Sloshing Requirements

Amended Rules and Guidance

Rules for the Survey and Construction of Steel Ships Part C
Guidance for the Survey and Construction of Steel Ships Parts C, and S

Reason for Amendment

A comprehensive revision of Part C of the Rules, which began in that latter half of 2017 and was carried out with the cooperation of relevant industry members, was published on 1 July 2022. As a part of this comprehensive review, research and development regarding sloshing loads and corresponding strength requirements for such loads, including tank tests and CFD series calculations using, was carried out.

Accordingly, new requirements based upon the latest sloshing load research and development results are added to Part C of the Rules.

Outline of Amendment

(1) Specifies new formulae for sloshing loads.
(2) Specifies new scantling formulae corresponding to (1) above.
(3) Amends requirements related to sloshing specified in Part S of the Guidance.

"Rules for the survey and construction of steel ships" has been partly amended as follows:

Part C HULL CONSTRUCTION AND EQUIPMENT

Part 1 GENERAL HULL REQUIREMENTS

Chapter 4 LOADS

4.8 Loads to be Considered in Additional Structural Requirements

4.8.2 Maximum Load Condition

Paragraph 4.8.2.1 has been amended as follows.

4.8.2.1 General

1 Slamming loads acting on the bottom structure are to be in accordance with **4.8.2.2**.
2 Loads due to bow impact are to be in accordance with **4.8.2.3**.
3 Sloshing loads are to be in accordance with **4.8.2.4**.

Paragraph 4.8.2.4 has been added as follows.

4.8.2.4 Sloshing Loads

1 Loads to be considered in tank structures for the sloshing specified in **10.9** are to be in accordance with **4.8.2.4**. The sloshing loads to be considered for filling ratios are to be in accordance with **Table 4.8.2-10**. These requirements apply to tank structures where the ratio of tank height to tank length is not less than 1/4 and not more than 4.0 for sloshing loads due to pitch, and where the ratio of tank height to tank breadth is not less than 1/4 and not more than 4.0 for sloshing loads due to roll.

2 Where the relationship between the natural period of tanks in which liquid height is considered and the natural period of ship motions corresponds to the following **(1)** and **(2)**, sloshing loads may be partially omitted from consideration. In applying the following **(1)** and **(2)**, T_{tk-X} and T_{tk-Y} may be calculated using the tank length or breadth without considering the effects of girders and/or wash bulkheads instead of using equivalent tank length $\ell_e(m)$ or equivalent tank breadth $b_e(m)$. These natural periods of tanks are to be calculated in accordance with the following **(3)**.

(1) Where the period of longitudinal oscillation $T_{tk-X}(s)$ of cargo tanks is not within the range of ±20 % of pitch period T_{ϕ_slh} specified in **Table 4.8.2-11** and not within ±1.5 *seconds* from the same period, sloshing loads due to pitch need not be considered. In calculating T_{ϕ_slh}, the parameters for the ballast condition are to be used.

(2) Where the period of transverse oscillation $T_{tk-Y}(s)$ of cargo tanks is not within the range of ±20 % of roll period T_θ specified in **4.2.2.1** and not within ±1.5 *seconds* from the same period, sloshing loads due to roll need not be considered. In calculating T_θ, the parameters for the ballast condition are to be used.

(3) $T_{tk-X}(s)$ and $T_{tk-Y}(s)$ are to be in accordance with the following formulae. The periods of tanks are to be calculated for each 10 % of the filling ratio $(0.1f_r)$.

$$T_{tk-X} = \frac{2\pi}{\sqrt{\frac{\pi}{\ell_e} \cdot g \cdot \tanh\left(\frac{\pi}{\ell_e} h_{lc}\right)}}$$

$$T_{tk-Y} = \frac{2\pi}{\sqrt{\frac{\pi}{b_e} \cdot g \cdot \tanh\left(\frac{\pi}{b_e} h_{lc}\right)}}$$

ℓ_e : Equivalent tank length (m) for calculating the natural period as specified in **Table 4.8.2-12**

b_e : Equivalent tank breadth (m) for calculating the natural period as specified in **Table 4.8.2-12**

h_{lc}: Liquid height under consideration (m)

Table 4.8.2-10 Filling Ratios and Sloshing Loads

Filling ratio f_r	Sloshing load
$0.2 \le f_r < 0.4$	Sloshing loads for low filling ratio
$0.4 \le f_r < 0.7$	Sloshing loads for middle filling ratio
$0.7 \le f_r \le 0.9$	Sloshing loads for high filling ratio

Notes:

f_r : Filling ratio of liquid cargo tanks, as given by the following formula:

$f_r = h_{lc}/h_{tk}$

h_{lc}: Liquid height under consideration (m)

h_{tk}: Maximum tank height (m)

Table 4.8.2-11 Pitch Period and Angular Acceleration to be Considered for Sloshing

Period (s)	Pitch angular acceleration (rad/s^2)
$T_{\phi\_slh} = 2\pi\sqrt{\frac{L_C B T_{LC} C_{B\_LC} {K_{yy}}^2 + A_\phi}{g {L_C}^3 B\left(2.2{C_{W\_LC}}^2 - 1.8C_{W\_LC} + 0.6\right)/12}}$	$a_{5\_slh} = \phi_{slh60}\left(\frac{2\pi}{T_{\phi slh}}\right)^2$

Notes:

Ballast condition is considered.

K_{yy}: Radius of gyration (m) around Y-axis, to be taken as:

$K_{yy} = 0.25L_C$

A_ϕ: Added moment of inertia of pitch, to be taken as:

$$A_\phi = \frac{\pi {L_C}^3 B^2 {C_{W\_LC}}^2}{48(3 - 2C_{W\_LC})(3 - C_{W\_LC})}\left(-1.8\frac{T_{LC}}{L_C} + 0.835\right)$$

ϕ_{slh60}: Maximum pitch angle (rad) under wave angle of 60 deg, to be taken as:

$\phi_{slh60} = \left(0.037{T_{LC}}^{0.91} + 0.11\right)\phi$

ϕ : Pitch angle (rad), as specified in **Table 4.2.2-2**

Table 4.8.2-12 Equivalent Tank Length and Equivalent Tank Breadth

	ℓ_e and b_e
Equivalent tank length	$\ell_e = \frac{(1+n_{WT}\,\alpha_{WT})(1+f_{wf}\,\alpha_{wf})}{(1+n_{WT})(1+f_{wf})}\ell_{tk-h}$
Equivalent tank breadth	$b_e = \frac{(1+n_{WL}\,\alpha_{WL})(1+f_{grd}\,\alpha_{grd})}{(1+n_{WL})(1+f_{grd})}b_{tk-h}$

Notes:

n_{WT}: Number of transverse wash bulkheads in tanks under consideration

n_{WL}: Number of longitudinal wash bulkheads in tanks under consideration

α_{WT}: Coefficient related to transverse wash bulkheads, to be taken as[(1)] (*See* **Fig. 4.8.2-4**):

$$\alpha_{WT} = \frac{A_{OWT}}{A_{tk-t-h}}$$

A_{OWT}: Total area of opening (m^2) in transverse section in way of the wash bulkhead below the liquid height under consideration h_{lc}

A_{tk-t-h}: Total transverse cross sectional area of the tank (m^2) below the liquid height under consideration h_{lc}

α_{WL}: Coefficient related to longitudinal wash bulkheads, to be taken as[(2)]:

$$\alpha_{WL} = \frac{A_{OWL}}{A_{tk-l-h}}$$

A_{OWL}: Total area of opening (m^2) in longitudinal section in way of the wash bulkhead below the liquid height under consideration h_{lc}

A_{tk-l-h}: Total longitudinal cross sectional area of the tank (m^2) below the liquid height under consideration h_{lc}

α_{wf}: Coefficient related to transverse girders, to be taken as[(3)] (*See* **Fig. 4.8.2-4**):

$$\alpha_{wf} = \frac{A_{O-wf-h}}{A_{tk-t-h}}$$

A_{O-wf-h}: Total area of opening (m^2) in the transverse section in way of girders below the liquid height under consideration h_{lc}

α_{grd}: Coefficient related to longitudinal girders, to be taken as[(4)]:

$$\alpha_{grd} = \frac{A_{O-grd-h}}{A_{tk-l-h}}$$

$A_{O-grd-h}$: Total area of opening (m^2) in the longitudinal section in way of girders below the liquid height under consideration h_{lc}

f_{wf}: Coefficient to consider the number of transverse girders and wash bulkheads in the tank, to be taken as:

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

n_{wf}: Number of transverse girders, excluding wash bulkheads, in the tank

f_{grd}: Coefficient to consider the number of longitudinal girders and wash bulkheads in tanks, to be taken as:

$$f_{grd} = \frac{n_{grd}}{1+n_{WL}}$$

n_{grd}: Number of longitudinal girders, excluding wash bulkheads, in the tank

ℓ_{tk-h}: Maximum value of tank length at the liquid height h_{lc} (m)

b_{tk-h}: Maximum value of tank breadth at the liquid height h_{lc} (m)

(1) For tanks whose shape changes along their length and/or with transverse wash bulkheads of different shapes, α_{WT} is to be taken as the average of all transverse wash bulkheads in the tank, as given by the following formula:

$$\alpha_{WT} = \frac{\sum_{i=1}^{n_{WT}} \frac{A_{OWT_i}}{A_{tk-t-h_i}}}{n_{WT}}$$

(2) For tanks whose shape changes along their breadth and/or with longitudinal wash bulkheads of different shapes, α_{WL} is to be taken as the average of all longitudinal wash bulkheads in the tank, as given by the following formula:

$$\alpha_{WL} = \frac{\sum_{i=1}^{n_{WL}} \frac{A_{OWL_i}}{A_{tk-L-h_i}}}{n_{WL}}$$

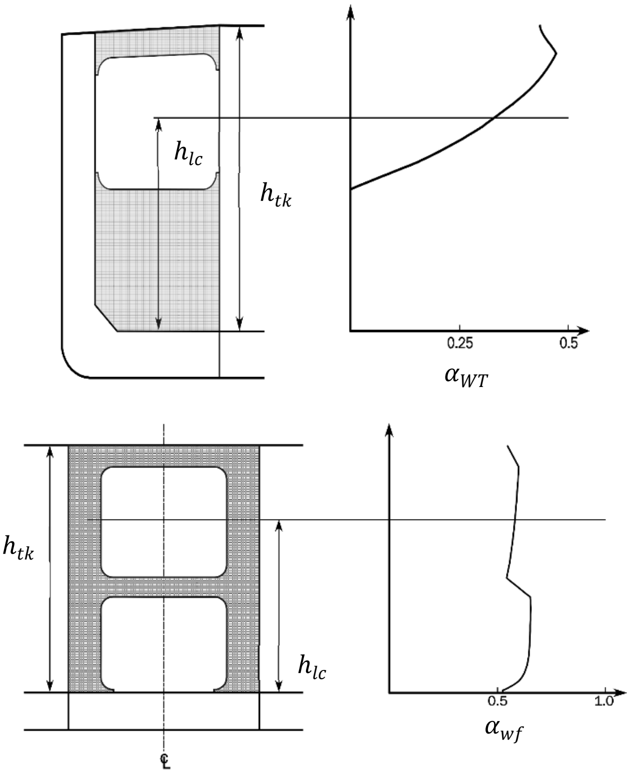
(3) For tanks whose shape changes along their length and/or with transverse girders of different shapes, α_{wf} is to be taken as the average of all transverse girders in the tank, as given by the following formula:

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

(4) For tanks whose shape changes shape along their breadth and/or with longitudinal girders of different shape, α_{grd} is to be taken as the average of all longitudinal girders in the tank, as given by the following formula:

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

Fig. 4.8.2-4 Coefficients for Wash Bulkheads and Girders



3 Impact pressure caused by liquid cargo impacting tank boundaries and internal structures with high velocity is to be treated as sloshing loads. In this **4.8.2.4**, the impact pressure is replaced with an equivalent pressure for plates and replaced with an equivalent bending moment for stiffeners. For tanks deemed necessary by the Society, consideration of loads may be required to be based on advanced methods such as numerical analysis or model tests.

4 Sloshing loads to be considered for plate panels are to be in accordance with the following **(1)** and **(2)**.

(1) Equivalent pressures P_{slh-p} (kN/m^2) obtained in accordance with **Table 4.8.2-13** are to be considered as sloshing loads due to pitch.

(2) Equivalent pressures P_{slh-r} (kN/m^2) obtained in accordance with **Table 4.8.2-14** are to be considered as sloshing loads due to roll.

Table 4.8.2-13 Equivalent Pressure for Plate Panels and Sloshing Loads Due to Pitch

Relevant ship motion	Equivalent pressure (kN/m^2)
Pitch	$P_{slh-p} = \dfrac{F_{slh-p}}{C_{slh1} \cdot \min(1000, C_{slh2})} \cdot 10^6$

Notes:

C_{slh1}, C_{slh2}: Coefficients related to member and panel length depending on the type of stiffened system, to be taken as:

$C_{slh1} = b$, $C_{slh2} = a$ for plate panels of stiffened system A

$C_{slh1} = a$, $C_{slh2} = b$ for plate panels of stiffened system B

$C_{slh1} = b_f$ or $b_w sin\theta$, $C_{slh2} = l$ for vertically corrugated bulkheads

Stiffened system A (1): Transverse bulkheads, transverse wash bulkheads, front and aft walls of tanks with vertically stiffened systems; vertical girders of vertically stiffened systems attached to longitudinal bulkheads or tank side walls; tank top plates of longitudinally stiffened systems; horizontal girders stiffened in parallel to depth direction of webs which are attached to transverse bulkheads or transverse wash bulkheads or front and aft walls of tanks

Stiffened system B(2): Transverse bulkheads, transverse wash bulkheads, front and aft walls of tanks with horizontally stiffened systems; vertical girders of horizontally stiffened systems attached to longitudinal bulkheads or tank side walls; tank top plates of transverse stiffened systems; horizontal girders in perpendicular to depth direction of webs which are attached to transverse bulkheads or transverse wash bulkheads or front and aft walls of tanks; cross-ties in transverse direction

a: Length (mm) of the longer side of the plate panel

b: Length (mm) of the shorter side of the plate panel

b_f, b_w: Width (mm) of the flange and web of corrugated bulkheads respectively, as specified in **10.9.2.1**

θ: Angle (rad) of corrugated bulkheads, as specified in **10.9.2.1**

l: Height (mm) of corrugated bulkheads, as specified in **7.2.7.3**

F_{slh-p}: Equivalent impact force (kN), to be taken as:

$F_{slh-p} = \rho_L \cdot C_{slh1\_mod} \cdot {\ell_{tk}}^{1.5} \cdot C_d \cdot C_{SS} \cdot a_{5\_slh} \cdot C_{slh3} \cdot 10^{-3}$

ρ_L: Maximum design cargo density (t/m^3) in considered h_{lc}. **Table 4.4.2-6** may be applied correspondingly.

C_{slh1_mod}: Where C_{slh1} is $b_w sin\theta$, to be replaced to b_w. In other cases, to be taken as C_{slh1}.

ℓ_{tk}: Maximum tank length (m)

C_d: Coefficient depending on aspect ratio of the tank, as given by the following formula:

$$C_d = 0.65 + 0.35 \tanh\left(4 - \frac{1.5\ell_{tk}}{h_{tk}}\right)$$

h_{tk}: Maximum tank height (m)

C_{SS}: Coefficient, as given by the following formula:

$$C_{SS} = \min\left(0.3 + \frac{L_C}{325}, 1.0\right)$$

a_{5_slh}: Pitch angular acceleration (rad/s^2), as specified in **Table 4.8.2-11**. The parameters for the ballast condition are to be used.

C_{slh3}: Coefficient related to members under consideration and the distance from the centre of gravity of the ship to the tank, to be taken as:

$C_{slh3} = C_{h1}(0.0104|x_{TG} - x_G| + 1.0)$

C_{h1} : Parameter depending on h_{lc}, as specified in **Table 4.8.2-15**.

x_{TG} : X coordinate (m) at the volumetric centre of gravity of the tank under consideration

x_G : X coordinate (m) at the centre of gravity of the ship, to be taken as $x_G = 0.45L_C$. Where deemed appropriate by the Society, the value may be defined by the designer.

(1) *See* **Fig. 10.9.3-1**

(2) *See* **Fig. 10.9.3-2**

Table 4.8.2-14 Equivalent Pressure for Plate Panels, Sloshing Load Due to Roll

Relevant ship motion	Equivalent pressure (kN/m^2)
Roll	$P_{slh-r} = \frac{F_{slh-r}}{C_{slh1} \cdot \min(1000, C_{slh2})} \cdot 10^6$

Notes:

C_{slh1}, C_{slh2}: Coefficients related to member and panel length depending on the type of stiffened system, to be taken as:

$C_{slh1} = b$, $C_{slh2} = a$ for plate panels of stiffened system A

$C_{slh1} = a$, $C_{slh2} = b$ for plate panels of stiffened system B

$C_{slh1} = b_f$ or $b_w sin\theta$, $C_{slh2} = l$ for vertically corrugated bulkheads

Stiffened system A (1): Longitudinal bulkheads, longitudinal wash bulkheads, tank side walls with vertically stiffened systems; vertical girders of vertically stiffened systems attached to transverse bulkheads or front and aft walls of tanks; tank top plates of transverse stiffened systems; horizontal girders stiffened in parallel to depth direction of webs which are attached to longitudinal bulkheads or longitudinal wash bulkheads or front and aft walls of tanks

Stiffened system B(2): Longitudinal bulkheads, longitudinal wash bulkheads, front and aft walls of tanks with longitudinally stiffened systems; vertical girders of horizontally stiffened systems attached to transverse bulkheads or front and aft walls of tanks; tank top plates of longitudinally stiffened systems; horizontal girders stiffened in perpendicular to depth direction of webs attached to longitudinal bulkheads or longitudinal wash bulkheads or tank side walls; cross-ties in longitudinal direction

a, b, b_f, b_w, θ, l: As specified in **Table 4.8.2-13**

F_{slh-r}: Equivalent impact force (kN), to be taken as:

$F_{slh-r} = \rho_L \cdot C_{slh1\_mod} \cdot {b_{tk}}^{1.5} \cdot a_4 \cdot C_{slh3} \cdot 10^{-3}$

ρ_L, C_{slh1_mod}: As specified in **Table 4.8.2-13**

b_{tk}: Maximum tank breadth (m)

a_4: Roll angular acceleration (rad/s^2), as specified in **4.2.3.4**. The parameters for the ballast condition are to be used.

C_{slh3}: Coefficient related to members under consideration, to be taken as:

$C_{slh3} = C_{h1}$

C_{h1} : Parameter depending on h_{lc}, as specified in **Table 4.8.2-15**

(1) *See* **Fig.10.9.3-1**

(2) *See* **Fig.10.9.3-2**

Table 4.8.2-15 Parameters for Sloshing Loads

Member to be assessed	C_{h1}		
	Low filling ratio $0.2 \leq f_r < 0.4$	Middle filling ratio $0.4 \leq f_r < 0.7$	High filling ratio $0.7 \leq f_r \leq 0.9$
- Front and aft walls / side walls of tanks - Transverse bulkheads / longitudinal bulkheads (including corrugated bulkheads)	8.63	16.1	22.3
- Transverse wash bulkheads - Longitudinal wash bulkheads	3.23	4.61	4.22
- Tank top plates[(1)]	1.18	11.0	8.63
- Vertical girders attached to front and aft walls / side walls of tanks - Vertical girders attached to longitudinal bulkheads / transverse bulkheads	3.63	6.28	4.80
- Horizontal girders attached to front and aft walls / side walls of tanks - Horizontal girders attached to longitudinal bulkheads / transverse bulkheads	For $h_{hg} \leq 0.5$, $3.14h_{hg}+0.68$ For $h_{hg} > 0.5$, $-1.37h_{hg}+2.935$	For $h_{hg} \leq 0.5$, $1.57h_{hg}+0.20$ For $h_{hg} > 0.5$, $-0.39h_{hg}+1.18$	$0.88h_{hg}+0.10$
- Cross-ties	3.24	4.61	4.22
- Sloping plates above side walls[(2)]	*NA*	$\alpha = 0$:11.0 $\alpha = 30$:1.97 $\alpha = 90$:16.0	$\alpha = 0$:8.63 $\alpha = 30$:3.92 $\alpha = 90$:22.3
- Sloping plates below side walls[(2)]	$\alpha = 0$:5.89 $\alpha = 30$:5.89 $\alpha = 90$:8.63	$\alpha = 0$:4.91 $\alpha = 30$:4.91 $\alpha = 90$:16.1	*NA*

Notes:
f_r: Filling ratio of liquid cargo tank, as specified in **Table 4.8.2-10.**
α: Acute angle (*deg*) of inclination angle to the horizontal plane of the panel under consideration
h_{hg}: Ratio of the distance (*m*) from tank bottom plate to the horizontal girders under consideration to maximum tank height h_{tk} (*m*)

(1) The parameters are for the plate panels within the range of $0.3\ell_{tk}$ from transverse bulkheads / front and aft walls of tank and within the *range* of $0.3b_{tk}$ from longitudinal bulkheads / tank side walls. Definitions of ℓ_{tk} and b_{tk} are specified in **Table 4.8.2-13** and **Table 4.8.2-14.**
(2) Intermediate values of α are to be obtained by linear interpolation.

5 Sloshing loads to be considered for stiffeners are to be in accordance with the following **(1)** and **(2).**

(1) Where **-4** above is applied and the stiffeners are attached to the plate panels with $C_{slh1} = b$ and $C_{slh2} = a$ (stiffeners in parallel to the direction a), the equivalent bending moments specified in the following formulae M_{slh-p} and M_{slh-r} (*kN-m*) are to be considered.

$M_{slh-p} = F_{slh-p}\ell_{slh}$ for sloshing loads due to pitch

$M_{slh-r} = F_{slh-r}\ell_{slh}$ for sloshing loads due to roll

F_{slh-p}, F_{slh-r}: As specified in **-4** above

ℓ_{slh}: Equivalent lever (*m*), to be taken as:

$\ell_{slh} = f_{bd}\ell_{bdg}$

f_{bd}: Coefficient considering boundary conditions, as specified in **Table 4.8.2-16**

ℓ_{bdg}: Effective bending span (*m*) of stiffeners, as specified in **3.6.1.2**

(2) Where **-4** above is applied and the stiffeners are attached to the plate panels with $C_{slh1} = a$ and $C_{slh2} = b$ (stiffeners in parallel to the direction a), the equivalent bending moments

specified in the following formulae M_{slh-p} and M_{slh-r} (*kN-m*) are to be considered.

$M_{slh-p} = 0.083 \cdot F_{slh-p} \cdot \ell_{bdg}$ for sloshing loads due to pitch

$M_{slh-r} = 0.083 \cdot F_{slh-r} \cdot \ell_{bdg}$ for sloshing loads due to roll

F_{slh-p}, F_{slh-r}: As specified in **-4** above

ℓ_{bdg}: As specified in **(1)** above

Table 4.8.2-16 Coefficient Considering Boundary Conditions

Member	f_{bd}
- Front and aft walls / side walls of cargo tanks including corrugated walls - Transverse bulkheads / longitudinal bulkheads (including corrugated bulkheads) - Tank top plates - Sloping plates above and below side walls	0.31
- Transverse wash bulkhead, longitudinal wash bulkhead - Vertical girders attached to front and aft walls of tanks / transverse bulkheads - Vertical girders attached to tank side walls / longitudinal bulkheads	0.43
- Horizontal girders attached to front and aft walls of tanks / transverse bulkheads - Horizontal girders attached to side walls of tanks / longitudinal bulkheads	1.70
- Cross-ties	0.39

6 For vertically corrugated bulkheads, in addition to the requirements of **-4** above, the equivalent bending moments M_{slh-p} and M_{slh-r} obtained from the following formulae are to be considered as loads (*kN-m*) for obtaining the section modulus.

$M_{slh-p} = F_{slh-p}\ell_{slh}$ for sloshing loads due to pitch

$M_{slh-r} = F_{slh-r}\ell_{slh}$ for sloshing loads due to pitch

F_{slh-p}, F_{slh-r}: As specified in **-5** above. The value of C_{slh1} is to be the value of 1/2 pitch (*mm*) specified in **7.2.7.2**.

ℓ_{slh}: Equivalent lever (*m*), to be taken as:

$\ell_{slh} = f_{bd}\ell$

f_{bd}: Coefficient considering boundary conditions, as specified in **Table 4.8.2-16**

ℓ: Bending span (*m*) of corrugated bulkheads, as specified in **7.2.7.3**

7 Hull girder load (*kN-m*) to be considered in longitudinal members is to be in accordance with absolute value of the following formulae, whichever is greater.

$M_{V-HG} = M_{SV\_max} + C_{slh-V}M_{WV-h}$

$M_{V-HG} = M_{SV\_min} + C_{slh-V}M_{WV-s}$

M_{SV_max}: Permissible maximum vertical still water bending moment (*kN-m*) specified in **4.3.2.2**

M_{SV_min}: Permissible minimum vertical still water bending moment (*kN-m*) specified in **4.3.2.2**

M_{WV-h}: Vertical wave bending moment (*kN-m*) in the hogging condition, to be taken as:

$M_{WV-h} = 0.19C_1C_2{L_C}^2BC_{B1}$

M_{WV-s}: Vertical wave bending moment (*kN-m*) in the sagging condition, to be taken as:

$M_{WV-s} = -0.11C_1C_2{L_C}^2B(C_{B1} + 0.7)$

C_2: As specified in **Table 4.4.2-14**. Intermediate vales are to be linear interpolation.

C_{slh-V}: 0.5 for sloshing loads due to pitch, 0.2 for sloshing loads due to roll

Chapter 10 ADDITIONAL STRUCTURAL REQUIREMENTS

Section 10.9 has been added as follows.

10.9 Tank Structures for Sloshing

10.9.1 General

10.9.1.1 Application*

1 For the members of liquid cargo tank structures which satisfy the following **(1)** to **(3)**, the scantlings specified in this **10.9** are considered to be satisfied when obtained using the sloshing loads specified in **4.8.2.4**.

(1) Cargo tanks with volumes of not less than 100 m^3

(2) Cargo tanks designed for possible to loading at filling ratios of not less than 20 % and not more than 90 %

(3) Where the period of longitudinal oscillation of cargo tanks is within the range of ±20 % of pitch period and within ±1.5 *seconds* from the same period, and where the period of transverse oscillation of cargo tanks is within the range of ±20 % of roll period and within ±1.5 *seconds* from the same period.

2 In applying **-1(3)** above, where only one of the conditions is applicable, only the sloshing load due to the relevant ship motion need be considered.

3 In applying **-1(3)** above, tank natural periods are to be calculated for each 10 % of the filling ratio, and only the sloshing load due to the filling ratio corresponding to the conditions of **-1(3)** above need be considered.

4 Notwithstanding **-1** above, the application of this **10.9** may be required for any tank structure deemed necessary by the Society.

5 Notwithstanding this **10.9**, advanced methods such as numerical calculations may be required in order to determine scantling where deemed appropriate by the Society.

10.9.1.2 Scantling Approach

The required scantlings specified in this **10.9** are to be net scantlings.

10.9.1.3 Members to be Assessed and Loads to be Applied

This **10.9** specifies the yield strength assessment of plates on which sloshing loads act (including plate panels constituting the webs of girders), and the stiffeners attached to them. Strength assessments for their members are to be performed considering the lateral loads and hull girder loads specified in **Table 10.9.1-1**.

Table 10.9.1-1 Loads for Each Member to be Assessed

Compartment to be assessed	Member	Load				Application
		Lateral load	Load type	Refer to the following		
				Lateral load (P_{slh}, M_{slh})	Hull girder load (M_{V-HG})	
Cargo tank	Plates	Internal pressure	Liquid loaded	**4.8.2.4-4**	**4.8.2.4-7**	**10.9.2.1**
	Stiffener			**4.8.2.4-5**		**10.9.3.1**
	Webs of girders			**4.8.2.4-4**		**10.9.4.1**
	Corrugated bulkheads			**4.8.2.4-6**	-	**10.9.2.1**
						10.9.5.1

10.9.1.4 Stress Due to Hull Girder Load

The stress σ_{BM} (*N/mm*^{2}) due to hull girder load at plates and stiffeners to be assessed is to be in accordance with the following formula.

$$\sigma_{BM} = \left| \frac{M_{V-HG}}{I_{y-n50}} (z - z_n) \right| \times 10^5$$

M_{V-HG}: Hull girder load (vertical bending moment) specified in **Table 10.9.1-1**(*kN-m*)

I_{y-n50}: Moment of inertia (*cm*^{4}) of the hull transverse section under consideration about its horizontal neutral axis. Corrosion additions considered in the calculation are to be as specified in **3.3.4**.

z: Z coordinate (*m*) at the load calculation point for the member under consideration. The coordinate systems and the load calculation points are as specified in **1.4.3.6, 3.7.1** and **3.7.2** respectively.

z_n: Vertical distance (*m*) from the top of the keel in the transverse section under consideration to the horizontal neutral axis

10.9.2 Plates

10.9.2.1

The thickness of plates on which sloshing loads act is to be not less than the value obtained from the following formula.

$$t = \frac{b}{2}\sqrt{\frac{P_{slh} \times 10^{-3}}{1.15 C_a \sigma_Y}} \ (mm)$$

σ_Y: Specified minimum yield stress (*N/mm*^{2})

b: Length (*mm*) of the shorter side of the plate panel. However, it is to be taken as breadth of flange b_f (*mm*) or breadth of web b_w(*mm*) in the case of corrugated bulkheads (*See* **Fig. 10.9.2-1**)

a: Length (*mm*) of the longer side of the plate panel.

α: Aspect ratio, to be taken as a/b.

P_{slh}: Equivalent pressure (*kN/m*^{2}) for the plate panels, as specified in **Table 10.9.2-1**

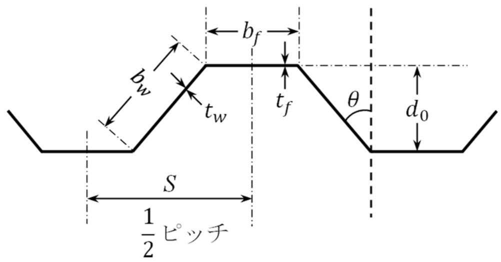
C_a: Coefficient of axial force effect as specified in **Table 6.3.2-3** when $\alpha \geq 2$ or **Table 6.3.2-4** when $\alpha < 2$. However, it is taken as 1.0 for corrugated bulkheads.

σ_{BM}: Stress (*N/mm*^{2}) due to hull girder bending, as specified in **10.9.1.4**

Table 10.9.2-1 Equivalent Pressure for Plate Panels

Member	P_{slh}
- Transverse bulkheads (including corrugated bulkheads) - Front and aft walls of tank - Transverse wash bulkheads - Tank top plates near transverse bulkheads / front and aft walls of tanks(1)	P_{slh-p} (4.8.2.4-4(1))
- Longitudinal bulkheads including corrugated bulkheads - Tank side walls - Longitudinal wash bulkheads - Tank top plates near longitudinal bulkheads / tank side walls(1)(2) - Sloping plates above and below longitudinal bulkheads	P_{slh-r} (4.8.2.4-4(2))
Notes: Numbers in parentheses indicate section number. (1) P_{slh-p} applies to plate panels within the range of $0.3\ell_{tk}$ from transverse bulkheads / front and aft walls of tanks, while P_{slh-r} applies to plate panels within the range of $0.3b_{tk}$ from longitudinal bulkheads / tank side walls. Definitions of ℓ_{tk} and b_{tk} are specified in **Table 4.8.2-13** and **Table 4.8.2-14.** (2) Notwithstanding **(1)** above, where large sloping plates (such as plates consisting of top side tanks) are arranged between tank top plates and longitudinal bulkheads /tank side walls, the tank top plates may be excluded from the members to be assessed.	

Fig. 10.9.2-1 1/2 Pitch of Corrugated Bulkheads



10.9.3 Stiffeners

10.9.3.1

The section modulus of stiffeners attached to plates on which sloshing loads act is to be not less than the value obtained from the following formula.

$$Z = \frac{M_{slh}}{C_s \sigma_Y} \times 10^3 (cm^3)$$

M_{slh}: Equivalent bending moment (kN-m), as specified in **Table 10.9.3-1.**

C_s: Coefficient of axial force effect, as specified in **Table 6.4.2-4.**

Table 10.9.3-1 Equivalent Bending Moment for Each Member to be Assessed

Member to be assessed	Stiffened system	M_{slh}
− Stiffeners attached to tank top plates[(1) (2)]	Longitudinal	M_{slh-p}(4.8.2.4-5(1)) M_{slh-r}(4.8.2.4-5(2))
	Transverse	M_{slh-p}(4.8.2.4-5(2)) M_{slh-r}(4.8.2.4-5(1))
− Stiffeners attached to transverse bulkheads / front and aft walls of tank − Stiffeners attached to transverse wash bulkheads − Stiffeners attached to vertical girders which are attached to longitudinal bulkheads / tank side walls − Stiffeners attached to horizontal girders which are attached to transverse bulkheads / front and aft walls of tank − Stiffeners attached to cross-tie of transverse direction	System A[(3)]	M_{slh-p}(4.8.2.4-5(1))
	System B[(4)]	M_{slh-p}(4.8.2.4-5(2))
− Stiffeners attached to longitudinal bulkheads / tank side walls − Stiffeners attached to longitudinal wash bulkheads − Stiffeners attached to sloping plates above and below longitudinal bulkheads / tank side walls − Stiffeners attached to vertical girders which are attached to transverse bulkheads − Stiffeners attached to horizontal girders which are attached to longitudinal bulkheads / tank side walls − Stiffeners attached to cross-tie of longitudinal direction	System A [(3)]	M_{slh-r} (4.8.2.4-5(1))
	System B [(4)]	M_{slh-r} (4.8.2.4-5(2))

Notes:
Numbers in parentheses indicate section number.

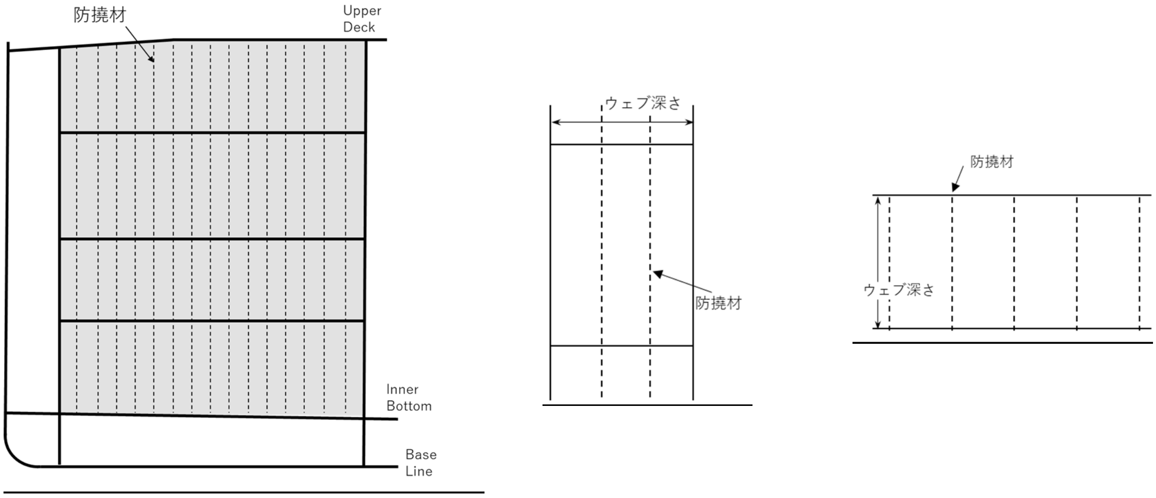
(1) M_{slh-p} applies to stiffeners attached to plate panels within the range of $0.3\ell_{tk}$ from transverse bulkheads / front and aft walls of tank, while M_{slh-r} applies to stiffeners attached to plate panels within the range of $0.3b_{tk}$ from longitudinal bulkheads / tank side walls. Definitions of ℓ_{tk} and b_{tk} are specified in **Table 4.8.2-13** and **Table 4.8.2-14.**

(2) Notwithstanding **(1)** above, where large sloping plates (such as plates consisting of top side tanks) are arranged between tank top plates and longitudinal bulkheads /tank side walls, tank top plates may be excluded from the members to be assessed.

(3) *See* **Fig. 10.9.3-1**

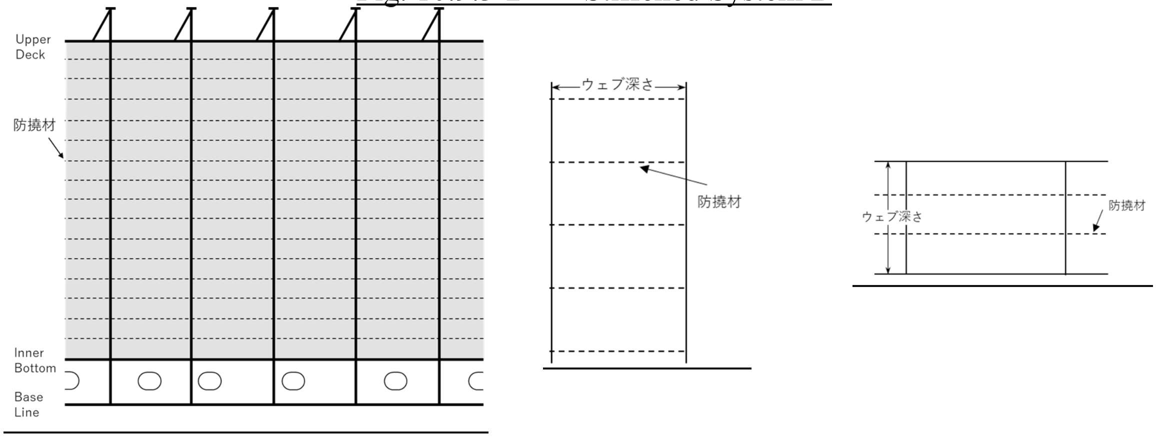
(4) *See* **Fig. 10.9.3-2**

Fig. 10.9.3-1 Stiffened System A



(a) Bulkhead, wash bulkhead (b) Vertical girder (c) Horizontal girder

Fig. 10.9.3-2 Stiffened System B



(a) Bulkhead (b) Vertical girder (c) Horizontal girder, cross-tie

10.9.4 Webs of Girders

10.9.4.1

The web thickness t_w of girders on which sloshing loads act is to be not less than the value obtained from the following formula.

$$t_w = \frac{b}{2}\sqrt{\frac{P_{slh} \times 10^{-3}}{1.15 C_a \sigma_Y}} \quad (mm)$$

P_{slh}: Equivalent pressure (kN/m^2) for the plate panels, as specified in **Table 10.9.4-1**

C_a: Coefficient of axial force effect as specified in **10.9.2.1**

b: Length (mm) of the shorter side of the plate panel

Table 10.9.4-1 Equivalent Pressure for Each Member to be Assessed

Member to be assessed	P_{slh}
− Horizontal girders attached to transverse bulkheads / front and aft walls of tanks − Horizontal girders attached to transverse wash bulkheads − Vertical girders attached to longitudinal bulkheads / tank side walls − Vertical girders attached to longitudinal wash bulkheads − Cross-ties in transverse direction	P_{slh-p} **(4.8.2.4-4(1))**
− Horizontal girders attached to longitudinal bulkheads / tank side walls − Horizontal girders attached to longitudinal wash bulkheads − Vertical girders attached to transverse bulkheads / front and aft walls of tanks − Vertical girders attached to transverse wash bulkheads − Cross-ties in longitudinal direction	P_{slh-r} **(4.8.2.4-4(2))**
Notes: Numbers in parentheses indicate section number.	

10.9.5 Corrugated Bulkheads

10.9.5.1

1 The thickness of flanges and webs of corrugated bulkheads is to be not less than the value specified in **10.9.2.1**.

2 The section modulus of 1/2 pitch of vertically corrugated bulkheads is to be not less than the value obtained from the following formula.

$$Z = \frac{M_{slh}}{\sigma_Y} \times 10^3 \ (cm^3)$$

M_{slh}: Equivalent bending moment (kN-m), as specified in **Table 10.9.5-1**

3 Notwithstanding **-1** and **-2** above, horizontally corrugated bulkheads are to be as deemed appropriate by the Society.

Table 10.9.5-1 Equivalent Bending Moment for Each Member to be Assessed

Member to be assessed	M_{slh}
Corrugated transverse bulkheads	M_{slh-p} **(4.8.2.4-6)**
Corrugated longitudinal bulkheads	M_{slh-r} **(4.8.2.4-6)**
Notes: Numbers in parentheses indicate section number.	

Part 2-3 ORE CARRIERS

Chapter 10 ADDITIONAL STRUCTURAL REQUIREMENTS

Section 10.5 has been renumbered to Section 10.6, and 10.5 has been added as follows.

10.5 Tank Structures for Sloshing

10.5.1 General

10.5.1.1 Application

1 For the members of ballast tank structures which satisfy the following **(1)** to **(3)**, the scantlings specified in this **10.5** are considered to be satisfied when obtained using the sloshing loads specified in **4.8.2.4, Part 1**.

(1) Ballast tanks with volumes of not less than 100 m^3

(2) Ballast tanks designed for possible to loading at filling ratios of not less than 20 % and not more than 90 %

(3) Where the period of longitudinal oscillation of ballast tanks is within the range of ±20 % of pitch period and within ±1.5 *seconds* from the same period, and where the period of transverse oscillation of ballast tanks is within the range of ±20 % of roll period and within ±1.5 *seconds* from the same period.

2 In applying **-1(3)** above, where only one of the conditions is applicable, only the sloshing load due to the relevant ship motion need be considered.

3 In applying **-1(3)** above, the tank natural periods are to be calculated for each 10 % of the filling ratio, and only the sloshing load due to the filling ratio corresponding to the conditions of **-1(3)** above need be considered.

10.5.1.2 Scantling Approach

The required scantlings specified in this **10.5** are to be net scantlings.

10.5.2 Plates

10.5.2.1

1 The plate thickness on which sloshing loads act is to be not less than the value obtained from **10.9.2, Part 1**.

2 Equivalent pressure for members to be assessed is to be in accordance with **Table 10.5.2-1**. The density of seawater (1.025 t/m^3), however, is to be considered instead of maximum design cargo density when calculating such pressure.

Table 10.5.2-1 Equivalent Pressure for Plate Panels

Member	P_{slh}
- Transverse bulkheads - Transverse wash bulkheads - Tank top plates near transverse bulkheads (1)	P_{slh-p} **(4.8.2.4-4(1), Part 1)**
- Longitudinal bulkheads - Side shells - Tank top plates near longitudinal bulkheads / side shells(1) - Sloping plates below longitudinal bulkheads(2)	P_{slh-r} **(4.8.2.4-4(2), Part 1)**
Notes: Numbers in parentheses indicate section number.	
(1) P_{slh-p} is to be applied to the plate panels within the range of $0.3\ell_{tk}$ from transverse bulkheads. In addition, P_{slh-r} is to be applied to the plate panels within the range of $0.3b_{tk}$ from longitudinal bulkheads. The definitions of ℓ_{tk} and b_{tk} are as specified in **Table 4.8.2-13** and **Table 4.8.2-14, Part 1**. (2) For sloping plates below longitudinal bulkheads, sloshing loads are to be calculated using the same parameters as those used for longitudinal bulkheads.	

10.5.3 Stiffeners

10.5.3.1

1 The section modulus of stiffeners attached to plates on which sloshing loads act is to be not less than the value obtained from the formula specified in **10.9.3, Part 1**.

2 Equivalent bending moments for members to be assessed are to be in accordance with **Table 10.5.3-1**. The density of seawater (1.025 t/m^3) is to be considered instead of maximum design cargo density when calculating such moments.

Table 10.5.3-1 Equivalent Bending Moment for Each Member to be Assessed

Member to be assessed	Stiffened system	M_{slh}
− Stiffeners attached to tank top plates[1]	Longitudinal	M_{slh-p}(**4.8.2.4-5(1), Part 1**) M_{slh-r}(**4.8.2.4-5(2), Part 1**)
	Transverse	M_{slh-p}(**4.8.2.4-5(2), Part 1**) M_{slh-r}(**4.8.2.4-5(1), Part 1**)
− Stiffeners attached to transverse bulkheads − Stiffeners attached to transverse wash bulkheads − Stiffeners attached to vertical girders which are attached to longitudinal bulkheads − Stiffeners attached to horizontal girders which are attached to transverse bulkheads − Stiffeners attached to cross-tie of transverse direction	System A[2]	M_{slh-p}(**4.8.2.4-5(1), Part 1**)
	System B[3]	M_{slh-p}(**4.8.2.4-5(2), Part 1**)
− Stiffeners attached to longitudinal bulkheads − Stiffeners attached to side shells − Stiffeners attached to sloping plates below longitudinal bulkheads − Stiffeners attached to vertical girders which are attached to transverse bulkheads − Stiffeners attached to horizontal girders which are attached to longitudinal bulkheads	System A [2]	M_{slh-r} (**4.8.2.4-5(1), Part 1**)
	System B [3]	M_{slh-r} (**4.8.2.4-5(2), Part 1**)

Notes:
Numbers in parentheses indicate section number.

(1) M_{slh-p} is to be applied to the stiffeners attached to the plate panels within the range of $0.3\ell_{tk}$ from transverse bulkheads. And M_{slh-r} is to be applied to the stiffeners attached to the plate panels within the range of $0.3b_{tk}$ from longitudinal bulkheads / side shells.
(2) See **Fig. 10.9.3-1, Part 1**
(3) See **Fig. 10.9.3-2, Part 1**

10.5.4 Webs of Girders

10.5.4.1

1 The web thickness t_w of girders on which sloshing loads act is to be not less than the value obtained from the formula specified in **10.9.4, Part 1**.
2 Equivalent pressure for members to be assessed is to be in accordance with **Table 10.5.4-1**.

Table 10.5.4-1 Equivalent Pressure for Each Member to be Assessed

Member to be assessed	P_{slh}
- Horizontal girders attached to transverse bulkheads / transverse wash bulkheads - Vertical girders attached to longitudinal bulkheads - Vertical girders attached to side shells - Cross-ties in transverse direction	P_{slh-p} (**4.8.2.4-4(1), Part 1**)
- Horizontal girders attached to longitudinal bulkheads - Vertical girders attached to transverse bulkheads / transverse wash bulkheads - Horizontal girders attached to side shells	P_{slh-r} (**4.8.2.4-4(2), Part 1**)

Notes:
Numbers in parentheses indicate section number.

10.~~5~~6 Other

10.~~5~~6.1 Special Requirements for Ship Intended for the Carriage of Cargoes Having Moisture Contents Which Exceed Transportable Moisture Limit

10.~~5~~6.1.1

The hull structural members of ships intended for the carriage of cargoes having moisture contents which exceed transportable moisture limit are to be in accordance with the following **(1)** or **(2)**.

(1) For ships intended for the carriage of nickel ore with a moisture content that exceeds the transportable moisture limit, the requirements specified in **"Guidelines for the Safe Carriage of Nickel Ore"**

(2) For ships intended for the carriage of cargoes other than nickel ore, evaluation methods deemed appropriate by the Society

Part 2-7 TANKERS

Chapter 2 GENERAL ARRANGEMENT DESIGN

2.1 Structural Arrangement

2.1.1 Arrangement and Separation

Paragraph 2.1.1.5 has been deleted, and Paragraph 2.1.1.6 has been renumbered to Paragraph 2.1.1.5.

~~**2.1.1.5 Arrangements of Swash Bulkheads**~~

~~Where the length or breadth of a cargo oil tank exceeds, 15 *m* or $0.1L_C$ (*m*), whichever is greater, swash bulkheads are to be provided in cargo oil tanks. However, in accordance with the requirement in **4.2.1 (2), Part S**, this requirement may be dispensed with if special consideration is given to sloshing.~~

2.1.1.~~6~~5 Length of Deep Tanks

The length of deep tanks is not to exceed $0.2L_f$ (*m*).

Part 2-9 SHIPS CARRYING LIQUEFIED GASES IN BULK (INDEPENDENT PRISMATIC TANKS TYPE A/B)

Chapter 10 has been added as follows.

Chapter 10 ADDITIONAL STRUCTURAL REQUIREMENTS

10.1 Tank Structures for Sloshing

10.1.1 General

10.1.1.1 Application

1 For the members of cargo tank structures of independent prismatic tanks type A/B which satisfy the following **(1)** to **(3)**, the scantlings specified in this **10.1** are considered to be satisfied when obtained using the sloshing loads specified in **4.8.2.4, Part 1**.

(1) Independent prismatic tanks with volumes of not less than 100 m^3

(2) Independent prismatic tanks designed for possible to loading at filling ratios of not less than 20 % and not more than 90 %

(3) Where the period of longitudinal oscillation of independent prismatic tanks is within the range of ±20 % of pitch period and within ±1.5 *seconds* from the same period, and where the period of transverse oscillation of independent prismatic tanks is within the range of ±20 % of roll period and within ±1.5 *seconds* from the same period.

2 In applying **-1(3)** above, where only one of the conditions is applicable, only the sloshing load due to the relevant ship motion need be considered.

3 In applying **-1(3)** above, tank natural periods are to be calculated for each 10 % of the filling ratio, and only the sloshing load due to the filling ratio corresponding to the conditions of **-1(3)** above need be considered.

10.1.1.2 Scantling Approach

The required scantlings specified in this **10.1** are to be net scantlings. Corrosion additions for independent prismatic tanks are to be in accordance with **3.3.4.3, Part 1**.

10.1.2 Plates

10.1.2.1 Tank Type A

The thickness of plates on which sloshing loads act is to be not less than the value obtained from the following formula.

$$t = \frac{b}{2}\sqrt{\frac{P_{slh} \times 10^{-3}}{1.15 C_a \sigma_{perm}}} \ (mm)$$

b: Length (*mm*) of the shorter side of the plate panel.

P_{slh}: Equivalent pressure (kN/m^2) for the plate panels, as specified in **Table 10.1.2-1**.

C_a: Coefficient of axial force effect, to be taken as 1.0.

σ_{perm}: Permissible stress (N/mm^2), as specified in **Table 10.1.2-2**.

Table 10.1.2-1 Equivalent Pressure for Plate Panels

Member to be assessed	P_{slh}
- Front and aft walls of tank - Transverse wash bulkheads - Tank top plates near front and aft walls of tank(1)	P_{slh-p} **(4.8.2.4-4(1), Part 1)**
- Tank side walls - Centreline bulkheads - Longitudinal wash bulkheads - Tank top plates near tank side walls(1) - Sloping plates above and below tank side walls(2)	P_{slh-r} **(4.8.2.4-4(2), Part 1)**
Notes: Numbers in parentheses indicate section number. (1) P_{slh-p} applies to plate panels within the range of $0.3\ell_{tk}$ from the front and aft walls of tanks, while P_{slh-r} applies to plate panels within the range of $0.3b_{tk}$ from centreline bulkheads / tank side walls. Definitions of ℓ_{tk} and b_{tk} are specified in **Table 4.8.2-13, Part 1** and **Table 4.8.2-14, Part 1.** (2) Notwithstanding **(1)** above, where large sloping plates are arranged between tank top plates and tank side walls, tank top plates may be excluded from the members to be assessed.	

Table 10.1.2-2 Permissible Stress (Tank Type A)

Member	σ_{perm}
− Ferrite steels	min $(0.79\sigma_Y, 0.53\sigma_B)$
Notes: σ_Y :Specified minimum yield stress (*N/mm*^{2}) σ_B :Specified minimum tensile stress at room temperature (*N/mm*^{2}), to be taken as: For *KL*24, taken as 400 For *KL*27, taken as 420 For *KL*33, taken as 440 For *KL*37, taken as 490	

10.1.2.2 Tank Type B

The thickness of plates on which sloshing loads act is to be not less than the value obtained from the formula specified in **10.1.2.1**. However, permissible stress σ_{perm} (*N/mm*^{2}) is to be in accordance with **Table 10.1.2-3.**

Table 10.1.2-3 Permissible Stress (Tank Type B)

Member to be assessed	σ_{perm}
- Nickel steels, carbon manganese steels	min $(0.83\sigma_Y, 0.5\sigma_B)$
- Austenitic steels and aluminum alloys	min $(0.83\sigma_Y, 0.4\sigma_B)$
Notes: σ_Y, σ_B: As specified in **Table 10.1.2-2**	

10.1.3 Stiffeners

10.1.3.1

The section modulus of stiffeners attached to plates on which sloshing loads act is to be not less than the value obtained from the following formula.

$$Z = \frac{M_{slh}}{C_s \sigma_{perm}} \times 10^3 (cm^3)$$

M_{slh}: Equivalent bending moment (*kN-m*), as specified in **Table 10.1.3-1**.

C_s : Coefficient of axial force effect, to be taken as 1.0.

σ_{perm}: Permissible stress (*N/mm*^{2}), as specified in **Table 10.1.2-2** or **Table 10.1.2-3**.

Table 10.1.3-1 Equivalent Bending Moment for Each Member to be Assessed

Member to be assessed	Stiffened system	M_{slh}
− Stiffeners attached to tank top plates(1)(2)	Longitudinal	M_{slh-p}**(4.8.2.4-5(1), Part 1)** M_{slh-r}**(4.8.2.4-5(2), Part 1)**
	Transverse	M_{slh-p}**(4.8.2.4-5(2), Part 1)** M_{slh-r}**(4.8.2.4-5(1), Part 1)**
- Stiffeners attached to front and aft walls of tank - Stiffeners attached to transverse wash bulkheads - Stiffeners attached to vertical girders which are attached to centreline bulkheads - Stiffeners attached to vertical girders which are attached to tank side walls - Stiffeners attached to horizontal girders which are attached to front and aft walls of tank - Stiffeners attached to cross-tie of transverse direction	System A(3)	M_{slh-p}**(4.8.2.4-5(1), Part 1)**
	System B(4)	M_{slh-p}**(4.8.2.4-5(2), Part 1)**
- Stiffeners attached to tank side walls - Stiffeners attached to longitudinal wash bulkheads - Stiffeners attached to sloping plates above and below tank side walls - Stiffeners attached to vertical girders which are attached to front and aft walls of tank - Stiffeners attached to horizontal girders which are attached to tank side walls - Stiffeners attached to horizontal girders which are attached to centreline bulkheads	System A (2)	M_{slh-r} **(4.8.2.4-5(1), Part 1)**
	System B (3)	M_{slh-r} **(4.8.2.4-5(2), Part 1)**

Notes:
Numbers in parentheses indicate section number.

(1) M_{slh-p} applies to stiffeners attached to plate panels within the range of $0.3\ell_{tk}$ from the front and aft walls of tanks, while M_{slh-r} applies to stiffeners attached to plate panels within the range of $0.3b_{tk}$ from centreline bulkheads / tank side walls. Definitions of ℓ_{tk} and b_{tk} are specified in **Table 4.8.2-13** and **Table 4.8.2-14, Part 1.**

(2) Notwithstanding (1) above, where large sloping plates are arranged between tank top plates and tank side walls, stiffeners attached to the tank top plates may be excluded from the members to be assessed.

(3) *See* **Fig. 10.9.3-1, Part 1**

(4) *See* **Fig. 10.9.3-2, Part 1**

10.1.4 Webs of Girders

10.1.4.1

The web thickness t_w for girders on which sloshing loads act is to be not less than the value obtained from the following formula.

$$t_w = \frac{b}{2}\sqrt{\frac{P_{slh} \times 10^{-3}}{1.15 C_a \sigma_{perm}}} (mm)$$

P_{slh}: Equivalent pressure (*kN/m*^{2}) for plate panels, as specified in **Table 10.1.4-1**

C_a: Coefficient of axial force effect, to be taken as 1.0
b: Length (*mm*) of the shorter side of the plate panel
σ_{perm}: Permissible stress (*N/mm*^{2}), as specified in **Table 10.1.2-2** or **Table 10.1.2-3**

Table 10.1.4-1 Equivalent Pressure for Each Member to be Assessed

Member to be assessed	P_{slh}
- Horizontal girders attached to front and aft walls of tanks / transverse wash bulkheads - Vertical girders attached to tank side walls / centreline bulkheads / longitudinal wash bulkheads - Cross-ties in transverse direction	P_{slh-p} **(4.8.2.4-4(1), Part 1)**
- Horizontal girders attached to tank side walls / centreline bulkheads / longitudinal wash bulkheads - Vertical girders attached to front and aft walls of tanks / transverse wash bulkheads - Cross-ties in longitudinal direction	P_{slh-r} **(4.8.2.4-4(2), Part 1)**
Note: Numbers in parentheses indicate section number.	

Part 2-11 SHIPS CARRYING LIQUEFIED GASES IN BULK (MEMBRANE TANKS)

Chapter 10 ADDITIONAL STRUCTURAL REQUIREMENTS

Section 10.2 has been added as follows.

10.2 Tank Structures for Sloshing

10.2.1 General

10.2.1.1 Application

1 For the members of hull structures acting as boundaries of cargo tanks which satisfy the following **(1)** to **(3)**, the scantlings specified in this **10.2** are considered to be satisfied when obtained using the sloshing loads specified in **4.8.2.4, Part 1**.

(1) Cargo tanks with volumes of not less than 100 m^3

(2) Cargo tanks designed for possible loading at filling ratios of not less than 20 % and not more than 90 %

(3) Where the period of longitudinal oscillation of cargo tanks is within the range of ±20 % of pitch period and within ±1.5 *seconds* from the same period, and where the period of transverse oscillation of cargo tanks is within the range of ±20 % of roll period and within ±1.5 *seconds* from the same period.

2 In applying **-1(3)** above, where only one of the conditions is applicable, only the sloshing load due to the relevant ship motion need be considered.

3 In applying **-1(3)** above, the tank natural periods are to be calculated for each 10 % of the filling ratio, and only the sloshing load due to the filling ratio corresponding to the conditions of **-1(3)** above need be considered.

10.2.1.2 Scantling Approach

The required scantlings specified in this **10.2** are to be net scantlings.

10.2.2 Plates

10.2.2.1

The thickness of plates on which sloshing loads act is to be not less than the value obtained from the formula specified in **10.9.2, Part 1**. Equivalent pressure is to be in accordance with **Table 10.2.2-1**.

Table 10.2.2-1 Equivalent Pressure for Plate Panels

Members to be assessed	P_{slh}
- Transverse bulkheads - Tank top plates near transverse bulkheads	$C_m P_{slh-p}$ **(4.8.2.4-4(1), Part 1)**
- Longitudinal bulkheads - Inner deck sloping plates - Bilge hopper plating	$C_m P_{slh-r}$ **(4.8.2.4-4(2), Part 1)**
Notes: Numbers in parentheses indicate section number. C_m: Coefficient, to be taken as 0.85	

10.2.3 Stiffeners

10.2.3.1

The section modulus of stiffeners attached to plates on which sloshing loads act is to be not less than the value obtained from the formula specified in **10.9.3, Part 1**. Equivalent bending moments are to be in accordance with **Table 10.2.3-1**.

Table 10.2.3-1 Equivalent Bending Moment for Each Member to be Assessed

Member to be assessed	Stiffened system	M_{slh}
- Stiffeners attached to transverse bulkheads	Vertical	$C_m M_{slh-p}$**(4.8.2.4-5(1), Part 1)**
	Horizontal	$C_m M_{slh-p}$**(4.8.2.4-5(2), Part 1)**
- Stiffeners attached to longitudinal bulkheads - Stiffeners attached to inner deck sloping plates - Stiffeners attached to bilge hopper plating	Longitudinal	$C_m M_{slh-r}$ **(4.8.2.4-5(1), Part 1)**

Notes:
Numbers in parentheses indicate section number.
C_m: Coefficient, to be taken as 0.85

"Guidance for the survey and construction of steel ships" has been partly amended as follows:

Part C HULL CONSTRUCTION AND EQUIPMENT

Part 1 GENERAL HULL REQUIREMENTS

C10 ADDITIONAL STRUCTURAL REQUIREMENTS

Section C10.9 has been added as follows.

C10.9 Tank Structures for Sloshing

C10.9.1 General

C10.9.1.1 Application

It is recommended that the design of tank structure satisfy the following **(1)** and **(2)**.

(1) The period of longitudinal oscillation of liquid cargo tanks is not within the range of ±20 % of pitch period and not within ±1.5 *seconds* from the same period.

(2) The period of transverse oscillation of liquid cargo tanks is not within the range of ±20 % of roll period and not within ±1.5 *seconds* from the same period.

Part S SHIPS CARRYING DANGEROUS CHEMICALS IN BULK

S4 CARGO CONTAINMENT

S4.2 Design and Construction

Paragraph S4.2.1 has been amended as follows.

S4.2.1 General

In ~~"dynamic load by ship motion at sea" in 4.2.1(1)(e)~~applying **4.2.1(2)**, **Part S of the Rules**, the following are to be satisfied.

(1) For ships subject to **Part C of the Rules**, **10.9, Part1, Part C of the Rules** is to be satisfied.

(2) For ships subject to **Part CS of the Rules**, when cargo is half loaded in a range from 20 to 80% of loading ratio in cargo tanks, the structural strength is to be determined in consideration of the effects of sloshing. However, in case where the length of tanks is not more than 10 *m* or 10% of the ship's length for freeboard (L_f), whichever is the greater, no consideration may be taken for sloshing effects.