacement, in t, of the ship at scantling draught:
\( \Delta \leq 100\,000 \)

8.2 Local scantlings

8.2.1 Side shell plating
The net thickness, in mm, of the side shell plating within the fender contact zone as specified in [8.1.2] shall not be less than:

\[
t = 26 \left( \frac{b}{1000} + 0.7 \right) \left( \frac{2 \cdot T_{SC}}{R_e H} \right)^{0.25}
\]

8.2.2 Side shell longitudinals
In order to withstand the load \( P_f \), induced by a fender the effective net plastic section modulus, in cm\(^3\), calculated in accordance with Ch.3 Sec.7 [1.4.5], of side shell longitudinals shall not be less than determined by the following formulae:

\[
Z_{pl} = \frac{M_f}{R_e H} \cdot 10^3
\]

where:
\( M_f \) = bending moment, in kNm, induced by fender, defined as:
\[
M_f = \frac{P_f}{f_{pl}} \left( I_{bdg} + 0.5 \right)
\]
\( f_{pl} \) = bending moment factor as defined in Sec.1
8.3 Primary supporting members

8.3.1 Web plating
In order to withstand the load on the web frames, the net thickness of web plating, in mm, within the fender contact zone as specified in [8.1.2] shall not be less than:

\[ t_s = 0.85 \left( \frac{1}{L_{bdg}} \right)^{0.25} \sqrt{\frac{P_f}{C + 0.17}} \]

where:

\[ P_f = \text{force, in kN, induced by fender contact according to [8.1.3]} \]
\[ L_{bdg} = \text{bending span, in m, of longitudinals, as defined in Ch.3 Sec.7 [1.1.2].} \]

9 Strengthening for tug contact

9.1 General

9.1.1 Application of tug contact zone requirement
In those zones of the side shell which may be exposed to concentrated loads due to harbour manoeuvres the scantling requirements defined in [9.2] shall be fulfilled. These zones are mainly the plates in way of the ship’s fore and aft shoulder and in addition amidships. The exact locations shall be identified on the shell expansion drawing. The length of the strengthened areas shall not be less than 5 m. The height of the strengthened area shall extend from about 0.5 m above ballast draught to about 4 m above scantling draught.

9.2 Scantlings

9.2.1 Plate thickness
The net thickness, in mm, in the strengthened areas shall not be less than:

\[ t = 0.65 \sqrt{P_{fl} k} \]

where:

\[ P_{fl} = \text{local design force, in kN, defined as:} \]
\[ P_{fl} = \Delta/100 \quad \text{with} \quad 200 < P_{fl} \leq 1000 \]
9.2.2 Side longitudinals
In the strengthened areas the net section modulus, in cm$^3$, of side longitudinals shall not be less than determined by the following formulae:

$$Z = 0.3 \rho_{fl} \ell_{bdg} k$$

$\ell_{bdg} = $ bending span, in m, of longitudinals, as defined in Ch.3 Sec.7 [1.1.2].

10 Wave breakers

10.1 General

10.1.1 Application
When a wave breaker or an equivalent protecting structure, e.g. whaleback or turtle deck, is installed, the requirements given in this sub-section shall be complied with.

10.1.2 Wave breaker width
The width of the wave breaker shall be at least the same as the width of the area intended for carriage of deck cargo.

10.1.3 Breakwater height
The minimum average height in m, of the wave breaker shall be as given by formula below, but need not be more than the maximum height of the deck cargo stowed between the wave breaker and 15 m aft of it.

$$h_{W,min} = 0.6[b_d C_W - (z_b - T_{SC})]$$

where:

$b_d = $ distribution factor, defined as

$$1.0 + 2.75 \left( \frac{z - 0.45}{c_B + 0.2} \right)^2$$

$z_b = $ $z$ coordinate of bottom line of wave breaker, in m.

The average height $h_W$ of whalebacks or turtle decks shall be determined as illustrated in Figure 6.

Figure 6 Whaleback
Guidance note:
The recommended average height in m, of the wave breaker is:
\[ h_{W,\text{rec}} = 0.8 \left[ b_d C_W - (z_b - T_{SC}) \right] \]

10.1.4 Stiffeners
Stiffeners shall be connected on both ends to the structural members supporting them.

10.1.5 Cut-outs in webs of primary supporting members
Cut-outs in the webs of primary supporting members of the wave breaker shall be reduced to a minimum. Free edges of the cut-outs shall be reinforced by stiffeners.

If cut-outs in the plating are provided to reduce the load on the wave breaker, the area of single cut-outs shall not exceed 0.2 m\(^2\) and the sum of the cut-out areas not 3% of the overall area of the wave breaker plating.

10.2 Loads on wave breakers and whalebacks

10.2.1 Wave breakers with and whalebacks with inclining angles greater than 20°
The design pressure in kN/m\(^2\) on wave breakers with inclining angles \(\alpha_W \leq 90°\) and whalebacks with inclining angles \(\alpha_W > 20°\) shall be determined by the following formula:
\[ P_{BW} = n \cdot \sin \alpha_w [b_d C_W - (z_b - T_{SC})] \]

without being taken less than the minimum design pressure \(P_{BW,\text{min}}\) in kN/m\(^2\) according to the table below:

<table>
<thead>
<tr>
<th>(L)</th>
<th>(P_{BW,\text{min}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 50</td>
<td>30</td>
</tr>
<tr>
<td>50 (\leq L \leq 250)</td>
<td>25 + (L/10)</td>
</tr>
<tr>
<td>&gt; 250</td>
<td>50</td>
</tr>
</tbody>
</table>

where:

\(n\) = distribution factor, defined as: \(n = 10 + \frac{L_2}{20}\)
\(\alpha_w\) = inclining angle of wave breaker or whaleback at centre line in degrees, see Figure 6.

10.2.2 Whalebacks with inclining angles equal or less than 20°
The design pressure on whalebacks with inclining angles \(\alpha_W \leq 20°\) shall be taken as:
\[ P_{BW} = P_D \]

where:

\(P_D\) = pressure in kN/m\(^2\) on exposed superstructure deck according to Ch.4 Sec.5 [2.2].
10.3 Local scantlings

10.3.1 Plate thickness of wave breakers and whalebacks with inclining angles greater than 20°
The net thickness, in mm, shall not be less than:

\[ t = \max\left(3.5 + \frac{L_2}{1000} \sqrt{K}; \frac{0.9b}{1000} \sqrt{P_{BW}}\right) \]

10.3.2 Section modulus of stiffeners of wave breakers and whalebacks with inclining angles greater than 20°
The net section modulus, in cm³, shall be determined by the following formula:

\[ Z = 0.07 \frac{s}{R_{eh}} \frac{t_{bdg}}{L_{BW}} \]

10.3.3 Scantlings of primary supporting members of wave breakers and whalebacks with inclining angles greater than 20°
Scantlings of primary supporting members shall be determined by direct calculations. The equivalent stress in N/mm² shall not exceed \( R_{eh} \).

10.3.4 Scantlings of whalebacks with inclining angles equal or less than 20°
The scantlings for plating, stiffeners and primary supporting members shall be determined according to requirements for superstructure decks.

11 Independent tanks

11.1 General

11.1.1 Independent tanks shall be adequately secured against forces due to the ship’s motions.

11.1.2 Independent tanks in cargo hold spaces shall also be provided with anti-floatation devices. Loads caused by the buoyance of an empty tank in cargo hold space flooded to the scantling draught shall be considered in the design of the anti-floatation chocks and the supporting hull structure. The acceptance criteria AC-III is applicable when the strength assessment is carried out based on Ch.6 or Ch.7. See also Pt.5 Ch.5 and Pt.5 Ch.6, if relevant. For independent tank for liquefied gas, the requirements are given in Pt.5 Ch.7.

11.1.3 Independent fuel oil tanks should not be installed in cargo holds. Where such an arrangement cannot be avoided, provisions shall be made to ensure that the cargo cannot be damaged by leakage oil.

11.1.4 Fittings and piping on independent tanks shall be protected by battens, and gutter ways shall be fitted on the outside of tanks for draining any leakage oil.

11.1.5 For tanks subjected to high or low cargo temperatures, see Ch.1 Sec.2 [3.7.2].


**CHANGES – HISTORIC**

**July 2016 edition**

**Main changes July 2016, entering into force as from date of publication**

- **Sec.1 Bow impact**
  - Sec.1 [2.1.1]: Bow impact clarification of load point for small ships.

- **Sec.2 Bottom slamming**
  - Sec.2 [3.3]: Updated bottom slamming requirements for primary supporting members.

- **Sec.5 Wheel loading**
  - Sec.5 [2.1.1]: Wheel load has been corrected for the harbour case.
  - Sec.5 [2.1.2]: Wheel load has been corrected for the harbour case.

- **Sec.6 Special hull structures**
  - Sec.6 [8.1.2]: Vertical extent of berting impact has been modified.

**October 2015 edition**

This is a new document.
The rules enter into force 1 January 2016.

**Amendments January 2016**

- **Sec.1 Bow impact**
  - [3.3]: Unit corrections, clarified buckling requirement and accounting for service area restrictions.

- **Sec.5 Wheel loading**
  - Clarified wheel load requirements.
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