Section8 SCANTLING REQUIREMENTS

1. Longitudinal Strength

1.1 Loading Guidance

1.1.1 General

1.1.1.1 All ships are to be provided with loading guidance information containing sufficient information to enable the master of the ship to maintain the ship within the stipulated operational limitations. The loading guidance information is to include an approved Loading Manual and Loading Computer System complying with the requirements given in **1.1.2** and **1.1.3** respectively.

1.1.1.2 The loading guidance information is to be based on the final data of the ship.

1.1.1.3 Modifications resulting in changes to the main data of the ship (lightship weight, buoyancy distribution, tank volumes or usage, etc), require the Loading Manual to be updated and re-approved, and subsequently the Loading Computer System to be updated and re-approved. However, new loading guidance need not be re-submitted provided that the resulting draughts, still water bending moments and shear forces do not differ from the originally approved data by more than 2%.

1.1.1.4 The loading guidance is to be prepared in a language understood by the users. If this language is not English, a translation into English shall be included. When applicable a document translating the language of the input and output data for the Loading Computer System into English is to be provided.

1.1.1.5 The loading guidance information is to include the following statement, to ensure the crew are aware of the operational limitations for minimum draught forward:

The scantlings are approved for a minimum draught forward, at F.P. In sea conditions where slamming is likely to occur, the forward draught is not to be less than the following:

(a)…m with double bottom ballast tanks No(s)... filled, or

(b)…m with double bottom ballast tanks No(s)… empty

1.1.2 Loading Manual

1.1.2.1 The Loading Manual is a document that:

- (a) describes the loading conditions on which the design and approval of the ship has been based for seagoing- and harbour/sheltered water operation
- (b) describes the results of the calculations of still water bending moments, shear forces and where applicable, limitations due to torsional and lateral loads
- (c) describes relevant operational limitations as given in **1.1.2.7**.

1.1.2.2 The following loading conditions and design loading and ballast conditions upon which the approval of the hull scantlings is based are, as a minimum, to be included in the Loading Manual:

- (a) Seagoing conditions including both departure and arrival conditions
  - ・homogeneous loading conditions including a condition at the scantling draft (homogeneous loading conditions shall not include filling of dry and clean ballast tanks)
  - ・a normal ballast condition where:

    the ballast tanks may be full, partially full or empty. Where partially full options are exercised, the conditions in **1.1.2.5** are to be complied with

    all cargo tanks are to be empty including cargo tanks suitable for the carriage of water ballast at sea

    the propeller is to be fully immersed, and

    the trim is to be by the stern and is not to exceed 0.015L, where L is as defined in **Section 4/1.1.1**
  - ・a heavy ballast condition where:

    all segregated ballast tanks in the cargo tank region are full or partially full. Where the partially full options are exercised, the conditions in **1.1.2.5** are to be complied with

    the lower fore peak water ballast tank is to be full (if fitted) any ballast tank aft of the cargo tank region may be full, partially full or empty. Where the partially full options are exercised, the conditions in **1.1.2.5** are to be complied with

all cargo tanks are to be empty including cargo tanks suitable for the carriage of water ballast at sea

the propeller immersion I/D_{prop} is to be at least 60% where

I = the distance from the propeller centreline to the waterline, in m

D_{prop} = propeller diameter, in m

・any specified non-uniform distribution of loading

・conditions with high density cargo including the maximum design cargo density, when applicable

・mid-voyage conditions relating to tank cleaning or other operations where these differ significantly from the ballast conditions

・conditions covering ballast water exchange procedures

(b) Harbour/sheltered water conditions

・conditions representing typical complete loading and unloading operations

・docking condition afloat

・propeller inspection afloat condition, in which the propeller shaft centre line is at least $D_{prop}/4$ above the waterline in way of the propeller, where D_{prop} is the propeller diameter

(c) Additional design conditions

・a design ballast condition in which all segregated ballast tanks in the cargo tank region are full and all other tanks are empty including fuel oil and fresh water tanks.

1.1.2.3 The calculation for the departure conditions are to be based on full tanks according to the applicable stability regulations for filling of tanks; note bunker tanks are not to be taken less than 95% full and other consumables are to be taken at 100% capacity. Arrival conditions are to be based on 10% of the maximum capacity of bunker, fresh water and stores.

1.1.2.4 Where the amount and disposition consumables at any intermediate stage of the voyage are considered more severe than of those described in **1.1.2.3**, calculations for such intermediate conditions are also to be submitted for approval.

1.1.2.5 Ballast loading conditions involving partially filled peak and/or other ballast tanks in any departure, arrival or intermediate condition are not permitted to be used as design loading conditions where alternative filling levels would result in higher stress levels. The partial filling of such tanks is however permitted in service providing, for all filling levels between empty and full, the stress levels are below the stress and buckling acceptance criteria. For design purposes this criteria will be satisfied if the stress levels are below the stress and buckling acceptance criteria for loading conditions with the appropriate tanks full and/or empty. The corresponding full or empty tank conditions are to be considered as design conditions for calculation of the still water bending moment and shear force, but these do not need to comply with propeller immersion and trim requirements as specified in **1.1.2.2(a)**.

1.1.2.6 In cargo loading conditions, partial filling of peak tanks is not permitted unless, for all filling levels between empty and full, the resulting stress levels are below the stress and buckling acceptance criteria. For design purposes this criteria will be satisfied if the stress levels are below the stress and buckling acceptance criteria for loading conditions with the appropriate tanks full and/or empty. The corresponding full or empty tank conditions are to be considered as design conditions for calculation of the still water bending moment and shear force, but these do not need to comply with propeller immersion and trim requirements.

1.1.2.7 The Loading Manual is to include the design basis and operational limitations upon which the approval of the hull scantlings are based. The information listed in **Table 8.1.1** is to be included in the Loading Manual.

1.1.2.8 The approval of the hull scantlings is based on the rule defined loading patterns and the loading conditions given in the Loading Manual.

Table8.1.1 Design Parameters

Parameter
Permissible limits of still water bending moments (seagoing operation and harbour/sheltered water operation)
Permissible limits of still water shear forces (seagoing operation and harbour/sheltered water operation)
Scantling draught, T_{sc}
Design minimum ballast draught at midships, T_{bal}
Design slamming draught forward with forward double bottom ballast tanks filled, $T_{FP\text{-}full}$
Design slamming draught forward with forward double bottom ballast tanks empty, $T_{FP\text{-}mt}$
Maximum allowable cargo density
Maximum cargo density in any loading condition in Loading Manual
Description of the ballast exchange operations including any limitations
Design speed

1.1.2.9 The following additional loading conditions are to be included in the Loading Manual if the ship is specifically approved and intended to be operated in such conditions:

(a) sea-going ballast conditions including water ballast carried in one or more cargo tanks which are intended for use in emergency situations as allowed by MARPOL ANNEX I, Regulation 13. (Ship approved for loading pattern A7 of **Table B.2.3** or **B7** of **Table B.2.4**)

(b) seagoing loading conditions where the net static upward load on the double bottom exceeds that given with the combination of an empty cargo tank and a mean ship's draught of $0.9T_{sc}$

(c) seagoing loading conditions with wing cargo tanks less than 25% full with the combination of mean ship's draught greater than $0.9T_{sc}$

(d) seagoing loading conditions where the net static downward load on the double bottom exceeds that given with the combination of a full cargo tank at a cargo density of 1.025 $tonnes/m^3$ and a mean ship's draught of $0.6T_{sc}$

(e) for ships arranged with cross ties in the centre cargo tank , seagoing loading conditions showing a non-symmetric loading pattern where the difference in filling level between wing and adjacent centre cargo tanks exceeds 25% of the filling height in the wing cargo tank (Ship approved for loading pattern A7 of **Table B.2.3** or B7 of **Table B.2.4**

1.1.2.10 This sub-section is not intended to prevent any other loading conditions to be included in the Loading Manual, nor is it intended to replace in any way the required Loading Manual/Instrument.

1.1.2.11 A tanker may in actual operation be loaded differently from the design loading conditions specified in the Loading Manual, provided limitations for longitudinal and local strength as defined in the Loading Manual and Loading Instrument onboard and applicable stability requirements are not exceeded.

1.1.3 Loading computer system

1.1.3.1 The loading computer system, is to be a system, which unless stated otherwise is digital and that can easily and quickly ascertain whether operational limitations are exceeded for any loading condition.

1.1.3.2 The loading computer system is to be approved based on **34.1.3, Part C** of the Rules.

1.1.3.3 The loading computer system is to be capable of producing any specific loading condition and verify that these comply with all the operational limitations given in **1.1.2.2**, and provide plots including input and output.

1.1.3.4 If any of the operational limitations are not checked, the user is to be properly informed when using the system, and by the plots provided, so that each such item is verified by other means. The loading computer system is as a minimum to verify that the following are satisfied:

(a) draught limitations

(b) still water bending moments and shear forces are reported at the specified locations/read-out points.

1.1.3.5 The final test conditions for the loading computer are to be based on conditions given in the final Loading Manual. The test conditions are subject to approval and the shear forces and bending moments calculated by the loading computer system, at each read out point, are to be within $0.02Q_{sw\text{-}perm}$ or $0.02M_{sw\text{-}perm}$ of the results given in the loading manual, where $Q_{sw\text{-}perm}$ and $M_{sw\text{-}perm}$ are the assigned permissible shear force and bending moment at each read out point respectively.

1.1.3.6 Before a loading computer system is accepted, all relevant aspects of the computer, including but not limited to the following, are to be demonstrated to the Surveyor:

(a) verification that the final data of the ship has been used
(b) verification that the relevant limits for all read-out points are correct
(c) that the operation of the system after installation onboard, is in accordance with the approved test conditions
(d) that the approved test conditions are available onboard
(e) that an operational manual is available onboard.

1.2 Hull Girder Bending Strength

1.2.1General

1.2.1.1 The net vertical hull girder section modulus, $Z_{v\text{-}net50}$, is to be equal to or greater than the requirements given by **1.2.2.2** and **1.2.3.2**. The net vertical hull girder moment of inertia, $I_{v\text{-}net50}$, as defined in **Section 4/2.6.1.1** is to be equal to or greater than the requirement given by **1.2.2.1.**

1.2.1.2 Scantlings of all continuous longitudinal members of the hull girder based on moment of inertia and section modulus requirement in **1.2.2.1** and **1.2.2.2** are to be maintained within 0.4L midships.

1.2.1.3 The hull girder section modulus requirements in **1.2.3** apply along the full length of the hull girder, from A.P. to F.P.

1.2.1.4 Structural members included in the hull girder section modulus are to satisfy the buckling criteria given in **1.4.**

1.2.2 Minimum requirements

1.2.2.1 At the midship cross section the net vertical hull girder moment of inertia about the horizontal neutral axis, $I_{v\text{-}net50}$, is not to be less than the rule minimum vertical hull girder moment of inertia, $I_{v\text{-}min}$, defined as:

$$I_{v-min} = 2.7kC_{wv}L^3B(C_b + 0.7)\cdot 10^{-8} \qquad (m^4)$$

Where:

C_{wv} : wave coefficient as defined in **Table 8.1.2**
L : rule length, in m, as defined in **Section 4/1.1.1.1**
B : moulded breadth, in m, as defined in **Section 4/1.1.3.1**
C_b : block coefficient, as defined in **Section 4/1.1.9.1** but is not to be taken as less than 0.70

Table8.1.2 Wave Coefficient C_{wv}

rule length	C_{wv}
$150 \le L \le 300$	$10.75 - [(300 - L) / 100]^{3/2}$
$300 < L < 350$	10.75
$350 \le L \le 500$	$10.75 - [(L - 350) / 150]^{3/2}$

1.2.2.2 At the midship cross section the net vertical hull girder section modulus, $Z_{v\text{-}min}$, at the deck and keel is not to be less than the rule minimum hull girder section modulus, $Z_{v\text{-}min}$, defined as:

$$Z_{v-min} = 0.9kC_{wv}L^2B(C_b + 0.7)\cdot 10^{-6} \qquad (m^3)$$

Where:

k : higher strength steel factor, as defined in **Section 6/1.1.4**
C_{wv} : wave coefficient as defined in **Table 8.1.2**
L : rule length, in m, as defined in **Section 4/1.1.1.1**
B : moulded breadth, in m, as defined in **Section 4/1.1.3.1**
C_b : block coefficient, as defined in **Section 4/1.1.11.1** but is not to be taken as less than 0.70

1.2.2.3 The net hull girder section modulus at keel, $Z_{v\text{-}net50\text{-}kl}$, is to be calculated in accordance with **Section 4/2.6.1.2** and taking z at the keel.

1.2.2.4 The net hull girder section modulus at deck, $Z_{v\text{-}net50\text{-}dk}$, is to be calculated in accordance with **Section 4/2.6.1.2** and taking z at the effective deck height, see **1.2.2.5.**

1.2.2.5 The effective deck height from the horizontal neutral axis for the hull girder section modulus, $z_{dk\text{-}eff}$, is to be taken as:

$$z_{dk-eff} = z_{dk-side} - z_{NA-net50} \qquad (m)$$

When no effective longitudinal strength members are positioned above a line extending from moulded deck line at side to a position
$(z_{dk\text{-}side}\text{-}z_{NA\text{-}net50})/0.9$ from the neutral axis at the centreline

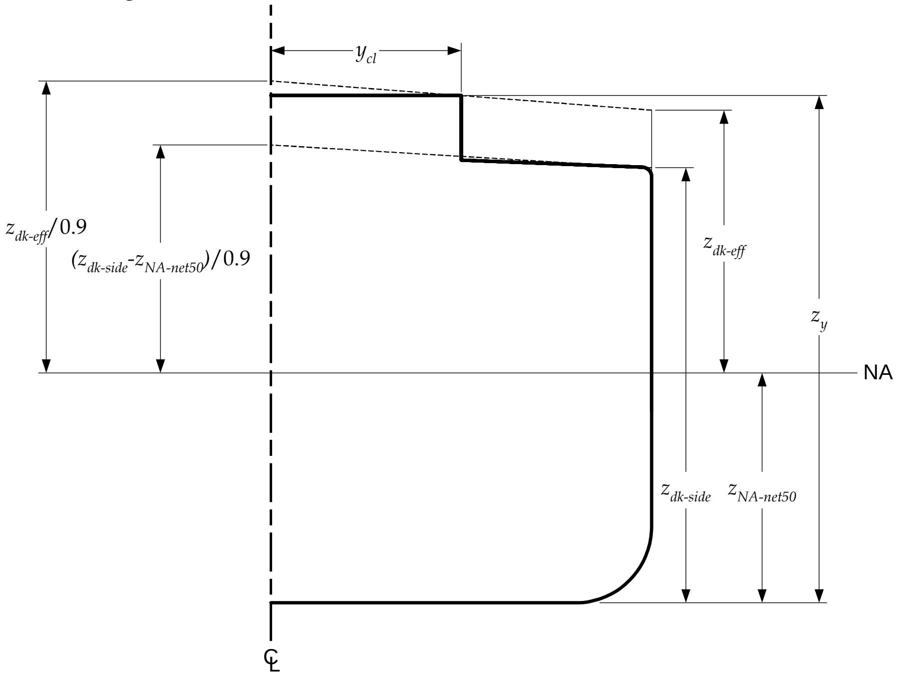
$$z_{dk-eff} = \left(z_y - z_{NA-net50}\right)\left(0.9 + 0.2\frac{y_{cl}}{B}\right) \qquad (m)$$

When any effective longitudinal strength members are positioned above a line extending from moulded deck line at side to a position
$(z_{dk\text{-}side}\text{-}z_{NA\text{-}net50})/0.9$ from the neutral axis at the centreline

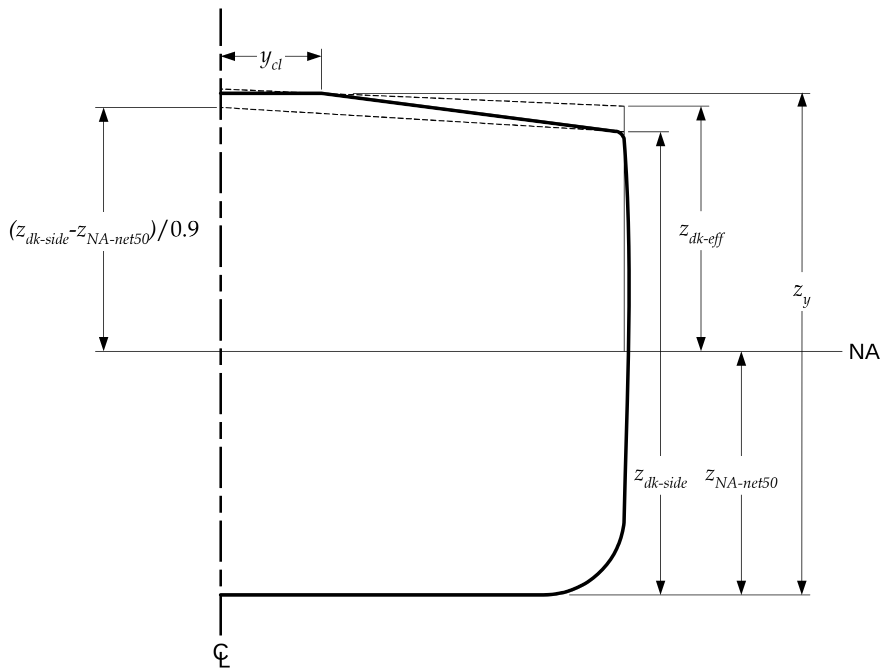
Where:

z_y	: distance from the baseline to top of the continuous strength member at a distance y from the centreline, in m, giving the largest value of $z_{dk\text{-}eff}$, see **Fig. 8.1.1**
$z_{NA\text{-}net50}$	: distance from baseline to horizontal neutral axis, in m, see **Fig. 8.1.1**
y_{cl}	: distance from the top of the continuous strength member to the centreline of the ship, in m, giving the largest value of $z_{dk\text{-}eff}$, see **Fig. 8.1.1**
B	: moulded breadth, in m, as defined in **Section 4/1.1.3.1**
$z_{dk\text{-}side}$	: distance from the baseline to the moulded deck line at side, in m, see **Fig. 8.1.1**

Fig. 8.1.1 Position for Calculation of Section Modulus Deck



(a) Trunk deck or continuous hatch coaming



(b) Ship with large camber

1.2.3 Hull girder requirement on total design bending moment

1.2.3.1 The net vertical hull girder section modulus requirement as defined in **1.2.3.2** is to be assessed for both hogging and sagging conditions.

1.2.3.2 The net hull girder section modulus about the horizontal neutral axis, $Z_{v\text{-}net50}$, is not to be less than the rule required hull girder section modulus, $Z_{v\text{-}req}$, based on the permissible still-water bending moment and design wave bending moment defined as:

$$Z_{v-req} = \frac{\left| M_{sw-perm} + M_{wv-v} \right|}{\sigma_{perm}} 10^{-3} \qquad (m^3)$$

Where:

$M_{sw\text{-}perm}$: permissible hull girder hogging or sagging still water bending moment as given in **Table 8.1.3**, in *kNm*

$M_{wv\text{-}v}$: hogging or sagging vertical wave bending moment, in *kNm* as given in **Table 8.1.3**

σ_{perm} : permissible hull girder bending stress as given in **Table 8.1.3**, in N/mm^2

Table 8.1.3 Loads and Corresponding Acceptance Criteria for Hull Girder Bending Assessment

Design load combination	Still water bending moment, $M_{sw\text{-}perm}$	Wave bending moment, $M_{wv\text{-}v}$	Permissible hull girder bending stress, σ_{perm} (1)	
(S)	$M_{sw\text{-}perm\text{-}harb}$	0	$143/k$	within $0.4L$ amidships
			$105/k$	at and forward of $0.9L$ from A.P. and at and aft of $0.1L$ from A.P.
(S + D)	$M_{sw\text{-}perm\text{-}sea}$	$M_{wv\text{-}v}$	$190/k$	within $0.4L$ amidships
			$140/k$	at and forward of $0.9L$ from A.P. and at and aft of $0.1L$ from A.P

Where:

$M_{sw\text{-}perm\text{-}harb}$: permissible hull girder hogging and sagging still water bending moment for harbour/sheltered water operation, in *kNm*, as defined in **Section 7/2.1.1**

$M_{sw\text{-}perm\text{-}sea}$: permissible hull girder hogging and sagging still water bending moment for seagoing operation, in *kNm*, as defined in **Section 7/2.1.1**

$M_{wv\text{-}v}$: hogging and sagging vertical wave bending moments, in *kNm*, as defined in **Section 7/3.4.1**
$M_{wv\text{-}v}$ is to be taken as
$M_{wv\text{-}hog}$ for assessment with respect to hogging vertical wave bending moment
$M_{wv\text{-}sag}$ for assessment with respect to sagging vertical wave bending moment

k : higher strength steel factor, as defined in **Section 6/1.1.4**

Note
1. σ_{perm} is to be linearly interpolated between values given.

1.3 Hull Girder Shear Strength

1.3.1 General

1.3.1.1 The hull girder shear strength requirements apply along the full length of the hull girder, from A.P to F.P.

1.3.2 Assessment of hull girder shear strength

1.3.2.1 The net hull girder shear strength capacity, $Q_{v\text{-}net50}$, as defined in **1.3.2.2** is not to be less than the required vertical shear force, $Q_{v\text{-}req}$, as indicated in the following:

$$Q_{v-req} = Q_{sw-perm} + Q_{wv} \qquad (kN)$$

Where:

$Q_{sw\text{-}perm}$: permissible hull girder positive or negative still water shear force as given in **Section 7/2.1.3**, in *kN*

Q_{wv} : vertical wave positive or negative shear force as defined in **Section 7/3.4.3**, in *kN*

1.3.2.2 The permissible positive and negative still water shear forces for seagoing and harbour/sheltered water operations, $Q_{sw\text{-}perm\text{-}sea}$ and $Q_{sw\text{-}perm\text{-}harb}$ are to satisfy:

$Q_{sw-perm} \leq Q_{v-net50} - Q_{wv-pos}$ (kN)

for maximum permissible positive shear force

$Q_{sw-perm} \geq -Q_{v-net50} - Q_{wv-neg}$ (kN)

for minimum permissible negative shear force

Where:

$Q_{sw-perm}$	: permissible hull girder still water shear force as given in **Table 8.1.4**, in kN
$Q_{v-net50}$	: net hull girder vertical shear strength to be taken as the minimum for all plate elements that contribute to the hull girder shear capacity $= \dfrac{\tau_{ij-perm} t_{ij-net50}}{1000 q_v}$ kN
$\tau_{ij-perm}$	: permissible hull girder shear stress, τ_{perm}, as given in **Table 8.1.4**, in N/mm^2 , for plate ij
Q_{wv-pos}	: positive vertical wave shear force, in kN, as defined in **Table 8.1.4**
Q_{wv-neg}	: negative vertical wave shear force, in kN, as defined in **Table 8.1.4**
$t_{ij-net50}$	: equivalent net thickness, t_{net50}, for plate ij, in mm. For longitudinal bulkheads between cargo tanks, t_{net50} is to be taken as $t_{sfc-net50}$ and t_{str-k} as appropriate, see **1.3.3.1** and **1.3.4.1**
t_{net50}	: net thickness of plate, in mm $= t_{grs} - 0.5 t_{corr}$
t_{grs}	: gross plate thickness, in mm. The gross plate thickness for corrugated bulkheads is to be taken as the minimum of t_{w-grs} and t_{f-grs}, in mm
t_{w-grs}	: gross thickness of the corrugation web, in mm
t_{f-grs}	: gross thickness of the corrugation flange, in mm
t_{corr}	: corrosion addition, in mm, as defined in **Section 6/3.2**
q_v	: unit shear flow per mm for the plate being considered and based on the net scantlings $= f_i \left(\dfrac{q_{1-net50}}{I_{v-net50}} \right) \cdot 10^{-9}$ (mm^{-1})
f_i	: shear force distribution factor for the main longitudinal hull girder shear carrying members being considered. For standard structural configurations f_i is as defined in **Fig. 8.1.2**
$q_{1-net50}$	: first moment of area about the horizontal neutral axis of the members between the vertical level at which the shear stress is being determined and the vertical extremity of effective shear carrying members, in cm^3. The first moment of area is to be based on the net thickness, t_{net50}
$I_{v-net50}$	: net vertical hull girder section moment of inertia, in m^4, as defined in **Section 4/2.6.1.1**

Table 8.1.4 Loads and Corresponding Acceptance Criteria for Hull Girder Shear Assessment

Design load combination	Still water shear force, $Q_{sw\text{-}perm}$	Vertical wave shear force, Q_{wv}	Permissible shear stress, τ_{perm}
Harbour/sheltered water operations (S)	$Q_{sw\text{-}perm\text{-}harb}$	0	105/k for plate ij
Seagoing operations (S + D)	$Q_{sw\text{-}perm\text{-}sea}$	$\boldsymbol{Q}_{wv}$	120/k for plate ij

Where:

$Q_{sw\text{-}perm\text{-}harb}$: permissible positive or negative hull girder still water shear force for harbour operation, in *kN*, as defined in **Section 7/2.1.3**

$Q_{sw\text{-}perm\text{-}sea}$: permissible positive or negative hull girder still water shear force for seagoing operation, in *kN*, as defined in **Section 7/2.1.3**

Q_{wv} : positive or negative vertical wave shear, in *kN*, as defined in **Section 7/3.4.3**. Q_{vw} is to be taken as

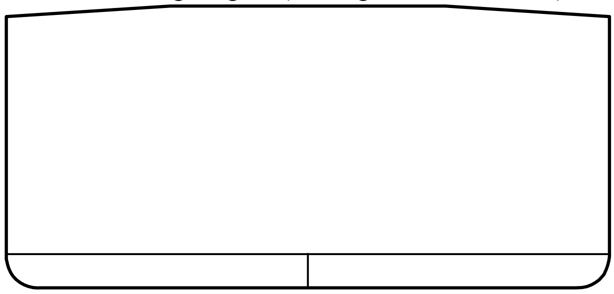
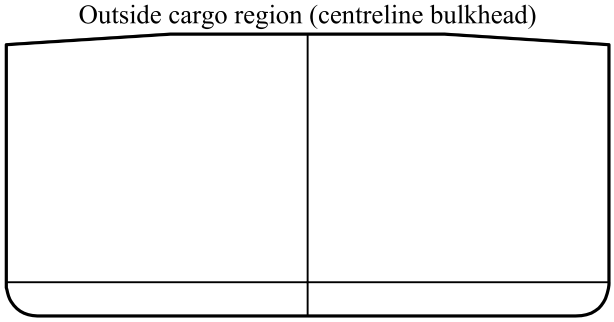
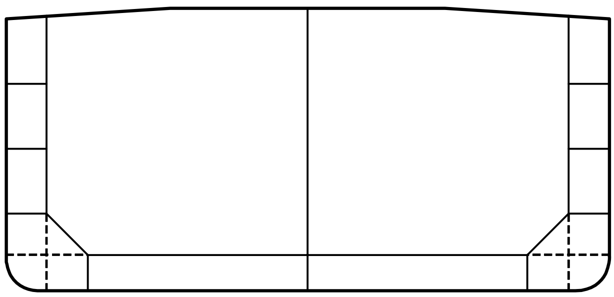
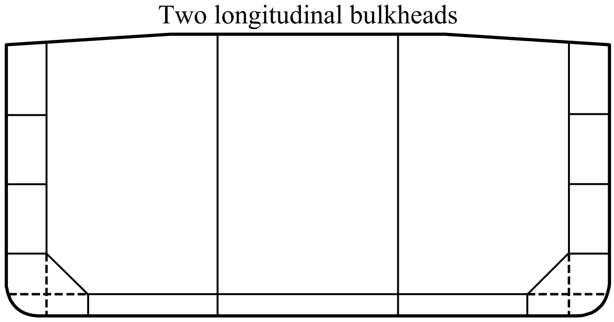
$Q_{wv\text{-}pos}$ for assessment with respect to maximum positive permissible still water shear force

$Q_{wv\text{-}neg}$ for assessment with respect to minimum negative permissible still water shear force

$p_{late\ ij}$: for each plate *j*, index *i* denotes the structural member of which the plate forms a component

k : higher strength steel factor, as defined in **Section 6/1.1.4**

Fig. 8.1.2 Shear Force Distribution Factors

Hull configuration	f_i factors
Outside cargo region (no longitudinal bulkhead) 	Side shell $f_1 = 0.5$
Outside cargo region (centreline bulkhead) 	Side shell $f_1 = 0.231 + 0.076\dfrac{A_{1-net50}}{A_{3-net50}}$ Longitudinal bulkhead $f_3 = 0.538 - 0.152\dfrac{A_{1-net50}}{A_{3-net50}}$
One centreline bulkhead 	Side shell $f_1 = 0.055 + 0.097\dfrac{A_{1-net50}}{A_{2-net50}} + 0.020\dfrac{A_{2-net50}}{A_{3-net50}}$ Inner hull $f_2 = 0.193 - 0.059\dfrac{A_{1-net50}}{A_{2-net50}} + 0.058\dfrac{A_{2-net50}}{A_{3-net50}}$ Longitudinal bulkhead $f_3 = 0.504 - 0.076\dfrac{A_{1-net50}}{A_{2-net50}} - 0.156\dfrac{A_{2-net50}}{A_{3-net50}}$
Two longitudinal bulkheads 	Side shell $f_1 = 0.028 + 0.087\dfrac{A_{1-net50}}{A_{2-net50}} + 0.023\dfrac{A_{2-net50}}{A_{3-net50}}$ Inner hull $f_2 = 0.119 - 0.038\dfrac{A_{1-net50}}{A_{2-net50}} + 0.072\dfrac{A_{2-net50}}{A_{3-net50}}$ Longitudinal bulkhead $f_3 = 0.353 - 0.049\dfrac{A_{1-net50}}{A_{2-net50}} - 0.095\dfrac{A_{2-net50}}{A_{3-net50}}$

Where:

i : index for the structural member under consideration

1, for the side shell

2, for the inner hull

3, for the longitudinal bulkhead

$A_{i-net50}$: net area as defined in **Section 4/2.6.4** and based on deduction of $0.5t_{corr}$, of the structural member, i, at one side of the section under consideration. The area $A_{3-net50}$ for the centreline bulkhead is not to be reduced for symmetry around the centreline.

1.3.3 Shear force correction for longitudinal bulkheads between cargo tanks

1.3.3.1 For longitudinal bulkheads between cargo tanks the effective net plating thickness, $t_{sfc\text{-}net50}$ for plate *ij,* used for calculation of hull girder shear strength, $Q_{v\text{-}.net50}$, is to be corrected for local shear distribution and is given by:

$$t_{sfc-net50} = t_{grs} - 0.5t_{corr} - t_{\Delta} \qquad (mm)$$

Where:

t_{grs}	: gross plate thickness, in *mm*
t_{corr}	: corrosion addition, in *mm*, as defined in **Section 6/3.2**
t_{Δ}	: thickness deduction for plate *ij*, in *mm*, as defined in **1.3.3.2**

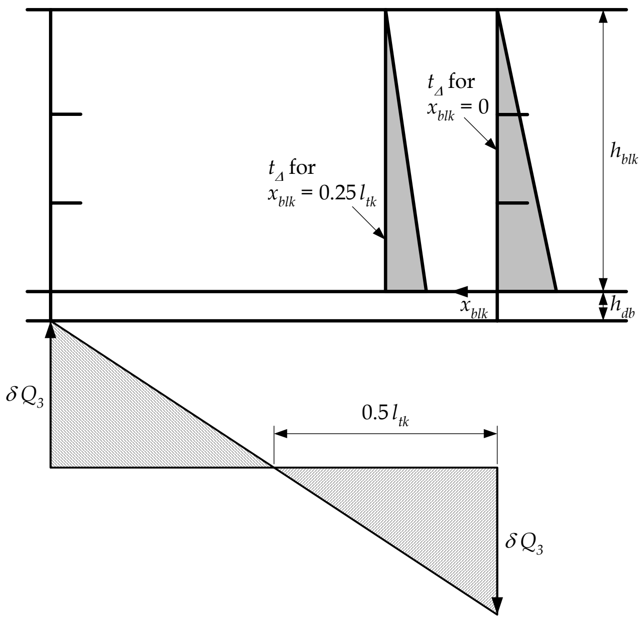
1.3.3.2 The vertical distribution of thickness reduction for shear force correction is assumed to be triangular as indicated in **Fig. 8.1.3**. The thickness deduction, t_{Δ}, to account for shear force correction is to be taken as:

$$t_{\Delta} = \frac{\delta Q_3}{h_{blk}\tau_{ij-perm}}\left(1 - \frac{x_{blk}}{0.5l_{tk}}\right)\left(2 - \frac{2(z_p - h_{db})}{h_{blk}}\right) \qquad (mm)$$

Where:

δ_{Q3}	: shear force correction for longitudinal bulkhead as defined in **1.3.3.3** and **1.3.3.5** for ships with one or two longitudinal bulkheads respectively, in *kN*.
l_{tk}	: length of cargo tank, in *m*
h_{blk}	: height of longitudinal bulkhead, in *m*, defined as the distance from inner bottom to the deck at the top of the bulkhead, as shown in **Fig. 8.1.3**
x_{blk}	: the minimum longitudinal distance from section considered to the nearest cargo tank transverse bulkhead, in *m*. To be taken positive and not greater than $0.5l_{tk}$
z_p	: the vertical distance from the lower edge of plate *ij* to the base line, in *m*
h_{db}	: height of double bottom, in *m*, as shown in **Fig. 8.1.3**
$\tau_{ij\text{-}perm}$	: permissible hull girder shear stress, τ_{perm}, in N/mm^2 for plate *ij* $= 120/k_{ij}$
k_{ij}	: higher strength steel factor, *k*, for plate *ij* as defined in **Section 6/1.1.4**

Fig. 8.1.3 Shear Force Correction for Longitudinal Bulkheads



1.3.3.3 For ships with a centreline bulkhead between the cargo tanks, the shear force correction in way of transverse bulkhead, δQ_3, is to be taken as:

$$\delta Q_3 = 0.5 K_3 F_{db} \qquad (kN)$$

Where:

K_3 : correction factor, as defined in **1.3.3.4**

F_{db} : maximum resulting force on the double bottom in a tank, in kN, as defined in **1.3.3.7**

1.3.3.4 For ships with a centreline bulkhead between the cargo tanks, the correction factor, K_3, in way of transverse bulkheads is to be taken as:

$$K_3 = \left[0.40\left(1 - \frac{1}{1+n}\right) - f_3\right]$$

Where:

n : number of floors between transverse bulkheads, excluding the floor in line with the wash bulkhead

f_3 : shear force distribution factor, see **Fig. 8.1.2**

1.3.3.5 For ships with two longitudinal bulkheads between the cargo tanks, the shear force correction, δQ_3, is to be taken as:

$$\delta Q_3 = 0.5 K_3 F_{db} \qquad (kN)$$

Where:

K_3 correction factor, as defined in **1.3.3.6**

F_{db} maximum resulting force on the double bottom in a tank, in kN, as defined in **1.3.3.7**

1.3.3.6 For ships with two longitudinal bulkheads between the cargo tanks, the correction factor, K_3, in way of transverse bulkhead is to be taken as:

$$K_3 = \left[0.5\left(1 - \frac{1}{1+n}\right)\left(\frac{1}{r+1}\right) - f_3\right]$$

Where:

n : number of floors between transverse bulkheads, excluding the floor in line with the wash bulkhead

r : ratio of the part load carried by the wash bulkheads and floors from longitudinal bulkhead to the double side and is given by

$$r = \frac{1}{\left[\dfrac{A_{3-net50}}{A_{1-net50} + A_{2-net50}} + \dfrac{2b_{80}(n_s+1)}{l_{tk}(n_s A_{T-net50} + R)}\right]}$$

Note: for preliminary calculations, r may be taken as 0.5

l_{tk} : length of cargo tank, between transverse bulkheads in the side cargo tank, in *m*

b_{80} : 80% of the distance from longitudinal bulkhead to the inner side, in *m*, at tank mid length

$A_{T-net50}$: net shear area of the transverse wash bulkhead, including the double bottom floor directly below, in the side cargo tank, in cm^2, taken as the smallest area in a vertical section. $A_{T-net50}$ is to be calculated with net thickness given by t_{grs} - $0.5t_{corr}$

$A_{1-net50}$: net area, as shown in **Fig. 8.1.2**, in m^2

$A_{2-net50}$: net area, as shown in **Fig. 8.1.2**, in m^2

$A_{3-net50}$: net area, as shown in **Fig. 8.1.2**, in m^2

F_3 : shear force distribution factor, as shown in **Fig. 8.1.2**

n_S : number of wash bulkheads in the side cargo tank

R : total efficiency of the transverse primary support members in the side tank

$$R = \left(\frac{n}{2} - 1\right)\frac{A_{Q-net50}}{\gamma} \qquad (cm^2)$$

$$\gamma = 1 + \frac{300 b_{80}{}^2 A_{Q-net50}}{I_{psm-net50}} \qquad (cm^2)$$

$A_{Q-net50}$: net shear area, in cm^2, of a transverse primary support member in the wing cargo tank, taken as the sum of the net shear areas of floor, cross ties and deck transverse webs.
$A_{Q-net50}$ is to be calculated using the net thickness given by t_{grs} - $0.5t_{corr.}$ The net shear area is to be calculated at the mid span of the members.

$I_{psm-net50}$: net moment of inertia for primary support members, in cm^4, of a transverse primary support member in the wing cargo tank, taken as the sum of the moments of inertia of transverses and cross ties. It is to be calculated using the net thickness given by t_{grs} - $0.5t_{corr.}$ The net moment of inertia is to be calculated at the mid span of the member including an attached plate width equal to the primary member spacing

t_{grs} : gross plate thickness, in *mm*

t_{corr} : corrosion addition, in *mm*, as defined in **Section 6/3.2**

1.3.3.7 The maximum resulting force on the double bottom in a tank, F_{db}, is to be taken as:

$$F_{db} = g\left|W_{CT} + W_{CWBT} - \rho_{sw} b_2 l_{tk} T_{mean}\right| \qquad (kN)$$

Where:

W_{CT} : weight of cargo, in *tonnes*, as defined in **Table 8.1.5**

W_{CWBT} : weight of ballast, in *tonnes*, as defined in **Table 8.1.5**

b_2 : breadth, in *m*, as defined in **Table 8.1.5**

l_{tk} : length of cargo tank, between watertight transverse bulkheads in the wing cargo tank, in *m*

T_{mean} : draught at the mid length of the tank for the loading condition considered, in *m*.

g	: acceleration due to gravity, 9.81 m/s^2
ρ_{sw}	: density of sea water, 1.025 $tonnes/m^3$

Table 8.1.5 Design Conditions for Double Bottoms

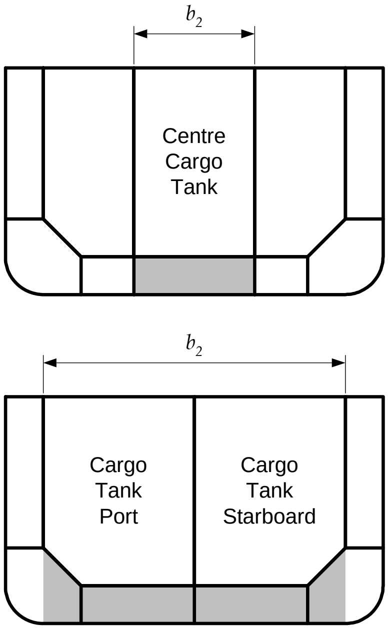
Structural Configuration	W_{CT}	W_{CWBT}	b_2
Ships with one longitudinal bulkhead	weight of cargo in cargo tanks, in *tonnes*, using a minimum specific gravity of 1.025 $tonnes/m^3$	weight of ballast between port and starboard inner sides, in *tonnes*	maximum breadth between port and starboard inner sides at mid length of tank, in *m*, as shown in **Fig. 8.1.4**
Ships with two longitudinal bulkheads	weight of cargo in the centre tank, in *tonnes*, using a minimum specific gravity of 1.025 $tonnes/m^3$	weight of ballast below the centre cargo tank, in *tonnes*	maximum breadth of the centre cargo tank at mid length of tank, in *m*, as shown in **Fig. 8.1.4**

1.3.3.8 The maximum resulting force on the double bottom in a tank, F_{db}, is in no case to be less than that given by the rule minimum conditions given in **Table 8.1.6.**

Table 8.1.6 Rule Minimum Conditions for Double Bottoms

Structural Configuration	Positive/negative force, F_{db}	Minimum condition
Ships with one longitudinal bulkhead	Max positive net vertical force, F_{db}+	$0.9T_{sc}$ and empty cargo and ballast tanks
	Max negative net vertical force, F_{db}-	$0.6T_{sc}$ and full cargo tanks and empty ballast tanks
Ships with two longitudinal bulkheads	Max positive net vertical force, F_{db}+	$0.9T_{sc}$ and empty cargo and ballast tanks
	Max negative net vertical force, F_{db}-	$0.6T_{sc}$ and full centre cargo tank and empty ballast tanks

Fig. 8.1.4 Tank Breadth to be Included for Different Tanker Types



1.3.4 Shear force correction due to loads from transverse bulkhead stringers

1.3.4.1 In way of transverse bulkhead stringer connections, within areas as specified in **Fig. 8.1.6**, the equivalent net thickness of plate used for calculation of the hull girder shear strength, $t_{str\text{-}k}$, where the index k refers to the identification number of the stringer, is not to be taken greater than:

$$t_{str-k} = t_{sfc-net50}\left(1-\frac{\tau_{str}}{\tau_{ij-perm}}\right) \qquad (mm)$$

Where:

$t_{sfc\text{-}net50}$: effective net plating thickness, in *mm*, as defined in **1.3.3.1** and calculated at the transverse bulkhead for the height corresponding to the level of the stringer

$\tau_{ij\text{-}perm}$: permissible hull girder shear stress, τ_{perm}, for plate ij $= 120/k_{ij}$ (N/mm^2)

k_{ij} : higher strength steel factor, *k*, for plate *ij* as defined in **Section 6/1.1.4**

τ_{str} $= \dfrac{Q_{str\text{-}k}}{l_{str}\, t_{sfc-net50}}$ (N/mm^2)

l_{str} : connection length of stringer, in *m*, see **Fig. 8.1.5**

$Q_{str\text{-}k}$: shear force on the longitudinal bulkhead from the stringer in loaded condition with tanks abreast full

$$= 0.8F_{str\text{-}k}\left(1-\frac{z_{str}-h_{db}}{h_{bhd}}\right) \qquad (kN)$$

$F_{str\text{-}k}$: total stringer supporting force, in *kN*, as defined in **1.3.4.2**

h_{db} : the double bottom height, in *m*, as shown in **Fig. 8.1.6**

h_{blk} : height of bulkhead, in *m*, defined as the distance from inner bottom to the deck at the top of the bulkhead, as shown in **Fig. 8.1.6**

z_{str} : the vertical distance from baseline to the considered stringer, in *m*.

1.3.4.2 The total stringer supporting force, $F_{str\text{-}k}$, in way of a longitudinal bulkhead is to be taken as:

$$F_{str-k} = \frac{P_{str} b_{str}\left(h_k + h_{k-1}\right)}{2} \qquad (kN)$$

Where:

P_{str}	: pressure on stringer, in kN/m^2, to be taken as $10h_{tt}$
h_{tt}	: the height from the top of the tank to the midpoint of the load area between $h_k/2$ below the stringer and $h_{k-1}/2$ above the stringer, in *m*
h_k	: the vertical distance from the considered stringer to the stringer below. For the lowermost stringer, it is to be taken as 80 % of the average vertical distance to the inner bottom, in *m*
h_{k-1}	: the vertical distance from the considered stringer to the stringer above. For the uppermost stringer, it is to be taken as 80 % of the average vertical distance to the upper deck, in *m*
b_{str}	: load breadth acting on the stringer, in *m*, see **Fig. 8.1.7** and **8.1.8**

Fig. 8.1.5 Effective Connection Length of Stringer

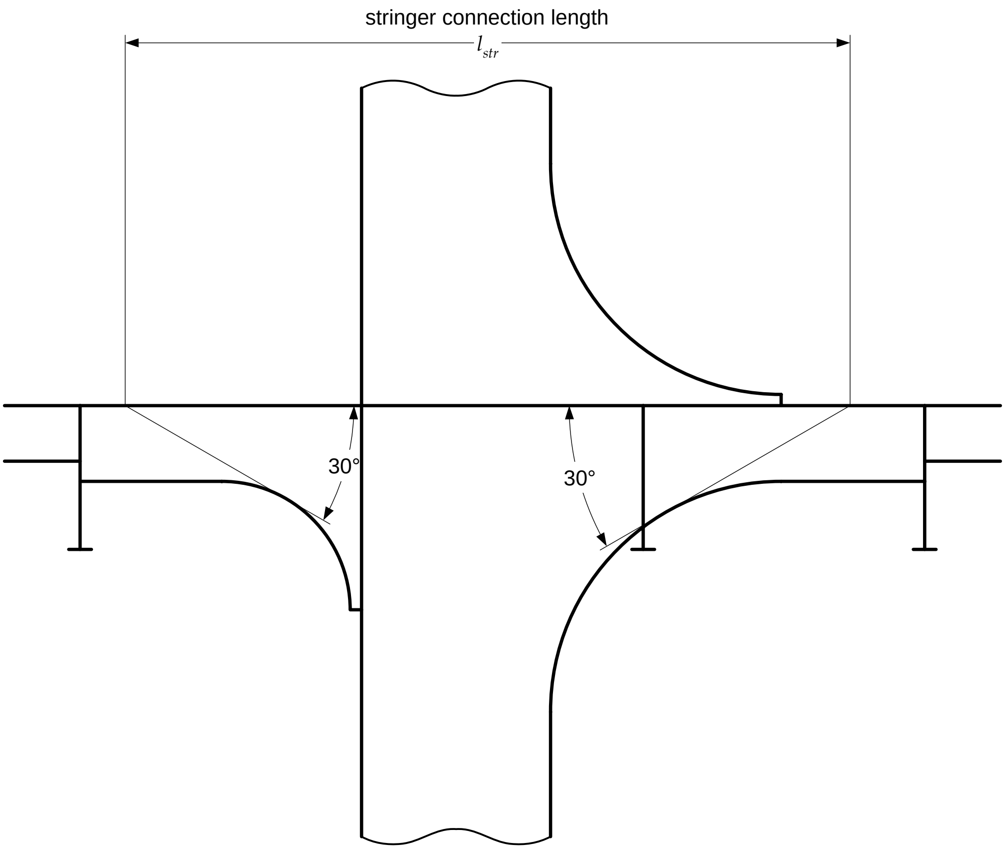


Fig. 8.1.6 Region for Stringer Correction, t_{ij}, for a Tanker with Three Stringers

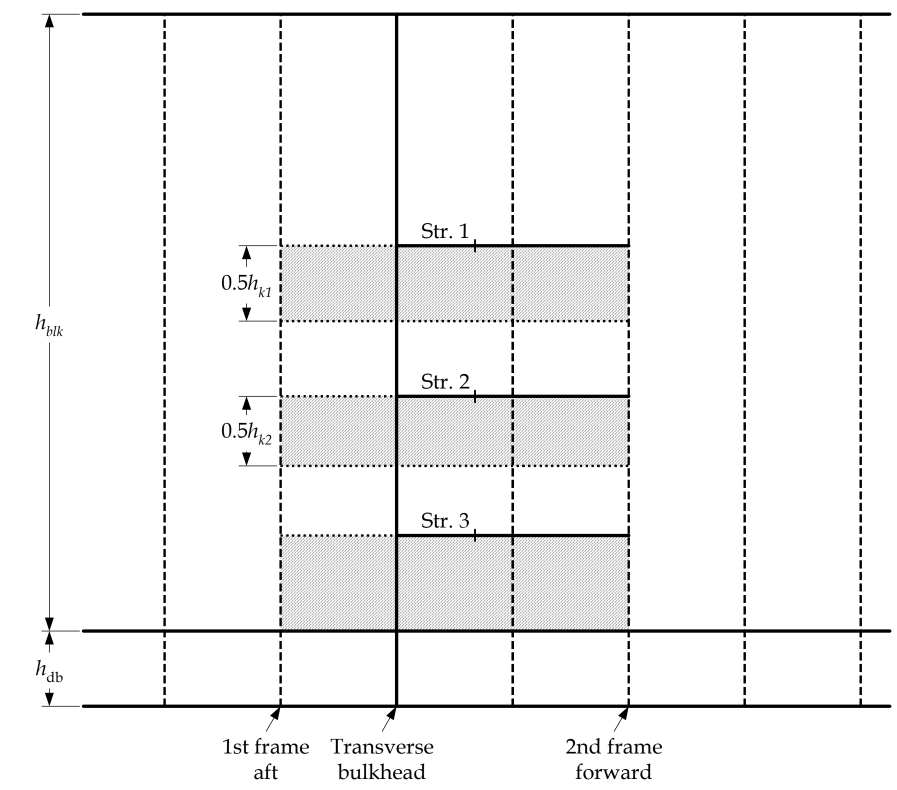
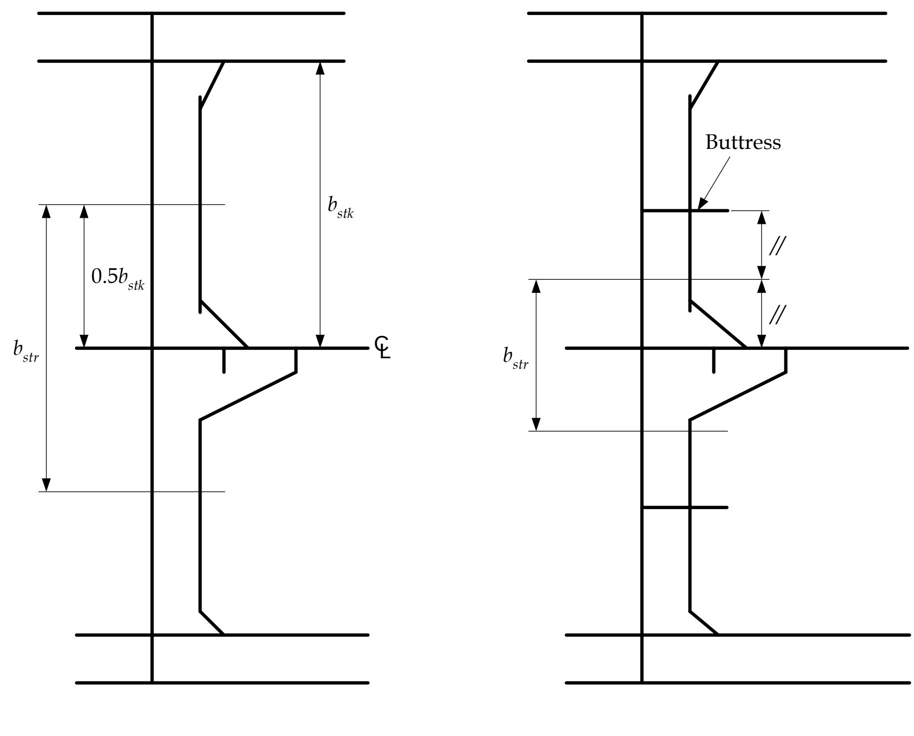
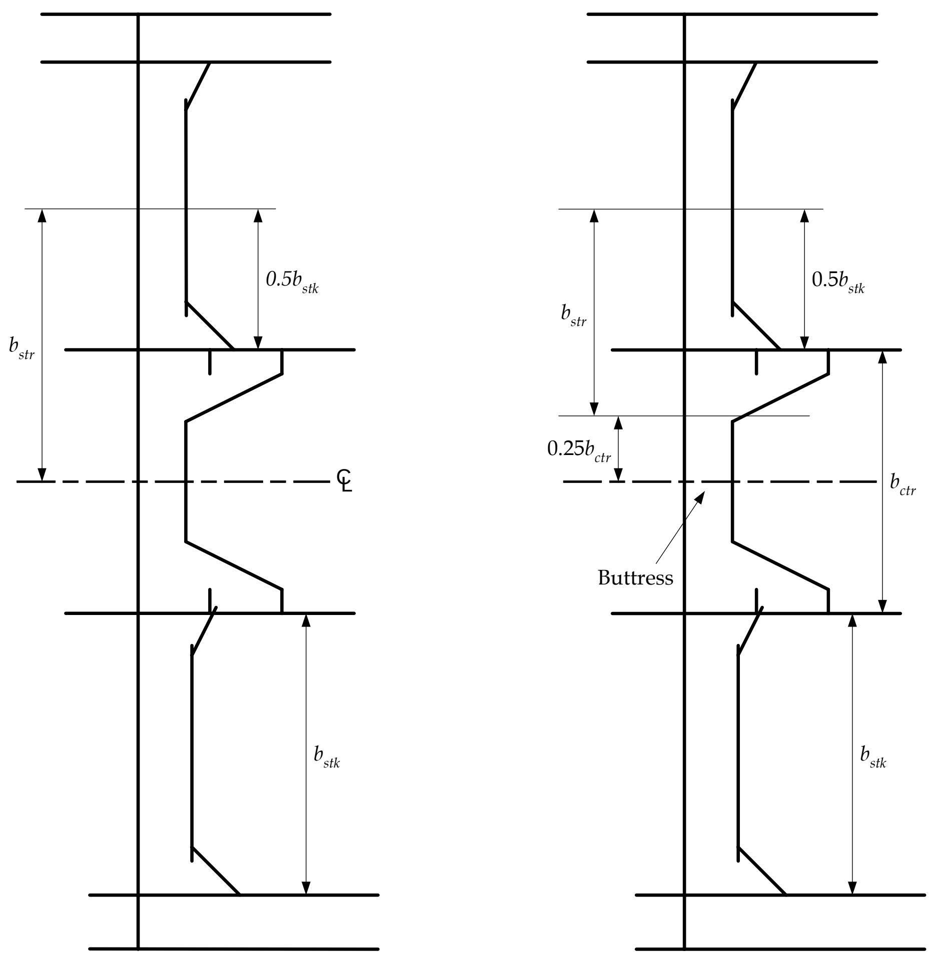


Fig. 8.1.7 Load Breadth of Stringers for Ships with a Centreline Bulkhead



1.3.4.3 Where reinforcement is provided to meet the above requirement, the reinforced area based on tstr-k is to extend longitudinally for the full length of the stringer connection and a minimum of one frame spacing forward and aft of the bulkhead. The reinforced area shall extend vertically from above the stringer level and down to 0.5hk below the stringer, where hk, the vertical distance from the considered stringer to the stringer below is as defined in **1.3.4.2.** For the lowermost stringer the plate thickness requirement tstr-k is to extend down to the inner bottom, see **Fig. 8.1.6**.

Fig. 8.1.8 Load Breadth of Stringers for Ships with Two Inner Longitudinal Bulkheads



Notes

1. b_{stk} is the breadth of wing cargo tank, in *m*.

2 .b_{ctr} is the breadth of centre cargo tank, in *m*.

1.4 Hull Girder Buckling Strength

1.4.1 General

1.4.1.1 These requirements apply to plate panels and longitudinals subject to hull girder compression and shear stresses. These stresses are to be based on the permissible values for still water bending and shear forces given in **Section 7/2.1**, and wave bending moments and shear forces given in **Section 7/3.4.**

1.4.1.2 The hull girder buckling strength requirements apply along the full length of the ship, from A.P to F.P.

1.4.1.3 For the purposes of assessing the hull girder buckling strength in this sub-section, the following are to be considered separately:

(a) axial hull girder compressive stress to satisfy requirements in **1.4.2.6** and **1.4.2.8**

(b) hull girder shear stress to satisfy requirements in **1.4.2.7**.

1.4.2 Buckling assessment

1.4.2.1 The buckling assessment of plate panels and longitudinals is to be determined according to **Section 10/3.1** with hull girder stresses calculated on net hull girder sectional properties.

1.4.2.2 The buckling strength for the buckling assessment is to be derived using local net scantlings, t_{net}, as follows:

$$t_{net} = t_{grs} - 1.0t_{corr} \qquad (mm)$$

Where:

t_{grs} : gross plate thickness, in *mm*

t_{corr} : corrosion addition, in *mm*, as defined in **Section 6/3.2**

1.4.2.3 The hull girder compressive stress due to bending, $\sigma_{hg-net50}$, for the buckling assessment is to be calculated using net hull girder sectional properties and is to be taken as the greater of the following:

$$\sigma_{hg-net50} = \left| \frac{(z - z_{NA-net50})(M_{sw-perm-sea} + M_{wv-v})}{I_{v-net50}} \right| 10^{-3} \qquad (N/mm^2)$$

$$\sigma_{hg-net50} = \frac{30}{k} \qquad (N/mm^2)$$

Where:

$M_{sw-perm-sea}$: permissible still water bending moment for seagoing operation, in *kNm*, as defined in **Section 7/2.1.1**, with signs as given in **1.4.2.4**

M_{wv-v} : hogging and sagging vertical wave bending moments, in *kNm*, as defined in **Section 7/3.4.1**, with signs as given in **1.4.2.4**
M_{wv-v} is to be taken as
M_{wv-hog} for assessment with the hogging still water bending moment
M_{wv-sag} for assessment with the sagging still water bending moment

z : distance from the structural member under consideration to the baseline, in *m*

$z_{NA-net50}$: distance from the baseline to the horizontal neutral, in *m*, see **Fig. 8.1.1**

$I_{v-net50}$: net vertical hull girder section moment of inertia, in m^4, as defined in **Section 4/2.6.1.1**

k : higher strength steel factor, as defined in **Section 6/1.1.4.1**

1.4.2.4 The sagging bending moment values of $M_{sw-perm-sea}$ and M_{wv-v} are to be taken for members above the neutral axis. The hogging bending moment values are to be taken for members below the neutral axis.

1.4.2.5 The design hull girder shear stress for the buckling assessment, $\tau_{hg-net50}$, is to be calculated based on net hull girder sectional properties and is to be taken as:

$$\tau_{hg-net50} = \left| (Q_{sw-perm-sea} + Q_{wv}) \left(\frac{1000 q_v}{t_{ij-net50}} \right) \right| \qquad (N/mm^2)$$

Where:

$Q_{sw-perm-sea}$: positive and negative still water permissible shear force for seagoing operation, in *kN*, as defined in **Section 7/2.1.3**

Q_{wv} : positive or negative vertical wave shear, in *kN*, as defined in **Section 7/3.4.3**.
Q_{vw} is to be taken as
Q_{wv-pos} for assessment with the positive permissible still water shear force
Q_{wv-neg} for assessment with the negative permissible still water shear force

$t_{ij-net50}$: net thickness for the plate *ij*, in *mm*
$= t_{ij-grs} - 0.5t_{corr}$

t_{ij-grs} : gross plate thickness of plate *ij*, in *mm*. The gross plate thickness for corrugated bulkheads is to be taken as the minimum of t_{w-grs} and t_{f-grs}, in *mm*

t_{w-grs} : gross thickness of the corrugation web, in *mm*

$t_{f\text{-}grs}$: gross thickness of the corrugation flange, in *mm*

t_{corr} : corrosion addition, in *mm*, as defined in **Section 6/3.2**

q_v : unit shear per *mm* for the plate being considered as defined in **1.3.2.2**

Note

1. Maximum of the positive shear (still water + wave) and negative shear (still water + wave) is to be used as the basis for calculation of design shear stress

2. All plate elements ij that contribute to the hull girder shear capacity are to be assessed. See also **Table 8.1.4** and **Fig. 8.1.2**

1.4.2.6 The compressive buckling strength, of plate panels, is to satisfy the following criteria:

$$\eta \le \eta_{allow}$$

Where:

η : buckling utilisation factor

$$\frac{\sigma_{hg-net50}}{\sigma_{cr}}$$

$\sigma_{hg\text{-}net50}$: hull girder compressive stress based on net hull girder sectional properties, in N/mm^2 as defined in **1.4.2.3**

σ_{cr} : critical compressive buckling stress, σ_{xcr} or σ_{ycr} as appropriate, in N/mm^2, as specified in **Section 10/3.2.1.3**. The critical compressive buckling stress is to be calculated for the effects of hull girder compressive stress only. The effects of other membrane stresses and lateral pressure are to be ignored.

η_{allow} : allowable buckling utilisation factor:

= 1.0 for plate panels above 0.5*D*

= 0.85 for plate panels below 0.5*D*

1.4.2.7 The shear buckling strength, of plate panels, is to satisfy the following criteria:

$$\eta \le \eta_{allow}$$

Where:

η : buckling utilisation factor

$$\frac{\tau_{hg-net50}}{\tau_{cr}}$$

$\tau_{\mathrm{hg\text{-}net50}}$: design hull girder shear stress, in N/mm^2, as defined in **1.4.2.5**

τ_{cr} : critical shear buckling stress, in N/mm^2, as specified in **Section 10/3.2.1.3**. The critical shear buckling stress is to be calculated for the effects of hull girder shear stress only. The effects of other membrane stresses and lateral pressure are to be ignored.

η_{allow} : allowable buckling utilisation factor

= 0.95

1.4.2.8 The compressive buckling strength of longitudinal stiffeners is to satisfy the following criteria:

$$\eta \le \eta_{allow}$$

Where:

η : greater of the buckling utilisation factors given in **Section 10/3.3.2.1** and **Section 10/3.3.3.1**. The buckling utilisation factor is to be calculated for the effects of hull girder compressive stress only. The effects of other membrane stresses and lateral pressure are to be ignored.

η_{allow} : allowable buckling utilisation factor

= 1.0 for stiffeners above 0.5*D*

= 0.85 for stiffeners below 0.5*D*

1.5 Hull Girder Fatigue Strength

1.5.1 General

1.5.1.1 The following provides a simplified fatigue control measure against the dynamic hull girder stresses in the longitudinal deck structure.

1.5.1.2 The requirements in **1.5.1.3** are not mandatory, but are recommended to be applied in the early design phase in order to give an indication of the required hull girder section modulus for compliance with the mandatory fatigue requirements specified in **Section 9/3** and **Appendix C**.

1.5.1.3 The fatigue life for the deck structure as required by **Section 9/3** and **Appendix C** is normally satisfied providing the net vertical hull girder section modulus at the moulded deck line at side, $Z_{v\text{-}net50}$, as defined in **Section 4/2.6.1.1**, is not less than the required hull girder section modulus, $Z_{v\text{-}fat}$, defined as:

$$Z_{v-fat} = \frac{M_{wv-hog} - M_{wv-sag}}{1000 R_{al}} \qquad (m^3)$$

Where:

$M_{wv\text{-}hog}$	: hogging vertical wave bending moment for fatigue, in *kNm*, as defined in **Section 7/3.4.1**
$M_{wv\text{-}sag}$	: sagging vertical wave bending moment for fatigue, in *kNm*, as defined in **Section 7/3.4.1**
R_{al}	: allowable stress range, in N/mm^2 = $0.17L + 86$ for class F-details = $0.15L + 76$ for class F2-details
L	: rule length, in *m*, as defined in **Section 4/1.1.1.1**

1.6 Tapering and Structural Continuity of Longitudinal Hull Girder Elements

1.6.1 Tapering based on minimum hull girder section property requirements

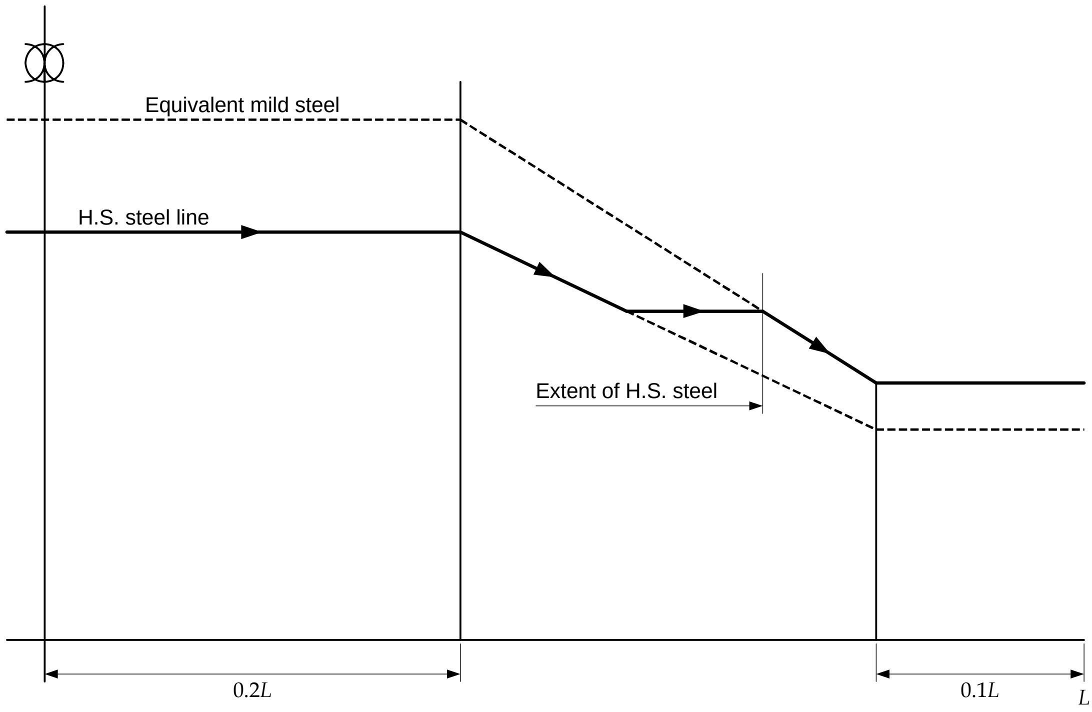
1.6.1.1 Scantlings of all continuous longitudinal members of the hull girder based on the moment of inertia and section modulus requirements given in **1.2.2** are to be maintained within 0.4*L* of amidships.

1.6.1.2 Scantlings outside of 0.4*L* amidships as required by the rule minimum moment of inertia and section modulus as given in **1.2.2** may be gradually reduced to the local requirements at the ends provided the hull girder bending and buckling requirements, along the full length of the ship, as given in **1.2.3** and **1.4** are complied with. For tapering of higher strength steel, see **1.6.2** and **1.6.3**.

1.6.2 Longitudinal extent of higher strength steel

1.6.2.1 Where used, the application of higher strength steel is to be continuous over the length of the ship up to locations where the longitudinal stress levels are within the allowable range for mild steel structure, see **Fig. 8.1.9**.

Fig. 8.1.9 Longitudinal Extent of Higher Strength Steel



1.6.3 Vertical extent of higher strength steel

1.6.3.1 The vertical extent of higher strength steel, z_{hts}, used in the deck or bottom and measured from the moulded deck line at side or keel is not to be taken less than the following, see also **Fig. 8.1.10.**

$$z_{hts} = z_1\left(1 - \frac{190}{\sigma_1 k_i}\right) \qquad (m)$$

Where:

z_1 : distance from horizontal neutral axis to moulded deck line or keel respectively, in m

σ_1 : to be taken as σ_{dk} or σ_{kl} for the hull girder deck and keel respectively, in N/mm^2

σ_{dk} : hull girder bending stress at moulded deck line given by:

$$= \frac{\left|M_{sw-perm-sea} + M_{wv-v}\right|}{I_{v-net50}}(z_{dk-side} - z_{NA-net50}) \cdot 10^{-3} \qquad (N/mm^2)$$

σ_{kl} : hull girder bending stress at keel given by:

$$= \frac{\left|M_{sw-perm-sea} + M_{wv-v}\right|}{I_{v-net50}}(z_{NA-net50} - z_{kl}) \cdot 10^{-3} \qquad (N/mm^2)$$

$M_{sw-perm-sea}$: permissible hull girder still water bending moment for seagoing operation, in kNm, as defined in **Section 7/2.1.1**

M_{wv-v} : hogging and sagging vertical wave bending moments, in kNm, as defined in **Section 7/3.4.1**

M_{wv-v} is to be taken as

M_{wv-hog} for assessment with respect to hogging vertical wave bending moment

M_{wv-sag} for assessment with respect to sagging vertical wave bending moment

$I_{v-net50}$: net vertical hull girder moment of inertia, in m^4, as defined in **Section 4/2.6.1.1**

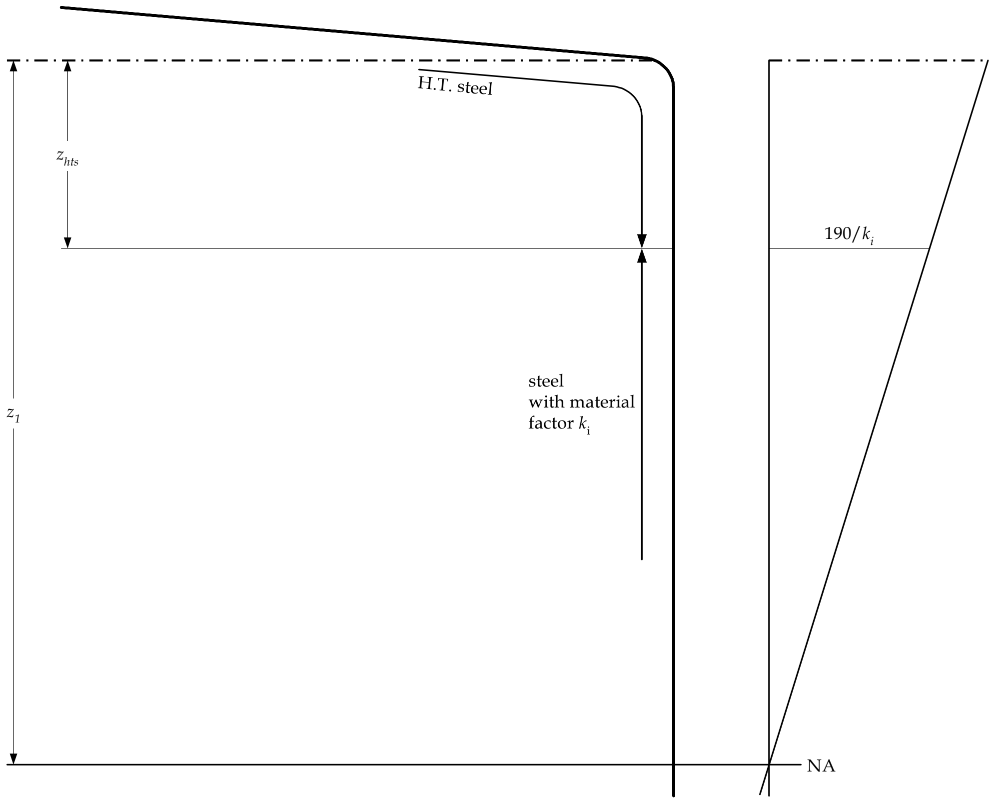
$z_{dk\text{-}side}$: distance from baseline to moulded deck line at side, in *m*

z_{kl} : vertical distance from the baseline to the keel, in *m*

$z_{NA\text{-}net50}$: distance from baseline to horizontal neutral axis, in *m*

k_i : higher strength steel factor for the area *i* defined in **Fig. 8.1.10**. The factor, *k*, is defined in **Section 6/1.1.4**

Fig. 8.1.10 Vertical Extent of Higher Strength Steel



1.6.4 Tapering of plate thickness due to hull girder shear requirement

1.6.4.1 Longitudinal tapering of shear reinforcement is permitted, provided that for any longitudinal position the requirements given in **1.3.2** are complied with. Control of the shear strength at intermediate positions is to be carried out by linear interpolation of permissible shear limits at the bulkhead and in the middle of the tank.

1.6.5 Structural continuity of longitudinal bulkheads

1.6.5.1 Suitable scarphing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes. In particular longitudinal bulkheads are to be terminated at an effective transverse bulkhead and large transition brackets shall be fitted in line with the longitudinal bulkhead.

1.6.6 Structural continuity of longitudinal stiffeners

1.6.6.1 Where longitudinal stiffeners terminate, and are replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover.

1.6.6.2 Where a deck longitudinal stiffener is cut, in way of an opening, compensation is to be arranged to ensure structural continuity of the area. The compensation area is to extend well beyond the forward and aft end of the opening and not be less than the area of the longitudinal that is cut. Stress concentration in way of the stiffener termination and the associated buckling strength of the plate and panel are to be considered.

2. Cargo Tank Region

2.1 General

2.1.1 Application

2.1.1.1 The requirements of this Sub-Section apply to the hull structure within the cargo tank region of the ship, for the shell, deck, inner bottom and bulkhead plating, stiffeners and primary support members.

2.1.2 Basis of scantlings

2.1.2.1 The net scantlings described in this Sub-Section are related to gross scantlings as follows:

(a) for application of the minimum thickness requirements specified in **2.1.5** and **2.1.6**, the gross thickness is obtained from the applicable requirements by adding the full corrosion additions specified in **Section 6/3**

(b) for plating and local support members, the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in **Section 6/3**

(c) for primary support members, the gross shear area, gross section modulus, and other gross cross sectional properties are obtained from the applicable requirements by adding one half of the relevant full corrosion addition specified in **Section 6/3**

(d) for application of the buckling requirements of **Section 10/3**, the gross thickness and gross cross-sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in **Section 6/3**.

2.1.3 Evaluation of scantlings

2.1.3.1 The following scantling requirements are based on the assumption that all structural joints and welded details are designed and fabricated, such that they are to be compatible with the anticipated working stress levels at the locations considered. The loading patterns, stress concentrations and potential failure modes of structural joints and details during the design of highly stressed regions are to be considered. Structural design details are to comply with the requirements given in **Section 4/3**.

2.1.3.2 The scantlings are to be assessed to ensure that the strength criteria are satisfied at all longitudinal positions, where applicable.

2.1.3.3 Local scantling increases are to be applied where applicable to cover local variations, such as increased spacing, increased stiffener spans and green sea pressure loads. Local scantling increases may also be required to cover fore end strengthening requirements, see **Section 8/3**.

2.1.4 General scantling requirements

2.1.4.1 The hull structure is to comply with the applicable requirements of:

(a) hull girder longitudinal strength, see **Section 8/1**

(b) strength against sloshing and impact loads, see **Section 8/6**

(c) hull girder ultimate strength, see **Section 9**

(d) strength assessment (FEM), see **Section 9**

(e) fatigue strength, see **Section 9/3**

(f) buckling and ultimate strength, see **Section 10**.

2.1.4.2 The net section modulus, shear areas and other sectional properties of the local and primary support members are to be determined in accordance with **Section 4/2**.

2.1.4.3 The section modulus, shear areas and other sectional properties of the local and primary support members apply to the areas clear of the end brackets.

2.1.4.4 The spans of the local and primary support members are defined in **Section 4/2.1**.

2.1.4.5 The moments of inertia for the primary support members are to be determined in association with the effective attached plating at the mid span as specified in **Section 4/2.3.2.3**.

2.1.4.6 Limber, drain and air holes are to be cut in all parts of the structure, as required, to ensure the free flow to the suction pipes and escape of air to the vents. See also **Section 4/3**.

2.1.4.7 All shell frames and tank boundary stiffeners are in general to be continuous, or are to be bracketed at their ends, except as permitted in **Sections 4/3.2.4** and **4/3.2.5**. See also **Section 4/3.2**.

2.1.5 Minimum thickness for plating and local support members

2.1.5.1 The thickness of plating and stiffeners in the cargo tank region is to comply with the appropriate minimum thickness requirements given in **Table 8.2.1**.

Table 8.2.1 Minimum Net Thickness for Plating and Local Support Members in the Cargo Tank Region

Scantling Location			Net Thickness (mm)
Plating	Hull envelope up to $T_{sc}+ \ 4.6m$	Keel plating	$5.5+0.03L_2$
		Bottom shell/bilge/side shell	$3.5+0.03L_2$
	Hull envelope above $T_{sc}+4.6m$	Side shell/upper deck	$4.5+0.02L_2$
	Hull internal structure	Hull internal tank boundaries	$4.5+0.02L_2$
		Non-tight bulkheads, bulkheads between dry spaces and other plates in general	$4.5+0.01L_2$
Local support members	Local support members on tight boundaries		$3.5+0.015L_2$
	Local support members on other structure		$2.5+0.015L_2$
Tripping brackets			$5.0+0.015L_2$
Where: T_{sc} : as defined in **Section 4/1.1.5.5** L_2 : rule length, L, as defined in **Section 4/1.1.1.1**, but need not be taken greater than 300m			

2.1.6 Minimum thickness for primary support members

2.1.6.1 The thickness of web plating and face plating of primary support members in the cargo tank region is to comply with the appropriate minimum thickness requirements given in **Table 8.2.2**.

Table 8.2.2 Minimum Net Thickness for Primary Support Members in Cargo Tank Region

Scantling Location	Net Thickness (mm)
Double bottom centreline girder	$5.5+0.025L_2$
Other double bottom girders	$5.5+0.02L_2$
Double bottom floors, web plates of side transverses and stringers in double hull	$5.0+0.015L_2$
Web and flanges of vertical web frames on longitudinal bulkheads, horizontal stringers on transverse bulkhead and deck transverses (above and below upper deck)	$5.5+0.015L_2$
Where: L_2 : rule length, L, as defined in **Section 4/1.1.1.1**, but need not be taken greater than 300m	

2.2 Hull Envelope Plating

2.2.1 Keel plating

2.2.1.1 Keel plating is to extend over the flat of bottom for the complete length of the ship. The breadth, b_{kl}, is not to be less than:

$$b_{kl} = 800 + 5L_2 \quad (mm)$$

Where:

L_2 : rule length, L, as defined in **Section 4/1.1.1.1**, but not to be taken greater than 300m

2.2.1.2 The thickness of the keel plating is to comply with the requirements given in **2.2.2**.

2.2.2 Bottom shell plating

2.2.2.1 The thickness of the bottom shell plating is to comply with the requirements in **Table 8.2.4**.

2.2.3 Bilge plating

2.2.3.1 The thickness of bilge plating is not to be less than that required for the adjacent bottom shell, see **2.2.2.1**, or adjacent side shell plating, see **2.2.4.1**, whichever is the greater.

2.2.3.2 The net thickness of bilge plating, t_{net}, without longitudinal stiffening is not to be less than:

$$t_{net} = \frac{\sqrt[3]{r^2 \, S_t \, P_{ex}}}{100} \qquad (mm)$$

Where:

P_{ex} : design sea pressure for the design load set 1 calculated at the lower turn of bilge, in kN/m^2

r : effective bilge radius

$= r_0 + 0.5(a + b) \qquad (mm)$

r_0 : radius of curvature, in mm. See **Fig. 8.2.1**

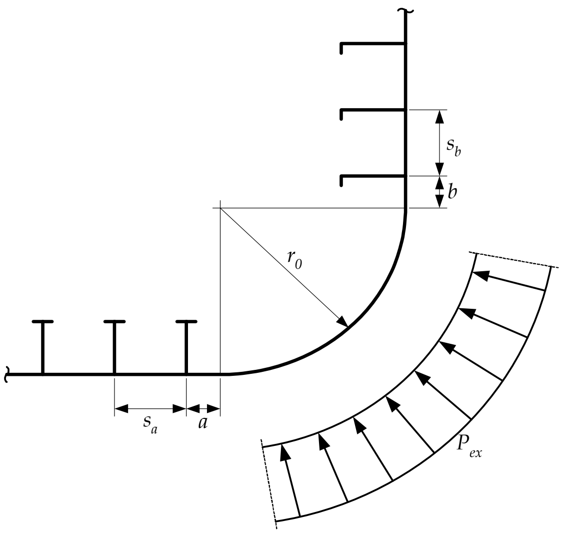
S_t : distance between transverse stiffeners, webs or bilge brackets, in m

a : distance between the lower turn of bilge and the outermost bottom longitudinal, in mm, see **Fig. 8.2.1** and **2.3.1.2**. Where the outermost bottom longitudinal is within the curvature, this distance is to be taken as zero.

b distance between the upper turn of bilge and the lowest side longitudinal, in mm, see **Fig. 8.2.1** and **2.3.1.2**. Where the lowest side longitudinal is within the curvature, this distance is to be taken as zero.

The bilge keel is not considered as "longitudinal stiffening" for the application of this requirement.

Fig. 8.2.1 Unstiffened Bilge Plating



2.2.3.3 Where bilge longitudinals are omitted, the bilge plate thickness outside 0.4L amidships will be considered in relation to the support derived from the hull form and internal stiffening arrangements. In general, outside of 0.4L amidships the bilge plate scantlings and arrangement are to comply with the requirements of ordinary side or bottom shell plating in the same region. Consideration is to be given where there is increased loading in the forward region.

2.2.4 Side shell plating

2.2.4.1 The thickness of the side shell plating is to comply with the requirements in **Table 8.2.4**.

2.2.4.2 The net thickness, t_{net}, of the side plating within the range as specified in **2.2.4.3** is not to be less than:

$$t_{net} = 26\left(\frac{s}{1000}+0.7\right)\left(\frac{BT_{sc}}{\sigma_{yd}^{2}}\right)^{0.25} \qquad (mm)$$

Where:

s	: stiffener spacing, in *mm*, as defined in **Section 4/2.2**
B	: moulded breadth, in *m* as defined in **Section 4/1.1.3.1**
T_{sc}	: scantling draught, in *m*, as defined in **Section 4/1.1.5.5**
σ_{yd}	: specified minimum yield stress of the material, in N/mm^2

2.2.4.3 The thickness in **2.2.4.2** is to be applied to the following extent of the side shell plating, see **Fig. 8.2.2**:

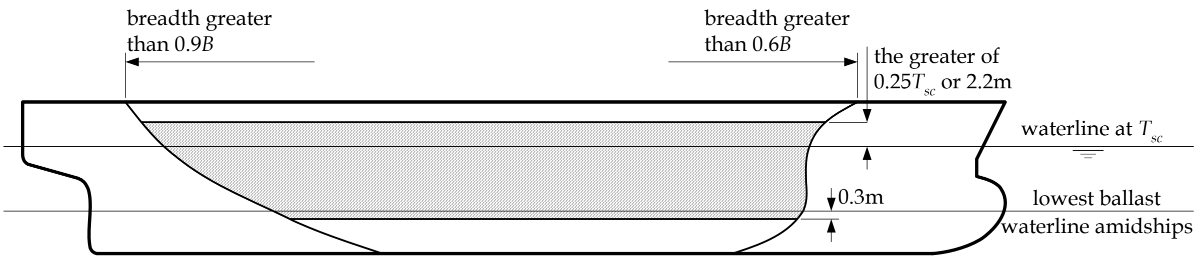
(a) longitudinal extent:

・ between a section aft of amidships where the breadth at the waterline exceeds 0.9*B*, and a section forward of amidships where the breadth at the waterline exceeds 0.6*B*

(b) vertical extent:

・ between 300*mm* below the lowest ballast waterline amidships to $0.25T_{sc}$ or 2.2*m*, whichever is greater, above the draught T_{sc}.

Fig. 8.2.2 Extent of Side Shell Plating



2.2.5 Sheer strake

2.2.5.1 The sheer strake is to comply with the requirements in **2.2.4**.

2.2.5.2 The welding of deck fittings to rounded sheer strakes is to be avoided within 0.6*L* of amidships.

2.2.5.3 Where the sheer strake extends above the deck stringer plate, the top edge of the sheer strake is to be kept free from notches and isolated welded fittings, and is to be smooth with rounded edges Grinding may be required if the cutting surface is not smooth. Drainage openings with a smooth transition in the longitudinal direction may be permitted.

2.2.6 Deck plating

2.2.6.1 The thickness of the deck plating is to comply with the requirements given in **Table 8.2.4**.

2.3 Hull Envelope Framing

2.3.1 General

2.3.1.1 The bottom shell, inner bottom and deck are to be longitudinally framed in the cargo tank region. The side shell, inner hull bulkheads and longitudinal bulkheads are generally to be longitudinally framed. Where the side shell is longitudinally framed, the inner hull bulkheads are to be similarly constructed. Suitable alternatives which take account of resistance to buckling will be specially considered.

2.3.1.2 Where longitudinals are omitted in way of the bilge, a longitudinal is to be fitted at the bottom and at the side close to the position where the curvature of the bilge plate starts. The distance between the lower turn of bilge and the outermost bottom longitudinal, *a*, is generally not to be greater than one-third of the spacing between the two outermost bottom longitudinals, s_a. Similarly, the distance between the upper turn of the bilge and the lowest side longitudinal, *b*, is generally not to be greater than one-third of the spacing between the two lowest side longitudinals, s_b. In addition, where no intermediate brackets are fitted between the transverses, s_a and s_b are not to be greater than one-third of the bilge radius or 50 *times* the applicable local shell plating thickness, whichever is the greater. See **Fig. 8.2.1**.

2.3.1.3 The longitudinals are to comply with the requirements of continuity given in **Section 4/3.2**.

2.3.2 Scantling criteria

2.3.2.1 The section modulus, and thickness, of the hull envelope framing is to comply with the requirements given in **Tables 8.2.5** and **8.2.6**.

2.3.2.2 Where the side shell longitudinal or the vertical stiffener is inclined to the longitudinal or vertical axis, respectively, the span is to be taken in accordance with **Section 4/2.1.3**.

2.3.2.3 For curved stiffeners, the span is to be taken in accordance with **Section 4/2.1.3**.

2.4 Inner Bottom

2.4.1 Inner bottom plating

2.4.1.1 The thickness of the inner bottom plating is to comply with the requirements given in **Table 8.2.4**.

2.4.1.2 In way of a welded hopper knuckle, the inner bottom is to be scarfed to ensure adequate load transmission to surrounding structure and reduce stress concentrations.

2.4.1.3 In way of corrugated bulkhead stools, where fitted, particular attention is to be given to the through-thickness properties, and arrangements for continuity of strength, at the connection of the bulkhead stool to the inner bottom. For requirements for plates with specified through-thickness properties, see **Section 6/1.1.5**.

2.4.2 Inner bottom longitudinals

2.4.2.1 The section modulus and web plate thickness of the inner bottom longitudinals are to comply with the requirements given in **Tables 8.2.5** and **8.2.6**.

2.5 Bulkheads

2.5.1 General

2.5.1.1 The inner hull and longitudinal bulkheads are generally to be longitudinally framed, and plane. Corrugated bulkheads are to comply with the requirements given in **2.5.6**.

2.5.1.2 Where bulkheads are penetrated by cargo or ballast piping, the structural arrangements in way are to be adequate for the loads imparted to the bulkheads by the hydraulic forces in the pipes.

2.5.2 Longitudinal tank boundary bulkhead plating

2.5.2.1 The thickness of the longitudinal tank boundary bulkhead plating is to comply with the requirements given in **Table 8.2.4**.

2.5.2.2 Inner hull and longitudinal bulkheads are to extend as far forward and aft as practicable and are to be effectively scarfed into the adjoining structure.

2.5.3 Hopper side structure

2.5.3.1 Knuckles in the hopper tank plating are to be supported by side girders and stringers, or by a deep longitudinal.

2.5.4 Transverse tank boundary bulkhead plating

2.5.4.1 The thickness of the transverse tank boundary bulkhead plating is to comply with the requirements given in **Table 8.2.4**.

2.5.5 Tank boundary bulkhead stiffeners

2.5.5.1 The section modulus and web thickness of stiffeners, on longitudinal or transverse tank boundary bulkheads, are to comply with the requirements given in **Tables 8.2.5** and **8.2.6**.

2.5.6 Corrugated bulkheads in cargo tanks

2.5.6.1 The scantlings relating to corrugated bulkheads defined in **2.5.6** and **2.5.7** are net scantling requirements. The gross scantling requirements are obtained from the applicable requirements by adding the full corrosion additions specified in **Section 6/3**.

2.5.6.2 In general, corrugated bulkheads are to be designed with the corrugation angles, ϕ, between 55 and 90 *degrees*, see **Fig. 8.2.3**.

2.5.6.3 The global strength of corrugated bulkheads, lower stools and upper stools, where fitted, and attachments to surrounding structures are to be verified with the cargo tank FEM model, see **Section 9/2**. The global strength of corrugated bulkheads outside of midship region are to be considered based on results from the cargo tank FEM model and using the appropriate pressure for the bulkhead being considered. Additional FEM analysis of cargo tank bulkheads forward and aft of the midship region may be necessary if the bulkhead geometry, structural details and support arrangement details differ significantly from bulkheads within the mid cargo tank region.

2.5.6.4 The net thicknesses, t_{net}, of the web and flange plates of corrugated bulkheads are to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.2.7**, and given by:

$$t_{net} = 0.0158\, b_p \sqrt{\frac{|P|}{C_a\, \sigma_{yd}}} \qquad (mm)$$

Where:

P : design pressure for the design load set being considered, calculated at the load point defined in **Section 3/5.1**, in kN/m^2

b_p : breadth of plate

= b_f for flange plating, in mm. See **Fig. 8.2.3**

= b_w for web plating, in mm. See **Fig. 8.2.3**

C_a : permissible bending stress coefficient

= 0.75 for acceptance criteria set AC1

= 0.90 for acceptance criteria set AC2

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

2.5.6.5 Where the flange and web plate thicknesses are different, then the thicker net plating thickness, $t_{m\text{-}net}$, is to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.2.7**, and given by:

$$t_{m-net} = \sqrt{\frac{0.0005\, {b_p}^2\, |P|}{C_a\, \sigma_{yd}} - {t_{n-net}}^2} \qquad (mm)$$

Where:

$t_{n\text{-}net}$: net thickness of the thinner plating, either flange or web, in mm

b_p : breadth of thicker plate, either flange or web, in mm

P : design pressure for the design load set being considered, calculated at the load point defined in **Section 3/5.1**, in kN/m^2

C_a : permissible bending stress coefficient

= 0.75 for acceptance criteria set AC1

= 0.90 for acceptance criteria set AC2

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

2.5.7 Vertically corrugated bulkheads

2.5.7.1 In addition to the requirements of **2.5.6**, vertically corrugated bulkheads are also to comply with the requirements of **2.5.7**.

2.5.7.2 The plate thicknesses as required by **2.5.7.5** and **2.5.7.6** are to be maintained up two thirds of the corrugation length, l_{cg}, from the lower end, where l_{cg} is as defined in **2.5.7.3**. Above that, the thickness of plating may be reduced by 20%.

2.5.7.3 The net web plating thickness of the lower 15% of the corrugation, $t_{w\text{-}net}$, is to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.2.7**, and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool, see **2.5.7.9**.

$$t_{w-net} = \frac{1000 |Q_{cg}|}{d_{cg}\, C_{t-cg}\, \tau_{yd}} \qquad (mm)$$

Where:

Q_{cg} : design shear force imposed on the web plating at the lower end of the corrugation

$$= \frac{s_{cg}\, l_{cg}\, |3P_l + P_u|}{8000} \qquad (kN)$$

P_l : design pressure for the design load set being considered, calculated at the lower end of the corrugation, in kN/m^2

P_u : design pressures for the design load set being considered, calculate at the upper end of the corrugation, in kN/m^2

s_{cg} : spacing of corrugation, in *mm*. See **Fig. 8.2.3**

l_{cg} : length of corrugation, which is defined as the distance between the lower stool and the upper stool or the upper end where no upper stool is fitted, in *m*, see **Fig. 8.2.3**

d_{cg} : depth of corrugation, in *mm*. See **2.5.7.4** and **Fig. 8.2.3**

C_{t-cg} : permissible shear stress coefficient

= 0.75 for acceptance criteria set AC1

= 0.90 for acceptance criteria set AC2

τ_{yd} $= \frac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

2.5.7.4 The depth of the corrugation, d_{cg}, is not to be less than:

$$d_{cg} = \frac{1000 l_{cg}}{15} \qquad (mm)$$

Where:

l_{cg} : length of corrugation, which is defined as the distance between the lower stool or the inner bottom if no lower stool is fitted and the upper stool or the upper end where no upper stool is fitted, in *m*, see **Fig. 8.2.3**

2.5.7.5 The net thicknesses of the flanges of corrugated bulkheads, $t_{f\text{-}net}$, are to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.2.7**, and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool, see **2.5.7.9**.

$$t_{f-net} = \frac{0.00657\, b_f \sqrt{\sigma_{bdg-max}}}{C_f} \qquad (mm)$$

Where:

$\sigma_{bdg\text{-}max}$: maximum value of the vertical bending stresses in the flange. The bending stress is to be calculated at the lower end and at the mid span of the corrugation length

$= \frac{1000 M_{cg}}{Z_{cg-act-net}}$ (N/mm^2)

M_{cg} : as defined in **2.5.7.6**

$Z_{cg\text{-}act\text{-}net}$: actual net section modulus at the lower end and at the mid length of the corrugation, in cm^3

b_f : breadth of flange plating, in *mm*. See **Fig. 8.2.3**

b_w : breadth of web plating, in *mm*. See **Fig. 8.2.3**

C_f : coefficient

$= 7.65 - 0.26\left(\frac{b_w}{b_f}\right)^2$

2.5.7.6 The net section modulus at the lower and upper ends of the corrugation and at the mid length of the corrugation ($l_{cg}/2$) of a unit corrugation, $Z_{cg\text{-}net}$, are to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.2.7**, and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool, see **2.5.7.9**.

$$Z_{cg-net} = \frac{1000 M_{cg}}{C_{s-cg}\, \sigma_{yd}} \qquad (cm^3)$$

Where:

M_{cg} $= \frac{C_i |P| s_{cg}\, l_o^2}{12000}$ (kNm)

P $= \frac{P_u + P_l}{2}$ (kN/m^2)

P_l, P_u : design pressure for the design load set being considered, calculated at the lower and upper ends of the corrugation, respectively, in kN/m^2
for transverse corrugated bulkheads, the pressures are to be calculated at a section located at $b_{tk}/2$ from the longitudinal bulkheads of each tank
for longitudinal corrugated bulkheads, the pressures are to be calculated at the ends of the tank, i.e., the intersection of the forward and aft transverse bulkheads and the longitudinal bulkhead

b_{tk} : maximum breadth of tank under consideration measured at the bulkhead, in *m*

s_{cg} : spacing of corrugation, in *mm*. See **Fig. 8.2.3**

l_o : effective bending span of the corrugation, measured from the mid depth of the lower stool to the mid depth of the upper stool, or upper end where no upper stool is fitted, in *m*, see **Fig. 8.2.3**

l_{cg} : length of corrugation, which is defined as the distance between the lower stool and the upper stool or the upper end where no upper stool is fitted, in *m*, see **Fig. 8.2.3**

C_i : the relevant bending moment coefficients as given in **Table 8.2.3**

$C_{s\text{-}cg}$: permissible bending stress coefficient
at the mid length of the corrugation length, l_{cg}
= c_e, but not to be taken as greater than 0.75 for acceptance criteria set AC1
= c_e, but not to be taken as greater than 0.90 for acceptance criteria set AC2

at the lower and upper ends of corrugation length, l_{cg}
= 0.75 for acceptance criteria set AC1
= 0.90 for acceptance criteria set AC2

c_e $= \dfrac{2.25}{\beta} - \dfrac{1.25}{\beta^2}$ for $\beta \geq 1.25$
$= 1.0$ for $\beta < 1.25$

β $= \dfrac{b_f}{t_{f-net}}\sqrt{\dfrac{\sigma_{yd}}{E}}$

b_f : breadth of flange plating, in *mm*, see **Fig. 8.2.3**

$t_{f\text{-}net}$: net thickness of the corrugation flange, in *mm*

E : modulus of elasticity, in N/mm^2

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

Table 8.2.3 Values of C_i

Bulkhead	At lower end of l_{cg}	At mid length of l_{cg}	At upper end of l_{cg}
Transverse Bulkhead	C_1	C_{m1}	$0.80C_{m1}$
Longitudinal Bulkhead	C_3	C_{m3}	$0.65C_{m3}$

Where:

C_1 $= a_1 + b_1\sqrt{\dfrac{A_{dt}}{b_{dk}}}$ but is not to be taken as less than 0.60

a_1 $= 0.95 - \dfrac{0.41}{R_{bt}}$

b_1 $= -0.20 + \dfrac{0.078}{R_{bt}}$

C_{m1} $= a_{m1} + b_{m1}\sqrt{\dfrac{A_{dt}}{b_{dk}}}$ but is not to be taken as less than 0.55

a_{m1} $= 0.63 + \dfrac{0.25}{R_{bt}}$

b_{m1} $= -0.25 - \dfrac{0.11}{R_{bt}}$

C_3 $= a_3 + b_3\sqrt{\dfrac{A_{dl}}{l_{dk}}}$ but is not to be taken as less than 0.60

a_3 $= 0.86 - \dfrac{0.35}{R_{bl}}$

b_3 $= -0.17 + \dfrac{0.10}{R_{bl}}$

C_{m3} $= a_{m3} + b_{m3}\sqrt{\dfrac{A_{dl}}{l_{dk}}}$ but is not to be taken as less than 0.55

a_{m3} $= 0.32 + \dfrac{0.24}{R_{bl}}$

b_{m3} $= -0.12 - \dfrac{0.10}{R_{bl}}$

R_{bt} $= \dfrac{A_{bt}}{b_{ib}}\left(1+\dfrac{l_{ib}}{b_{ib}}\right)\left(1+\dfrac{b_{av-t}}{h_{st}}\right)$ for transverse bulkheads

R_{bl} $= \dfrac{A_{bl}}{l_{ib}}\left(1+\dfrac{l_{ib}}{b_{ib}}\right)\left(1+\dfrac{b_{av-l}}{h_{sl}}\right)$ for longitudinal bulkheads

A_{dt} : cross sectional area enclosed by the moulded lines of the transverse bulkhead upper stool, in m^2
= 0 if no upper stool is fitted

A_{dl} : cross sectional area enclosed by the moulded lines of the longitudinal bulkhead upper stool, in m^2
= 0 if no upper stool is fitted

A_{bt} : cross sectional area enclosed by the moulded lines of the transverse bulkhead lower stool, in m^2

A_{bl} : cross sectional area enclosed by the moulded lines of the longitudinal bulkhead lower stool, in m^2

b_{av-t} : average width of transverse bulkhead lower stool, in m. See **Fig. 8.2.3**

b_{av-l} : average width of longitudinal bulkhead lower stool, in m. See **Fig. 8.2.3**

h_{st} : height of transverse bulkhead lower stool, in m. See **Fig. 8.2.3**

h_{sl} : height of longitudinal bulkhead lower stool, in m. See **Fig. 8.2.3**

b_{ib} : breadth of cargo tank at the inner bottom level between hopper tanks, or between the hopper tank and centreline lower stool, in m. See **Fig. 8.2.3**

b_{dk} : breadth of cargo tank at the deck level between upper wing tanks, or between the upper wing tank and centreline deck box or between the corrugation flanges if no upper stool is fitted, in m. See **Fig. 8.2.3**

l_{ib} : length of cargo tank at the inner bottom level between transverse lower stools, in m. See **Fig. 8.2.3**

l_{dk} : length of cargo tank at the deck level between transverse upper stools or between the corrugation flanges if no upper stool is fitted, in m. See **Fig. 8.2.3**

2.5.7.7 For tanks with effective sloshing breadth, b_{slh}, greater than $0.56B$ or effective sloshing length l_{slh}, greater than $0.13L$, additional sloshing analysis is to be carried out to assess the section modulus of the unit corrugation in accordance with the requirements of the Society.

2.5.7.8 For ships with a moulded depth, see **Section 4/1.1.4**, equal to or greater than 16*m*, a lower stool is to be fitted in compliance with the following requirements:

(a) general:

- the height and depth are not to be less than the depth of the corrugation
- the lower stool is to be fitted in line with the double bottom floors or girders
- the side stiffeners and vertical webs (diaphragms) within the stool structure are to align with the structure below, as far as is practicable, to provide appropriate load transmission to structures within the double bottom.

(b) stool top plating:

- the net thickness of the stool top plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation
- the extension of the top plate beyond the corrugation is not to be less than the as-built flange thickness of the corrugation.

(c) stool side plating and internal structure:

- within the region of the corrugation depth from the stool top plate the net thickness of the stool side plate is not to be less than 90% of that required by **2.5.7.2** for the corrugated bulkhead flange at the lower end and is to be of at least the same material yield strength
- the net thickness of the stool side plating and the net section modulus of the stool side stiffeners is not to be less than that required by **2.5.2, 2.5.4** and **2.5.5** for transverse or longitudinal bulkhead plating and stiffeners
- the ends of stool side vertical stiffeners are to be attached to brackets at the upper and lower ends of the stool
- continuity is to be maintained, as far as practicable, between the corrugation web and supporting brackets inside the stool. The bracket net thickness is not to be less than 80% of the required thickness of the corrugation webs and is to be of at least the same material strength
- scallops in the diaphragms in way of the connections of the stool sides to the inner bottom and to the stool top plate are not permitted.

2.5.7.9 For ships with a moulded depth, see **Section 4/1.1.4**, less than 16*m*, the lower stool may be eliminated provided the following requirements are complied with:

(a) general:

- double bottom floors or girders are to be fitted in line with the corrugation flanges for transverse or longitudinal bulkheads, respectively
- brackets/carlings are to be fitted below the inner bottom and hopper tank in line with corrugation webs. Where this is not practicable gusset plates with shedder plates are to be fitted, see item **(c)** below and **Fig. 8.2.3**
- the corrugated bulkhead and its supporting structure is to be assessed by Finite Element (FE) analysis in accordance with **Section 9/2**. In addition the local scantlings requirements of **2.5.6.4** and **2.5.6.5** and the minimum corrugation depth requirement of **2.5.7.4** are to be applied.

(b) inner bottom and hopper tank plating:

- the net thickness of the inner bottom and hopper tank in way of the corrugation is not to be less than the net thickness of the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation

(c) supporting structure:

- within the region of the corrugation depth below the inner bottom the net thickness of the supporting double bottom floors or girders is not to be less than the net thickness of the corrugated bulkhead flange at the lower end and is to be of at least the same material yield strength
- the upper ends of vertical stiffeners on supporting double bottom floors or girders are to be bracketed to adjacent structure
- brackets/carlings arranged in line with the corrugation web are to have a depth of not less than 0.5 *times* the corrugation depth and a net thickness not less than 80% of the net thickness of the corrugation webs and are to be of at least the same material strength

・ cut outs for stiffeners in way of supporting double bottom floors and girders in line with corrugation flanges are to be fitted with full collar plates

・ where support is provided by gussets with shedder plates, the height of the gusset plate, see h_g in **Fig. 8.2.3**, is to be at least equal to the corrugation depth, and gussets with shedder plates are to be arranged in every corrugation. The gusset plates are to be fitted in line with and between the corrugation flanges. The net thickness of the gusset and shedder plates are not to be less than 100% and 80%, respectively, of the net thickness of the corrugation flanges and are to be of at least the same material strength. Also see **2.5.7.11**.

・ scallops in brackets, gusset plates and shedder plates in way of the connections to the inner bottom or corrugation flange and web are not permitted.

2.5.7.10 In general, an upper stool is to be fitted in compliance with the following requirements:

(a) general:

・ where no upper stool is fitted, finite element analysis is to be carried out to demonstrate the adequacy of the details and arrangements of the bulkhead support structure to the upper deck structure

・ side stiffeners and vertical webs (diaphragms) within the stool structure are to align with adjoining structure to provide for appropriate load transmission

・ brackets are to be arranged in the intersections between the upper stool and the structure on deck

(b) stool bottom plating:

・ the net thickness of the stool bottom plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation

・ the extension of the bottom plate beyond the corrugation is not to be less than the attached as-built flange thickness of the corrugation.

(c) stool side plating and internal structure:

・ within the region of the corrugation depth above the stool bottom plate the net thickness of the stool side plate is to be not less than 80% of that required by **2.5.7.2** for the corrugated bulkhead flange at the upper end where the same material is used. If material of different yield strength is used the required thickness is to be adjusted by the ratio of the two material factors (k). k is defined in **Section 6/1.1.4.1**

・ the net thickness of the stool side plating and the net section modulus of the stool side stiffeners is not to be less than that required by **2.5.2**, **2.5.4** and **2.5.5** for the transverse or longitudinal bulkhead plating and stiffeners

・ the ends of stool side vertical stiffeners are to be attached to brackets at the upper and lower ends of the stool

・ scallops in the diaphragms in way of the connections of the stool sides to the deck and to the stool bottom plate are not permitted.

2.5.7.11 Where gussets with shedder plates or shedder plates (slanting plates) are fitted at the end connection of the corrugation to the lower stool or to the inner bottom, appropriate means are to be provided to prevent the possibility of gas pockets being formed by these plates.

2.5.7.12 Welding for all connections and joints is to comply with **Section 6/5**.

2.5.8 Non-tight bulkheads

2.5.8.1 Non-tight bulkheads (wash bulkheads), where fitted, are to be in line with transverse webs, bulkheads or similar structures. They are to be of plane construction, horizontally or vertically stiffened, and are to comply with the sloshing requirements given in **6.2**. In general, openings in the non-tight bulkheads are to have generous radii and their aggregate area is not to be less than 10% of the area of the bulkhead.

Fig. 8.2.3 Definition of Parameters for Corrugated Bulkhead (Tankers with Longitudinal Bulkhead at Centreline)

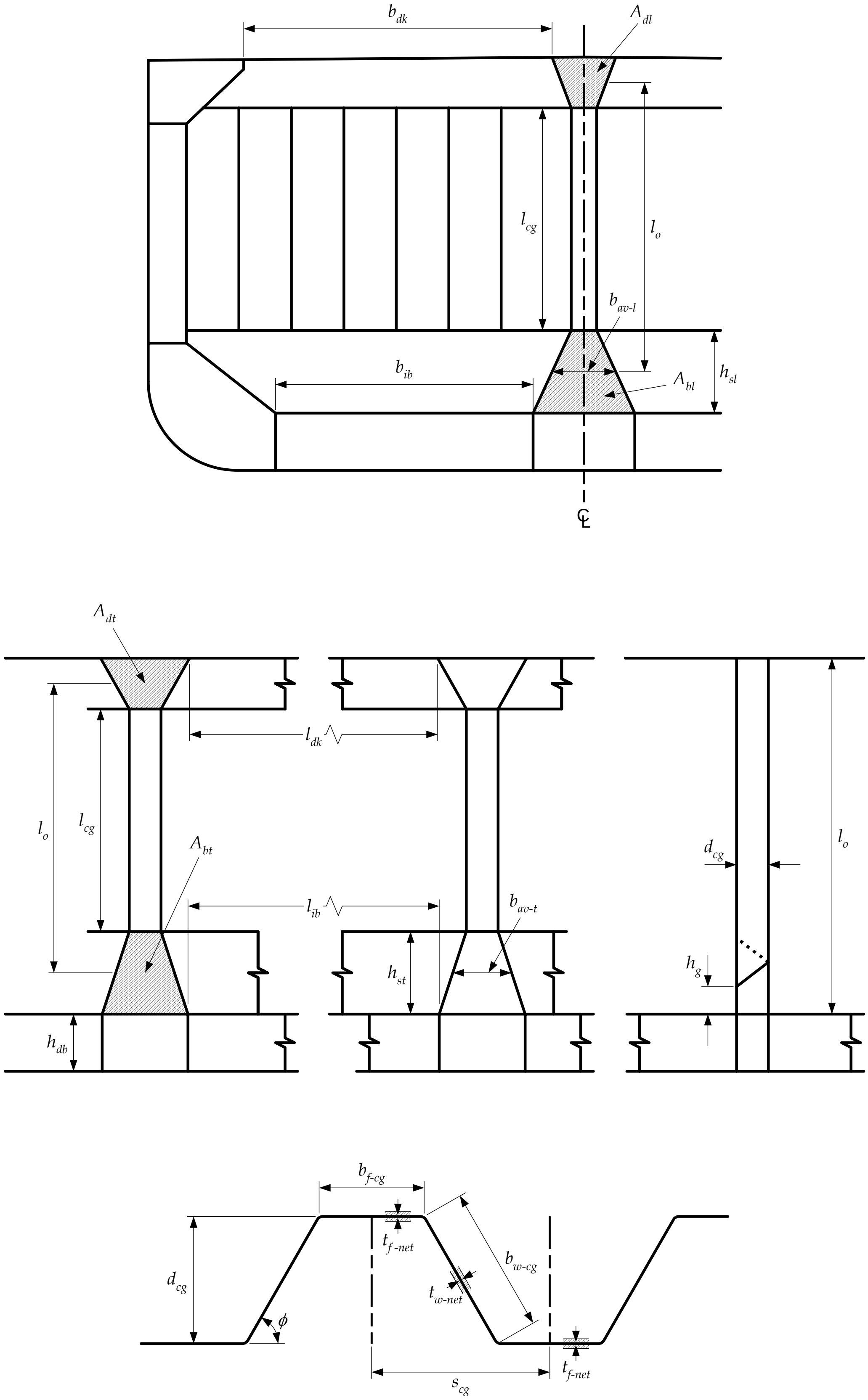


Table 8.2.4 Thickness Requirements for Plating

The minimum net thickness, t_{net}, is to be taken as the greatest value for all applicable design load sets, as given in **Table 8.2.7**, and given by:

$$t_{net} = 0.0158\alpha_p s \sqrt{\frac{|P|}{C_a \sigma_{yd}}} \qquad (mm)$$

Where:

P : design pressure for the design load set being considered and calculated at the load calculation point defined in **Section 3/5.1**, in kN/m^2

α_p : correction factor for the panel aspect ratio

$= 1.2 - \dfrac{s}{2100 l_p}$ but is not to be taken as greater than 1.0

s : as defined in **Section 4/2.2**, in mm

l_p : length of plate panel, to be taken as the spacing of primary support members, S, unless carlings are fitted, in m

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

C_a : permissible bending stress coefficient for the design load set being considered

$= \beta_a - \alpha_a \dfrac{|\sigma_{hg}|}{\sigma_{yd}}$ but not to be taken greater than $C_{a\text{-}max}$

Acceptance Criteria Set	Structural Member		β_a	α_a	$C_{a\text{-}max}$
AC1	Longitudinal Strength Members	Longitudinally stiffened plating	0.9	0.5	0.8
		Transversely or vertically stiffened plating	0.9	1.0	0.8
	Other members		0.8	0	0.8
AC2	Longitudinal Strength Members	Longitudinally stiffened plating	1.05	0.5	0.95
		Transversely or vertically stiffened plating	1.05	1.0	0.95
	Other members, including watertight boundary plating		1.0	0	1.0

σ_{hg} : hull girder bending stress for the design load set being considered and calculated at the load calculation point defined in **Section 3/5.1.2**

$$= \left(\frac{(z - z_{NA-net50}) M_{v-total}}{I_{v-net50}} - \frac{y M_{h-total}}{I_{h-net50}} \right) 10^{-3} \qquad (N/mm^2)$$

$M_{v\text{-}total}$: design vertical bending moment at the longitudinal position under consideration for the design load set being considered, in kNm. The still water bending moment, $M_{sw\text{-}perm}$, is to be taken with the same sign as the simultaneously acting wave bending moment, M_{wv}, see **Table 7.6.1**

$M_{h\text{-}total}$: design horizontal bending moment at the longitudinal position under consideration for the design load set being considered, in kNm

$I_{v\text{-}net50}$: net vertical hull girder moment of inertia, at the longitudinal position being considered, as defined in **Section 4/2.6.1**, in m^4

$I_{h\text{-}net50}$: net horizontal hull girder moment of inertia, at the longitudinal position being considered, as defined in **Section 4/2.6.2**, in m^4

y : transverse coordinate of load calculation point, in m

z : vertical coordinate of the load calculation point under consideration, in m

$z_{NA\text{-}net50}$: distance from the baseline to the horizontal neutral axis, as defined in **Section 4/2.6.1**, in m

Table 8.2.5 Section Modulus Requirements for Stiffeners

The minimum net section modulus, Z_{net}, is to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.2.7**, and given by:

$$Z_{net} = \frac{|P| s\, l_{bdg}^{\,2}}{f_{bdg}\, C_s\, \sigma_{yd}} \qquad (cm^3)$$

Where:

P : design pressure for the design load set being considered and calculated at the load calculation point defined in **Section 3/5.2**, in kN/m^2

f_{bdg} : bending moment factor
for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having as fixed ends
= 12 for horizontal stiffeners
= 10 for vertical stiffeners
for stiffeners with reduced end fixity see **Sub-section 7**.

l_{bdg} : effective bending span, in m, as defined in **Section 4/2.1.1**

s : as defined in **Section 4/2.2**, in mm

σ_{yd} : specified minimum yield stress of the material, see also **Section 3/5.2.6.5**, in N/mm^2

C_s : permissible bending stress coefficient for the design load set being considered, to be taken as

Sign of Hull Girder Bending Stress, σ_{hg}	Side Pressure Acting On	Acceptance Criteria
Tension (+ve)	Stiffener side	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{\sigma_{yd}}$ but not to be taken greater than $C_{s\text{-}max}$
Compression (-ve)	Plate side	
Tension (+ve)	Plate side	$C_s = C_{s\text{-}max}$
Compression (-ve)	Stiffener side	

Acceptance Criteria Set	Structural Member	β_s	α_s	$C_{s\text{-}max}$
AC1	Longitudinal strength member	0.85	1.0	0.75
	Transverse or vertical strength member	0.75	0	0.75
AC2	Longitudinal strength member	1.0	1.0	0.9
	Transverse or vertical strength member	0.9	0	0.9
	Watertight boundary Stiffeners	0.9	0	0.9

σ_{hg} : hull girder bending stress for the design load set being considered and calculated at the reference point defined in **Section 3/5.2.2.5**

$$= \left(\frac{(z - z_{NA-net50})\, M_{v-total}}{I_{v-net50}} - \frac{y\, M_{h-total}}{I_{h-net50}} \right) 10^{-3} \qquad (N/mm^2)$$

$M_{v\text{-}total}$: design vertical bending moment at longitudinal position under consideration for the design load set being considered, in kNm.
$M_{v\text{-}total}$ is to be calculated in accordance with **Table 7.6.1** using the permissible hogging or sagging still water bending moment, $M_{sw\text{-}perm}$, to be taken as

Stiffener Location	$M_{sw\text{-}perm}$	
	Pressure acting on Plate Side	Pressure acting on Stiffener Side
Above Neutral Axis	Sagging SWBM	Hogging SWBM
Below Neutral Axis	Hogging SWBM	Sagging SWBM

$M_{h\text{-}total}$: design horizontal bending moment at longitudinal position under consideration for the design load set being considered, see **Table 7.6.1**, in kNm

$I_{v\text{-}net50}$: net vertical hull girder moment of inertia, at the longitudinal position being considered, as defined in **Section 4/2.6.1**, in m^4

$I_{h\text{-}net50}$: net horizontal hull girder moment of inertia, at the longitudinal position being considered, as defined in **Section 4/2.6.2**, in m^4

y : transverse coordinate of the reference point defined in **Section 3/5.2.2.5**, in m

z : vertical coordinate of the reference point defined in **Section 3/5.2.2.5**, in m

$z_{NA\text{-}net50}$: distance from the baseline to the horizontal neutral axis, as defined in **Section 4/2.6.1**, in m

Table 8.2.6 Web Thickness Requirements for Stiffeners

The minimum net web thickness, $t_{w\text{-}net}$, is to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.2.7**, and given by: $t_{w-net} = \dfrac{f_{shr} \lvert P \rvert s\, l_{shr}}{d_{shr}\, C_t\, \tau_{yd}}$ (mm)	
Where:	
P	: design pressure for the design load set being considered and calculated at the load calculation point defined in **Section 3/5.1**, in kN/m^2
f_{shr}	: shear force distribution factor for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having as fixed ends = 0.5 for horizontal stiffeners = 0.7 for vertical stiffeners for stiffeners with reduced end fixity, see **Sub-section 7**
d_{shr}	: as defined in **Section 4/2.4.2.2**, in mm
C_t	: permissible shear stress coefficient for the design load set being considered, to be taken as = 0.75 for acceptance criteria set AC1 = 0.9 for acceptance criteria set AC2
s	: as defined in **Section 4/2.2**, in mm
l_{shr}	: effective shear span, in m, see **Section 4/2.1.2**
τ_{yd}	$= \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2
σ_{yd}	: specified minimum yield stress of the material, in N/mm^2

Table 8.2.7 Design Load Sets for Plating and Local Support Members

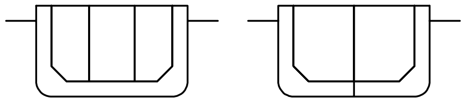
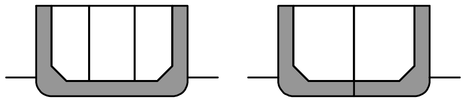
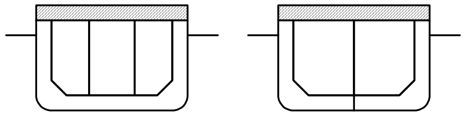
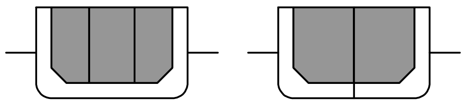
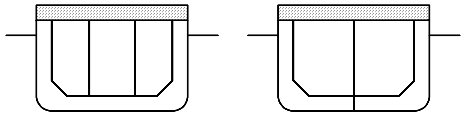
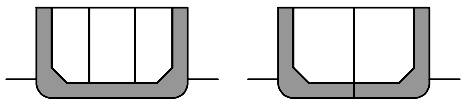
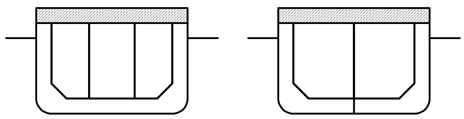
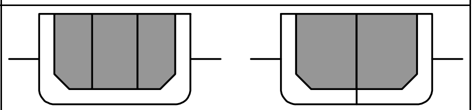
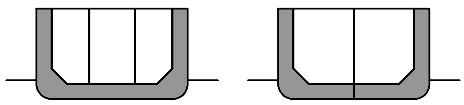
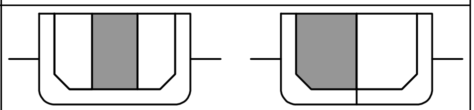
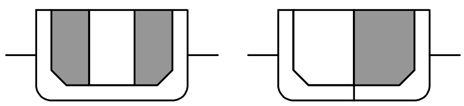
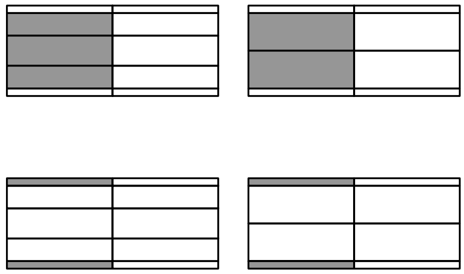
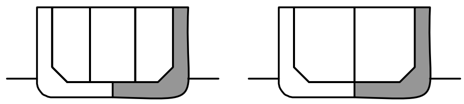
Structural Member		Design Load Set [1, 2, 3]	Load Component	Draught	Comment	Diagrammatic Representation
Keel, Bottom Shell, Bilge, Side Shell, Sheer strake		1	P_{ex}	T_{sc}	Sea pressure only	
		2	P_{ex}	T_{sc}		
		7	$P_{in} - P_{ex}$	T_{bal}	Net pressure difference between water ballast pressure and sea pressure	
		8	$P_{in} - P_{ex}$	$0.25T_{sc}$		
Deck	In way of cargo tanks	1	P_{ex}	T_{sc}	Green sea pressure only or other loads on deck	
		3	P_{in}	$0.6T_{sc}$	Cargo pressure only	
		4	P_{in}	-		
		11	$P_{in\text{-}flood}$	-		
	In way of other tanks	1	P_{ex}	T_{sc}	Green sea pressure only or other loads on deck	
		5	P_{in}	T_{bal}	Water ballast or other liquid pressure only	
		6	P_{in}	$0.25T_{sc}$		
		11	$P_{in\text{-}flood}$	-		
	Any location	9	P_{dk}	T_{bal}	Distributed or concentrated loads only. Simultaneously occurring green sea pressure may be ignored	
		10	P_{dk}	-		
Inner Bottom, Inner hull, Hopper side		3	P_{in}	$0.6T_{sc}$	Cargo pressure only	
		4	P_{in}	-		
		5	P_{in}	T_{bal}	Water ballast or other liquid pressure only	
		6	P_{in}	$0.25T_{sc}$		
		11	$P_{in\text{-}flood}$	-		
Longitudinal Bulkhead, Centreline Bulkhead		3	P_{in}	$0.6T_{sc}$	Pressure from one side only. Full cargo tank with adjacent cargo tank empty. Two cases are to be evaluated: 1. Inner empty, outer full 2. Inner full, outer empty	 
		4	P_{in}	-		
		11	$P_{in\text{-}flood}$	-		

Table 8.2.7 (Continued) Design Load Sets for Plating and Local Support Members

Structural Member		Design Load Set [1, 2, 3]	Load Component	Draught	Comment	Diagrammatic Representation
Transverse Bulkhead	In way of cargo tanks	3	P_{in}	$0.6T_{sc}$	Pressure from one side only. Full cargo tank with adjacent fwd or aft cargo tank empty. Need to evaluate 2 cases 1) Fwd empty, aft full 2) Fwd full, aft empty	
		4	P_{in}	-		
		11	$P_{in\text{-}flood}$	-		
	In way of other tanks	5	P_{in}	T_{bal}		
		6	P_{in}	$0.25T_{sc}$		
		11	$P_{in\text{-}flood}$	-		
Other tank boundaries, e.g. Girders, Floors, Stringers		5	P_{in}	T_{bal}	Pressure from one side only. Full tank with adjacent tank empty. Need to evaluate 2 cases, see above	
		6	P_{in}	$0.25T_{sc}$		
		11	$P_{in\text{-}flood}$	-		

Where:

T_{sc} : scantling draught, in m, as defined in **Section 4/1.1.5.5**

T_{bal} : minimum design ballast draught, in m, as defined in **Section 4/1.1.5.2**

Notes

1. Specification of design load combination, load component, acceptance criteria and other load parameters for each design load set are given in **Table 8.2.8**
2. When the ship's configuration cannot be described by the above, then the applicable Design Load Sets to determine the scantling requirements of structural boundaries are to be selected so as to specify a full tank on one side with the adjacent tank or space empty. The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents and are to maximise the pressure on the structural boundary, the draught to use is to be taken in accordance with the Design Load Set and this table. Design Load Sets covering the S and S+D design load combinations are to be selected. See **Note 4** and **Table 8.2.8**.
3. The boundaries of void and dry space not forming part of the hull envelope are to be evaluated using Design Load Set 11. See **Note 2**.
4. Design load sets (DLS) for some structural members not covered by the above:
   For the boundaries of a stool water ballast tank with the cargo tank:
   DLSs 5, 6 and 11 are to be applied for pressure from the WB tank side
   DLSs 3, 4 and 11 for pressure from the cargo tank side
   For a double bottom girder separating two water ballast tanks or separating a water ballast and fuel oil tank:
   DLSs 5, 6 and 11 are to be applied for pressure from each side in turn
   For the boundary of a stool void space to the cargo tank:
   DLSs 3, 4 and 11 for pressure from the cargo tank side
   DLS 11 for pressure from the void space side

Table 8.2.8 Specification of Design Load Combination, Acceptance Criteria and other Load Parameters for each Design Load Set

Design Load Set	Load Component [(1)]	Design Load Combination [(2)]	Acceptance Criteria Set	Parameters for Calculating Load Components		
				DLCF [(3)]	*GM*	$r_{roll\text{-}gyr}$
Hull envelope (*PSM* and *LSM*)						
1	Sea pressures P_{ex}	*S+D*	AC2	Loaded *DLCF*	0.12*B*	0.35*B*
2		*S*	AC1			
Cargo tank boundaries (*PSM* and *LSM*)						
3	Cargo pressures P_{in}	*S+D*	AC2	Loaded *DLCF*	0.24*B*	0.40*B*
4		*S*	AC1			
Boundaries of water ballast and other tanks (*PSM* and *LSM*)						
5	Water ballast or other liquid tank pressures P_{in}	*S+D*	AC2	Ballast *DLCF*	0.33*B*	0.45*B*
6		*S*	AC1			
7	Net water ballast minus sea pressures $P_{in} - P_{ex}$	*S+D*	AC2	Ballast *DLCF*	0.33*B*	0.45*B*
8		*S*	AC1			
Decks (*LSM* and *PSM*)						
9	Distributed and concentrated loads on deck P_{dk}	*S+D*	AC2	Ballast *DLCF*	0.33*B*	0.45*B*
10		*S*	AC1			
Watertight boundaries (*LSM* and *PSM*)						
11	Accidental flooding $P_{in\text{-}flood}$	*A*	AC2			
Hull envelope (*PSM*)						
12	Net cargo pressure minus sea pressure $P_{in} - P_{ex}$	*S+D*	AC2	Loaded *DLCF*	0.24*B*	0.40*B*
13		*S*	AC1			
14	Average cargo and sea pressure $(P_{in} + P_{ex})/2$	*S+D*	AC2	Loaded *DLCF*	0.12*B*	0.35*B*
15		*S+D*	AC2	Loaded *DLCF*	0.24*B*	0.40*B*
16		*S*	AC1			

Where:

PSM : Primary Support Members
LSM : Local Support Members
DLCF : Dynamic Load Combination Factors
P_{in} P_{ex} P_{dk} $P_{in\text{-}flood}$: as given in **Table 7.6.1** and as shown in **Table 8.2.7** or **Table 8.2.9**
B : moulded breadth, in *m*, as defined in **Section 4/1.1.3.1**

Note

1. Structural members are to be designed using all design load sets which are applicable. This table gives the pressure load component of the design load set. The hull girder bending moments are given in **Tables 8.2.4** and **8.2.5** for local support members.
2. This column specifies which column in the design load combination table is to be applied for each design load set, see **Table 7.6.1**. Where *S* denotes the static design load combination, *S+D* denotes the static plus dynamic design load combination and *A* denotes the accidental design load combination.
3. This column specifies which dynamic load combination factor table is to be used for the deviation of the pressure components and global load components, see **Table 7.6.1**

2.6 Primary Support Members

2.6.1 General

2.6.1.1 The following requirements relate to the determination of scantlings of the primary support members in the cargo tank region for the extents shown in **Fig. 8.2.4**.

2.6.1.2 The section modulus and shear area criteria for primary support members contained in **2.6** apply to structural configurations shown in **Fig. 2.3.1** and are applicable to the following structural elements:

(a) floors and girders within the double bottom;
(b) deck transverses fitted below the upper deck;
(c) side transverses within double side structure;
(d) vertical web frames on longitudinal bulkheads with or without cross ties;
(e) horizontal stringers on transverse bulkheads, except those fitted with buttresses or other intermediate supports; and
(f) cross ties in wing cargo and centre cargo tanks.

The section modulus and shear area criteria for primary support members of structural configurations other than those listed above are to be obtained by calculation methods as described in **Section 8/7**.

2.6.1.3 The scantlings of primary support members are to be verified by the Finite Element (FE) cargo tank structural analysis defined in **Section 9/2**.

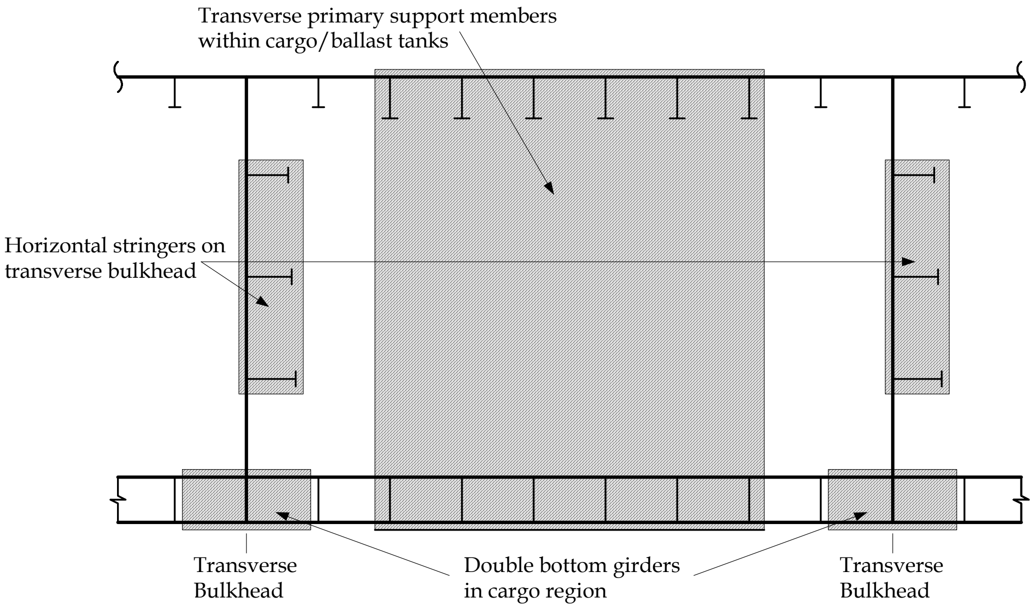
2.6.1.4 The section modulus and/or shear area of a primary support member and/or the cross sectional area of a primary support member cross tie may be reduced to 85% of the prescriptive requirements provided that the reduced scantlings comply with the FE cargo tank structural analysis and with **2.1.6**.

2.6.1.5 In general, primary support members are to be arranged in one plane to form continuous transverse rings. Brackets forming connections between primary support members of the ring are to be designed in accordance with **Section 4/3.3.3**.

2.6.1.6 Webs of the primary support members are to be stiffened in accordance with **Section 10/2.3**.

2.6.1.7 Webs of the primary support members are to have a depth of not less than given by the requirements of **2.6.4.1**, **2.6.6.1** and **2.6.7.1**, as applicable. Lesser depths may be accepted where equivalent stiffness is demonstrated. See **3/5.3.3.4**. Primary support members that have open slots for stiffeners are to have a depth not less than 2.5 *times* the depth of the slots.

Fig. 8.2.4 Depiction of Applicable Extents



2.6.2 Design load sets and permissible stress coefficients for primary support members

2.6.2.1 The design load sets for the evaluation of the primary support members are given in **Table 8.2.9**.

2.6.2.2 The permissible bending and shear stress coefficients for the evaluation of the primary support members are given in **Table 8.2.10**.

Table 8.2.9 Design Load Sets for Primary Support Members

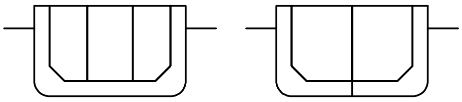
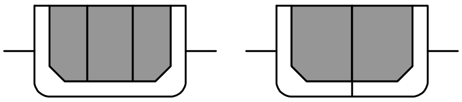
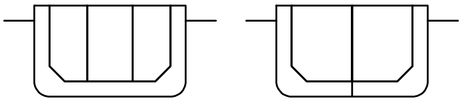
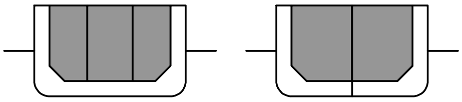
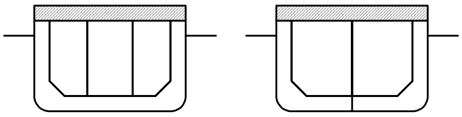
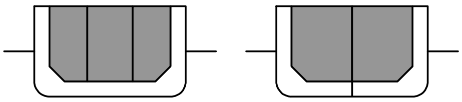
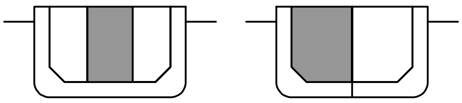
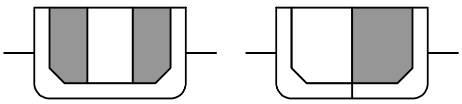
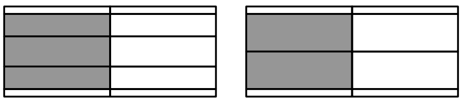
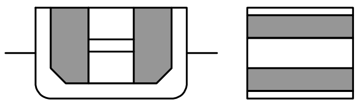
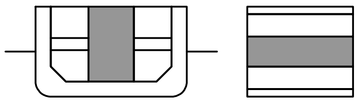
Structural Member	Design Load Set (1, 5, 6)	Load Component	Draught	Comment	Diagrammatic Representation
Double bottom floors and girders (3)	1	P_{ex}	$0.9T_{sc}$ (2)	Sea pressure only	
	2	P_{ex}	T_{sc}		
	12	$P_{in} - P_{ex}$	$0.6T_{sc}$	Net pressure difference between cargo pressure and sea pressure	
	13	$P_{in} - P_{ex}$	(4)		
Side transverses (3)	1	P_{ex}	$0.9T_{sc}$	Sea pressure only	
	2	P_{ex}	T_{sc}		
	3	P_{in}	$0.6T_{sc}$	Cargo pressure only	
	4	P_{in}	-		
Deck transverses	1	P_{ex}	T_{sc}	Green sea pressure only or other loads on deck	
	3	P_{in}	$0.6T_{sc}$	Cargo pressure only	
	4	P_{in}	-		
Vertical web frames on longitudinal bulkheads	3	P_{in}	$0.6T_{sc}$	Pressure from one side only. Full cargo tank with adjacent cargo tank empty	
	4	P_{in}	-		
	3	P_{in}	$0.6T_{sc}$	Pressure from one side only. Full cargo tank with adjacent cargo tank empty	
	4	P_{in}	-		
Horizontal stringers on transverse bulkhead	3	P_{in}	$0.6T_{sc}$	Pressure from one side only. Full cargo tank with adjacent forward or aft cargo tank empty. Two cases are to be evaluated: 1. forward empty/aft full 2. forward full/aft empty	
	4	P_{in}	-		
	11	$P_{in\text{-}flood}$	-		
Cross ties in centre tanks	3	$\frac{P_{in-pt} + P_{in-stb}}{2}$	$0.6T_{sc}$	Full wing cargo tanks, centre tank empty.	
	4	P_{in}	-		
Cross ties in wing tanks	14	$\frac{P_{in} + P_{ex}}{2}$	T_{sc}	Full centre tank, wing cargo tanks empty.	
	15	$\frac{P_{in} + P_{ex}}{2}$	$0.6T_{sc}$		
	16	$\frac{P_{in} + P_{ex}}{2}$	T_{sc}		

Table 8.2.9 (Continued) Design Load Sets for Primary Support Members

Where:	
$P_{in\text{-}pt}$	: design pressure from port side wing cargo tank, in kN/m^2
$P_{in\text{-}stb}$	: design pressure from starboard side wing cargo tank, in kN/m^2
T_{sc}	: scantling draught, in m, as defined in **Section 4/1.1.5.5**
T_{bal}	: minimum design ballast draught, in m, as defined in **Section 4/1.1.5.2**
Notes	
1.	Specification of design load combination, load component, acceptance criteria set and other load parameters for each design load set are given in **Table 8.2.8**.
2.	See **1.1.2.9(b)**
3.	Draughts specified for bottom floors, girders and side transverses are based on operational limits specified in **1.1.2**. Where the optional loading conditions exceed the minimum Rule required loading conditions the draughts will be subject to special consideration.
4.	For tankers with two oil-tight longitudinal bulkheads, the draught is to be taken as $0.25T_{sc}$. For tankers with a centreline bulkhead, the draught is to be taken as $0.33T_{sc}$.
5.	When the ship's configuration cannot be described by the structural members or structural configurations identified above, then the applicable Design Load Sets to determine the scantling requirements of primary support member are to be selected so as to specify all applicable cases from the following: ・ a full tank on one side of the member with the tank or space on the other side empty ・ a full tank on one side of the member with the external pressure minimised ・ external pressure maximised with the adjacent tank or space empty The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents and are to maximise the net pressure on the structural boundary, the draught to use is to be taken in accordance with the Design Load Set and this table. Design Load Sets covering the S and S+D design load combinations are to be selected. Design Load Set 11 may also need to be applied, depending on the particular structural configuration. See **Note 4** on **Table 8.2.7** and **Table 8.2.8**.
6.	For a void or dry space, the pressure component from the void side is to be ignored, except where Design Load Set 11 needs to be applied.

Table 8.2.10 Permissible Stress Coefficients, $C_{s\text{-}pr}$ and $C_{t\text{-}pr}$, for Primary Support Members

Acceptance criteria set	Permissible bending stress coefficient, $C_{s\text{-}pr}$	Permissible shear stress coefficient, $C_{t\text{-}pr}$
AC1	0.70	0.70
AC2	0.85	0.85

2.6.3 Floors and girders in double bottom

2.6.3.1 Continuous double bottom girders are to be arranged at the centreline or duct keel, at the hopper side and in way of longitudinal bulkheads and bulkhead stools. Plate floors are to be arranged in way of transverse bulkheads and bulkhead stools.

2.6.3.2 The net shear area, $A_{shr\text{-}net50}$, of the floors at any position in the floor is not to be less than:

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\,\tau_{yd}} \qquad (cm^2)$$

Where:

Q : design shear force

$= f_{shr} P S l_{shr}$ (kN)

f_{shr} : shear force distribution factor

$$= f_{shr-i}\left(1-\frac{2y_i}{l_{shr}}\right) \qquad \text{but not to be taken as less than 0.2}$$

f_{shr-i}	: shear force distribution factor at the end of the span, l_{shr}, as given in **Table 8.2.11**
l_{shr}	: effective shear span, of the double bottom floor, in *m*, as shown in **Fig**. **8.2.6.** In way of bracket ends, the effective shear span is measured to the toes of the effective end bracket, as defined in **Section 4/2.1.5**. Where the floor ends on a girder at a hopper or stool structure, the effective shear span is measured to a point that is one-half of the distance from the girder to the adjacent bottom and inner-bottom longitudinal, as shown in **Fig. 8.2.6**.
y_i	: distance from the considered cross-section of the floor to the nearest end of the effective shear span, l_{shr}, in *m*
S	: primary support member spacing, in *m*, as defined in **Section 4/2.2.2**
P	: design pressure for the design load set being considered, calculated at mid point of effective shear span, l_{shr}, of a floor located midway between transverse bulkheads or transverse bulkhead and wash bulkhead, where fitted, in kN/m^2
C_{t-pr}	: permissible shear stress coefficient for primary support member as given in **Table 8.2.10**
τ_{yd}	$= \frac{\sigma_{yd}}{\sqrt{3}}$ (N/mm^2)
σ_{yd}	: specified minimum yield stress of the material, in N/mm^2

Table 8.2.11 Shear Force Distribution Factors of Floors

Structural Configuration	Centre tank (f_{shr3} in **Fig. 8.2.5**)	Wing Tank	
		At inboard end (f_{shr2} in **Fig. 8.2.5**)	At hopper knuckle end (f_{shr1} in **Fig. 8.2.5**)
Ships with centreline longitudinal bulkhead	-	0.4	0.6
Ships with two longitudinal bulkheads	0.5	0.50	0.65

Fig. 8.2.5 Floor Shear Force Distribution Factors of Floors

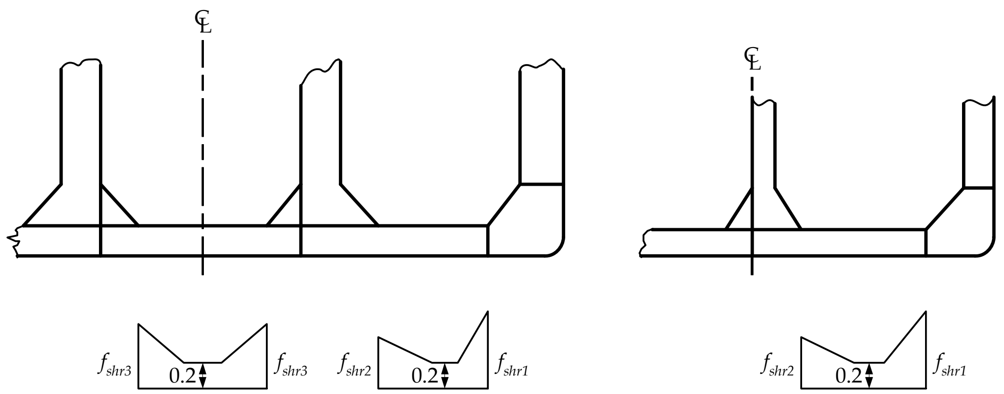
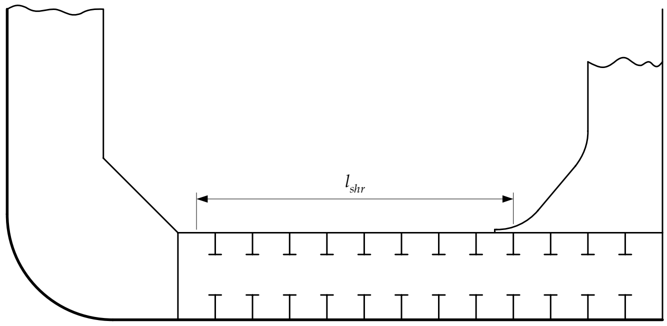
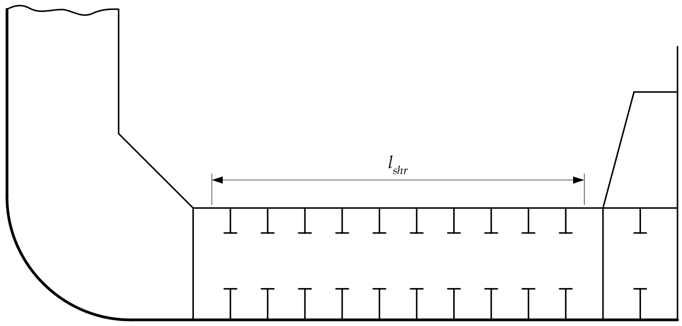


Fig. 8.2.6 Effective Shear Span of Floors



typical arrangement with hopper and end bracket



typical arrangement with hopper and stool

2.6.3.3 For double bottom centre girders where no longitudinal bulkhead is fitted above, the net shear area, $A_{shr\text{-}net50}$, of the double bottom centre girder in way of the first bay from each transverse bulkhead and wash bulkhead, where fitted, is not to be less than:

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\,\tau_{yd}} \qquad (cm^2)$$

Where:

Q : design shear force

$$= 0.21 n_1 n_2 P l_{shr}^{\ 2} \qquad kN$$

l_{shr} : effective shear span, of the double bottom floor, in m, as shown in **Fig. 8.2.6**. In way of bracket ends, the effective shear span is measured to the toes of the effective end bracket, as defined in **Section 4/2.1.5**. Where the floor ends on a girder at a hopper or stool structure, the effective shear span is measured to a point that is one-half of the distance from the girder to the adjacent bottom and inner-bottom longitudinal, as shown in **Fig. 8.2.6**.

P : design pressure for the design load set being considered, calculated at mid point of effective shear span, l_{shr}, of a floor located midway between transverse bulkheads or transverse bulkhead and wash bulkhead, where fitted, in kN/m^2

n_1 $$= 0.00935\left(\frac{l_{shr}}{S}\right)^2 - 0.163\left(\frac{l_{shr}}{S}\right) + 1.289$$

n_2 $\qquad = 1.3 - \left(\dfrac{S}{12}\right)$

S : double bottom floor spacing, in *m*, as defined in **Section 4/2.2.2**

$C_{t\text{-}pr}$: permissible shear stress coefficient for primary support member as given in **Table 8.2.10**

τ_{yd} $\qquad = \dfrac{\sigma_{yd}}{\sqrt{3}} \qquad (N/mm^2)$

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

2.6.3.4 For double bottom side girders where no longitudinal bulkhead is fitted above, the net shear area, $A_{shr\text{-}net50}$, of the double bottom side girder in way of the first bay from each transverse bulkhead and wash bulkhead, where fitted, is not to be less than:

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\,\tau_{yd}} \qquad (cm^2)$$

Where:

Q : design shear force

$\qquad = 0.14 n_3 n_4 P l_{shr}^{\ 2} \qquad (kN)$

n_3 $\qquad = 1.072 - 0.0357\left(\dfrac{l_{shr}}{S}\right)$

n_4 $\qquad = 1.2 - \left(\dfrac{S}{18}\right)$

l_{shr} : effective shear span, of the double bottom floor, in *m*, as shown in **Fig. 8.2.6**. In way of bracket ends, the effective shear span is measured to the toes of the effective end bracket, as defined in **Section 4/2.1.5**. Where the floor ends on a girder at a hopper or stool structure, the effective shear span is measured to a point that is one-half of the distance from the girder to the adjacent bottom and inner-bottom longitudinal, as shown in **Fig. 8.2.6**.

S : double bottom floor spacing, in *m*, as defined in **Section 4/2.2.2**

P : design pressure for the design load set being considered, calculated at mid point of effective shear span, l_{shr}, of a floor located midway between transverse bulkheads or transverse bulkhead and wash bulkhead, where fitted, in kN/m^2

$C_{t\text{-}pr}$: permissible shear stress coefficient for primary support member as given in **Table 8.2.10**

τ_{yd} $\qquad = \dfrac{\sigma_{yd}}{\sqrt{3}} \qquad (N/mm^2)$

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

2.6.4 Deck transverses

2.6.4.1 The web depth of deck transverses is not to be less than:

(a) 0.20 l_{bdg-dt} for deck transverses in the wing cargo tanks of ships with two longitudinal bulkheads
(b) 0.13 l_{bdg-dt} for deck transverses in the centre cargo tanks of ships with two longitudinal bulkheads. The web depth of deck transverses in the centre cargo tank is not to be less than 90% of that of the deck transverses in the wing cargo tank
(c) 0.10 l_{bdg-dt} for the deck transverses of ships with a centreline longitudinal bulkhead.
(d) See also **2.6.1.7**

Where:

l_{bdg-dt} : effective bending span of the deck transverse, in *m*, see **Section 4/2.1.4** and **Fig. 8.2.7**, but is not to be taken as less than 60% of the breadth of the tank

2.6.4.2 The moment of inertia of the deck transverses, with associated deck plating, is to comply with **Section 10/2.3.2.3** to control the overall deflection of the deck structure.

2.6.4.3 The net section modulus of deck transverses is not to be less than $Z_{in-net50}$ and $Z_{ex-net50}$ as given by the following. The net section modulus of the deck transverses in the wing cargo tanks is also not to be less than required for the deck transverses in the centre tanks.

$$Z_{in-net50} = \frac{1000 M_{in}}{C_{s-pr}\,\sigma_{yd}} \qquad (cm^3)$$

$$Z_{ex-net50} = \frac{1000 M_{ex}}{C_{s-pr}\,\sigma_{yd}} \qquad (cm^3)$$

Where:

M_{in} : design bending moment due to cargo pressure, in *kNm*, to be taken as

(a) for deck transverses in wing cargo tanks of ships with two longitudinal bulkheads, and for deck transverses in cargo tanks of ships with a centreline longitudinal bulkhead:

$= 0.042\,\varphi\,P_{in-dt}\,S\,l_{bdg-dt}^{\ 2} + M_{st}$ but is not to be taken as less than M_o

(b) for deck transverses in centre cargo tank of ships with two longitudinal bulkheads:

$= 0.042\,\varphi\,P_{in-dt}\,S\,l_{bdg-dt}^{\ 2} + M_{vw}$ but is not to be taken as less than M_o

M_{st} : bending moment transferred from the side transverse

$= c_{st}\,\beta_{st}\,P_{in-st}\,S\,l_{bdg-st}^{\ 2} \qquad (kNm)$

where a cross tie is fitted in a wing cargo tank and $l_{bdg-st-ct}$ is greater than $0.7 l_{bdg-st}$, then l_{bdg-st} in the above formula may be taken as $l_{bdg-st-ct}$.

M_{vw} : bending moment transferred from the vertical web frame on the longitudinal bulkhead

$= c_{vw}\,\beta_{vw}\,P_{in-vw}\,S\,l_{bdg-vw}^{\ 2} \qquad (kNm)$

where $l_{bdg-vw-ct}$ is greater than $0.7 l_{bdg-vw}$, then l_{bdg-vw} in the above formula may be taken as $l_{bdg-vw-ct}$.

for vertically corrugated bulkheads, M_{vw} is to be taken equal to bending moment in upper end of corrugation over the spacing between deck transverses

M_0 : minimum bending moment

$= 0.083\,P_{in-dt}\,S\,l_{bdg-dt}^{\ 2} \qquad (kNm)$

M_{ex} : design bending moment due to green sea pressure

$$= 0.067\, P_{ex-dt}\, S\, l_{bdg-dt}{}^2 \qquad (kNm)$$

P_{in-dt} : design cargo pressure for the design load set being considered, calculated at mid point of effective bending span, l_{bdg-dt}, of the deck transverse located at mid tank, in kN/m^2

P_{in-st} : corresponding design cargo pressure in wing cargo tank for the design load set being considered, calculated at the mid point of effective bending span, l_{bdg-st}, of the side transverse located at mid tank, in kN/m^2

P_{in-vw} : corresponding design cargo pressure in the centre cargo tank of ships with two longitudinal bulkheads for the design load set being considered, calculated at mid point of effective bending span, l_{bdg-vw}, of the vertical web frame on the longitudinal bulkhead located at mid tank, in kN/m^2

P_{ex-dt} : design green sea pressure for the design load set being considered, calculated at mid point of effective bending span, l_{bdg-dt}, of the deck transverse located at mid tank, in kN/m^2

φ $= 1 - 5\left(\dfrac{y_{toe}}{l_{bdg-dt}}\right)$ but is not to be taken as less than 0.6

y_{toe} : distance from the end of effective bending span, l_{bdg-dt}, to the toe of the end bracket of the deck transverse, in m

$\beta_{\sigma\tau}$ $= 0.9\left(\dfrac{l_{bdg-st}}{l_{bdg-dt}}\right)\left(\dfrac{I_{dt}}{I_{st}}\right)$ but is not to be taken as less than 0.10 or greater than 0.65

$\beta_{\varpi\omega}$ $= 0.9\left(\dfrac{l_{bdg-vw}}{l_{bdg-dt}}\right)\left(\dfrac{I_{dt}}{I_{vw}}\right)$ but is not to be taken as less than 0.10 or greater than 0.50

S : primary support member spacing, in m, as defined in **Section 4/2.2.2**

l_{bdg-dt} : effective bending span of the deck transverse, in m, see **Section 4/2.1.4** and **Fig. 8.2.7**, but is not to be taken as less than 60% of the breadth of the tank

l_{bdg-st} : effective bending span of the side transverse, in m, between the deck transverse and the bilge hopper, see **Section 4/2.1.4** and **Fig. 8.2.7**

$l_{bdg-st-ct}$: effective bending span of the side transverse, in m, between the deck transverse and the mid depth of the cross tie, where fitted in wing cargo tank, see **Section 4/2.1.4**

l_{bdg-vw} : effective bending span of the vertical web frame on the longitudinal bulkhead, in m, between the deck transverse and the bottom structure, see **Section 4/2.1.4** and **Fig. 8.2.7.**

$l_{bdg-vw-ct}$: effective bending span of the vertical web frame on longitudinal bulkhead, in m, between the deck transverse and the mid depth of the cross tie, see **Section 4/2.1.4**

I_{dt} : net moment of inertia of the deck transverse with an effective breadth of attached plating specified in **Section 4/2.3.2.3**, in cm^4

I_{st} : net moment of inertia of the side transverse with an effective breadth of attached plating specified in **Section 4/2.3.2.3**, in cm^4

I_{vw} : net moment of inertia of the longitudinal bulkhead vertical web frame with an effective breadth of attached plating specified in **Section 4/2.3.2.3**, in cm^4

c_{st} : as defined in **Table 8.2.12**

c_{vw} : as defined in **Table 8.2.12**

$C_{s\text{-}pr}$: permissible bending stress coefficient for primary support member as given in **Table 8.2.10**

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

Table 8.2.12 Values of c_{st} and c_{vw} for Deck Transverses

Structural Configuration			c_{st}	c_{vw}
Ships with centreline longitudinal bulkhead			0.056	-
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank	M_{vw} based on $l_{bdg\text{-}vw\text{-}ct}$	-	0.044
		M_{st} based on $l_{bdg\text{-}st}$ or M_{vw} based on $l_{bdg\text{-}vw}$	0.044	0.016
	Cross ties in wing cargo tanks	M_{st} based on $l_{bdg\text{-}st\text{-}ct}$ or M_{vw} based on $l_{bdg\text{-}vw\text{-}ct}$	0.044	0.044
		M_{st} based on $l_{bdg\text{-}st}$ or M_{vw} based on $l_{bdg\text{-}vw}$	0.041	0.015

2.6.4.4 The net shear area of deck transverses is not to be less than $A_{shr\text{-}in\text{-}net50}$ and $A_{shr\text{-}ex\text{-}net50}$ as given by:

$$A_{shr-in-net50} = \frac{10Q_{in}}{C_{t-pr}\,\tau_{yd}} \qquad (cm^2)$$

$$A_{shr-ex-net50} = \frac{10Q_{ex}}{C_{t-pr}\,\tau_{yd}} \qquad (cm^2)$$

Where:

Q_{in} : design shear force due to cargo pressure

$$= 0.65\,P_{in-dt}\,S\,l_{shr} + c_1\,D\,b_{ctr}\,S\,\rho\,g \qquad (kN)$$

Q_{ex} : design shear force due to green sea pressure

$$= 0.65\,P_{ex-dt}\,S\,l_{shr} \qquad (kN)$$

$P_{in\text{-}dt}$: design cargo pressure for the design load set being considered, calculated at mid point of effective bending span, $l_{bdg\text{-}dt}$, of the deck transverse located at mid tank, in kN/m^2

$P_{ex\text{-}dt}$: design green sea pressure for the design load set being considered, calculated at mid point of effective bending span, $l_{bdg\text{-}dt}$, of the deck transverse located at mid tank, in kN/m^2

S : primary support member spacing, in m, as defined in **Section 4/2.2.2**

l_{shr} : effective shear span, of the deck transverse, in m, see **Section 4/2.1.5**

$l_{bdg\text{-}dt}$: effective bending span of the deck transverse, in m, see **Section 4/2.1.4** and **Fig. 8.2.7**, but is not to be taken as less than 60% of the breadth of the tank

c_1 = 0.04 in way of wing cargo tanks of ships with two longitudinal bulkheads
= 0.00 in way of centre tank of ships with two longitudinal bulkheads
= 0.00 for ships with a centreline longitudinal bulkhead

D : moulded depth, in m, as defined in **Section 4/1.1.4**

b_{ctr} : breadth of the centre tank, in m

ρ : density of liquid in the tank, in $tonnes/m^3$, not to be taken less than 1.025, see **Section 2/5.1.8**

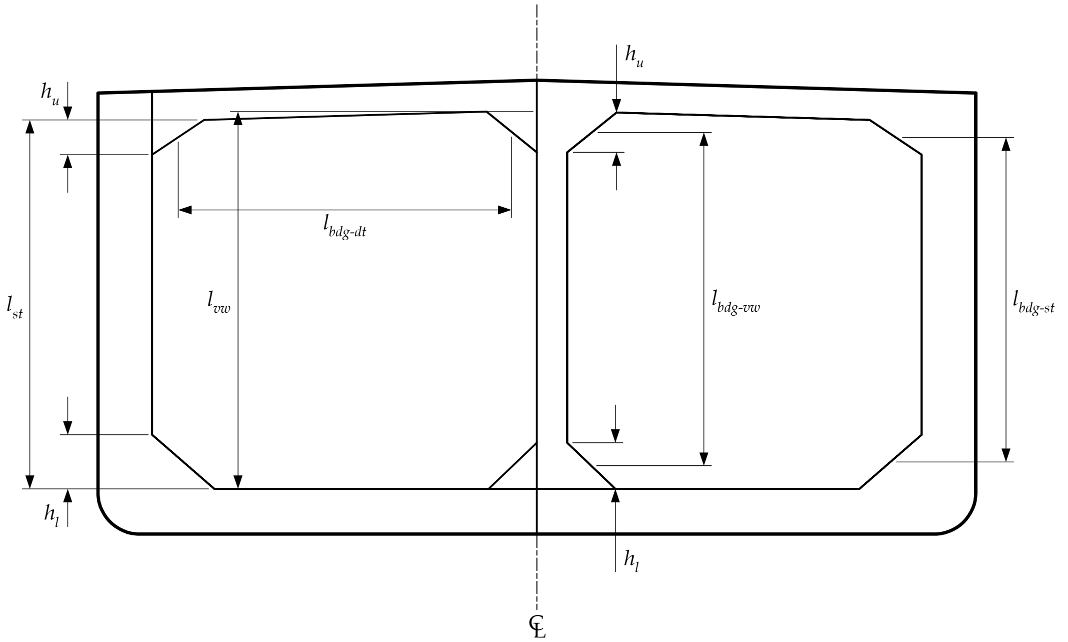
g : acceleration due to gravity, 9.81 m/s^2

$C_{t\text{-}pr}$: permissible shear stress coefficient for primary support member as given in **Table 8.2.10**

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

Fig. 8.2.7 Definition of Spans of Deck, Side Transverses, Vertical Web Frames on Longitudinal Bulkheads and Horizontal Stringers on Transverse Bulkheads



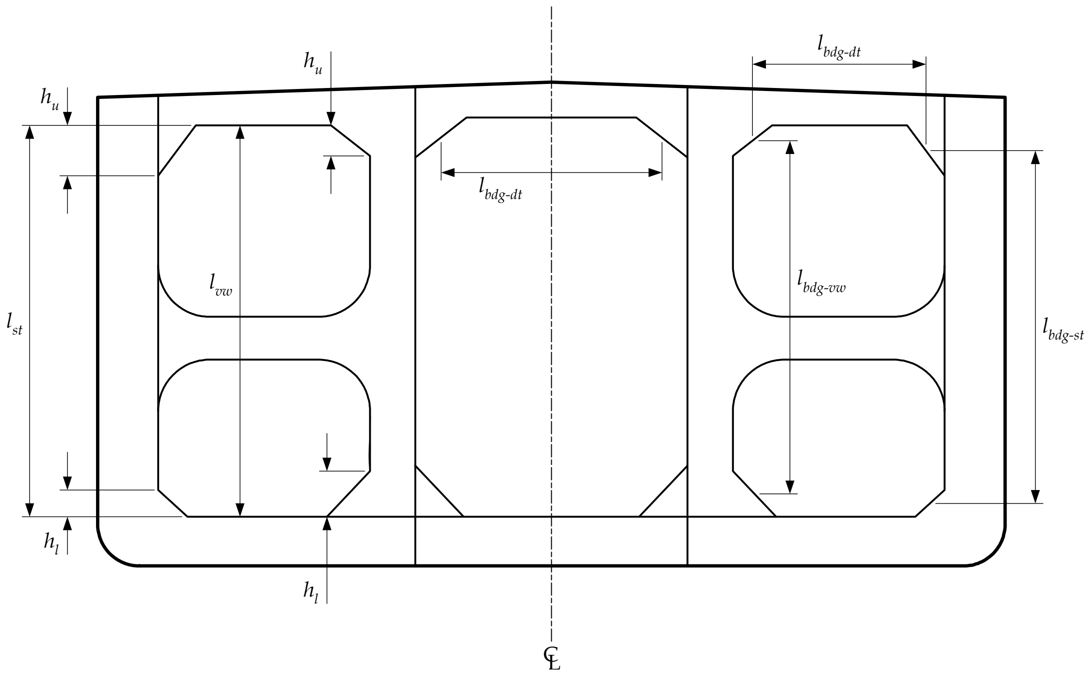
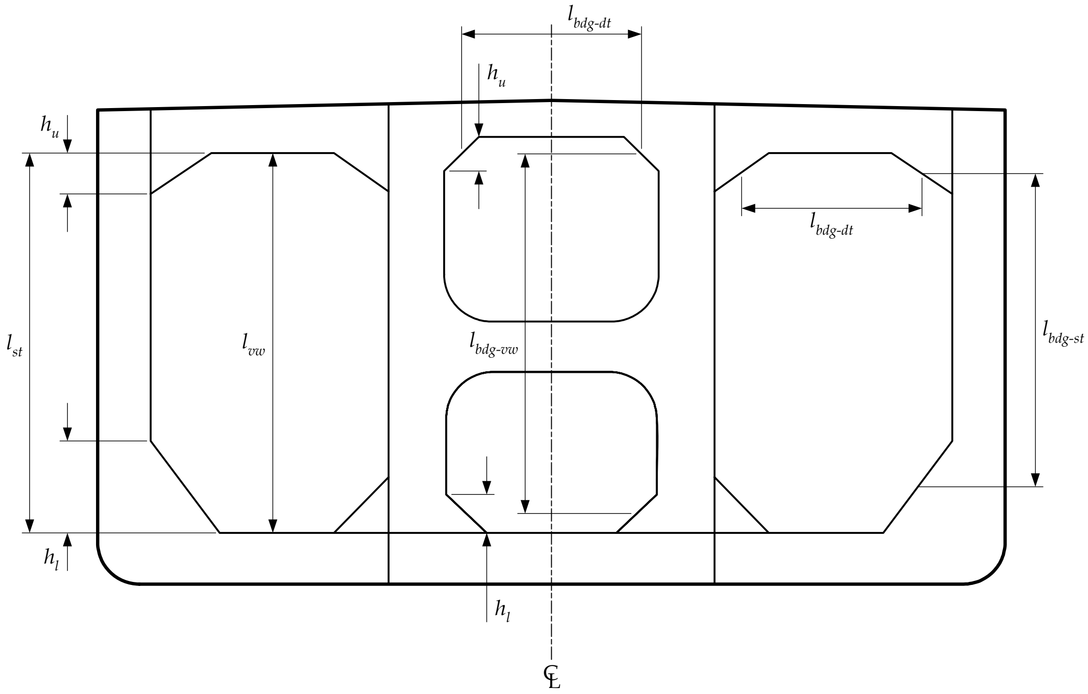
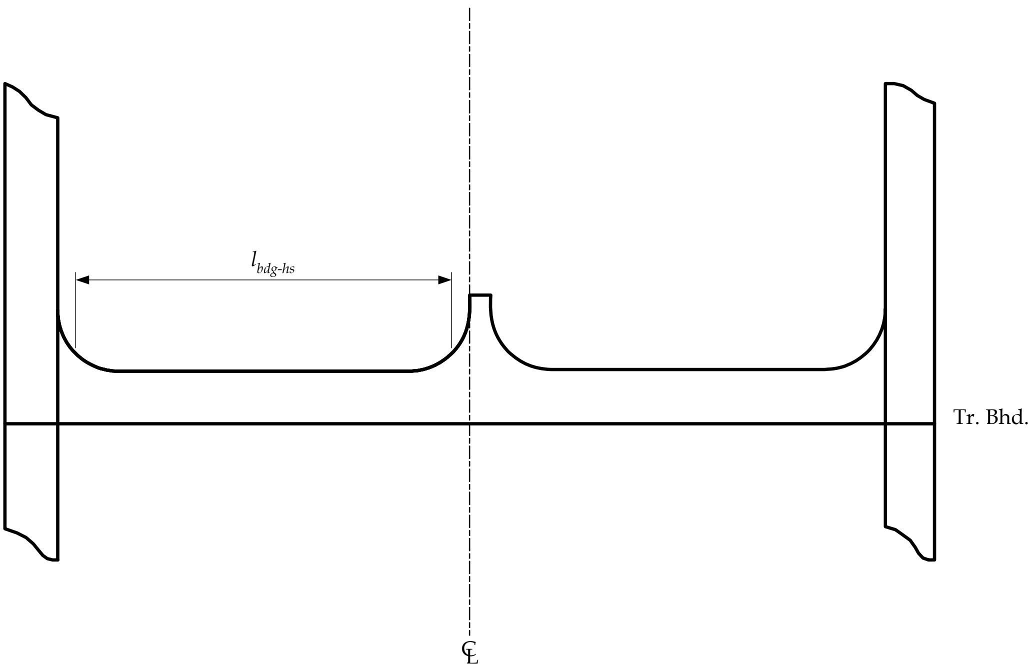


Fig. 8.2.7 (Continued) Definition of Spans of Deck, Side Transverses, Vertical Web Frames on Longitudinal Bulkheads and Horizontal Stringers on Transverse Bulkheads





2.6.5 Side transverses

2.6.5.1The net shear area, $A_{shr\text{-}net50}$, of side transverses is not to be less than:

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\,\tau_{yd}} \qquad cm^2$$

Where:

Q : design shear force as follows, in kN

$= Q_u$ for upper part of the side transverse

$= Q_l$ for lower part of the side transverse

Q_u $= \; S[c_u\, l_{st}\,(P_u + P_l) - h_u\, P_u]$

where a cross tie is fitted in a wing cargo tank and l_{st-ct} is greater than $0.7l_{st}$, then l_{st} in the above formula may be taken as l_{st-ct}.

Q_l : to be taken as the greater of the following

$$S[c_l\, l_{st}\, (P_u + P_l) - h_l\, P_l]$$

$$0.35 c_l\, S\, l_{st}\, (P_u + P_l)$$

$$1.2Q_u$$

where a cross tie is fitted in a wing cargo tank and l_{st-ct} is greater than $0.7l_{st}$, then l_{st} in the above formula may be taken as l_{st-ct}.

P_u : design pressure for the design load set being considered, in *kN/m²*, calculated at mid tank as follows

where deck transverses are fitted below deck, P_u is to be calculated at mid height of upper bracket of the side transverse, h_u

where deck transverses are fitted above deck, P_u is to be calculated at the elevation of the deck at side, except in cases where item **(c)** applies

where deck transverses are fitted above deck and the inner hull longitudinal bulkhead is arranged with a top wing structure as follows

- the breadth at top of the wing structure is greater than 1.5 *times* the breadth of the double side and
- the angle along a line between the point at base of the slope plate at its intersection with the inner hull longitudinal bulkhead and the point at the intersection of top wing structure and deck is 30 *degrees* or more to vertical

P_u is to be calculated at mid depth of the top wing structure

P_l : corresponding design pressure for the design load set being considered, calculated at mid height of bilge hopper, h_l, located at mid tank, in *kN/m²*.

l_{st} : length of the side transverse, in *m*, and is to be taken as follows

where deck transverses are fitted below deck, l_{st} is the length between the flange of the deck transverse and the inner bottom, see **Fig. 8.2.7**

where deck transverses are fitted above deck, l_{st} is the length between the elevation of the deck at side and the inner bottom

l_{st-ct} : length of the side transverse, in *m*, and is to be taken as follows

where deck transverses are fitted below deck, l_{st} is the length between the flange of the deck transverse and mid depth of cross tie, where fitted in wing cargo tank

where deck transverses are fitted above deck, l_{st} is the length between the elevation of the deck at side and mid depth of the cross tie, where fitted in wing cargo tank

S : primary support member spacing, in *m*, as defined in **Section 4/2.2.2**

h_u : effective length of upper bracket of the side transverse, in *m*, and is to be taken as follows

where deck transverses are fitted below deck, h_u is as shown in **Fig. 8.2.7** and as described in **Section 4/2.1.5**.

where deck transverses are fitted above deck, h_u is to be taken as 0.0, except in cases where item **(c)** applies.

where deck transverses are fitted above deck and the inner hull longitudinal bulkhead is arranged with a top wing structure as follows

the breadth at top of the wing structure is greater than 1.5 *times* the breadth of the double side, and

the angle along a line between the point at base of the slope plate at its intersection with the inner hull longitudinal bulkhead and the point at the intersection of top wing structure and the deck is 30 *degrees* or more to vertical

h_u is to be taken as the distance between the deck at side and the lower end of slope plate of the top wing structure.

h_l : height of bilge hopper, in *m*, as shown in **Fig. 8.2.7**

$c_{u\ and\ cl}$: as defined in **Table 8.2.13**

$C_{t\text{-}pr}$: permissible shear stress coefficient for primary support member as given in **Table 8.2.10**

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ (N/mm^2)

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

Table 8.2.13 Values of c_u and c_l for Side Transverses

Structural Configuration			c_u		c_l	
Number of the sitde stringers			Less than three	Equal to or greater than three	Less than three	Equal to or greater than three
Ships with a centreline longitudinal bulkhead			0.12	0.09	0.29	0.21
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank		0.12	0.09	0.29	0.21
	Cross ties in wing cargo tanks	Q_u or Q_l based on $l_{st\text{-}ct}$	0.12	0.09	0.29	0.21
		Q_u or Q_l based on l_{st}	0.08		0.20	

2.6.5.2 The shear area over the length of the side transverse is to comply with the following:

(a) the required shear area for the upper part is to be maintained over the upper 0.2 l_{shr}

(b) the required shear area for the lower part is to be maintained over the lower 0.2 l_{shr}

(c) where Q_u and Q_l are determined based on $l_{st\text{-}ct}$, the required shear area for the lower part is also to be maintained below the cross tie

(d) for ships without cross ties in the wing cargo tanks, the required shear area between the upper and lower parts is to be reduced linearly towards 50% of the required shear area for the lower part at mid span

(e) for ships with cross ties in the wing cargo tanks, the required shear area along the span is to be tapered linearly between the upper and lower parts

Note

When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress

Where:

l_{shr} : effective shear span of the side transverse, in *m*

$= l_{st} - h_u - h_l$ where Q_u and Q_l are determined based on l_{st}

$= l_{st-ct} - h_u$ where Q_u and Q_l are determined based on $l_{st\text{-}ct}$

l_{st}, $l_{st\text{-}ct}$, h_u, h_l, Q_u *and* Q_l : as defined in **2.6.5.1**

2.6.6 Vertical web frames on longitudinal bulkhead

2.6.6.1 The web depth of the vertical web frame on the longitudinal bulkhead is not to be less than:

(a) 0.14 $l_{bdg\text{-}vw}$for ships with a centreline longitudinal bulkhead

(b) 0.09 $l_{bdg\text{-}}$for ships with two longitudinal bulkheads

(c) see also **2.6.1.7**

Where:

$l_{bdg\text{-}vw}$: effective bending span of the vertical web frame on the longitudinal bulkhead, see **2.6.6.2** and **Fig. 8.2.7**

2.6.6.2 The net section modulus, Z_{net50}, of the vertical web frame is not to be less than:

$$Z_{net50} = \frac{1000M}{C_{s-pr}\,\sigma_{yd}} \qquad (cm^3)$$

Where:

M : design bending moment, in kNm, as follows

$= c_u P S\, l_{bdg-vw}^{\ 2}$ for upper part of the web frame

$= c_l P S\, l_{bdg-vw}^{\ 2}$ for lower part of the web frame

where a cross tie is fitted and $l_{bdg\text{-}vw\text{-}ct}$ is greater than $0.7 l_{bdg\text{-}vw}$, then $l_{bdg\text{-}vw}$ in the above formula may be taken as $l_{bdg\text{-}vw\text{-}ct}$.

P : design pressure for the design load set being considered, calculated at mid point of the effective bending span, $l_{bdg\text{-}vw}$, of the vertical web frame located at mid tank, in kN/m^2

$l_{bdg\text{-}vw}$: effective bending span of the vertical web frame on the longitudinal bulkhead, between the deck transverse and the bottom structure, in m, see **Section 4/2.1.4** and **Fig. 8.2.7**.

$l_{bdg\text{-}vw\text{-}ct}$: effective bending span of the vertical web frame on longitudinal bulkhead, between the deck transverse and mid depth of the cross tie on ships with two longitudinal bulkheads, in m, see **Section 4/2.1.4**

S : primary support member spacing, in m, as defined in **Section 4/2.2.2**

$C_{s\text{-}pr}$: permissible bending stress coefficient as given in **Table 8.2.10**

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

c_u and c_l : as defined in **Table 8.2.14**

Table 8.2.14 Values of c_u and c_l for Vertical Web Frame on Longitudinal Bulkheads

Structural Configuration			c_u	c_l
Ships with a centreline longitudinal bulkhead			0.057	0.071
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank		0.012	0.028
	Cross ties in wing cargo tanks	M based on $l_{bdg\text{-}vw\text{-}ct}$	0.057	0.071
		M based on $l_{bdg\text{-}vw}$	0.016	0.032

2.6.6.3 The section modulus over the length of the vertical web frame on the longitudinal bulkhead is to comply with the following:

(a) the required section modulus for the upper part is to be maintained over the upper $0.2\, l_{bdg\text{-}vw}$ or $0.2\, l_{bdg\text{-}vw\text{-}ct}$, as applicable

(b) the required section modulus for the lower part is to be maintained over the lower $0.2\, l_{bdg\text{-}vw}$ or $0.2\, l_{bdg\text{-}vw\text{-}ct}$, as applicable

(c) where the required section modulus is determined based on $l_{bdg\text{-}vw\text{-}ct}$, the required section modulus for the lower part is also to be maintained below the cross tie

(d) the required section modulus between the upper and lower parts is to be reduced linearly to 70% of the required section modulus for the lower part at mid span

Note

When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

Where:

$l_{bdg\text{-}vw}$ and $l_{bdg\text{-}vw\text{-}ct}$ as defined in **2.6.6.2**

2.6.6.4 The net shear area, $A_{shr\text{-}net50}$, of the vertical web frame is not to be less than:

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\,\tau_{yd}} \quad (cm^2)$$

Where:

Q	:design shear force as follows, in kN
	$= Q_u$ for upper part of the web frame
	$= Q_l$ for lower part of the web frame
Q_u	$= S\ [c_u\, l_{vw}\,(P_u + P_l) - h_u\, P_u]$
	where a cross tie is fitted in a centre or wing cargo tank and $l_{vw\text{-}ct}$ is greater than $0.7l_{vw}$, then l_{vw} in the above formula may be taken as $l_{vw\text{-}ct}$.
Q_l	to be taken as the greater of the following
	$S[c_l\, l_{vw}\,(P_u + P_l) - h_l\, P_l]$
	$c_w\, S\, c_l\, l_{vw}\,(P_u + P_l)$
	$1.2Q_u$
	where a cross tie is fitted in a centre or wing cargo tank and $l_{vw\text{-}ct}$ is greater than $0.7l_{vw}$, then l_{vw} in the above formula may be taken as $l_{vw\text{-}ct}$.
P_u	: design pressure for the design load set being considered, calculated at mid height of upper bracket of the vertical web frame, h_u, located at mid tank, in kN/m^2
Pl	: design pressure for the design load set being considered, calculated at mid height of lower bracket of the vertical web frame, h_l, located at mid tank, in kN/m^2
l_{vw}	: length of the vertical web frame, in m, between the flange of the deck transverse and the inner bottom, see **Fig. 8.2.7**
$l_{vw\text{-}ct}$	: length of the vertical web frame, in m, between the flange of the deck transverse and mid depth of the cross tie, where fitted
S	: primary support member spacing, in m, as defined in **Section 4/2.2.2**
h_u	: effective length of upper bracket of the vertical web frame, in m, as shown in **Fig. 8.2.7** and as described in **Section 4/2.1.5**
h_l	: effective length of lower bracket of the vertical web frame, in m, as shown in **Fig. 8.2.7** and as described in **Section 4/2.1.5**
c_u and c_l	: as defined in **Table 8.2.15**
C_w	0.57 for ships with a centreline longitudinal bulkhead
	0.50 for ships with two longitudinal bulkheads
$C_{t\text{-}pr}$	: permissible shear stress coefficient for primary support member as given in **Table 8.2.10**
τ_{yd}	$= \dfrac{\sigma_{yd}}{\sqrt{3}}$ (N/mm^2)
σ_{yd}	: specified minimum yield stress of the material, in N/mm^2

Table 8.2.15 Values of c_u and c_l for Vertical Web Frame on Longitudinal Bulkhead

Structural Configuration		cu	cl
Ships with a centreline longitudinal bulkhead		0.17	0.28
Ships with two longitudinal bulkheads	Q_u or Q_l based on l_{vw-ct}		
	Q_u or Q_l based on l_{vw}	0.075	0.18

2.6.6.5 The shear area over the length of the vertical web frame on the longitudinal bulkhead is to comply with the following:

(a) the required shear area for the upper part is to be maintained over the upper 0.2 l_{shr}

(b) the required shear area for the lower part is to be maintained over the lower 0.2 l_{shr}

(c) where Q_u and Q_l are determined based on l_{vw-ct}, the required shear area for the lower part is also to be maintained below the cross tie

(d) for ships without cross ties in the wing or centre cargo tanks, the required shear area between the upper and lower parts is to be reduced linearly towards 50% of the required shear area for the lower part at mid span

(e) for ships with cross ties in the wing or centre cargo tanks, the required shear area along the span is to be tapered linearly between the upper and lower parts

Note

When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

Where:

l_{shr} : effective shear span of the side transverse

$= l_{vw} - h_u - h_l$ where Q_u and Q_l are determined based on l_{vw}

$= l_{vw-ct} - h_u$ where Q_u and Q_l are determined based on l_{vw-ct}

l_{vw}, l_{vw-ct}, h_u, h_l, Q_u and Q_l : as defined in **2.6.6.4**

2.6.7 Horizontal stringers on transverse bulkheads

2.6.7.1 The web depth of horizontal stringers on transverse bulkhead is not to be less than:

(a) 0.28 l_{bdg-hs} for horizontal stringers in wing cargo tanks of ships with two longitudinal bulkheads

(b) 0.20 l_{bdg-hs} for horizontal stringers in centre tanks of ships with two longitudinal bulkheads, but the web depth of horizontal stringers in centre tank is not to be less than required depth for a horizontal stringer in wing cargo tanks

(c) 0.20 l_{bdg-hs} for horizontal stringers of ships with a centreline longitudinal bulkhead

(d) see also **2.6.1.7**.

Where:

l_{bdg-hs} : effective bending span of the horizontal stringer, in *m*, but is not to be taken as less than 50% of the breadth of the tank, see **Section 4/2.1.4** and **Fig. 8.2.7**

2.6.7.2 The net section modulus, Z_{net50}, of the horizontal stringer over the end $0.2 l_{bdg-hs}$ is not to be less than:

$$Z_{net50} = \frac{1000M}{C_{s-pr}\sigma_{yd}} \qquad (cm^3)$$

Where:

M : design bending moment

$= c\,P\,S\,l_{bdg-hs}^{\ 2}$ kNm

P : design pressure for the design load set being considered, calculated at mid point of effective bending span, l_{bdg-hs}, of the horizontal stringer, in kN/m^2

S : sum of the half spacing (distance between stringers) on each side of the horizontal stringer under consideration, in *m*

l_{bdg-hs} : effective bending span of the horizontal stringer, in *m*, but is not to be taken as less than 50% of the breadth of the tank, see **Section 4/2.1.4** and **Fig. 8.2.7**

c 0.073 for horizontal stringers in cargo tanks of ships with a centreline bulkhead

0.083 for horizontal stringers in wing cargo tanks of ships with two longitudinal bulkheads

0.063 for horizontal stringers in the centre tank of ships with two longitudinal bulkheads

C_{s-pr} : permissible bending stress coefficient as given in **Table 8.2.10**

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

2.6.7.3 The required section modulus at mid effective bending span is to be taken as 70% of that required at the ends, intermediate values are to be obtained by linear interpolation. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

2.6.7.4 The net shear area, $A_{shr-net50}$, of the horizontal stringer over the end 0.2 l_{shr} is not to be less than:

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\,\tau_{yd}} \qquad (cm^2)$$

Where:

Q : design shear force

$= 0.5\,P\,S\,l_{shr}$ (kN)

P : design pressure for the design load set being considered, calculated at mid point of effective bending span, l_{bdg-hs}, of the horizontal stringer, in kN/m^2

S : sum of the half spacing (distance between stringers), on each side of the horizontal stringer under consideration, in *m*

l_{shr} : effective shear span of the horizontal stringer, in *m*, see **Section4/2.1.5**

C_{t-pr} : permissible shear stress coefficient as given in **Table 8.2.10**

τ_{yd} $= \frac{\sigma_{yd}}{\sqrt{3}}$ (N/mm^2)

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

2.6.7.5 The required shear area at mid effective shear span is to be taken as 50% of that required in the ends, intermediate values are to be obtained by linear interpolation. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

2.6.8 Cross ties

2.6.8.1 The maximum applied design axial load on cross ties, W_{ct}, is to be less than or equal to the permissible load, $W_{ct-perm}$, as given by:

$$W_{ct} \le W_{ct-perm}$$

Where:

W_{ct} : applied axial load

$= P\,b_{ct}\,S$ (kN)

$W_{ct-perm}$: permissible load

$= 0.1\,A_{ct-net50}\,\eta_{ct}\,\sigma_{cr}$ (kN)

P : maximum design pressure for all the applicable design load sets being considered, calculated at centre of the area supported by the cross tie located at mid tank, in kN/m^2

b_{ct} : where cross tie is fitted in centre cargo tank

$= 0.5\,l_{bdg-vw}$

: where cross ties are fitted in wing cargo tanks

= 0.5 l_{bdg-vw}, for design cargo pressure from the centre cargo tank

= 0.5 l_{bdg-st} for design sea pressure

l_{bdg-vw} : effective bending span of the vertical web frame on the longitudinal bulkhead, in *m*, see **Section 4/2.1.4** and **Fig. 8.2.7**.

l_{bdg-st} : effective bending span of the side transverse, in *m*, see **Section 4/2.1** and **Fig. 8.2.7.**

S : primary support member spacing, in *m*, as defined in **Section 4/2.2.2**

η_{ct} : utilisation factor, to be taken as

= 0.50 for acceptance criteria set AC1

= 0.60 for acceptance criteria set AC2

σ_{cr} : critical buckling stress in compression of the cross tie, in N/mm^2, as calculated using the net sectional properties in accordance with **Section 10/3.5.1**, where the effective length of the cross tie is to be taken as follows, in *m*

(a) for cross tie in centre tank:
distance between the flanges of longitudinal stiffeners on the starboard and port longitudinal bulkheads to which the cross tie's horizontal stiffeners are attached

(b) for cross tie in wing tank:
distance between the flanges of longitudinal stiffeners on the longitudinal bulkhead to which the cross tie's horizontal stiffeners are attached, and the inner hull plating

$A_{ct-net50}$: net cross sectional area of the cross tie, in cm^2

2.6.8.2 Special attention is to be paid to the adequacy of the welded connections for the transmission of the forces, and also to the stiffening arrangements, in order to provide effective means for transmission of the compressive forces into the webs. Particular attention is to be paid to the welding at the toes of all end brackets of the cross ties.

2.6.8.3 Horizontal stiffeners are to be located in line with, and attached to, the longitudinals at the ends of the cross ties.

2.6.9 Primary support members located beyond 0.4*L* amidships

2.6.9.1 If a cargo tank FE analysis is not available for the region outside of 0.4*L* amidships, the requirements given in **2.6.9.2** and **2.6.9.3** may be used to obtain the scantlings of primary support members located beyond 0.4*L* of amidships. Scantlings used for the 0.4*L* amidships are to be those required by **Sections 8/2** and **Section 9/2**, see **2.6.1.3** and **2.6.1.4**.

2.6.9.2 The net section modulus of primary support members, $Z_{end-net50}$, located beyond 0.4*L* of amidships is not to be less than:

$$Z_{end-net50} = \frac{Z_{mid-net50}\,\sigma_{yd-mid}\,M_{end}}{\sigma_{yd-end}\,M_{mid}} \qquad (cm^3)$$

Where:

M^{end} : bending moment, in *kNm*, for the structural member under consideration located beyond 0.4*L* amidships, calculated in accordance with corresponding requirements of **2.6.3** to **2.6.8** and using the design pressure specified for the given location

M_{mid} : bending moment, in *kNm*, for the corresponding structural member and location of cross section, amidships, obtained from the corresponding requirements of **2.6.2** to **2.6.8**

$Z_{mid-net50}$: net section modulus at the flange of the corresponding structural member and location of cross section amidships, in cm^3

σ_{yd-end} : specified minimum yield stress of the flange of the structural member under consideration located beyond 0.4*L* amidships, in N/mm^2

σ_{yd-mid} : specified minimum yield stress of the flange of the structural member under consideration amidships, in N/mm^2

2.6.9.3 The net shear area for primary support members, $A_{shr\text{-}end\text{-}net50}$, located beyond 0.4$L$ amidships is not to be less than:

$$A_{shr-end-net50} = \frac{A_{shr-mid-net50}\ \tau_{yd-mid}\ Q_{end}}{\tau_{yd-end}\ Q_{mid}} \qquad (cm^2)$$

Where:

Q_{end} : shear force, in kN, for the structural member under consideration located beyond 0.4L of amidships, calculated in accordance with the corresponding requirements of **2.6.3** to **2.6.8** and using the design pressure, specified for the given location

Q_{mid} : shear force, in kN, for the corresponding structural member and corresponding location of cross section, amidships, obtained from the requirements of **2.6.2** to **2.6.8**

$A_{shr\text{-}mid\text{-}net50}$: shear area of corresponding structural member and location of cross section amidships, in cm^2

$\tau_{yd\text{-}end}$ $= \dfrac{\sigma_{yd-end}}{\sqrt{3}}$

$\tau_{yd\text{-}mid}$ $= \dfrac{\sigma_{yd-mid}}{\sqrt{3}}$

$\sigma_{yd\text{-}end}$: specified minimum yield stress of the structural member under consideration located beyond 0.4L amidships, in N/mm^2

$\sigma_{yd\text{-}mid}$: specified minimum yield stress of the structural member under consideration amidships, in N/mm^2

3. Forward of the Forward Cargo Tank

3.1 General

3.1.1 Application

3.1.1.1 The requirements of this Sub-Section apply to structure forward of the forward end of the foremost cargo tank. Where the forward end of the foremost cargo tank is aft of $0.1L$ of the ship's length, measured from the F.P., special consideration will be given to the applicability of these requirements and the requirements of **Section 8/2**.

3.1.1.2 The net scantlings described in this Sub-Section are related to gross scantlings as follows:

(a) for application of the minimum thickness requirements of **3.1.4**, the gross thickness is obtained from the applicable requirements by adding the full corrosion additions specified in **Section 6/3**.

(b) for plating and local support members, the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in **Section 6/3**

(c) for primary support members, the gross shear area, gross section modulus and other gross cross sectional properties are obtained from the applicable requirements by adding one half of the relevant full corrosion additions specified in **Section 6/3**

(d) for application of buckling requirements of **Section 10/2** the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in **Section 6/3**.

3.1.2 General scantling requirements

3.1.2.1 The hull structure is to comply with the applicable requirements of:

(a) hull girder longitudinal strength, see **Section 8/1**
strength against sloshing and impact loads, see **Section 8/6**
buckling/ultimate strength, see **Section 10**.

3.1.2.2 The deck plating thickness and supporting structure are to be suitably reinforced in way of the anchor windlass and other deck machinery, and in way of cranes, masts and derrick posts. See **Section 11/3**.

3.1.2.3 The net section modulus, shear area and other sectional properties of local and primary support members are to be determined in accordance with **Section 4/2**.

3.1.2.4 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus and cross sectional shear areas of the primary support members are to be applied as required in the notes to **Table 8.3.5**.

3.1.2.5 The scantling criteria are based on assumptions that all structural joints and welded details are designed and fabricated such that they are compatible with the anticipated working stress levels at the locations considered. The loading patterns, stress concentrations and potential failure modes of structural joints and details during the design of highly stressed regions are to be considered. Structural design details are to comply with the requirements in **Section 4/3**.

3.1.2.6 Limber, drain and air holes are to be cut in all parts of the structure, as required, to ensure free flow to the suction pipes and the escape of air to the vents. Arrangements are to be made for draining the spaces above deep tanks. See also **Section 4/3**.

3.1.2.7 Web stiffeners are to be fitted on primary support members at each longitudinal on the side and bottom shell. Alternative arrangements may be accepted where adequacy of stiffener end connections and strength of adjoining web and bulkhead plating is demonstrated.

3.1.3 Structural continuity

3.1.3.1 Scantlings of the shell envelope, upper deck and inner bottom are to be tapered towards the forward end. See also **1.6**.

3.1.3.2 In the transition zone aft of the fore peak into the forward cargo tank, due consideration is to be given to the arrangement of major longitudinal members in order to avoid abrupt changes in section. Structures within the fore peak, such as flats, decks, horizontal ring frames or side stringers, are to be scarphed effectively into the structure aft

into the cargo tank. Where such structures are in line with longitudinal members aft of the forward cargo tank bulkhead fitting of tapered transition brackets may be used.
3.1.3.3 Where inner hull or longitudinal bulkhead structures terminate at the forward bulkhead of the forward cargo tank, adequate backing structure is to be provided together with tapering brackets to ensure continuity of strength.
3.1.3.4 Longitudinal framing of the strength deck is to be carried as far forward as practicable.
3.1.3.5 All shell frames and tank boundary stiffeners are to be continuous, or are to be bracketed at their ends, except as permitted in **Sections 4/3.2.4** and **4/3.2.5**.

3.1.4 Minimum thickness

3.1.4.1 In addition to the thickness, section modulus and stiffener web shear area requirements as given in this Sub-Section, the thickness of plating and stiffeners in the forward region are to comply with the appropriate minimum thickness requirements given in **Table 8.3.1**.

3.2 Bottom Structure

3.2.1 Plate keel

3.2.1.1 A flat plate keel is to extend as far forward as practical and is to satisfy the scantling requirements given in **2.2.1**.

3.2.2 Bottom shell plating

3.2.2.1 The thickness of the bottom shell plating is to comply with the requirements in **3.9.2.1**.

3.2.3 Bottom longitudinals

3.2.3.1 Bottom longitudinals are to be carried as far forward as practicable. Beyond this, suitably stiffened frames are to be fitted.
3.2.3.2 The section modulus and thickness of the bottom longitudinals are to comply with the requirements in **3.9.2.2** and **3.9.2.3**.

Table 8.3.1 Minimum Net Thickness of Structure Forward of the Forward Cargo Tank

<table>
<tr><th colspan="3">Scantling Location</th><th>Net Thickness (mm)</th></tr>
<tr><td rowspan="8">Plating</td><td rowspan="2">Hull envelope up to T_{sc} + 4.6m</td><td>Keel plating</td><td>See 2.1.5.1</td></tr>
<tr><td>Bottom shell/bilge/side shell plating</td><td>See 2.1.5.1</td></tr>
<tr><td>Hull envelope above T_{sc} + 4.6m</td><td>Side shell/upper deck plating</td><td>See 2.1.5.1</td></tr>
<tr><td rowspan="4">Hull internal structure</td><td>Hull internal tank boundaries</td><td>See 2.1.5.1</td></tr>
<tr><td>Non-tight bulkheads, bulkheads between dry spaces and other plates in general</td><td>See 2.1.5.1</td></tr>
<tr><td>Pillar bulkheads</td><td>7.5</td></tr>
<tr><td>Breasthooks</td><td>6.5</td></tr>
<tr><td colspan="3">Floors and bottom girders</td><td>$5.5 + 0.02L_2$</td></tr>
<tr><td colspan="3">Web plating of primary support members</td><td>$6.5 + 0.015L_2$</td></tr>
<tr><td colspan="3">Local support members</td><td>See 2.1.5.1</td></tr>
<tr><td colspan="3">Tripping brackets</td><td>See 2.1.5.1</td></tr>
<tr><td colspan="4">Where:
T_{sc} : scantling draught, in m, as defined in Section 4/1.1.5.5
L_2 : rule length, L, in m, as defined in Section 4/1.1.1.1, but need not be taken greater than 300m</td></tr>
</table>

3.2.4 Bottom floors

3.2.4.1 Bottom floors are to be fitted at each web frame location. The minimum depth of the floor at the centreline is to be not to be less than the required depth of the double bottom of the cargo tank region. See **Section 5/3.2.1.1**.

3.2.5 Bottom girders

3.2.5.1 A supporting structure is to be provided at the centreline either by extending the centreline girder to the stem or by providing a deep girder or centreline bulkhead.

3.2.5.2 Where a centreline girder is fitted, the minimum depth and thickness is not to be less than that required for the depth of the double bottom in the cargo tank region, and the upper edge is to be stiffened. Where a centreline wash bulkhead is fitted, the lowest strake is to have thickness not less than required for a centreline girder.

3.2.5.3 Where a longitudinal wash bulkhead supports bottom transverses, the details and arrangements of openings in the bulkhead are to be configured to avoid areas of high stresses in way of the connection of the wash bulkhead with bottom transverses.

3.2.6 Plate stems

3.2.6.1 Plate stems are to be supported by stringers and flats, and by intermediate breasthook diaphragms spaced not more than 1500*mm* apart, measured along the stem. Where the stem radius is large, a centreline support structure is to be fitted.

3.2.6.2 Between the minimum ballast draught waterline at the stem and the scantling draught, T_{sc}, the plate stem net thickness, $t_{stem-net}$, is not to be less than:

$$t_{stem-net} = \frac{L_2\sqrt{\dfrac{235}{\sigma_{yd}}}}{12}$$ (*mm*), but need not be taken as greater than 21*mm*

Where:

L_2 : rule length, *L,* in *m*, as defined in **Section 4/1.1.1.1***,* but need not be taken greater than 300*m*

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

Above the summer load waterline the thickness of the stem plate may be tapered to the requirements for the shell plating at the upper deck.

Below the ballast draught waterline the thickness of the stem plate may be tapered to the requirements for the plate keel.

3.2.7 Floors and girders in spaces aft of the collision bulkhead

3.2.7.1 Floors and girders which are aft of the collision bulkhead and forward of the forward cargo tank, are to comply with the requirements in **3.2.4** and **3.2.5** and are to comply with the shear area requirements in **3.9.3.3**.

3.3 Side Structure

3.3.1 Side shell plating

3.3.1.1 The thickness of the side shell plating is to comply with the requirements in **3.9.2.1**. Where applicable, the thickness of the side shell plating is to comply with the requirements in **2.2.4.2**.

3.3.1.2 Where a forecastle is fitted, the side shell plating requirements are to be applied to the plating extending to the forecastle deck elevation.

3.3.2 Side shell local support members

3.3.2.1 Longitudinal framing of the side shell is to be carried as far forward as practicable.

3.3.2.2 The section modulus and thickness of the hull envelope framing is to comply with the requirements in **3.9.2.2** and **3.9.2.3**.

3.3.2.3 End connections of longitudinals at transverse bulkheads are to provide adequate fixity, lateral support, and where not continuous are to be provided with soft-nosed brackets. Brackets lapped onto the longitudinals are not to be used.

3.3.3 Side shell primary support structure

3.3.3.1 In general, the spacing of web frames, *S* as defined in **Section 4/2.2.2***,* is to be taken as:

$$S = 2.6 + 0.005L_2$$ (*m*), but not to be taken greater than 3.5*m*

Where:

L_2 : rule length, *L,* as defined in **Section 4/1.1.1.1**, but is not to be taken greater than 300*m*

3.3.3.2 In general, the transverse framing forward of the collision bulkhead stringers are to be spaced approximately 3.5*m* apart. Stringers are to have an effective span not greater than 10*m*, and are to be adequately supported by web frame structures. Aft of the collision bulkhead, where transverse framing is adopted, the spacing of stringers may be increased.

3.3.3.3 Perforated flats are to be fitted to limit the effective span of web frames to not greater than 10*m*.

3.3.3.4 The scantlings of web frames supporting longitudinal frames, and stringers and/or web frames supporting transverse frames in the forward region are to be determined from **3.9.3**, with the following additional requirements:

(a) where no cross ties are fitted:
- the required section modulus of the web frame is to be maintained for 60% of the effective span for bending, measured from the lower end. The value of the bending moment used for calculation of the required section modulus of the remainder of the web frame may be appropriately reduced, but not greater than 20%
- the required shear area of the lower part of the web frame is to be maintained for 60% of the shear span measured from the lower end.

(b) where one cross tie is fitted:
- the effective spans for bending and shear of a web frame or stringer are to be taken ignoring the presence of the cross tie. The shear forces and bending moments may be reduced to 50% of the values that are calculated ignoring the presence of the cross ties. For a web frame, the required section modulus and shear area of the lower part of the web frame is to be maintained up to the cross tie, and the required section modulus and shear area of the upper part of the web frame is to be maintained for the section above the cross tie
- cross ties are to satisfy the requirements of **2.6.8** using the design loads specified in **Table 8.3.8**.

(c) configurations with multiple cross ties are to be specially considered, in accordance with **3.3.3.4(d)**

(d) where complex grillage structures are employed the suitability of the scantlings of the primary support members is to be determined by more advanced calculation methods.

3.3.3.5 The web depth of primary support members is not to be less than 14% of the bending span and is to be at least 2.5 *times* as deep as the slots for stiffeners if the slots are not closed.

3.4 Deck Structure

3.4.1 Deck plating

3.4.1.1 The thickness of the deck plating is to comply with the requirements in **3.9.2.1** with the applicable lateral pressure, green sea and deck loads.

3.4.1.2 In addition to the requirements of **3.4.1.1**, the net plating thickness of decks, t_{net}, is not to be less than:

$$t_{net} = 0.009s \qquad (mm)$$

Where:

s : stiffener spacing, in *mm* , as defined in **Section 4/2.2**

3.4.2 Deck stiffeners

3.4.2.1 The section modulus and thickness of deck stiffeners are to comply with the requirements in **3.9.2.2** and **3.9.2.3**, with the applicable lateral pressure, green sea and deck loads.

3.4.3 Deck primary support structure

3.4.3.1 The section modulus and shear area of primary support members are to comply with the requirements in **3.9.3**.

3.4.3.2 Web plating of primary support members is to have a depth of not less than 10% of the unsupported span in bending.

3.4.3.3 In way of concentrated loads from heavy equipment, the scantlings of the deck structure are to be determined based on the actual loading. See also **Section 11/3**.

3.4.4 Pillars

3.4.4.1 Pillars are to be fitted in the same vertical line wherever possible and effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

3.4.4.2 Tubular and hollow square pillars are to be attached at their heads and heels by efficient brackets or doublers/insert plates, where applicable, to transmit the load effectively. Pillars are to be attached at their heads and heels by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be distributed by brackets or other equivalent means.

3.4.4.3 Pillars in tanks are to be of solid section. Where the hydrostatic pressure may result in tensile stresses in the pillar, the tensile stress in the pillar and its end connections is not to exceed 45% of the specified minimum yield stress of the material.

3.4.4.4 The scantlings of pillars are to comply with the requirements in **3.9.5**.

3.4.4.5 Where the loads from heavy equipment exceed the design load of **3.9.5**, the pillar scantlings are to be determined based on the actual loading.

3.5 Tank Bulkheads

3.5.1 General

3.5.1.1 Tanks may be required to have divisions or deep wash plates in order to minimise the dynamic stress on the structure.

3.5.2 Construction

3.5.2.1 In no case are the scantlings of tank boundary bulkheads to be less than the requirements for watertight bulkheads.

3.5.3 Scantlings of tank boundary bulkheads

3.5.3.1 The thickness of tank boundary plating is to comply with the requirements in **3.9.2.1**.

3.5.3.2 The section modulus and thickness of stiffeners are to comply with the requirements in **3.9.2.2** and **3.9.2.3**.

3.5.3.3 The section modulus and shear area of primary support members are to comply with the requirements in **3.9.3**.

3.5.3.4 Web plating of primary support members is to have a depth of not less than 14% of the unsupported span in bending.

3.5.3.5 Scantlings of corrugated bulkheads are to comply with the requirements in **3.9.4**.

3.6 Watertight Boundaries

3.6.1 General

3.6.1.1 Watertight boundaries are to be fitted in accordance with **Section 5/2**.

3.6.2 Collision bulkhead

3.6.2.1 The scantlings of structural components of the collision bulkheads are to comply with the requirements in **3.6.3**, as applicable. Additionally, the collision bulkhead is to comply with the requirements in **3.6.2.2** to **3.6.2.4**.

3.6.2.2 The position of the collision bulkhead is to be in accordance with **Section 5/2.2**.

3.6.2.3 Doors, manholes, permanent access openings or ventilation ducts are not to be cut in the collision bulkhead below the freeboard deck. Where the collision bulkhead is extended above the freeboard deck, the number of openings in the extension is to be kept to a minimum compatible with the design and proper working of the ship. The openings are to be fitted with weathertight closing appliances. The collision bulkhead may be pierced by pipes necessary for dealing with the contents of tanks forward of the bulkhead, provided the pipes are fitted with valves capable of being operated from above the freeboard deck. The valves are generally to be fitted on the collision bulkhead inside the fore peak and are not to be fitted inside the cargo tank.

3.6.2.4 Compartments forward of the collision bulkhead may not be arranged for the carriage of flammable liquids.

3.6.3 Scantlings of watertight boundaries

3.6.3.1 The thickness of boundary plating is to comply with the requirements in **3.9.2.1**.

3.6.3.2 The section modulus and thickness of stiffeners are to comply with the requirements in **3.9.2.2** and **3.9.2.3**.

3.6.3.3 The section modulus and shear area of primary support members are to comply with the requirements in **3.9.3**.
3.6.3.4 Web plating of primary support members is to have a depth of not less than 10% of the unsupported span in bending.
3.6.3.5 Scantlings of corrugated bulkheads are to comply with the requirements in **3.9.4**.

3.7 Superstructure

3.7.1 Forecastle structure

3.7.1.1 Forecastle structures are to be supported by girders with deep beams and web frames, and in general, arranged in complete transverse belts and supported by lines of pillars extending down into the structure below. Deep beams and girders are to be arranged, where practicable, to limit the spacing between deep beams, web frames, and/or girders to about 3.5*m*. Pillars are to be provided as required by **3.4.4**. Main structural intersections are to be carefully developed with special attention given to pillar head and heel connections, and to the avoidance of stress concentrations.

3.7.2 Forecastle end bulkhead

3.7.2.1 The details and scantlings of the forecastle end bulkhead are to meet the requirements of **Section 11/1.4**.

3.8 Miscellaneous Structures

3.8.1 Pillar bulkheads

3.8.1.1 Bulkheads that support girders, or pillars and longitudinal bulkheads which are fitted in lieu of girders, are to be stiffened to provide supports not less effective than required for stanchions or pillars. The acting load and the required net cross sectional area of the pillar section are to be determined using the requirements of **3.4.4**. The net moment of inertia of the stiffener is to be calculated with a width of 40*tnet*, where *tnet* is the net thickness of plating, in *mm*.
3.8.1.2 Pillar bulkheads are to comply with the following requirements:

(a) the distance between bulkhead stiffeners is not to exceed 1500*mm*
(b) where corrugated, the depth of the corrugation is not to be less than 100*mm*.

3.8.2 Bulbous bow

3.8.2.1 Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure.
3.8.2.2 At the forward end of the bulb the structure is generally to be supported by horizontal diaphragm plates spaced about 1*m* apart in conjunction with a deep centreline web.
3.8.2.3 In general, vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing.
3.8.2.4 In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is generally to be fitted.
In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or substantial web frames is to be fitted.
The shell plating is to be increased in thickness at the forward end of the bulb and also in areas likely to be subjected to contact with anchors and chain cables during anchor handling. The increased plate thickness is to be the same as that required for plated stems.

3.8.3 Chain lockers

3.8.3.1 Chain lockers are to meet the requirements of **Section 11/4.2.9**.

3.8.4 Bow thruster tunnels

3.8.4.1 The net thickness of the tunnel plating, $t_{tun-net}$, is not to be less than as required for the shell plating in the vicinity of the bow thruster. In addition, $t_{tun-net}$ is not to be taken less than:

$$t_{tun-net} = 0.008 d_{tun} + 1.8 \qquad (mm)$$

Where:

d_{tun} : inside diameter of the tunnel, in *mm*, but not to be taken less than 970*mm*

3.8.4.2 Where the outboard ends of the tunnel are provided with bars or grids, the bars or grids are to be effectively secured.

3.9 Scantling Requirements

3.9.1 General

3.9.1.1 The design load sets are to be applied to the structural requirements for the local support and primary support members as given in **Table 8.3.8**. The static and dynamic load components are to be combined in accordance with **Table 7.6.1** and the procedure given in **Section 7/6.3**.

3.9.2 Plating and local support members

3.9.2.1 For plating subjected to lateral pressure, the net plating thickness, t_{net}, is to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.3.8**, and given by:

$$t_{net} = 0.0158\alpha_p s\sqrt{\frac{|P|}{C_a\sigma_{yd}}} \qquad (mm)$$

Where:

α_p : correction factor for the panel aspect ratio

$$= 1.2 - \frac{s}{2100 l_p}$$

P : design pressure for the design load set being considered, calculated at the load calculation point defined in **Section 3/5.1.2**, in kN/m^2

s : stiffener spacing, in *mm* , as defined in **Section 4/2.2**

l_p : length of plate panel, to be taken as the spacing of primary support members, unless carlings are fitted, in *m*

C_a : permissible bending stress coefficient for the acceptance criteria set being considered, as given in **Table 8.3.2**

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

Table 8.3.2 Permissible Bending Stress Coefficient for Plating

Acceptance criteria set	Structural member	C_a
AC1	All plating	0.80
AC2	Hull envelope plating	0.95
	Internal boundary plating (1)	1.00
Note 1. Collision bulkhead plating is to be evaluated for design load set 11 (accidental flooding) using acceptance criteria set AC1		

3.9.2.2 For stiffeners subjected to lateral pressure, the net section modulus, Z_{net}, is to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.3.8**, and given by:

$$Z_{net} = \frac{|P| s\, l_{bdg}^{\ 2}}{f_{bdg} C_s \sigma_{yd}} \qquad (cm^3)$$

Where:

P : design pressure for the design load set being considered, calculated at the load calculation point defined in **Section 3/5.2.2**, in kN/m^2

s : stiffener spacing, in *mm* , as defined in **Section 4/2.2**

l_{bdg} : effective bending span, as defined in **Section 4/2.1.1**, in *m*

f_{bdg} : bending moment factor

for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having fixed ends

12. for horizontal stiffeners

10. for vertical stiffeners

for other configurations the bending moment factor may be taken as in **Table 8.3.5**.

C_s : permissible bending stress coefficient for the acceptance criteria set being considered, as given in **Table 8.3.3**

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

Table 8.3.3 Permissible Bending Stress Coefficient for Stiffeners

Acceptance criteria set	Structural member	C_s
AC1	All stiffeners	0.75
AC2	All stiffeners (1)	0.90
Note 1. Collision bulkhead stiffeners are to be evaluated for design load set 11 (accidental flooding) using acceptance criteria set AC1		

3.9.2.3 For stiffeners subjected to lateral pressure, the net web thickness based on shear area requirements, t_{w-net}, is to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.3.8**, and given by:

$$t_{w-net} = \frac{f_{shr} \left| P \right| s \, l_{shr}}{d_{shr} \, C_t \, \tau_{yd}} \qquad (mm)$$

Where:

P : design pressure for the design load set being considered, calculated at the load calculation point defined in **Section 3/5.2.2**, in kN/m^2

f_{shr} : shear force factor

for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having fixed ends:

0.5 for horizontal stiffeners

0.7 for vertical stiffeners

for other configurations the shear force factor may be taken as in **Table 8.3.5**.

s : stiffener spacing, in *mm* , as defined in **Section 4/2.2**

l_{shr} : effective shear span, as defined in **Section 4/2.1.2**, in *m*

d_{shr} : effective web depth of stiffeners, in *mm*, as defined in **Section 4/2.4.2.2**

C_t : permissible shear stress coefficient for the acceptance criteria set being considered, as given in **Table 8.3.4**

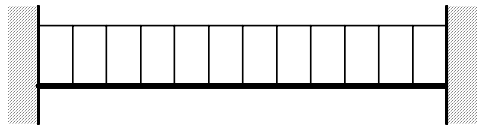
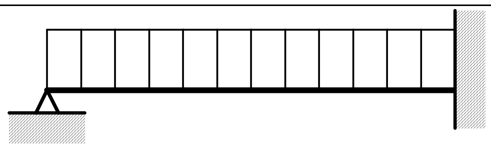
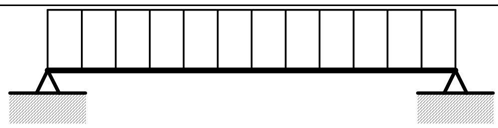
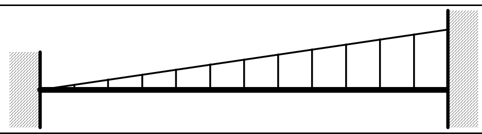
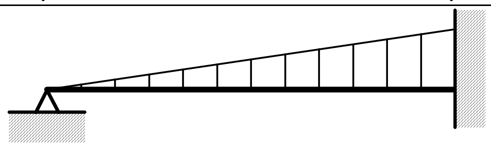
τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}} \qquad (N/mm^2)$

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

Table 8.3.4 Permissible Shear Stress Coefficient for Stiffeners

Acceptance criteria set	Structural member	C_t
AC1	All stiffeners	0.75
AC2	All stiffeners [1]	0.90
Note 1. Collision bulkhead stiffeners are to be evaluated for design load set 11 (accidental flooding) using acceptance criteria set AC1		

Table 8.3.5 Bending Moment and Shear Force Factors, f_{bdg} and f_{shr}

Load and boundary condition				Bending moment and shear force factor (based on load at mid span, where load varies)		
Position				1	2	3
Load model	1 Support	2 Field	3 Support	f_{bdg1} f_{shr1}	f_{bdg2} -	f_{bdg3} f_{shr3}
A				12.0 0.50	24.0 -	12.0 0.50
B				- 0.38	14.2 -	8.0 0.63
C				- 0.50	8.0 -	- 0.50
D				15.0 0.30	23.3 -	10.0 0.70
E				- 0.20	16.8 -	7.5 0.80

Note

1. The bending moment factor f_{bdg} for the support positions are applicable for a distance of $0.2l_{bdg}$ from the end of the effective bending span for both local and primary support members.
2. The shear force factor f_{shr} for the support positions are applicable for a distance of $0.2l_{shr}$ from the end of the effective shear span for both local and primary support members.
3. Application of f_{bdg} and f_{shr} for local support members:
   the section modulus requirement of local support members is to be determined using the lowest value of f_{bdg1} , f_{bdg2} and f_{bdg3}
   the shear area requirement of local support members is to be determined using the greatest value of f_{shr1} and f_{shr3}.
4. Application of f_{bdg} and f_{shr} for primary support members:
   the section modulus requirement within $0.2l_{bdg}$ from the end of the effective span is generally to be determined using the applicable f_{bdg1} and f_{bdg3}, however f_{bdg} is not to be taken greater than 12
   the section modulus of mid span area is to be determined using f_{bdg} =24, or f_{bdg2} from the table if lesser
   the shear area requirement of end connections within $0.2l_{shr}$ from the end of the effective span is to be determined using f_{shr} = 0.5 or the applicable f_{shr1} or f_{shr3}, whichever is greater
   for models A through E the value of f_{shr} may be gradually reduced outside of $0.2l_{shr}$ towards $0.5f_{shr}$ at mid span where f_{shr} is the greater value of f_{shr1} and f_{shr3}.
5. For other load models see **Table 8.7.1**.

3.9.3 Primary support members

3.9.3.1 For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include allowance for the curvature of the hull. For side transverse frames, the requirements may be reduced due to the presence of cross ties, see **3.3.3.4**.

3.9.3.2 For primary support members subjected to lateral pressure, the net section modulus, Z_{net50}, is to be taken as the greatest value for all applicable design load sets, as given in **Table 8.3.8**, and given by:

$$Z_{net50} = 1000 \frac{|P| S\, l_{bdg}^2}{f_{bdg} C_s \sigma_{yd}} \qquad (cm^3)$$

Where:

P	: design pressure for the design load set being considered, calculated at the load calculation point defined in **Section 3/5.3.3**, in kN/m^2
S	: primary support member spacing, in m, as defined in Section **4/2.2.2**
l_{bdg}	: effective bending span, as defined in **Section 4/2.1.4**, in m
f_{bdg}	: bending moment factor, as given in **Table 8.3.5**
C_s	: permissible bending stress coefficient for the acceptance criteria set being considered, as given in **Table 8.3.6**
σ_{yd}	: specified minimum yield stress of the material, in N/mm^2

Table 8.3.6 Permissible Bending Stress Coefficient for Primary Support Members

Acceptance criteria set	Structure attached to primary support member	C_s
AC1	All boundaries, including decks and flats	0.70
AC2	All boundaries, including decks and flats (1)	0.85
Note 1. Collision bulkhead primary support members are to be evaluated for design load set 11 (accidental flooding) using acceptance criteria set AC1		

3.9.3.3 For primary support members subjected to lateral pressure, the effective net web area, $A_{w\text{-}net50}$, is to be taken as the greatest value for all applicable design load sets, as given in **Table 8.3.8**, and given by:

$$A_{w-net50} = 10 \frac{f_{shr} |P| S\, l_{shr}}{C_t \tau_{yd}} \qquad (cm^2)$$

Where:

P	: design pressure for the design load set being considered, calculated at the load calculation point defined in **Section 3/5.3.2**, in kN/m^2
S	: primary support member spacing, in m, as defined in **Section 4/2.2.2**
l_{shr}	: effective shear span, as defined in **Section 4/2.1.5**, in m
f_{shr}	: shear force factor, as given in **Table 8.3.5**
C_t	: permissible shear stress coefficient for the acceptance criteria set being considered, as given in **Table 8.3.7**
τ_{yd}	$= \frac{\sigma_{yd}}{\sqrt{3}} \quad (N/mm^2)$
σ_{yd}	: specified minimum yield stress of the material, inN/mm^2

Table 8.3.7 Permissible Shear Stress Coefficient for Primary Support Members

Acceptance criteria set	Structure attached to primary support member	C_t
AC1	All boundaries, including decks and flats	0.70
AC2	All boundaries, including decks and flats (1)	0.85
Note 1.Collision bulkhead primary support members are to be evaluated for design load set 11 (accidental flooding) using acceptance criteria set AC1		

3.9.3.4 Primary support members are to generally be analysed with the specific methods as described for the particular structure type. More advanced calculation methods may be necessary to ensure that nominal stress level for all primary support members are less than the permissible stresses and stress coefficients given in **3.9.3.2** and **3.9.3.3** when subjected to the applicable design load sets.

3.9.4 Corrugated bulkheads

3.9.4.1 Special consideration will be given to the approval of corrugated bulkheads where fitted.

Guidance Note

Scantling requirements of corrugated bulkheads in the cargo tank region may be used as a basis, see **2.5.6** and **2.5.7**.

3.9.5 Pillars

3.9.5.1 The maximum load on a pillar, W_{pill}, is to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.3.8**, and is to be less than or equal to the permissible pillar load as given by the following equation, where

$W_{pill\text{-}perm}$ is based on the net properties of the pillar.

$$W_{pill} \le W_{pill-perm}$$

Where:

W_{pill} : applied axial load on pillar

$= P\, b_{a-\sup}\, l_{a-\sup} + W_{pill-upr}$ (kN)

$W_{pill\text{-}perm}$: permissible load on a pillar

$= 10 A_{pill-net50}\, \eta_{pill}\, \sigma_{crb}$ (kN)

P : design pressure for the design load set being considered, calculated at centre of the deck area supported by the pillar being considered, in kN/m^2

$b_{a\text{-}sup}$: mean breadth of area supported, in m

$l_{a\text{-}sup}$: mean length of area supported, in m

$W_{pill\text{-}upr}$: axial load from pillar or pillars above, in kN

$A_{pill\text{-}net50}$: net cross section area of the pillar, in cm^2

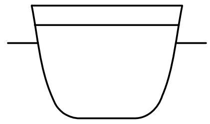
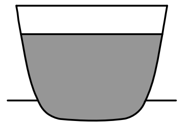
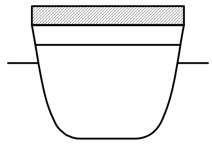
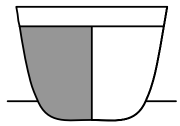
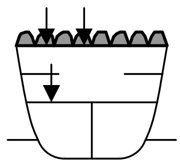
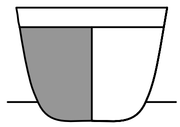
η_{pill} : utilisation factor for the design load set being considered

= 0.5 for acceptance criteria set AC1

= 0.6 for acceptance criteria set AC2

σ_{crb} : critical buckling stress in compression of pillar based on the net sectional properties calculated in accordance with **Section 10/3.5.1**, in N/mm^2

Table 8.3.8 Design Load Sets for Plating, Local Support Members and Primary Support Members

Type of Local Support and Primary Support Member	Design Load Set [(1)]	Load Component	External Draught	Comment	Diagrammatic Representation
Shell Envelope	1	P_{ex}	T_{sc}	Sea pressure only	
	2	P_{ex}	T_{sc}		
	5	P_{in}	T_{bal}	Tank pressure only. Sea pressure to be ignored	
	6	P_{in}	$0.25T_{sc}$		
External Decks	1	P_{ex}	T_{sc}	Green sea pressure only	
Decks forming Tank Boundaries and/or Watertight Boundaries	5	P_{in}	T_{bal}	Pressure from one side only Full tank with adjacent tank empty	
	6	P_{in}	$0.25T_{sc}$		
	11	$P_{in\text{-}flood}$	-		
Internal and External Decks or Flats	9	P_{dk}	T_{bal}	Distributed or concentrated loads only. Adjacent tanks empty. Green sea pressure may be ignored	
	10	P_{dk}	T_{bal}		
Other Tank Boundaries or Watertight Boundaries	5	P_{in}	T_{bal}	Pressure from one side only. Full tank with adjacent tank empty	
	6	P_{in}	$0.25T_{sc}$		
	11	$P_{in\text{-}flood}$	-		

Where:

T_{sc} : scantling draught, in *m*, as defined in **Section 4/1.1.5.5**

T_{bal} : minimum design ballast draught, in *m*, as defined in **Section 4/1.1.5.2**

Notes

1. The specification of design load combinations and other load parameters for the design load sets are given in **Table 8.2.8**
2. When the ship's configuration cannot be described by the above, then the applicable Design Load Sets to determine the scantling requirements of structural boundaries are to be selected so as to specify a full tank on one side with the adjacent tank or space empty. The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents and are to maximise the pressure on the structural boundary, the draught to use is to be taken in accordance with the Design Load Set and this table. Design Load Sets covering the S and S+D design load combinations are to be selected. See **Note 4** on **Table 8.2.7** and **Table 8.2.8**.
3. The boundaries of void and dry space not forming part of the hull envelope are to be evaluated using Design Load Set 11. See **Note 2**.

4. Machinery Space

4.1 General

4.1.1 Application

4.1.1.1 The requirements of this Sub-Section apply to machinery spaces situated in the aft end region, aft of the aftermost cargo tank bulkhead and forward of, and including, the aft peak bulkhead.

4.1.1.2 The net scantlings described in this Sub-Section are related to gross scantlings as follows:

(a) for application the minimum thickness requirements of **4.1.5**, the gross thickness is obtained from the applicable requirements by adding the full corrosion additions as specified in **Section 6/3**.

(b) for plating and local support members, the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions as specified in **Section 6/3**.

(c) for primary support members, the gross shear area, gross section modulus and other gross cross sectional properties are obtained from the applicable requirements by adding one half of the relevant full corrosion additions as specified in **Section 6/3**.

(d) for application of buckling requirements of **Section 10/2** the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions as specified in **Section 6/3**.

4.1.2 General scantling requirements

4.1.2.1 The hull structure is to comply with the applicable requirements of:

(a) hull girder longitudinal strength, see **Section 8/1**

(b) strength against sloshing and impact loads, see **Section 8/6**

(c) buckling/ultimate strength, see **Section 10**.

4.1.2.2 The net section modulus, shear area and other sectional properties of local and primary support members are to be determined in accordance with **Section 4/2**.

4.1.2.3 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus and cross sectional shear areas of the primary support members are to be applied as required in the notes to **Table 8.3.5**.

4.1.2.4 The scantling criteria are based on assumptions that all structural joints and welded details are designed and fabricated such that they are compatible with the anticipated working stress levels at the locations considered. The loading patterns, stress concentrations and potential failure modes of structural joints and details during the design of highly stressed regions are to be considered. Structure design details are to comply with the requirements in **Section 4/3**.

4.1.2.5 Limber, drain and air holes are to be cut in all parts of the structure, as required, to ensure the free flow to the suction pipes and the escape of air to the vents. Arrangements are to be made for draining the spaces above tanks. See also **Section 4/3**.

4.1.3 Structural continuity

4.1.3.1 Scantlings of the shell envelope, upper deck and inner bottom are to be properly tapered towards the aft end. See also **1.6**.

4.1.3.2 Suitable arrangements are to be made to ensure continuity of strength and the avoidance of abrupt discontinuities when structure that contributes to the main longitudinal strength of the ship is omitted in way of the machinery space.

4.1.3.3 Where inner hull or longitudinal bulkhead structures terminate at the forward engine room bulkhead, adequate backing structure is to be provided together with tapering brackets to ensure continuity of strength.

4.1.3.4 All shell frames and tank boundary stiffeners are to be continuous throughout, or are to be bracketed at their ends, except as permitted in **Sections 4/3.2.4** and **4/3.2.5**. See also **Section 4/3.2**.

4.1.3.5 Longitudinal primary support members, lower decks, and bulkheads arranged in the engine room are to be aligned with similar structures in the cargo tank region, as far as practicable. Where direct alignment is not possible, suitable scarphing arrangements such as taper brackets are to be provided.

4.1.4 Arrangements

4.1.4.1 Where openings in decks/bulkheads are provided in the machinery space, the arrangements are to ensure support for deck, side, and bottom structure.

4.1.4.2 All parts of the machinery, shafting, etc., are to be supported to distribute the loads into the ship's structure. The adjacent structure is to be suitably stiffened.

4.1.4.3 Primary support members are to be positioned giving consideration to the provision of through stiffeners and in-line pillar supports to achieve an efficient structural design.

4.1.4.4 These requirements are formulated assuming conventional single screw, single engine propulsion arrangements. Twin-screw or multi-engine vessels, or vessels of higher power, may require additions to the scantlings of the structure and the area of attachments, which are proportional to the weight, power and proportions of the machinery especially where the engines are positioned relatively high in proportion to the width of the bed plate.

4.1.4.5 The foundations for main propulsion units, reduction gears, shaft and thrust bearings, and the structure supporting those foundations are to maintain the required alignment and rigidity under all anticipated conditions of loading. Consideration is to be given to the submittal of the following plans to the machinery manufacturer for review:

(d) foundations for main propulsion units
(e) foundations for reduction gears
(f) foundations for thrust bearings
(g) structure supporting **(a)**, **(b)** and **(c)**.

4.1.4.6 A cofferdam is to be provided to separate the cargo tanks from the machinery space. Pump room, ballast tanks, or fuel oil tanks may be considered as cofferdams for this purpose.

4.1.5 Minimum thickness

4.1.5.1 In addition to the requirements for thickness, section modulus and shear area, as given in **4.2** to **4.8**, the thickness of plating and stiffeners in the machinery space is to comply with applicable minimum thickness requirements given in **Table 8.4.1**.

Table 8.4.1 Minimum Net Thickness of Structure in the Machinery Space

<table>
<tr><th colspan="3">Scantling Location</th><th>Net Thickness (mm)</th></tr>
<tr><td rowspan="7">Plating</td><td rowspan="2">Hull envelope up to T_{sc} + 4.6m</td><td>Keel plating</td><td>See 2.1.5.1</td></tr>
<tr><td>Bottom shell/bilge/side shell plating</td><td>See 2.1.5.1</td></tr>
<tr><td>Hull envelope above T_{sc} + 4.6m</td><td>Side shell/upper deck plating</td><td>See 2.1.5.1</td></tr>
<tr><td rowspan="4">Hull internal structure</td><td>Hull internal tank boundaries</td><td>See 2.1.5.1</td></tr>
<tr><td>Non-tight bulkheads, bulkheads between dry spaces and other plates in general</td><td>See 2.1.5.1</td></tr>
<tr><td>Lower decks and flats</td><td>$3.3 + 0.0067s$</td></tr>
<tr><td>Inner bottom</td><td>$6.5 + 0.02L_2$</td></tr>
<tr><td colspan="3">Bottom centreline girder</td><td>See 2.1.6.1</td></tr>
<tr><td colspan="3">Floors and bottom longitudinal girders off centreline</td><td>$5.5 + 0.02\ L_2$</td></tr>
<tr><td colspan="3">Web plating of primary support members</td><td>$5.5 + 0.015\ L_2$</td></tr>
<tr><td colspan="3">Local support members</td><td>See 2.1.5.1</td></tr>
<tr><td colspan="3">Tripping brackets</td><td>See 2.1.5.1</td></tr>
<tr><td colspan="4">Where:
T_{sc} : scantling draught, in m, as defined in Section 4/1.1.5.5
L_2 : rule length, L, as defined in Section 4/1.1.1.1, but need not be taken greater than 300m
s : stiffener spacing, in mm, as defined in Section 4/2.2</td></tr>
</table>

4.2 Bottom Structure

4.2.1 General

4.2.1.1 In general, a double bottom is to be fitted in the machinery space. The depth of the double bottom is to be at least the same as required in the cargo tank region, see **Section 5/3.2.1**. Where the depth of the double bottom in the machinery space differs from that in the adjacent spaces, continuity of the longitudinal material is to be maintained by sloping the inner bottom over a suitable longitudinal extent.

4.2.2 Bottom shell plating

4.2.2.1 The keel plate thickness is to comply with the requirements in **Section 8/2.2.1**.

4.2.2.2 The thickness of the bottom shell plating is to comply with the requirements in **4.8.1.1**.

4.2.3 Bottom shell stiffeners

4.2.3.1 The section modulus and thickness of bottom shell stiffeners are to comply with the requirements in **4.8.1.2** and **4.8.1.3**.

4.2.4 Girders and floors

4.2.4.1 The double bottom is to be arranged with a centreline girder. The depth of the centreline girder is to be at least the same as the required depth for the double bottom in the cargo tank region, see **Section 5/3.2.1**.

4.2.4.2 Full depth bottom girders are to be arranged in way of the main machinery to effectively distribute its weight, and to ensure rigidity of the structure. The girders are to be carried as far forward and aft as practicable, and suitably supported at their ends to provide distribution of loads from the machinery. The girders are to be tapered beyond their required extent.

4.2.4.3 Where fitted, side girders are to align with the bottom side girders in the adjacent space.

4.2.4.4 Where the double bottom is transversely framed, plate floors are to be fitted at every frame.

4.2.4.5 Where the double bottom is longitudinally framed, plate floors are to be fitted at every frame under the main engine and thrust bearing. Outboard of the engine and bearing seatings, the floors may be fitted at alternate frames.

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

4.2.5 Inner bottom plating

4.2.5.1 Where main engines or thrust bearings are bolted directly to the inner bottom, the net thickness of the inner bottom plating is to be at least 19*mm*. Hold-down bolts are to be arranged as close as possible to floors and longitudinal girders. Plating thickness and the arrangements of hold-down bolts are also to consider the manufacturer's recommendations.

4.2.6 Sea chests

4.2.6.1 Where the inner bottom or double bottom structure forms part of a sea chest, the thickness of the plating is not to be less than that required for the shell at the same location, taking into account the maximum unsupported width of the plating.

4.3 Side Structure

4.3.1 General

4.3.1.1 The scantlings of the side shell plating and longitudinals are to be properly tapered from the midship region towards the aft end.

4.3.1.2 A suitable scarphing arrangement of the longitudinal framing is to be arranged where the longitudinal framing terminates and is replaced by transverse framing.

4.3.1.3 Stiffeners and primary support members are to be supported at their ends.

4.3.2 Side shell plating

4.3.2.1 The thickness of the side shell plating is to comply with the requirements in **4.8.1.1**. Where applicable, the thickness of the side shell plating is to comply with the requirements in **2.2.4.2**.

4.3.3 Side shell local support members

4.3.3.1 The section modulus and thickness of side longitudinal and vertical stiffeners are to comply with the requirements in **4.8.1.2** and **4.8.1.3**.

4.3.3.2 The span of the longitudinal or vertical stiffeners is to be measured along the member.

4.3.3.3 End connections of longitudinals at transverse bulkheads are to provide fixity, lateral support, and when not continuous are to be provided with soft-nosed brackets. Brackets lapped onto the longitudinals are not to be fitted.

4.3.4 Side shell primary support members

4.3.4.1 Web frames are to be connected at the top and bottom to members of suitable stiffness, and supported by deck transverses.

4.3.4.2 The spacing of web frames in way of transversely framed machinery spaces is generally not to exceed five transverse frame spaces.

4.3.4.3 The section modulus and shear area of primary support members are to comply with the requirements in **4.8.2**.

4.3.4.4 The web depth is to be not less than 2.5 *times* the web depth of the adjacent frames if the slots are not closed.

4.3.4.5 Web plating of primary support members is to have a depth of not less than 14% of the unsupported span in bending.

4.4 Deck Structure

4.4.1 General

4.4.1.1 All openings are to be framed. Attention is to be paid to structural continuity. Abrupt changes of shape, section or plate thickness are to be avoided.

4.4.1.2 The corners of the machinery space openings are to be of suitable shape and design to minimise stress concentrations.

4.4.1.3 In way of machinery openings, deck or flats are to have sufficient strength where they are intended as effective supports for side transverse frames or web frames.

4.4.1.4 Where a transverse framing system is adopted, deck stiffeners are to be supported by a suitable arrangement of longitudinal girders in association with pillars or pillar bulkheads. Where fitted, deck transverses are to be arranged in line with web frames to provide end fixity and transverse continuity of strength.

4.4.1.5 Where a longitudinal framing system is adopted, deck longitudinals are to be supported by deck transverses in line with web frames in association with pillars or pillar bulkheads.

4.4.1.6 Machinery casings are to be supported by a suitable arrangement of deck transverses and longitudinal girders in association with pillars or pillar bulkheads. In way of particularly large machinery casing openings, cross ties may be required. These are to be arranged in line with deck transverses.

4.4.1.7 The structural scantlings are to be not less than the requirement for tank boundaries if the deck forms the boundary of a tank.

4.4.1.8 The structural scantlings are to be not less than the requirement for watertight bulkheads if the deck forms the boundary of a watertight space.

4.4.2 Deck scantlings

4.4.2.1 The plate thickness of deck plating is to comply with the requirements in **4.8.1.1**.

4.4.2.2 The section modulus and thickness of deck stiffeners are to comply with the requirements in **4.8.1.2** and *4.8.1.3*.

4.4.2.3 The web depth of deck stiffeners is to be not less than 60*mm*.

4.4.2.4 The section modulus and shear area of primary support members are to comply with the requirements in **4.8.2**.

4.4.2.5 Web plating of primary support members is to have a depth of not less than 10% of the unsupported span in bending.

4.4.2.6 In way of concentrated loads from heavy equipment, the scantlings of the deck structure are to be determined based on the actual loading.

4.4.3 Pillars

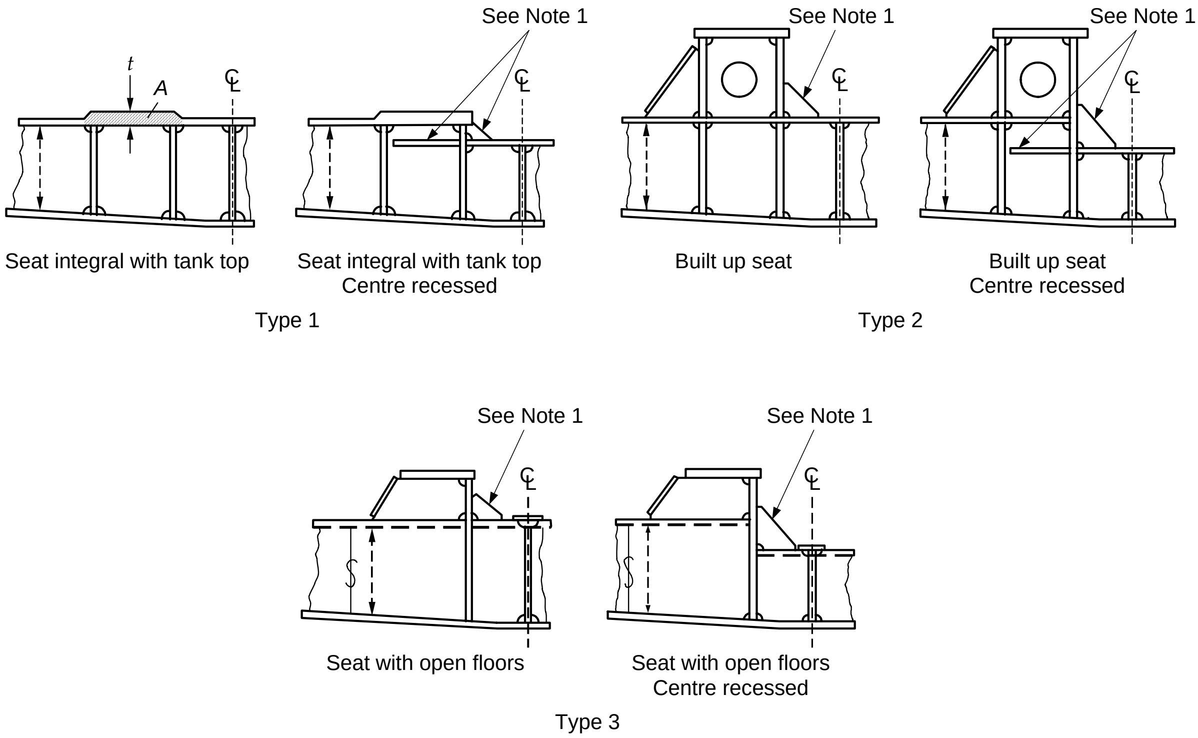
4.4.3.1 Pillars are to be fitted in the same vertical line wherever possible, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.
4.4.3.2 Tubular and hollow square pillars are to be attached at their heads and heels by efficient brackets, or doublers/insert plates, where applicable, to transmit the load effectively. Pillars are to be attached at their heads and heels by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be distributed by brackets or other equivalent means.
4.4.3.3 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars.
4.4.3.4 Pillars in tanks are to be of solid section. Where the hydrostatic pressure may result in tensile stresses in the pillar, the tensile stress in the pillar and its end connections is not to exceed 45%of the specified minimum yield stress of the material.
4.4.3.5 The scantlings of pillars are to comply with the requirements in **4.8.4**.
4.4.3.6 Where the pillar loads from heavy equipment exceed the design load required by **4.8.4**, the pillar scantlings are to be determined based on the actual loading.

4.5 Machinery Foundations

4.5.1 General

4.5.1.1 Main engines and thrust bearings are to 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.
4.5.1.2 In the case of higher power internal combustion engines or turbine installations, the foundations are generally to be integral with the double bottom structure. Consideration is to 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 **Fig. 8.4.1**, Type 1.
4.5.1.3 For main machinery supported on foundations of Type 2, as shown in **Fig. 8.4.1**, the forces from the engine into the adjacent structure are to be distributed as uniformly as possible. Longitudinal members supporting the foundation are to be aligned with girders in the double bottom, and transverse stiffening is to be arranged in line with the floors, see **Fig. 8.4.1**, Type 2.
4.5.1.4 For ships with open floors in the machinery space, the foundations are generally to be arranged above the level of the top of the floors and securely bracketed, see **Fig. 8.4.1**, Type 3.

Fig. 8.4.1 Machinery Foundations



Note

1. Brackets are to be as large as possible. Brackets may be omitted to avoid interference with the girders of the engine foundation, in accordance with recommendations of the engine manufacturer.

4.5.2 Foundations for internal combustion engines and thrust bearings

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

4.5.2.2 Generally two girders are to be fitted in way of the foundation for internal combustion engines and thrust bearings.

<u>Guidance Note</u>

In general, the gross thickness of foundation top plates is not to be less than 45*mm*, where the maximum continuous output of the propulsion machinery is 3500*kw* or greater.

4.5.3 Auxiliary foundations

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

4.6 Tank Bulkheads

4.6.1 General

4.6.1.1 Tanks may be required to have divisions or deep wash plates to minimise the dynamic stress on the structure.

4.6.2 Construction

4.6.2.1 In no case are the scantlings of tank boundary bulkheads to be less than the requirements for watertight bulkheads.

4.6.3 Scantlings of tank boundary bulkheads

4.6.3.1 The thickness of tank boundary plating is to comply with the requirements in **4.8.1.1**.

4.6.3.2 The section modulus and thickness of stiffeners are to comply with the requirements in **4.8.1.2** and **4.8.1.3**.

4.6.3.3 The section modulus and shear area of primary support members are to comply with the requirements in **4.8.2**.

4.6.3.4 Web plating of primary support members is to have a depth of not less than 14% of the unsupported span in bending.

4.7 Watertight Boundaries

4.7.1 General

4.7.1.1 Watertight boundaries within the machinery space are to be fitted in accordance with **Section 5/2**.

4.7.2 Scantlings of watertight boundaries

4.7.2.1 The thickness of watertight boundary plating is to comply with the requirements in **4.8.1.1**.

4.7.2.2 The section modulus and thickness of stiffeners are to comply with the requirements in **4.8.1.2** and **4.8.1.3**.

4.7.2.3 The section modulus and shear area of primary support members are to comply with the requirements in **4.8.2**.

4.7.2.4 Web plating of primary support members is to have a depth of not less than 10% of the unsupported span in bending.

4.8 Scantling Requirements

4.8.1 Plating and local support members

4.8.1.1 For plating subjected to lateral pressure the net plating thickness is to comply with the requirements in **3.9.2.1**, but using the permissible bending stress coefficient, C_a, defined in **Table 8.4.2**.

4.8.1.2 For stiffeners subjected to lateral pressure the net section modulus requirement is to comply with the requirements in **3.9.2.2**, but using the permissible bending stress coefficient, C_s, defined in **Table 8.4.3**.

4.8.1.3 For stiffeners subjected to lateral pressure the net web thickness based on shear area requirements is to comply with the requirements in **3.9.2.3**.

Table 8.4.2 Permissible Bending Stress Coefficient for Plating

The permissible bending stress coefficient, C_a, for the design load set being considered is to be taken as:

$C_a = \beta_a - \alpha_a \frac{|\sigma_{hg}|}{\sigma_{yd}}$ but not to be taken greater than $C_{a\text{-}max}$

Where:

β_a, α_a, $C_{a\text{-}max}$

Acceptance Criteria Set	Structural Member		β_a	α_a	$C_{a\text{-}max}$
AC1	Longitudinal Strength Members	Longitudinally stiffened plating	0.9	0.5	0.8
		Transversely or vertically stiffened plating	0.9	1.0	0.8
	Other members		0.8	0	0.8
AC2	Longitudinal Strength Members	Longitudinally stiffened plating	1.05	0.5	0.95
		Transversely or vertically stiffened plating	1.05	1.0	0.95
	Other members, including watertight boundary plating		1.0	0	1.0

σ_{hg} : hull girder bending stress for the design load set being considered and calculated at the load calculation point defined in **Section 3/5.1.2**

$$= \frac{(z - z_{NA-net50})\, M_{v-total}}{I_{v-net50}} 10^{-3} \quad N/mm^2$$

$M_{v\text{-}total}$: design vertical bending moment at the longitudinal position under consideration for the design load set being considered, in kNm. The still water bending moment, $M_{sw\text{-}perm}$, is to be taken with the same sign as the simultaneously acting wave bending moment, M_{wv}, see **Table 7.6.1**

$I_{v\text{-}net50}$: net vertical hull girder moment of inertia, at the longitudinal position being considered, as defined in **Section 4/2.6.1**, in m^4

z : vertical coordinate of the load calculation point under consideration, in m

$z_{NA\text{-}net50}$: distance from the baseline to the horizontal neutral axis, as defined in **Section 4/2.6.1**, in m

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

Table 8.4.3 Permissible Bending Stress Coefficient for Stiffeners

The permissible bending stress coefficient C_s is to be taken as:

Sign of Hull Girder Bending Stress, σ_{hg}	Side that Pressure is Acting On	Acceptance Criteria
Tension (+ve)	Stiffener side	$C_s = \beta_s - \alpha_s \dfrac{\lvert\sigma_{hg}\rvert}{\sigma_{yd}}$ but not to be taken greater than $C_{s\text{-}max}$
Compression (-ve)	Plate side	
Tension (+ve)	Plate side	$C_s = C_{s\text{-}max}$
Compression (-ve)	Stiffener side	

Where:

β_s, α_s, $C_{s\text{-}max}$ permissible bending stress factors and are to be taken as:

Acceptance Criteria Set	Structural Member	β_s	α_s	$C_{s\text{-}max}$
AC1	Longitudinally effective stiffeners	0.85	1.0	0.75
	Other stiffeners	0.75	0	0.75
AC2	Longitudinally effective stiffeners	1.0	1.0	0.9
	Other stiffeners	0.9	0	0.9
	Watertight boundary stiffeners	0.9	0	0.9

σ_{hg} : hull girder bending stress for the design load set being considered and calculated at the reference point defined in **Section 3/5.2.2.5**

$$= \left(\frac{(z - z_{NA-net50})\, M_{v-total}}{I_{v-net50}} \right) 10^{-3} \qquad N/mm^2$$

$M_{v\text{-}total}$: design vertical bending moment at longitudinal position under consideration for the design load set being considered, in *kNm*

$M_{v\text{-}total}$ is to be calculated in accordance with **Table 7.6.1** using the sagging or hogging still water bending moment

Stiffener Location	$M_{sw\text{-}perm}$	
	Pressure acting on Plate Side	Pressure acting on Stiffener Side
Above Neutral Axis	Sagging SWBM	Hogging SWBM
Below Neutral Axis	Hogging SWBM	Sagging SWBM

$I_{v\text{-}net50}$: net vertical hull girder moment of inertia, at the longitudinal position being considered, as defined in **Section 4/2.6.1**, in m^4

z : vertical coordinate of the reference point defined in **Section 3/5.2.2.5**, in *m*

$z_{NA\text{-}net50}$: distance from the baseline to the horizontal neutral axis, as defined in **Section 4/2.6.1**, in *m*

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

4.8.2 Primary support members

4.8.2.1 For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include allowance for the curvature of the hull.

4.8.2.2 For primary support members subjected to lateral pressure the net section modulus requirement is to comply with the requirements in **3.9.3.2**.

4.8.2.3 For primary support members subjected to lateral pressure the net cross sectional area of the web is to comply with the requirements in **3.9.3.3**.

4.8.2.4 Primary support members are to generally be analysed with the specific methods as described for the particular structure type. More advanced calculation methods may be required to ensure that nominal stress level for all primary support members are less than permissible stresses and stress coefficients given in **3.9.3.2** and **3.9.3.3** when subjected to the applicable design load sets.

4.8.3 Corrugated bulkheads

4.8.3.1 Special consideration will be given to the approval of corrugated bulkheads where fitted.

Guidance Note

Scantling requirements of corrugated bulkheads in the cargo tank region may be used as a basis, see **2.5.6** and **2.5.7**.

4.8.4 Pillars

4.8.4.1 The maximum load on a pillar is to be less than the permissible pillar load as given by the requirements in **3.9.5**.

5. Aft End

5.1 General

5.1.1 Application

5.1.1.1 The requirements of this Sub-Section apply to structure located between the aft peak bulkhead and the aft end of the ship.

5.1.1.2 The requirements of this Sub-Section do not apply to the following:

(a) rudder horns

(b) structures which are not integral with the hull, such as rudders, steering nozzles and propellers

(c) other appendages permanently attached to the hull.

Where such items are fitted, the requirements of the Society are to be complied with.

5.1.1.3 The net scantlings described in **5.1** to **5.7** are related to gross scantlings as follows:

(a) for application the minimum thickness requirements of **5.1.4**, the gross thickness is obtained from the applicable requirements by adding the full corrosion additions specified in **Section 6/3**.

(b) for plating and local support members, the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in **Section 6/3**

(c) for primary support members, the gross shear area, gross section modulus and other gross cross sectional properties are obtained from the applicable requirements by adding one half of the relevant full corrosion additions specified in **Section 6/3**

(d) for application of buckling requirements of **Section 10/2** the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in **Section 6/3**.

5.1.2 General scantling requirements

5.1.2.1 The hull structure is to comply with the applicable requirements of:

(a) hull girder longitudinal strength, see **Section 8/1**

(b) strength against sloshing and impact loads, see **Section 8/6**

(c) buckling/ultimate strength, see **Section 10**.

5.1.2.2 The deck plating thickness and supporting structure are to be suitably reinforced for the steering gear, mooring windlasses, and other deck machinery. See **Section 11/3**.

5.1.2.3 The net section modulus, shear area and other sectional properties of local and primary support members are to be determined in accordance with **Section 4/2**.

5.1.2.4 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus and cross sectional shear areas of the primary support members are to be applied as required in the notes to **Table 8.3.5**.

5.1.2.5 The scantling criteria are based on assumptions that all structural joints and welded details are designed and fabricated such that they are compatible with the anticipated working stress levels at the locations considered. The loading patterns, stress concentrations and potential failure modes of structural joints and details during the design of highly stressed regions are to be considered. Structure design details are to comply with the requirements in **Section 4/3**.

5.1.2.6 Limber, drain and air holes are to be cut in all parts of the structure, as required, to ensure the free flow to the suction pipes and the escape of air to the vents. Arrangements are to be made for draining the spaces above deep tanks. See also **Section 4/3**.

5.1.3 Structural continuity

5.1.3.1 Scantlings of the shell envelope, upper deck and inner bottom are to be tapered towards the aft end. See also **1.6**.

5.1.3.2 In transition zones forward of the aft peak into the machinery space, due consideration is to be given to the tapering of primary support members.

5.1.3.3 Longitudinal framing of the strength deck is to be carried aft to the stern.
5.1.3.4 All shell frames and tank boundary stiffeners are in general to be continuous, or are to be bracketed at their ends, except as permitted in **Sections 4/3.2.4** and **4/3.2.5**. See also **Section 4/3.2**.

5.1.4 Minimum thickness

5.1.4.1 In addition to the thickness, section modulus and stiffener web shear area requirements as given in **5.2** to **5.7**, the thickness of plating and stiffeners in the aft end region is to comply with the appropriate minimum thickness requirements given in **Table 8.5.1**.

Table 8.5.1 Minimum Net Thickness of Structure Aft of the Aft Peak Bulkhead

Scantling Location			Net Thickness (*mm*)
Plating	Hull envelope up to $T_{sc} + 4.6m$	Keel plating	See **2.1.5.1**
		Bottom shell/bilge/side shell plating	See **2.1.5.1**
	Hull envelope above $T_{sc} + 4.6m$	Side shell/upper deck plating	See **2.1.5.1**
	Hull internal structure	Hull internal tank boundaries	See **2.1.5.1**
		Non-tight bulkheads, bulkheads between dry spaces and other plates in general	See **2.1.5.1**
		Pillar bulkheads	7.5
Bottom girders and aft peak floors			$5.5 + 0.02L_2$
Web plating of primary support members			$6.5 + 0.015L_2$
Local support members			See **2.1.5.1**
Tripping brackets			See **2.1.5.1**
Where: T_{sc} : scantling draught, in *m*, as defined in **Section 4/1.1.5.5** L_2 : rule length, *L,* as defined in **Section 4/1.1.1.1**, but need not be taken greater than 300*m*			

5.2 Bottom Structure

5.2.1 General

5.2.1.1 Floors are to be fitted at each frame space in the aft peak and carried to a height at least above the stern tube. Where floors do not extend to flats or decks they are to be stiffened by flanges at their upper end.
5.2.1.2 The centreline bottom girder is to extend as far aft as is practicable and is to be attached to the stern frame.

5.2.2 Aft peak floors and girders

5.2.2.1 The height of stiffeners, h_{stf}, on the floors and girders are to be not less than:

$h_{stf} = 80.0\, l_{stf}$ (*mm*), for flat bar stiffeners

$h_{stf} = 70.0\, l_{stf}$ (*mm*), for bulb profiles and flanged stiffeners

Where:

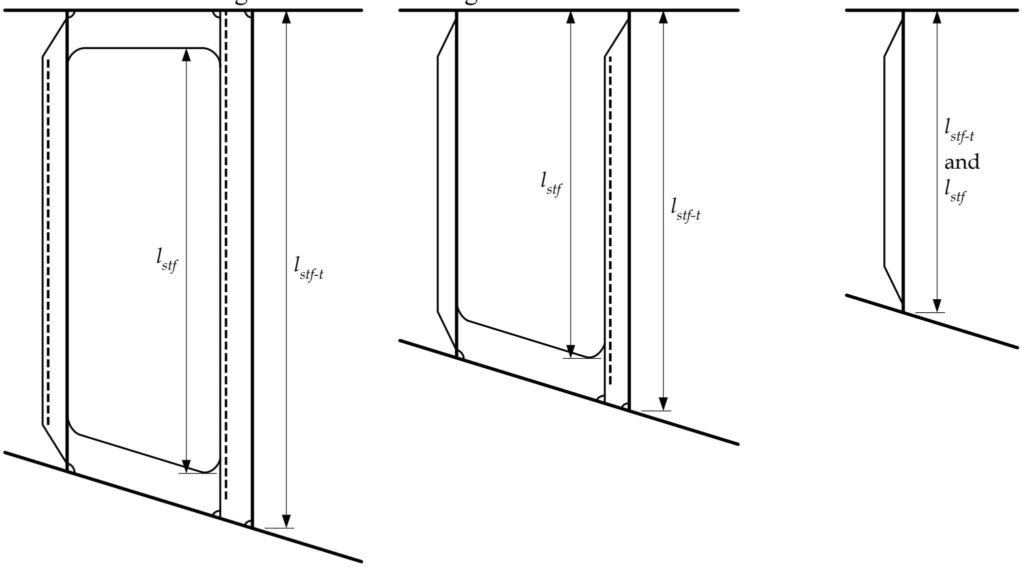
l_{stf} : length of stiffener as shown in **Fig. 8.5.1**, in *m*

5.2.2.2 In conjunction with the requirements of **5.2.2.1**, stiffeners are to be provided with end brackets as follows:
(a) brackets are to be fitted at the lower and upper ends when l_{stf-t} exceeds 4*m*
(b) brackets are to be fitted at the lower end when l_{stf-t} exceeds 2.5*m*.

Where:

l_{stf-t} total length of stiffener as shown in **Fig. 8.5.1**, in *m*

Fig. 8.5.1 Stiffening of Floors and Girders in the Aft Peak



a) when $l_{stf-t} > 4$ b) when $l_{stf-t} > 2.5$ c) when $l_{stf-t} \leq 2.5$

5.2.2.3 Heavy plate floors are to be fitted in way of the aft face of the horn and in line with the webs in the rudder horn. They may be required to be carried up to the first deck or flat. In this area, cut outs, scallops or other openings are to be kept to a minimum.

5.2.3 Stern frames

5.2.3.1 Stern frames may be fabricated from steel plates or made of cast steel. For applicable material specifications and steel grades see **Table 6.1.3**. Stern frames of other material or construction will be specially considered.

5.2.3.2 Scantlings below the propeller boss on stern frames for single screw vessels are to comply with the requirements in **5.2.3.3** or **5.2.3.4**, as applicable.

5.2.3.3 Fabricated stern frames are to satisfy the following criteria:

(a) $t_{grs} \geq 2.25\sqrt{L}$ (mm)

(b) $w_{stn} \geq 450$ (mm)

(c) $t_{grs} \geq \dfrac{C_f L^{1.5}}{w_{stn}^{\;2}\sqrt{1+\left(\dfrac{2l_{stn}}{w_{stn}}\right)^2}}$ (mm)

Where:

t_{grs} : gross thickness of side plating, in *mm*
w_{stn} : width of stern frame, in *mm*, see **Fig. 8.5.2a**
l_{stn} : length of stern frame, in *mm*, see **Fig. 8.5.2a**
L : rule length, as defined in **Section 4/1.1.1.1**
C_f = 9600

5.2.3.4 Cast stern frames are to satisfy the following criteria:

(a) $t_{1-grs} \geq 3.0\sqrt{L}$ (mm), but not to be less than 25*mm*

(b) $t_{2-grs} \geq 1.25 t_{1-grs}$ (mm)

(c) $\dfrac{(t_{1-grs}+t_{2-grs})}{2} \geq \dfrac{C_f L^{1.5}}{w_{stn}^{\;2}\sqrt{1+\left(\dfrac{2l_{stn}}{w_{stn}}\right)^2}}$ (mm)

Where:

t_{1-grs} : gross thickness of casting at end, in *mm*, see **Fig. 8.5.2b**
t_{2-grs} : gross thickness of casting at mid length, in *mm*, see **Fig. 8.5.2b**

w_{stn} : width of stern frame, in *mm*, see **Fig. 8.5.2b**

l_{stn} : length of stern frame, in *mm*, see **Fig. 8.5.2b**

L : rule length, as defined in **Section 4/1.1.1.1**

C_f = 8400

The thickness of butt welding to shell plating may be tapered below t_1 with a length of taper that is at least three *times* the offset. The castings are to be cored out to avoid large masses of thick material likely to contain defects and are to maintain a relatively uniform section throughout. Suitable radii are to be provided in way of changes in section.

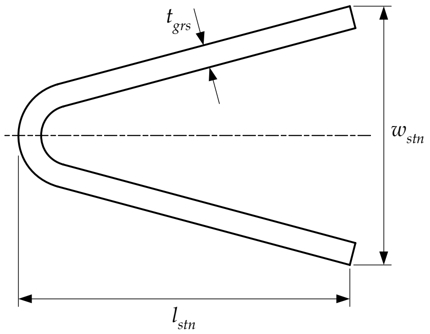
5.2.3.5 Above the propeller boss, the scantlings are to be in accordance with **5.2.3.2** to **5.2.3.4** except that in the upper part of the propeller aperture, where the hull form is full and centreline supports are provided, the thickness may be reduced to 80% of the applicable requirements in **5.2.3.2** to **5.2.3.4**.

5.2.3.6 Where round bars are used at the aft edge of stern frames, their scantlings and connection details are to facilitate welding.

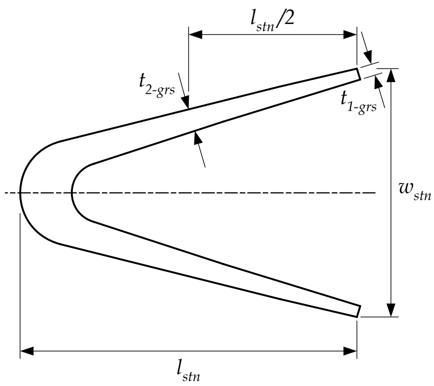
5.2.3.7 Ribs or horizontal brackets of thickness not less than $0.8t_{grs}$ or $0.8t_{1\text{-}grs}$ are to be provided at suitable intervals, where t_{grs} and $t_{1\text{-}grs}$ are as defined in **5.2.3.3** and **5.2.3.4**. When t_{grs} or $t_{1\text{-}grs}$ is reduced in accordance with **5.2.3.5**, a proportionate reduction in the thickness of ribs or horizontal brackets may be made.

5.2.3.8 Rudder gudgeons are to be an integral part of the stern frame and are to meet the requirements of the Society.

Fig. 8.5.2 Stern Frame



a Fabricated



b Cast

5.3 Shell Structure

5.3.1 Shell plating

5.3.1.1 The net thickness of the side shell and transom plating, t_{net}, is to comply with the requirements in **3.9.2.1** and is not to be less than:

$$t_{net} = 0.035(L_2 - 42) + 0.009s \qquad (mm)$$

Where:

L_2 : rule length, *L*, as defined in **Section 4/1.1.1.1**, but need not be taken greater than 300*m*

s : stiffener spacing, in *mm*, as defined in **Section 4/2.2**

5.3.1.2 The net plating thickness of shell, t_{net}, attached to the stern frame is to comply with the requirements in **3.9.2.1** and is not to be less than:

$$t_{net} = 0.094(L_2 - 43) + 0.009s \quad (mm)$$

Where:

L_2 : rule length, *L,* as defined in **Section 4/1.1.1.1***,* but need not be taken greater than 300*m*

s : stiffener spacing, in *mm*, as defined in **Section 4/2.2**

5.3.1.3 In way of the boss and heel plate, the shell net plating thickness, t_{net}, is not to be less than:

$$t_{net} = 0.105(L_2 - 47) + 0.011s \quad (mm)$$

Where:

L_2 : rule length, *L,* as defined in **Section 4/1.1.1.1***,* but need not be taken greater than 300*m*

s : stiffener spacing, in *mm*, as defined in **Section 4/2.2**

5.3.1.4 Within the extents specified in **2.2.4.3**, the thickness of the side shell plating is to comply with the requirements in **2.2.4.2**.

5.3.1.5 Heavy shell plates are to be fitted locally in way of the heavy plate floors as required by **5.2.2.3**. Outboard of the heavy floors, the heavy shell plates may be reduced in thickness in as gradual a manner as practicable. Where the horn plating is radiused into the shell plating, the radius at the shell connection, *r*, is not to be less than:

$$r = 150 + 0.8L_2 \quad (mm)$$

Where:

L_2 : rule length, *L,* as defined in **Section 4/1.1.1.1***,* but need not be taken greater than 300*m*

5.3.2 Shell local support members

5.3.2.1 The section modulus and thickness of the hull envelope framing are to comply with the requirements in **3.9.2.2** and **3.9.2.3**.

5.3.3 Shell primary support members

5.3.3.1 The requirements of **5.3.3** apply to single side skin construction supported by system of vertical webs and/or horizontal stringers or flats.

5.3.3.2 Where a longitudinal framing system is adopted, longitudinals are to be supported by vertical primary support members extending from the floors to the upper deck. Deck transverses are to be fitted in line with the web frames.

5.3.3.3 Where a transverse framing system is adopted, frames are to be supported by horizontal primary support members spanning between the vertical primary support members.

5.3.3.4 The scantlings of web frames supporting; longitudinal framing, stringers and transverse framing are to be determined from **3.9.3**.

5.3.3.5 The web depth of primary support members is not to be less than 14% of the bending span and is to be at least 2.5 *times* as deep as the slots for stiffeners if the slots are not closed.

5.4 Deck Structure

5.4.1 Deck plating

5.4.1.1 The thickness of the deck plating is to comply with the requirements in **3.9.2.1**.

5.4.1.2 In addition to the requirements of **5.4.1.1**, the net plating thickness of decks, t_{net}, is not to be less than:

$$t_{net} = 0.009s \quad (mm)$$

Where:

s : stiffener spacing, in *mm*, as defined in **Section 4/2.2**

5.4.2 Deck stiffeners

5.4.2.1 The section modulus and thickness of deck stiffeners are to comply with the requirements in **3.9.2.2** and **3.9.2.3**.

5.4.3 Deck primary support members

5.4.3.1 The section modulus and shear area of primary support members are to comply with the requirements in **3.9.3**.

5.4.3.2 Web plating of primary support members is to have a depth of not less than 10% of the unsupported span in bending.

5.4.3.3 In way of concentrated loads from heavy equipment, the scantlings of the deck structure are to be determined based on the actual loading. See also **Section 11/3**.

5.4.4 Pillars

5.4.4.1 Pillars are to be fitted in the same vertical line wherever possible and effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

5.4.4.2 Tubular and hollow square pillars are to be attached at their heads and heels by efficient brackets, or doublers/insert plates, where applicable, to transmit the load effectively. Pillars are to be attached at their heads and heels by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be distributed by brackets or other equivalent means.

5.4.4.3 Pillars in tanks are to be of solid section. Where the hydrostatic pressure may result in tensile stresses in the pillar, the tensile stress in the pillar and its end connections is not to exceed 45%of the specified minimum yield stress of the material.

5.4.4.4 The scantlings of pillars are to comply with the requirements in **3.9.5**.

5.4.4.5 Where the loads from heavy equipment exceed the design load of **3.9.5**, the pillar scantlings are to be determined based on the actual loading.

5.5 Tank Bulkheads

5.5.1 General

5.5.1.1 Tanks may be required to have divisions or deep wash structures to minimise the dynamic stress on the structure.

5.5.2 Construction

5.5.2.1 In no case are the scantlings of tank boundary bulkheads to be less than the requirements for watertight bulkheads.

5.5.3 Scantlings of tank boundary bulkheads

5.5.3.1 The thickness of tank boundary plating is to comply with the requirements in **3.9.2.1**.

5.5.3.2 The section modulus and thickness of stiffeners are to comply with the requirements in **3.9.2.2** and **3.9.2.3**.

5.5.3.3 The section modulus and shear area of primary support members are to comply with the requirements in **3.9.3**.

5.5.3.4 Web plating of primary support members is to have a depth of not less than 14% of the unsupported span in bending.

5.6 Watertight Boundaries

5.6.1 General

5.6.1.1 Watertight boundaries are to be fitted in accordance with **Section 5/2**.

5.6.1.2 The number of openings in watertight bulkheads is to be kept to a minimum compatible with the design and operation of the ship. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity.

5.6.2 Aft peak bulkhead

5.6.2.1 An aft peak bulkhead complying with **Section 5/2.3** is to be provided.

5.6.2.2 The scantlings of structural components of the aft peak bulkhead are to comply with the requirements in **5.5** and **5.6.3**, as applicable.

5.6.3 Scantlings of watertight boundaries

5.6.3.1 The thickness of boundary plating is to comply with the requirements in **3.9.2.1**.
5.6.3.2 The section modulus and thickness of stiffeners are to comply with the requirements in **3.9.2.2** and **3.9.2.3**.
5.6.3.3 The section modulus and shear area of primary support members are to comply with the requirements in **3.9.3**.
5.6.3.4 Web plating of primary support members is to have a depth of not less than 10% of the unsupported span in bending.

5.7 Miscellaneous Structures

5.7.1 Pillar bulkheads

5.7.1.1 Bulkheads that support girders, or pillars and longitudinal bulkheads which are fitted in lieu of girders, are to be stiffened to provide supports not less effective than required for stanchions or pillars. The acting load and the required net cross sectional area of the pillar section is to be determined using the requirements of **5.4.4**. The net moment of inertia of the stiffener is to be calculated with a width of 40*tnet* of the plating, where *tnet* is net plating thickness in *mm*.
5.7.1.2 Pillar bulkheads are to meet the following requirements:

(a) the distance between bulkhead stiffeners is not to exceed 1500*mm*

(b) where corrugated, the depth of the corrugation is not to be less than 100*mm*.

5.7.2 Rudder trunk

5.7.2.1 The scantlings of the rudder trunk are to be in accordance with the shell plating and framing in **5.3.1** and **5.3.2**. Where the rudder trunk is open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline to prevent water from entering the steering gear compartment.

5.7.3 Stern thruster tunnels

5.7.3.1 The net thickness of the tunnel plating, $t_{tun\text{-}net}$, is not to be less than required for shell plating in the vicinity of the thruster. In addition $t_{tun\text{-}net}$ is not to be taken less than:

$$t_{tun-net} = 0.008 d_{tun} + 1.8 \qquad (mm)$$

Where:

d_{tun} : inside diameter of the tunnel, in *mm*, but not to be taken less than 970 *mm*

5.7.3.2 Where the outboard ends of the tunnel are provided with bars or grids, the bars or grids are to be effectively secured.

6. Evaluation of Structure for Sloshing and Impact Loads

6.1 General

6.1.1 Application

6.1.1.1 The requirements of this Sub-Section cover the strengthening requirements for localised sloshing loads that may occur in tanks carrying liquid and local impact loads that may occur in the forward structure. The sloshing and impact loads to be applied in **6.2** to **6.4** are described in **Section 7/4**.

6.1.1.2 The net scantlings described in this Sub-Section are related to gross scantlings as follows:

(a) for plating and local support members, the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in **Section 6/3**

(b) for primary support members, the gross sectional area, gross section modulus and other gross cross sectional properties are obtained from the applicable requirements by adding one half of the full corrosion additions specified in **Section 6/3**.

6.1.2 General scantling requirements

6.1.2.1 The requirements of **6.2** to **6.4** are to be applied in addition to the applicable requirements in **Section 8**.

6.1.2.2 Local scantling increases due to impact or sloshing loads are to be made with due consideration given to details and avoidance of hard spots, notches and other harmful stress concentrations.

6.2 Sloshing in Tanks

6.2.1 Scope and limitations

6.2.1.1 The requirements of **6.2** specify the scantling requirements for boundary and internal structure of tanks subject to sloshing loads, as given in **Section 7/4.2**, due to the free movement of liquid in tanks.

6.2.1.2 The structure of cargo tanks, slop tanks, ballast tanks and large deep tanks, e.g. fuel oil bunkering tanks and main fresh water tanks, are to be assessed for sloshing. Small tanks do not need to be assessed for sloshing pressures.

6.2.1.3 All cargo and ballast tanks are to have scantlings suitable for unrestricted filling heights.

6.2.1.4 The following structural members are to 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 support members located in tanks

(d) tripping brackets supporting primary support members in tanks.

6.2.1.5 For tanks with effective sloshing breadth, b_{slh}, greater than $0.56B$ or effective sloshing length, l_{slh}, greater than $0.13L$, an additional sloshing impact assessment is to be carried out in accordance with the Society's procedures. The effective sloshing length, l_{slh}, and breadth, b_{slh}, are defined in **Section 7/4.2.2** and **Section 7/4.2.3** respectively.

6.2.2 Application of sloshing pressure

6.2.2.1 The following tanks are to be assessed for the design sloshing pressures $P_{slh-lng}$ and P_{slh-t} in accordance with **6.2.2.2** to **6.2.2.5**:

(a) cargo and slop tanks

(b) fore peak and aft peak ballast tanks

(c) other tanks which allow free movement of liquid, except as follows:

- where the effective sloshing length is less than $0.03L$, calculations involving $P_{slh-lng}$ are not required and
- where the effective sloshing breadth is less than $0.32B$, calculations involving P_{slh-t} are not required.

The design sloshing pressure for other tanks mentioned in **6.2.1.2** is to be taken as the minimum sloshing pressure, $P_{slh-min}$, as defined in **Section 7/4.2.4**.

6.2.2.2 The design sloshing pressure due to longitudinal liquid motion, $P_{slh-lng}$, as defined in **Section 7/4.2.2.1** is to be applied to the following members as shown in **Fig. 8.6.1**:

(a) transverse tight bulkheads

(b) transverse wash bulkheads

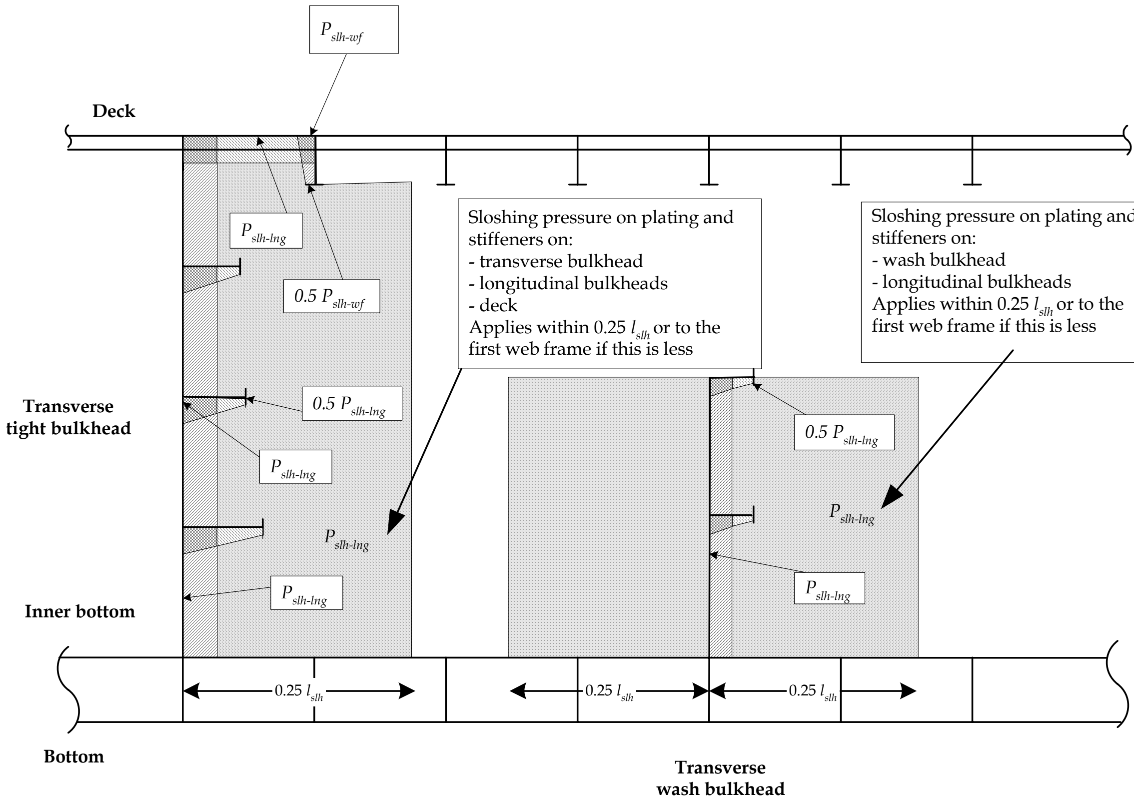
(c) stringers on transverse tight and wash bulkheads

(d) plating and stiffeners on the longitudinal bulkheads, deck and inner hull which are between the transverse bulkhead and the first web frame from the bulkhead or the bulkhead and $0.25l_{slh}$, whichever is lesser.

6.2.2.3 In addition to **6.2.2.2**, the first web frame next to a transverse tight or wash bulkhead if the web frame is located within 0.25*lslh* from the bulkhead, as shown in **Fig. 8.6.1**, is to be assessed for the web frame reflected sloshing pressure, $P_{slh\text{-}wf}$, as defined in **Section 7/4.2.2.5**.

6.2.2.4 The minimum sloshing pressure, $P_{slh\text{-}min}$, as defined in **Section 7/4.2.4** is to be applied to all other members.

Fig. 8.6.1 Application of Sloshing Loads due to Longitudinal Liquid Motion



6.2.2.5 The design sloshing pressure due to transverse liquid motion, $P_{shl\text{-}t}$, as defined in **Section 7/4.2.3.1**, is to be applied to the following members as shown in **Fig. 8.6.2**:

(a) longitudinal tight bulkhead

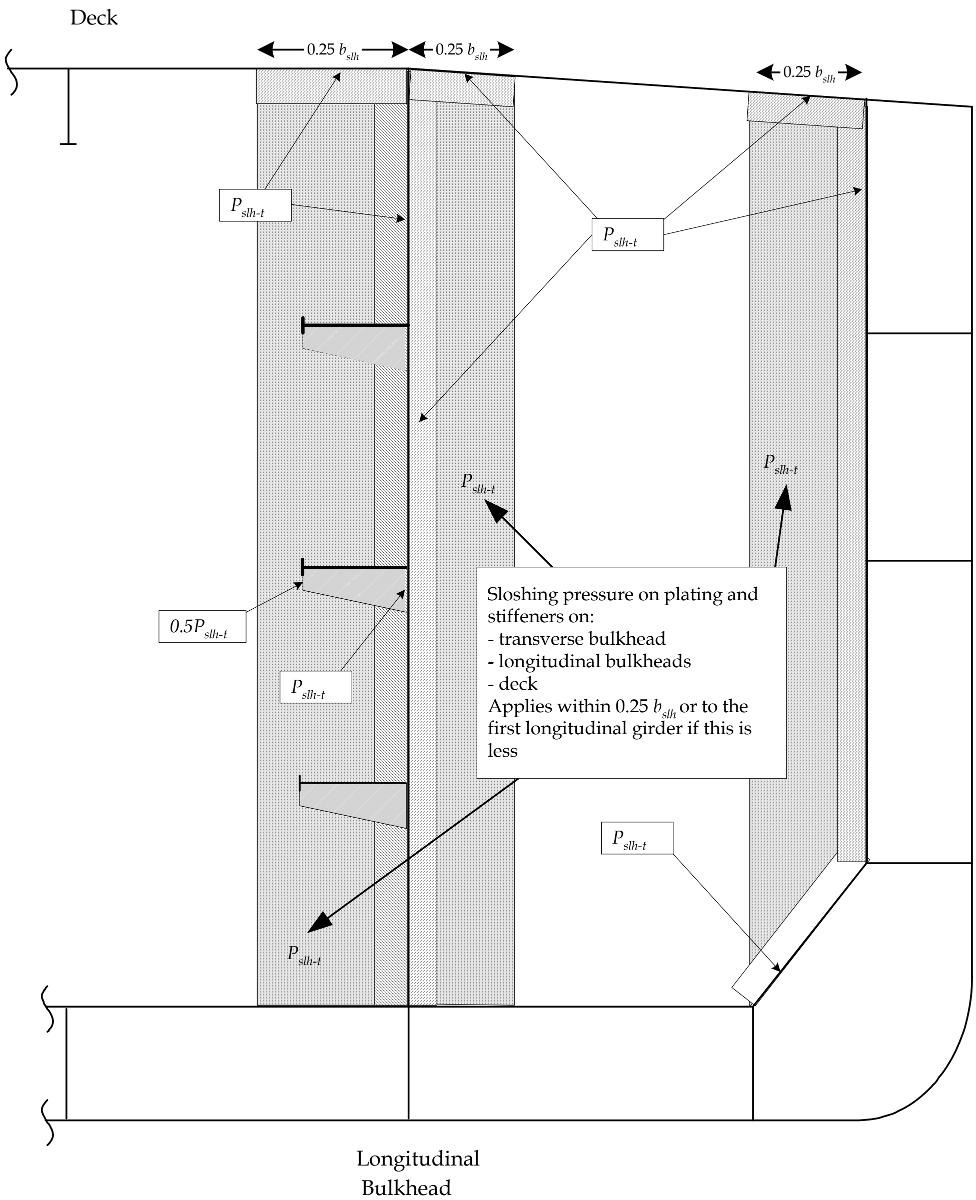
(b) longitudinal wash bulkhead

(c) horizontal stringers and vertical webs on longitudinal tight and wash bulkheads

(d) plating and stiffeners on the transverse tight bulkheads including stringers, deck and inner bottom which are between the longitudinal bulkhead and the first girder from the bulkhead or the bulkhead and $0.25b_{slh}$ whichever is lesser.

6.2.2.6 In addition to **6.2.2.5**, the first girder next to longitudinal tight or wash bulkhead if the girder is located within $0.25b_{slh}$ from the longitudinal bulkhead, as shown in **Fig. 8.6.2**, is to be assessed for the reflected sloshing pressure, $P_{slh\text{-}grd}$ as defined in **Section 7/4.2.3.5**.

Fig. 8.6.2 Application of Sloshing Loads due to Transverse Liquid Motion



6.2.2.7 The minimum sloshing pressure, $P_{slh-min}$, as defined in **Section 7/4.2.4**, is to be applied to all other members.

6.2.2.8 The sloshing pressures due to transverse and longitudinal fluid motion are assumed to act independently. Structural members are therefore to be evaluated based on the greatest sloshing pressure due to longitudinal and transverse fluid motion.

6.2.3 Sloshing assessment of plating forming tank boundaries

6.2.3.1 The net thickness of plating forming tank boundaries, t_{net}, subjected to sloshing pressures is not to be less than:

$$t_{net} = 0.0158\alpha_p\, s\sqrt{\frac{P_{slh}}{C_a \sigma_{yd}}} \qquad (mm)$$

Where:

α_p : correction factor for the panel aspect ratio

$$= 1.2 - \frac{s}{2100\, l_p} \qquad \text{but not to be taken as greater than 1.0}$$

s : stiffener spacing, in *mm*, as defined in **Section 4/2.2**

l_p : length of plate panel, to be taken as the spacing of primary support members, S, unless carlings are fitted, in m

P_{slh} : the greater of $P_{slh-lng}$, P_{slh-t} or $P_{slh-min}$ as specified in **6.2.2**

C_a : permissible plate bending stress coefficient as given in **Table 8.6.1**

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

6.2.4 Sloshing assessment of stiffeners on tank boundaries

6.2.4.1 The net section modulus, Z_{net}, of stiffeners on tank boundaries subjected to sloshing pressures is not to be less than:

$$Z_{net} = \frac{P_{slh}\ s\ l_{bdg}^{\ 2}}{f_{bdg}\ C_s\ \sigma_{yd}} \qquad (cm^3)$$

Where:

l_{bdg} : effective bending span, of stiffener, as defined in **Section 4/2.1**, in m

C_s : permissible bending stress coefficient as given in **Table 8.6.2**

P_{slh} : the greater of $P_{slh-lng}$, P_{slh-t} or $P_{slh-min}$ as specified in **6.2.2**

s : stiffener spacing, in mm, as defined in **Section 4/2.2**

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

f_{bdg} : bending moment factor
= 12 for stiffeners fixed against rotation at each end. This is generally to be applied for scantlings of all continuous stiffeners
= 8 for stiffeners with one or both ends not fixed against rotation. This is generally to be applied to discontinuous stiffeners
for other configurations the bending moment factor may be taken as given in **Table 8.3.5**

6.2.5 Sloshing assessment of primary support members

6.2.5.1 Web plating, web stiffeners and tripping brackets on stringers, girders and web frames in cargo and ballast tanks are to be assessed based on sloshing pressures as given in **6.2.2**.

6.2.5.2 The web plating net thickness of primary support members, t_{net}, is not to be less than:

$$t_{net} = 0.0158\,\alpha_p\, s \sqrt{\frac{P_{slh}}{C_a \sigma_{yd}}} \qquad (mm)$$

Where:

α_p : correction factor for the panel aspect ratio

$$= 1.2 - \frac{s}{2100\, l_p} \qquad \text{but not to be taken as greater than 1.0}$$

s : stiffener spacing, in mm, as defined in **Section 4/2.2**

l_p : length of plate panel, mean spacing between local support members on the long edges of the panel, typically between tripping brackets, in m

P_{slh} : the greater of $P_{slh-lng}$, P_{slh-t}, P_{slh-wf}, $P_{slh-grd}$ or $P_{slh-min}$ as specified in **6.2.2**. The pressure is to be calculated at the load application point, defined in **Section 3/5.1.2**, taking into account the distribution over the height of the member, as shown in **Fig. 8.6.1**

C_a : permissible plate bending stress coefficient as given in **Table 8.6.1**

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

6.2.5.3 The net section modulus, Z_{net}, of each individual stiffener on the web plating of primary support members subjected to sloshing pressures is not to be less than:

$$Z_{net} = \frac{P_{slh}\ s\ l_{bdg}^{\ 2}}{f_{bdg}\ C_s\ \sigma_{yd}} \qquad (cm^3)$$

Where:

P_{slh} : the greater of $P_{slh-lng}$, P_{slh-t}, P_{slh-wf}, $P_{slh-grd}$ or $P_{slh-min}$ as specified in **6.2.2**. The pressure is to be calculated at the load application point taking into account the distribution over the height of the member, as shown in **Fig. 8.6.1** and **8.6.2**.

s : stiffener spacing, in *mm*, as defined in **Section 4/2.2**

l_{bdg} : effective bending span, in *m*, of web stiffener as defined in **Section 4/2.1**

C_s : permissible bending stress coefficient as given in **Table 8.6.2**

f_{bdg} : bending moment factor

= 12 for stiffeners fixed against rotation at each end. This is generally to be applied for scantlings of all continuous stiffeners

= 8 for stiffeners with one or both ends not fixed against rotation. This is generally to be applied to discontinuous stiffeners for other configurations the bending moment factor may be taken as given in **Table 8.3.5**

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

6.2.5.4 The net section modulus, Z_{net}, in way of the base of tripping brackets supporting primary support members in cargo and ballast tanks is not to be less than:

$$Z_{net} = \frac{1000\, P_{slh}\ s_{trip}\ l_{trip}^2}{2\, C_s\, \sigma_{yd}} \qquad (cm^3)$$

Where:

P_{slh} : the greater of $P_{slh-lng}$, P_{slh-t}, P_{slh-wf}, $P_{slh-grd}$ and $P_{slh-min}$ as defined in **6.2.2**. The average pressure may be calculated at mid point of the tripping bracket taking into account the distribution as shown in **Fig. 8.6.1** and **8.6.2**

s_{trip} : mean spacing, between tripping brackets or other primary support members or bulkheads, in *m*

l_{trip} : length of tripping bracket, see **Fig. 8.6.3**, in *m*

C_s : permissible bending stress coefficient for tripping brackets
= 0.75

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

6.2.5.5 The net shear area, $A_{shr-net}$, after deduction of cut-outs and slots, of tripping brackets supporting primary support members in cargo and ballast tanks is not to be less than:

$$A_{shr-net} = 10 \frac{P_{slh}\ s_{trip}\ l_{trip}}{C_t \tau_{yd}} \qquad (cm^2)$$

Where:

P_{slh} : the greater of $P_{slh-lng}$, P_{slh-t}, P_{slh-wf}, $P_{slh-grd}$ and $P_{slh-min}$ as defined in **6.2.2**. The average pressure may be calculated at mid point of the tripping bracket taking into account the distribution as shown in **Fig. 8.6.1** and **8.6.2**

s_{trip} : mean spacing, between tripping brackets or other primary support members or bulkheads, in *m*

l_{trip} : length of tripping bracket, see **Fig. 8.6.3**, in *m*

C_t : permissible shear stress coefficient, as given in **Table 8.6.3**

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ (N/mm^2)

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

Fig.8.6.3 Effective Length of Tripping Bracket

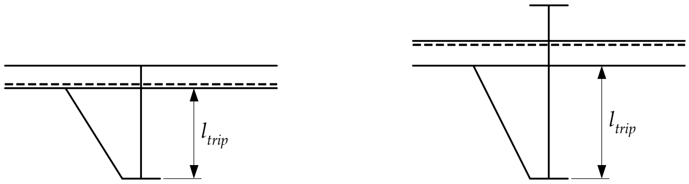


Table 8.6.1 Allowable Plate Bending Stress Coefficient, C_a, for Assessment of Sloshing on Plates

The permissible bending stress coefficient for the design load set being considered is to be taken as:

$$C_a = \beta_a - \alpha_a \frac{|\sigma_{hg}|}{\sigma_{yd}}$$ but not to be taken greater than $C_{a\text{-}max}$

Where:

α_a, β_a, $C_{a\text{-}max}$ permissible bending stress factors and are to be taken as follows

Acceptance Criteria Set	Structural Member		β_a	α_a	$C_{a\text{-}max}$
AC1	Longitudinal strength members in the cargo tank region including: deck longitudinal plane bulkhead horizontal corrugated longitudinal bulkhead longitudinal girders and stringers within the cargo tank region	Longitudinally stiffened plating	0.9	0.5	0.8
		Transversely or vertically stiffened plating	0.9	1.0	0.8
	Other strength members including: vertical corrugated longitudinal bulkhead transverse plane bulkhead transverse corrugated bulkhead transverse stringers and web frames plating of tank boundaries and primary support members outside the cargo tank region		0.8	0	0.8

σ_{hg} : hull girder bending stress for the design load set being considered and calculated at the load calculation point defined in **Section 3/5.1.2**

$$= \left(\frac{(z - z_{NA-net50})\, M_{sw-perm-sea}}{I_{v-net50}}\right) 10^{-3} \qquad (N/mm^2)$$

z : vertical coordinate of the load calculation point under consideration, in *m*

$z_{NA\text{-}net50}$: distance from the baseline to the horizontal neutral axis, as defined in **Section 4/2.6.1**, in *m*

$M_{sw\text{-}perm\text{-}sea}$: permissible hull girder hogging and sagging still water bending moment for seagoing operation at the location being considered, in *kNm*. The greatest of the sagging and hogging bending moment is to be used, see **Section 7/2.1**.

$I_{v\text{-}net50}$: net vertical hull girder moment of inertia, at the longitudinal position being considered, as defined in **Section 4/2.6.1**, in m^4

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

Table 8.6.2 Allowable Bending Stress Coefficient, C_s, for Assessment of Sloshing on Stiffeners

The permissible bending stress coefficient for the design load set being considered is to be taken as:

$$C_s = \beta_s - \alpha_s \frac{|\sigma_{hg}|}{\sigma_{yd}}$$ but not to be taken greater than $C_{s\text{-}max}$

Where:

α_s, β_s , $C_{s\text{-}max}$: permissible bending stress factors and are to be taken as follows

Acceptance Criteria Set	Structural Member		β_s	α_s	$C_{s\text{-}max}$
AC1	Longitudinal strength members in the cargo tank region including: deck stiffeners stiffeners on longitudinal bulkheads stiffeners on longitudinal girders and stringers within the cargo tank region	Longitudinal stiffeners	0.85	1.0	0.75
		Transverse or vertical stiffeners	0.7	0	0.7
	Other strength members including: stiffeners on transverse bulkheads stiffeners on transverse stringers and web frames stiffeners on tank boundaries and primary support members outside the cargo tank region		0.75	0	0.75

σ_{hg} : hull girder bending stress for the design load set being considered at the reference point defined in **Section 3/5.2.2.5**

$$= \left(\frac{(z - z_{NA-net50})\,M_{sw-perm-sea}}{I_{v-net50}}\right)10^{-3} \qquad (N/mm^2)$$

z : vertical coordinate of the reference point defined in **Section 3/5.2.2.5**, in *m*

$z_{NA\text{-}net50}$: distance from the baseline to the horizontal neutral axis, as defined in **Section 4/2.6.1**, in *m*

$M_{sw\text{-}perm\text{-}sea}$: permissible hull girder hogging and sagging still water bending moment for seagoing operation at the location being considered, in *kNm*. The greatest of the sagging and hogging bending moment is to be used, see **Section 7/2.1**.

$I_{v\text{-}net50}$: net vertical hull girder moment of inertia, at the longitudinal position being considered, as defined in **Section 4/2.6.1**, in m^4

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

Table 8.6.3 Permissible Shear Stress Coefficient

Acceptance Criteria Set	Structural member	C_t
AC1	Tripping brackets	0.75

6.3 Bottom Slamming

6.3.1 Application

6.3.1.1 Where the minimum draughts forward, $T_{FP\text{-}mt}$ or $T_{FP\text{-}full}$, as specified in **Section 7/4.3.2.1**, is less than 0.045L, the bottom forward is to be additionally strengthened to resist bottom slamming pressures.

6.3.1.2 The draughts for which the bottom has been strengthened are to be indicated on the shell expansion plan and loading guidance information, see **1.1**.

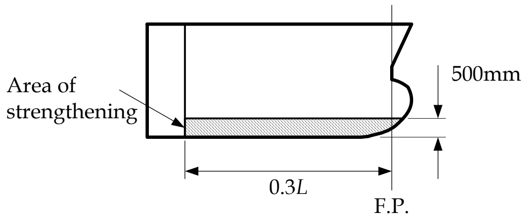
6.3.1.3 The scantlings described in **6.3** are net scantlings, which are related to gross scantlings as described in **6.1.1.2**. The section modulus and shear area of the primary support members is to be determined as specified in **Section 4/2.5**.

6.3.1.4 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The cross sectional shear areas of primary support members are to be applied as required by **6.3.7.3** and **6.3.7.4**.

6.3.2 Extent of strengthening

6.3.2.1 The strengthening is to extend forward of 0.3L from the F.P. over the flat of bottom and adjacent plating with attached stiffeners up to a height of 500*mm* above the baseline, see **Fig. 8.6.4**.

Fig. 8.6.4 Extent of strengthening against bottom slamming



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

6.3.3 Design to resist bottom slamming loads

6.3.3.1 The design of end connections of stiffeners in the bottom slamming region is to ensure end fixity, either by making the stiffeners continuous through supports or by providing end brackets complying with **Section 4/3.2.3**. Where it is not practical to comply with this requirement the net plastic section modulus, $Z_{pl\text{-}alt\text{-}net}$, for alternative end fixity arrangements is not to be less than:

$$Z_{pl\text{-}alt\text{-}net} = \frac{16 Z_{pl-net}}{f_{bdg}} \qquad (cm^3)$$

Where:

$Z_{pl\text{-}net}$: net plastic section modulus, in cm^3, as required by **6.3.5.1**

f_{bdg} : bending moment factor

$$= 8\left(1 + \frac{n_s}{2}\right)$$

n_s = 0 for both ends with low end fixity (simply supported)

= 1 for one end equivalent to built in and one end simply supported

6.3.3.2 Scantlings and arrangements at primary support members, including bulkheads, are to comply with **6.3.7**.

6.3.4 Hull envelope plating

6.3.4.1 The net thickness of the hull envelope plating, t_{net}, is not to be less than:

$$t_{net} = \frac{0.0158\,\alpha_p\,s}{C_d}\sqrt{\frac{P_{slm}}{C_a \sigma_{yd}}} \qquad (mm)$$

Where:

α_p : correction factor for the panel aspect ratio

$$= 1.2 - \frac{s}{2100 l_p}$$ but not to be taken as greater than 1.0

s : stiffener spacing, in *mm*, as defined in **Section 4/2.2**

l_p : length of plate panel, to be taken as the spacing between primary support members (see **Section 4/2.2.2**) or panel breakers, in *m*

P_{slm} : bottom slamming pressure as given in **Section 7/4.3** and calculated at the load calculation point defined in **Section 3/5.1.2**, in kN/m^2

C_d : plate capacity correction coefficient

= 1.3

C_a : permissible bending stress coefficient

= 1.0 for acceptance criteria set AC3

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

6.3.5 Hull envelope stiffeners

6.3.5.1 The net plastic section modulus, $Z_{pl\text{-}net}$, of each individual stiffener, is not to be less than:

$$Z_{pl-net} = \frac{P_{slm}\, s l_{bdg}^{\;2}}{f_{bdg}\, C_s\, \sigma_{yd}} \qquad (cm^3)$$

Where:

P_{slm} : bottom slamming pressure as given in **Section 7/4.3** and calculated at the load calculation point defined in **Section 3/5.2.2**, in kN/m^2

s : stiffener spacing, in *mm*, as defined in **Section 4/2.2**

l_{bdg} : effective bending span, as defined in **Section 4/2.1.1**, in *m*

f_{bdg} : bending moment factor

$= 8\left(1 + \frac{n_s}{2}\right)$

n_s = 2.0 for continuous stiffeners or where stiffeners are bracketed at both ends

see **6.3.3.1** for alternative arrangements

C_s : permissible bending stress coefficient

= 0.9 for acceptance criteria set AC3

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

6.3.5.2 The net web thickness, t_{w-net}, of each longitudinal is not to be less than:

$$t_{w-net} = \frac{P_{slm}\, s l_{shr}}{2 d_{shr} C_t\, \tau_{yd}} \qquad (mm)$$

Where:

l_{shr} : effective shear span, as defined in **Section 4/2.1.2**, in *m*

s : stiffener spacing, in *mm*, as defined in **Section 4/2.2**

P_{slm} : bottom slamming pressure as given in **Section 7/4.3** and calculated at the load calculation point defined in **Section 3/5.2.2**, in kN/m^2

d_{shr} : effective web depth of stiffener, in *mm*, as defined in **Section 4/2.4.2.2**

C_t : permissible shear stress coefficient

= 1.0 for acceptance criteria set AC3

τ_{yd} $= \frac{\sigma_{yd}}{\sqrt{3}}$ (N/mm^2)

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

6.3.5.3 The slenderness ratio of each longitudinal is to comply with **Section 10/2**.

6.3.6 Definition of idealised bottom slamming load area for primary support members

6.3.6.1 The scantlings of items in **6.3.7** are based on the application of the slamming pressure defined in **Section 7/4.3** to an idealised area of hull envelope plating, the slamming load area, A_{slm}, given by:

$$A_{slm} = \frac{1.1 L B C_b}{1000} \qquad (m^2)$$

Where:

L : rule length, as defined in **Section 4/1.1.1.1**

B : moulded breadth, in *m*, as defined in **Section 4/1.1.3.1**

C_b : block coefficient, as defined in **Section 4/1.1.9.1**

6.3.7 Primary support members

6.3.7.1 The size and number of openings in web plating of the floors and girders is to be minimised considering the required shear area as given in **6.3.7.2**.

6.3.7.2 The net shear area, $A_{w-net50}$, of each primary support member web at any position along its span is not to be less than:

$$A_{w-net50} = 10\frac{Q_{slm}}{C_t \tau_{yd}} \qquad (cm^2)$$

Where:

Q_{slm} : the greatest shear force due to slamming for the position being considered, in *kN*, based on the application of a patch load, F_{slm} to the most onerous location, as determined in accordance with **6.3.7.3**

C_t : permissible shear stress coefficient

= 0.9 for acceptance criteria set AC3

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ (N/mm^2)

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

6.3.7.3 For simple arrangements of primary support members, where the grillage affect may be ignored, the shear force, Q_{slm}, is given by:

$$Q_{slm} = f_{pt} f_{dist} F_{slm} \qquad (kN)$$

Where:

f_{pt} : Correction factor for the proportion of patch load acting on a single primary support member

$= 0.5\left(f_{slm}{}^3 - 2f_{slm}{}^2 + 2\right)$

f_{slm} : patch load modification factor

$= 0.5\dfrac{b_{slm}}{S}$

f_{dist} : factor for the greatest shear force distribution along the span, see **Fig. 8.6.5**

F_{slm} $= P_{slm}\, l_{slm}\, b_{slm}$

P_{slm} : bottom slamming pressure as given in **Section 7/4.3** and calculated at the load calculation point defined in **Section 3/5.3.2**, in kN/m^2

l_{slm} : extent of slamming load area along the span

$= \sqrt{A_{slm}}$ m, but not to be greater than l_{shr}

l_{shr} : effective shear span, as defined in **Section 4/2.1.5**, in m

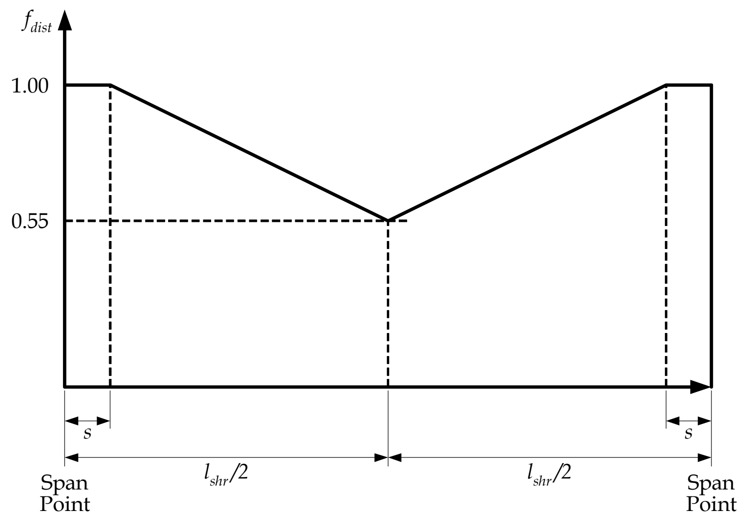
b_{slm} : breadth of impact area supported by primary support member

$= \sqrt{A_{slm}}$ m, but not to be greater than S

A_{slm} : as defined in **6.3.6.1**

S : primary support member spacing, in m, as defined in **Section 4/2.2.2**

Fig. 8.6.5 Distribution of f_{dist} along the Span of Simple Primary Support Members



Where:

s stiffener spacing

l_{shr} : effective shear span, in m, as defined in **Section 4/2.1.5**

6.3.7.4 For complex arrangements of primary support members, the greatest shear force, Q_{slm}, at any location along the span of each primary support member is to be derived by direct calculation in accordance with **Table 8.6.4**.

Table 8.6.4 Direct Calculation Methods for Derivation of Q_{slm}

Type of analysis	Beam theory	Double bottom grillage
Model extent	Overall span of member between effective bending supports	Longitudinal extent to be one cargo tank length Transverse extent to be between inner hopper knuckle and centreline
Assumed end fixity of floors	Fixed at ends	Floors and girders to be fixed at boundaries of the model
Note 1. The envelope of greatest shear force along each primary support member is to be derived by applying the load patch to a number of locations along the span, see **6.3.7.2**.		

6.3.7.5 The net web thickness, $t_{w\text{-}net}$, of primary support members adjacent to the shell is not to be less than:

$$t_{w-net} = \frac{s}{70}\sqrt{\frac{\sigma_{yd}}{235}} \quad (mm)$$

Where:

s : stiffener spacing, in mm, as defined in **Section 4/2.2**

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

6.3.8 Connection of longitudinals to primary support members

6.3.8.1 Longitudinals are, in general, to be continuous. Where this not practicable end brackets complying with **4/3.2.3** are to be provided.

6.3.8.2 The scantlings in way of the end connections of each longitudinal are to comply with the requirements of **Section 4/3.4**.

6.4 Bow Impact

6.4.1 Application

6.4.1.1 The side structure in the area forward of $0.1L$ from the F.P. is to be strengthened against bow impact pressures.

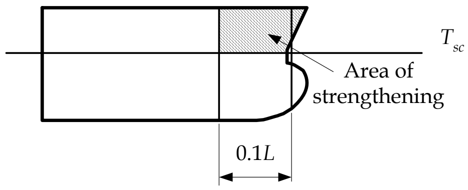
6.4.1.2 The scantlings described in **6.4** are net scantlings, which are related to gross scantlings as described in **6.1.1.2**.

6.4.1.3 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus of the primary support member is to apply along the bending span clear of end brackets and cross sectional areas of the primary support member is to be applied at the ends/supports and may be gradually reduced along the span and clear of the ends/supports following the distribution of f_{dist} indicated in **Fig. 8.6.5**.

6.4.3 Extent of strengthening

6.4.3.1 The strengthening is to extend forward of $0.1L$ from the F.P. and vertically above the scantling draught, T_{sc}, see **Fig. 8.6.6.**

Fig. 8.6.6 Extent of Strengthening Against Bow Impact



6.4.3.2 Outside the strengthening region as given in **6.4.2.1** the scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.

6.4.3 Design to resist bow impact loads

6.4.3.1 In the bow impact region, longitudinal framing is to be carried as far forward as practicable.

6.4.3.2 The design of end connections of stiffeners in the bow impact region are to ensure end fixity, either by making the stiffeners continuous through supports or by providing end brackets complying with **Section 4/3.2.3**. Where it is not practical to comply with this requirement the net plastic section modulus, $Z_{pl-alt-net}$, for alternative end fixity arrangements is not to be less than:

$$Z_{pl-alt-net} = \frac{16 Z_{pl-net}}{f_{bdg}} \qquad (cm^3)$$

Where:

Z_{pl-net}	: effective net plastic section modulus, required by **6.4.5**, in cm^3
f_{bdg}	: bending moment factor $= 8\left(1 + \frac{n_s}{2}\right)$
n_s	= 0 for both ends with low end fixity (simply supported) = 1.0 for one end equivalent to built in and one end simply supported

6.4.3.3 Scantlings and arrangements at primary support members, including decks and bulkheads, are to comply with **6.4.7**. In areas of greatest bow impact load the adoption of web stiffeners arranged perpendicular to the hull envelope plating and the provision of double sided lug connections is, in general to be fitted.

6.4.3.4 The main stiffening direction of decks and bulkheads supporting shell framing is to be arranged parallel to the span direction of the supported shell frames, to protect against buckling.

6.4.4 Side shell plating

6.4.4.1 The net thickness of the side shell plating, t_{net}, is not to be less than:

$$t_{net} = 0.0158\,\alpha_p\, s \sqrt{\frac{P_{im}}{C_a \sigma_{yd}}} \qquad (mm)$$

Where:

α_p	: correction factor for the panel aspect ratio $= 1.2 - \frac{s}{2100\, l_p}$ but is not to be taken as greater than 1.0
s	: stiffener spacing, in mm, as defined in **Section 4/2.2**
l_p	: length of plate panel, to be taken as the spacing between the primary support members, see **Section 4/2.2.2**, or panel breakers, in m
P_{im}	: bow impact pressure as given in **Section 7/4.4** and calculated at the load calculation point defined in **Section 3/5.1.2**, in kN/m^2
C_a	: permissible bending stress coefficient = 1.0 for acceptance criteria set AC3
σ_{yd}	: specified minimum yield stress of the material, in N/mm^2

6.4.5 Side shell stiffeners

6.4.5.1 The effective net plastic section modulus, Z_{pl-net}, of each stiffener, in association with the effective plating to which it is attached, is not to be less than:

$$Z_{pl-net} = \frac{P_{im}\, s l_{bdg}^{\ 2}}{f_{bdg}\, C_s\, \sigma_{yd}} \qquad (cm^3)$$

Where:

P_{im}	: bow impact pressure as given in **Section 7/4.4** and calculated at the load calculation point defined in **Section 3/5.2.2**, in kN/m^2
s	: stiffener spacing, in *mm*, as defined in **Section 4/2.2**
l_{bdg}	: effective bending span, as defined in **Section 4/2.1.1**, in *m*
f_{bdg}	: bending moment factor $= 8\left(1 + \frac{n_s}{2}\right)$
n_s	= 2.0 for continuous stiffeners or where stiffeners are bracketed at both ends; see **6.3.3.1** for alternative arrangements
C_s	: permissible bending stress coefficient = 0.9 for acceptance criteria set AC3
σ_{yd}	: specified minimum yield stress of the material, in N/mm^2

6.4.5.2 The net web thickness, t_{w-net}, of each stiffener is not to be less than:

$$t_{w-net} = \frac{P_{im}\, s l_{shr}}{2 d_{shr} C_t \tau_{yd}} \qquad (mm)$$

Where:

l_{shr}	: effective shear span, as defined in **Section 4/2.1.2**, in *m*
s	: stiffener spacing, in *mm*, as defined in **Section 4/2.2**
P_{im}	: bow impact pressure as given in **Section 7/4.4** and calculated at the load calculation point defined in **Section 3/5.2.2**, in kN/m^2
d_{shr}	: effective web depth of stiffener, in *mm*, as defined in **Section 4/2.4.2.2**
C_t	: permissible shear stress coefficient = 1.0 for acceptance criteria set AC3
τ_{yd}	$= \frac{\sigma_{yd}}{\sqrt{3}} \qquad (N/mm^2)$
σ_{yd}	: specified minimum yield stress of the material, in N/mm^2

6.4.5.3 The slenderness ratio of each longitudinal is to comply with **Section 10/2**.

6.4.5.4 The minimum net thickness of breasthooks/diaphragm plates, t_{w-net}, is not to be less than:

$$t_{w-net} = \frac{s}{70}\sqrt{\frac{\sigma_{yd}}{235}} \qquad (mm)$$

Where:

s	: spacing of stiffeners on the web, as defined in **Section 4/2.2**, in *mm*. Where no stiffeners are fitted s is to be taken as the depth of the web
σ_{yd}	: specified minimum yield stress of the material, in N/mm^2

6.4.6 Definition of idealised bow impact load area for primary support members

6.4.6.1 The scantlings of items in **6.4.7** are based on the application of the bow impact pressure, as defined in **Section 7/4.4**, to an idealised area of hull envelope plating, where the bow impact load area, A_{slm}, is given by:

$$A_{slm} = \frac{1.1 L B C_b}{1000} \qquad (m^2)$$

Where:

L	: rule length, as defined in **Section 4/1.1.1.1**
B	: moulded breadth, in *m*, as defined in **Section 4/1.1.3.1**
C_b	: block coefficient, as defined in **Section 4/1.1.9.1**

6.4.7 Primary support members

6.4.7.1 Primary support members in the bow impact region are to be configured to ensure effective continuity of strength and the avoidance of hard spots.

6.4.7.2 To limit the deflections under extreme bow impact loads and ensure boundary constraint for plate panels, the spacing, S, measured along the shell girth of web frames supporting longitudinal framing or stringers supporting transverse framing is not to be greater than:

$$S = 3+0.008L_2 \qquad (m)$$

Where:

L_2 : rule length, L, as defined in **Section 4/1.1.1.1**, but not to be taken greater than 300m

6.4.7.3 End brackets of primary support members are to be suitably stiffened along their edge. Consideration is to be given to the design of bracket toes to minimise abrupt changes of cross-section.

6.4.7.4 Tripping arrangements are to comply with **Section 10/2.3.3**. In addition, tripping brackets are to be fitted at the toes of end brackets and at locations where the primary support member flange is knuckled or curved.

6.4.7.5 The net section modulus of each primary support member, Z_{net50}, is not to be less than:

$$Z_{net50} = 10\frac{f_{bdg-pt} P_{im}\, b_{slm} f_{slm}\, l_{bdg}^{\,2}}{f_{bdg} C_s \sigma_{yd}} \qquad (cm^3)$$

Where:

f_{bdg-pt} : correction factor for the bending moment at the ends and considering the patch load

$= 3f_{slm}^{\,3} - 8f_{slm}^{\,2} + 6f_{slm}$

f_{slm} : patch load modification factor

$= \frac{l_{slm}}{l_{bdg}}$

l_{slm} : extent of bow impact load area along the span

$= \sqrt{A_{slm}}$ (m), but not to be taken as greater than l_{bdg}

A_{slm} : bow impact load area, in m^2, as defined in **6.4.6.1**

l_{bdg} : effective bending span, as defined in **Section 4/2.1.4***,* in m

P_{im} : bow impact pressure as given in **Section 7/4.4** and calculated at the load calculation point defined in **Section 3/5.3.3**, in kN/m^2

b_{slm} : breadth of impact load area supported by the primary support member, to be taken as the spacing between primary support members as defined in **Section 4/2.2.2**, but not to be taken as greater than l_{slm}, in m

f_{bdg} : bending moment factor

= 12 for primary support members with end fixed continuous face plates, stiffeners or where stiffeners are bracketed in accordance with **Section 4/3.3** at both ends

C_s : permissible bending stress coefficient

= 0.8 for acceptance criteria set AC3

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

6.4.7.6 The net area of the web, $A_{w-net50}$, of each primary support member at the support/toe of end brackets is not to be less than:

$$A_{w-net50} = \frac{5 f_{pt} P_{im} b_{slm} l_{shr}}{C_t \tau_{yd}} \qquad (cm^2)$$

Where:

f_{pt} : patch load modification factor

$$= \frac{l_{slm}}{l_{shr}}$$

l_{slm} : extent of bow impact load area along the span

$= \sqrt{A_{slm}}$ (m), but not to be taken as greater than l_{shr}

l_{shr} : effective shear span, as defined in **Section 4/2.1.2**, in m

P_{im} : bow impact pressure as given in **Section 7/4.4** and calculated at the load calculation point defined in **Section 3/5.3.2**, in kN/m^2

b_{slm} : breadth of impact load area supported by the primary support member, to be taken as the spacing between primary support members as defined in **Section 4/2.2.2**, but not to be taken as greater than l_{slm}, in m

C_t : permissible shear stress coefficient

= 0.75 for acceptance criteria set AC3

τ_{yd} $= \frac{\sigma_{yd}}{\sqrt{3}}$ (N/mm^2)

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

6.4.7.7 The net web thickness of each primary support member, $t_{w\text{-}net}$, including decks/bulkheads in way of the side shell is not to be less than:

$$t_{w-net} = \frac{P_{im}\, b_{slm}}{\sin\phi_w\, \sigma_{crb}} \qquad (mm)$$

Where:

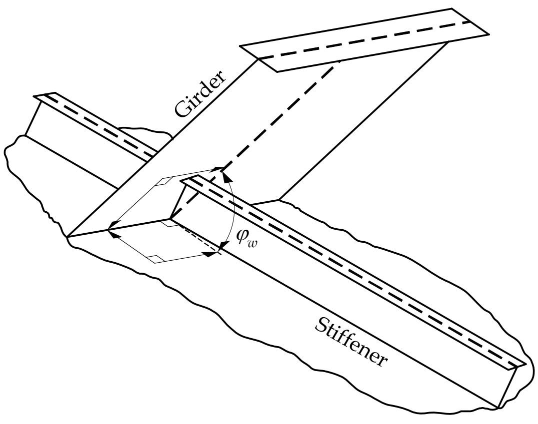
P_{im} : bow impact pressure as given in **Section 7/4.4** and calculated at the load calculation point defined in **Section 3/5.3.2** or at the intersection of the side shell with the deck/bulkhead, in kN/m^2

b_{slm} : breadth of impact load area supported by the primary support member, to be taken as spacing between primary support members as defined in **Section 4/2.2.2**, but not to be taken as greater than l_{slm}, in m

φ_w : angle, in *degrees*, between the primary support member web and the shell plate, see **Fig. 8.6.7**

σ_{crb} : critical buckling stress in compression of the web of the primary support member or deck/bulkhead panel in way of the applied load given by **Section 10/3.2.1**, in N/mm^2

Fig. 8.6.7 Angle between Shell Primary Member and Shell Plate



6.4.8 Connection of stiffeners to primary support members

6.4.8.1 Stiffeners are, in general, to be continuous. Where this not practicable end brackets complying with **Section 4/3.2.3** are to be provided.

6.4.8.2 The scantlings of the end connection of each stiffener are to comply with **Section 4/3.4**.

7. Application of Scantling Requirements to Other Structure

7.1 General

7.1.1 Application

7.1.1.1 The requirements of this Sub-Section apply to local and primary support members where the basic structural configurations or strength models assumed in **Section 8/2** to **8/5** are not appropriate. These are general purpose strength requirements to cover various load assumptions and end support conditions. These requirements are not to be used as an alternative to the requirements of **Section 8/2** to **8/5** where those sections can be applied.

7.1.1.2 The net scantlings described in **7.2** are related to gross scantlings as follows:

(a) for plating and local support members, the gross thickness and gross cross- sectional properties are obtained from the requirements of **7.2.2** by adding the full corrosion additions specified in **Section 6/3**.

(b) for primary support members, the gross shear area, gross section modulus and other gross cross-sectional properties are obtained from the requirements of **7.2.3** by adding one half of the relevant full corrosion additions specified in **Section 6/3**.

7.1.1.3 These requirements are to be applied in conjunction with all other appropriate requirements in **Sections 8, 9** and **10** for the particular structural member under consideration, including longitudinal strength, minimum thickness, proportions and structural stability, strength assessment (FEM), fatigue and hull girder ultimate strength.

7.1.1.4 The requirements for local and primary support members are to be specially considered when the member is:

(a) part of a grillage structure

(b) subject to large relative deflection between end supports

(c) where the load model or end support condition is not given in **Table 8.7.1**.

7.1.1.5 The application of alternative or more advanced calculation methods will be specially considered.

7.2 Scantling Requirements

7.2.1 General

7.2.1.1 The design load sets to be applied to the structural requirements for the local and primary support members are given in **Table 8.7.2**, as applicable for the particular structure under consideration. The static and dynamic load components are to be combined in accordance with **Table 7.6.1** and the requirements given in **Section 7/6.3**.

7.2.2 Plating and local support members

7.2.2.1 For plating subjected to lateral pressure the net thickness, t_{net}, is to be taken as the greatest value for all applicable design load sets given in **Table 8.7.2**, and given by:

$$t_{net} = 0.0158\alpha_p s\sqrt{\frac{|P|}{C_a\sigma_{yd}}} \qquad (mm)$$

Where:

α_p : correction factor for the panel aspect ratio

$$= 1.2 - \frac{s}{2100 l_p}$$

P : design pressure for the design load set being considered, calculated at the load calculation point defined in **Section 3/5.1.2**, in kN/m^2

s : stiffener spacing, in mm, as defined in **Section 4/2.2**

l_p : length of plate panel, to be taken as the spacing of primary support members, S, unless carlings are fitted, in m

C_a : permissible bending stress coefficient for the design load set being considered, as given in **Tables 8.2.4**, **8.3.2** or **8.4.2**, as applicable for the individual member being considered

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

7.2.2.2 For stiffeners subjected to lateral pressure, point loads, or some combination thereof, the net section modulus requirement, Z_{net}, is to be taken as the greatest value for all applicable design load sets given in **Table 8.7.2**, and given by:

$$Z_{net} = \frac{|P| s l_{bdg}^2}{f_{bdg} C_s \sigma_{yd}} \quad (cm^3)\text{, for lateral pressure loads}$$

$$Z_{net} = \frac{1000\,|F| l_{bdg}}{f_{bdg}\, C_s\, \sigma_{yd}} \quad (cm^3)\text{, for point loads}$$

$$Z_{net} = \frac{\left|\sum \frac{P_i\, s\, l_{bdg}^2}{f_{bdg-i}} + \sum \frac{1000 F_j\, l_{bdg}}{f_{bdg-j}}\right|}{C_s\, \sigma_{yd}} \quad (cm^3)\text{, for a combination of loads}$$

Where:

P	: design pressure for the design load set being considered, calculated at the load calculation point defined in **Section 3/5.2.2**, in kN/m^2
s	: stiffener spacing, in *mm*, as defined in **Section 4/2.2**
l_{bdg}	: effective bending span, as defined in **Section 4/2.1.1**
f_{bdg}	: bending moment factor for continuous stiffeners and where end connections are fitted consistent with idealization of the stiffener as having fixed ends = 12 for horizontal stiffeners = 10 for vertical stiffeners for other configurations the bending moment factor may be taken as in **Table 8.7.1**
C_s	: permissible bending stress coefficient for the design load set being considered as given in **Tables 8.2.5**, **8.3.3** or **8.4.3**, as applicable for the individual member being considered
σ_{yd}	: specified minimum yield stress of the material, in N/mm^2
F	: point load for the design load set being considered, in *kN*
i	: indices for load component i
j	: indices for load component j

7.2.2.3 For stiffeners subjected to lateral pressure, point loads, or some combination thereof, the net web thickness, t_{w-net}, based on shear area requirements is to be taken as the greatest value for all applicable design load sets given in **Table 8.7.2**, and given by:

$$t_{w-net} = \frac{f_{shr}\,|P|\, s\, l_{shr}}{d_{shr}\, C_t\, \tau_{yd}} \quad (mm)\text{, for lateral pressure loads}$$

$$t_{w-net} = \frac{1000 f_{shr}\,|F|}{d_{shr}\, C_t \tau_{yd}} \quad (mm)\text{, for point loads}$$

$$t_{w-net} = \frac{\left|\sum f_{shr-i}\, P_i\, s\, l_{shr} + \sum 1000 f_{shr-j}\, F_j\right|}{d_{shr}\, C_t \tau_{yd}} \quad (mm)\text{, for a combination of loads}$$

Where:

P	: design pressure for the design load set being considered, calculated at the load calculation point defined in **Section 3/5.2.2**, in kN/m^2
f_{shr}	: shear force factor for continuous stiffeners and where end connections are fitted consistent with idealization of the stiffener as having fixed ends: = 0.5 for horizontal stiffeners = 0.7 for vertical stiffeners for other configurations the shear force factor may be taken as in **Table 8.7.1**.

s	: stiffener spacing, in *mm*, as defined in **Section 4/2.2**
l_{shr}	: effective shear span, as defined in **Section 4/2.1.2**
d_{shr}	: as defined in **Section 4/2.4.2.2**
C_t	: permissible shear stress coefficient for the design load set being considered as given in **Tables 8.2.6** or **8.3.4**, as applicable for the individual member being considered
τ_{yd}	$= \dfrac{\sigma_{yd}}{\sqrt{3}}$ (N/mm^2)
σ_{yd}	: specified minimum yield stress of the material, in N/mm^2
F	: point load for the design load set being considered, in *kN*
i	: indices for load component *i*
j	: indices for load component *j*

7.2.3 Primary support members

7.2.3.1 The requirements in **7.2.3** are applicable where the primary support member is idealised as a simple beam. More advanced calculation methods may be required to ensure that nominal stress level for all primary support members are less than the permissible stresses and stress coefficients given in **7.2.3.4** and **7.2.3.5** when subjected to the applicable design load sets. See also **7.1.1.4**.

7.2.3.2 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus and cross sectional shear areas of the primary support member are to be applied as required in the notes of **Table 8.7.1**.

7.2.3.3 For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include an allowance for the curvature of the hull.

7.2.3.4 For primary support members the net section modulus requirement, Z_{net50}, is to be taken as the greatest value for all applicable design load sets given in **Table 8.7.2**, and given by:

$$Z_{net50} = \frac{1000\ |P|\, S\, l_{bdg}^2}{f_{bdg}\ C_s\ \sigma_{yd}} \quad (cm^3)\text{, for lateral pressure loads}$$

$$Z_{net50} = \frac{1000\ |F|\, l_{bdg}}{f_{bdg}\ C_s\ \sigma_{yd}} \quad (cm^3)\text{, for point loads}$$

$$Z_{net50} = \frac{\left| \sum \frac{1000 P_i\, S\, l_{bdg}^2}{f_{bdg-i}} + \sum \frac{1000 F_j\, l_{bdg}}{f_{bdg-j}} \right|}{C_s\ \sigma_{yd}} \quad (cm^3)\text{, for a combination of loads}$$

Where:

P	: design pressure for the design load set being considered, calculated at the load calculation point defined in **Section 3/5.3.3**, in kN/m^2
S	: primary support member spacing, in *m*, as defined in **Section 4/2.2.2**
l_{bdg}	: effective bending span, as defined in **Section 4/2.1.4**
f_{bdg}	: bending moment factor, as given in **Table 8.7.1**.
C_s	: permissible bending stress coefficient for the design load set being considered as given in **Tables 8.2.10** or **8.3.6**, as applicable for the individual member being considered
σ_{yd}	: specified minimum yield stress of the material, in N/mm^2
F	: point load for the design load set being considered, in *kN*
i	: indices for load component *i*
j	: indices for load component *j*

7.2.3.5 For primary support members the net shear area of the web, $A_{w-net50}$, is to be taken as the greatest value for all applicable design load sets given in **Table 8.7.2**, and given by:

$$A_{w-net50} = \frac{10 f_{shr} |P| S l_{shr}}{C_t \tau_{yd}} \quad (cm^2)\text{, for lateral pressure loads}$$

$$A_{w-net50} = \frac{10 f_{shr} |F|}{C_t \tau_{yd}} \quad (cm^2), \text{ for point loads}$$

$$A_{w-net50} = \frac{\left| \sum 10 f_{shr-i} P_i l_{shr} + \sum 10 f_{shr-j} F_j \right|}{C_t \tau_{yd}} \quad (cm^2), \text{ for a combination of loads}$$

Where:

P : design pressure for the design load set being considered, calculated at the load calculation point defined in **Section 3/5.3.2**, in kN/m^2

S : primary support member spacing, in m, as defined in **Section 4/2.2.2**

l_{shr} : effective shear span, as defined in **Section 4/2.1.5**

f_{shr} : shear force factor, as given in **Table 8.7.1**

C_t : permissible shear stress coefficient for the design load set being considered as given in **Tables 8.2.10** or **8.3.7**, as applicable for the individual member being considered

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ (N/mm^2)

σ_{yd} : specified minimum yield stress of the material, in N/mm^2

F : point load for the design load set being considered, in kN

i : indices for load component i

j : indices for load component j

Table 8.7.1 Values of f_{bdg} and f_{shr}

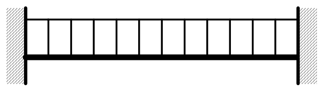
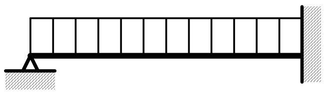
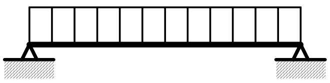
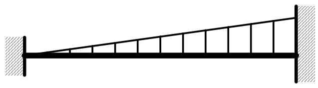
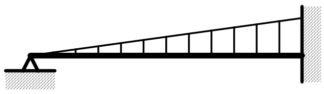
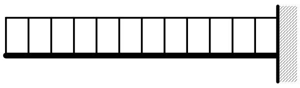
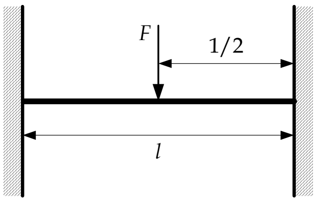
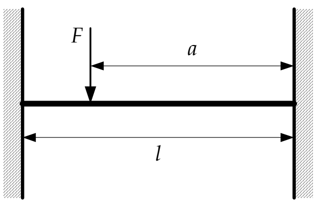
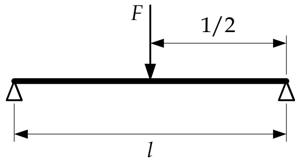
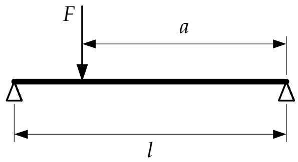
Load model	Load and boundary conditions Position (1) 1 Support / 2 Field / 3 Support	Bending moment and shear force factor (based on load at mid span where load varies) 1 f_{bdg1} f_{shr1}	 2 f_{bdg2} -	 3 f_{bdg3} f_{shr3}	Application
A		12.0 0.50	24.0 -	12.0 0.50	Built in at both ends. Uniform pressure distribution
B		- 0.38	14.2 -	8.0 0.63	Built in one end plus simply supported one end. Uniform pressure distribution
C		- 0.50	8.0 -	- 0.50	Simply supported, (both ends are free to rotate). Uniform pressure distribution
D		15.0 0.30	23.3 -	10.0 0.70	Built in both ends. Linearly varying pressure distribution
E		- 0.20	16.8 -	7.5 0.80	Built in one end plus simply supported one end. Linearly varying pressure distribution
F		- -	- -	2.0 1.0	Cantilevered beam. Uniform pressure distribution
G		8.0 0.5	8.0 -	8.0 0.5	Built in at both ends. Single point load in the centre of the span
H		$\frac{l^3}{a^2(l-a)}$ $\frac{a^2(3l-2a)}{l^3}$	$\frac{l^4}{2a^2(l-a)^2}$ -	$\frac{l^3}{a(l-a)^2}$ $\frac{(l-a)^2(l+2a)}{l^3}$	Built in at both ends. Single point load, with load anywhere in the span

Table 8.7.1 (Continued) Values of f_{bdg} and f_{shr}

Load and boundary conditions				Bending moment and shear force factor (based on load at mid span where load varies)			Application
Load model	Position (1)			1	2	3	
	1 Support	2 Field	3 Support	f_{bdg1} f_{shr1}	f_{bdg2} -	f_{bdg3} f_{shr3}	
I				- 0.5	4 -	- 0.5	Simply supported. Single point load in the centre of the span
J				- $\frac{a}{l}$	$\frac{l^2}{a(l-a)}$ -	- $\frac{l-a}{l}$	Simply supported. Single point load, load anywhere along the span

Note

1. The bending moment factor f_{bdg} for the support positions are applicable for a distance of $0.2l_{bdg}$ from the end of the effective bending span for both local and primary support members.
2. The shear force factor f_{shr} for the support positions are applicable for a distance of $0.2l_{shr}$ from the end of the effective shear span for both local and primary support members.
3. Application of f_{bdg} and f_{shr} for local support members:
   the section modulus requirement of local support members is to be determined using the lowest value of f_{bdg1} , f_{bdg2} and f_{bdg3}
   the shear area requirement of local support members is to be determined using the greatest value of f_{shr1} and f_{shr3}.
4. Application of f_{bdg} and f_{shr} for primary support members:
   the section modulus requirement within $0.2l_{bdg}$ from the end of the effective span is generally to be determined using the applicable f_{bdg1} and f_{bdg3}, however f_{bdg} is not to be taken greater than 12
   the section modulus of mid span area is to be determined using f_{bdg} =24, or f_{bdg2} from the table if lesser
   the shear area requirement of end connections within $0.2l_{shr}$ from the end of the effective span is to be determined using f_{shr} = 0.5 or the applicable f_{shr1} or f_{shr3}, whichever is greater
   for models A through F the value of f_{shr} may be gradually reduced outside of $0.2l_{shr}$ towards $0.5f_{shr}$ at mid span where f_{shr} is the greater value of f_{shr1} and f_{shr3}.

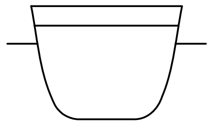
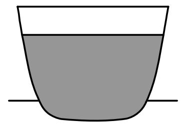
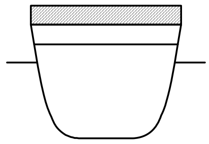
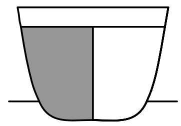
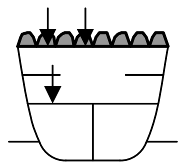
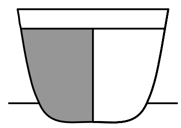
Where:

l : effective span, l_{bdg} and l_{shr} as applicable

l_{bdg} : as defined in **Section 4/2.1.1** for local support members and **Section 4/2.1.4** for primary support members

l_{shr} : as defined in **Section 4/2.1.2** for local support members and **Section 4/2.1.5** for primary support members

Table 8.7.2 Design Load Sets for Plating, Local Support Members and Primary Support Members

Type of Local Support and Primary Support Member	Design Load Set [1]	Load Component	External Draught	Comment	Diagrammatic Representation
Shell Envelope	1	P_{ex}	T_{sc}	Sea pressure only	
	2	P_{ex}	T_{sc}		
	5	P_{in}	T_{bal}	Tank pressure only. Sea pressure to be ignored	
	6	P_{in}	$0.25T_{sc}$		
External Decks	1	P_{ex}	T_{sc}	Green sea pressure only	
Decks forming Tank Boundaries and/or Watertight Boundaries	5	P_{in}	T_{bal}	Pressure from one side only Full tank with adjacent tank empty	
	6	P_{in}	$0.25T_{sc}$		
	11	$P_{in\text{-}flood}$	-		
Internal and External Decks or Flats	9	P_{dk}	T_{bal}	Distributed or concentrated loads only. Adjacent tanks empty. Green sea pressure may be ignored	
	10	P_{dk}	T_{bal}		
Other Tank Boundaries or Watertight Boundaries	5	P_{in}	T_{bal}	Pressure from one side only Full tank with adjacent tank empty	
	6	P_{in}	$0.25T_{sc}$		
	11	$P_{in\text{-}flood}$	-		

Where:

T_{sc} : scantling draught, in *m*, as defined in **Section 4/1.1.5.5**

T_{bal} : minimum design ballast draught, in *m*, as defined in **Section 4/1.1.5.2**

Notes

1. The specification of design load combinations, and other load parameters for the design load sets are given in **Table 8.2.8**
2. When the ship's configuration cannot be described by the above, then the applicable Design Load Sets to determine the scantling requirements of structural boundaries are to be selected so as to specify a full tank on one side with the adjacent tank or space empty. The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents and are to maximise the pressure on the structural boundary, the draught to use is to be taken in accordance with the Design Load Set and this table. Design Load Sets covering the S and S+D design load combinations are to be selected. See **Note 4** on **Table 8.2.7** and **Table 8.2.8**.
3. The boundaries of void and dry space not forming part of the hull envelope are to be evaluated using Design Load Set **11**. See **Note 2**.